WINTER VIEW OF MOUNT McKINLEY FROM THE NORTHWEST.

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

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 907

GEOLOGY OF THE ALASKA RAILROAD REGION

BY

STEPHEN R. CAPPS

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1940

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price $1.25 (paper)

QE 75
B9
no. 907

CONTENTS

G-2639

ILLUSTRATIONS

GEOLOGY OF THE ALASKA RAILROAD REGION

By Stephen R. Capps

ABSTRACT

The Alaska Railroad region, as here defined, covers an area about 140 miles wide and 450 miles long from north to south, reaching from the Gulf of Alaska northward into the Yukon Basin. The Government-owned and operated Alaska Railroad lies along the axis of this belt. The region contains important mineral deposits, particularly gold and coal, and has produced some $150,000,000 worth of minerals in the last 40 years. Its known reserves of minerals are large, and the possibilities of future discoveries have by no means been exhausted. It also contains extensive areas that are suitable for agriculture and for grazing. A considerable portion of the Mount McKinley National Park falls within this area. The railroad region includes portions of seven rather distinct geographic provinces and thus exhibits a wide range of geologic formations and structures. During the last 40 years more than 100 parties of the Geological Survey have carried out studies in this region, and the results of that work have appeared in an even larger number of maps and written reports published by the Survey or in the technical press. Many of these publications are now out of print and not easy of reference. Furthermore, as knowledge of the region has grown, many of the earlier conclusions with regard to the stratigraphic sequence and structure have been changed.

The present report is an attempt to bring together in condensed form the present state of knowledge of the geology of the region. Limitations of space have necessitated great condensation of the material available, but references are given to the published works of the original authors, and a chronologic list is presented of field work that has been done. It has been necessary to generalize the geology in such a way as to bring into accord the results of different workers, but in almost all instances where that has been done, or where changes in age assignment of formations have been made, it has been with the concurrence of the original authors, on the basis of more recent information.

Brief descriptions are given of the history of exploration, climate, vegetation, animal life, population, routes of travel, agriculture, and of Mount McKinley National Park.

INTRODUCTION

The completion of the Government railroad from Seward, on the Pacific coast, to Fairbanks, in the Tanana Basin, in the spring of 1923 was a historic event in the industrial development of Alaska. Since 1867, when the Territory was purchased from Russia, most of Alaska except the immediate seaboard had been difficult of access, and travel through it had been wasteful in time, energy, and money.

As a result of this isolation the agricultural lands of the Territory remained almost untouched and only the richest mines could be exploited at a profit. Alaska is still a frontier country and is very thinly populated. The census of 1910 showed a total population of 64,356, largely distributed along the seaboard. Of these people about 36,000 were whites. By 1915 the white population had increased somewhat, but by 1918 the population had decreased to about 50,000, largely as the result of the call to military service of 3,500 men and of the high wages that could be obtained in the States. The labor shortage and the high wages so increased the cost of mining under war conditions that mining was restricted or completely stopped on many claims that had previously been worked. The census of 1920, however, showed a slight increase again to more than 55,000 persons and the census of 1930 to more than 59,000, of whom over 28,000 were whites and almost 30,000 were natives, the others being foreigners of various nationalities. Of this number, over two-thirds, or more than 40,000 people, live on the coast. The remainder, including both whites and natives, less than 20,000 in number are scattered in a few small towns or in small groups throughout an area of about 500,000 square miles, or an average of only one person to 25 square miles. For these people the only avenues of communication during the summer have been the few navigable streams, most notable of which are the Yukon, Tanana, and Kuskokwim Rivers, and a thin network of roads and trails. Before the completion of the Alaska Railroad a single railroad, the Copper River & Northwestern, ran from tidewater across the coastal mountains and gave access to the lower Copper River Basin and a part of Chitina Valley. This railroad was supplemented by an automobile road, the Richardson Highway, from Valdez and Chitina to Fairbanks, on the Tanana River. It must be remembered, too, that at the time when construction of a railroad from the coast to the interior of Alaska was under consideration there were no commercial air lines in operation in the territory, and no landing fields. In fact, commercial aviation even in well-settled parts of the United States was only in its beginning. Interior Alaska was therefore almost completely isolated during the more than 7 months from middle October to early June, for during that period the streams are ice-bound, the river steamers are in winter quarters, and travel was mainly on foot or by sled over frozen trails and streams. Furthermore, in spring, during the "break-up" period, when the snow is melting and the ice is running in the rivers travel overland is nearly impossible, as it is also in the fall, during the "freeze-up" and until sufficient snow to afford good sledding has accumulated. It is therefore difficult to exaggerate the value of all-year rail transportation to those parts of Alaska that are tributary to the Alaska Railroad. This area includes rich mineral deposits and agricultural lands, as well as valuable fisheries.

Its natural richness had been sufficient to encourage the development, even in advance of adequate transportation, of the gold lodes of the Willow Creek district, the gold placers of the Yentna, Valdez Creek, and Bonnifield districts, and both placer and lode deposits in the Fairbanks and Kantishna districts. The salmon fisheries of Cook Inlet have for many years contributed largely to the Nation's food supply. As soon as even local railroad transportation became available coal mining was started in the Matanuska and Nenana coal fields, and developments looking toward active mining were carried out on the gold lodes of Broad Pass. The promise and realization of rail connections with the coast and with interior Alaska have encouraged a noteworthy farm colonization in the Matanuska Valley and stimulated the already well-established farming industry near Fairbanks.

The area served by the railroad is unusually large compared with the length of the railroad, for it embraces not only all of Kenai Peninsula, the Susitna Basin, and that part of the Tanana Basin through which the line runs (fig. 1) but also all those parts of the

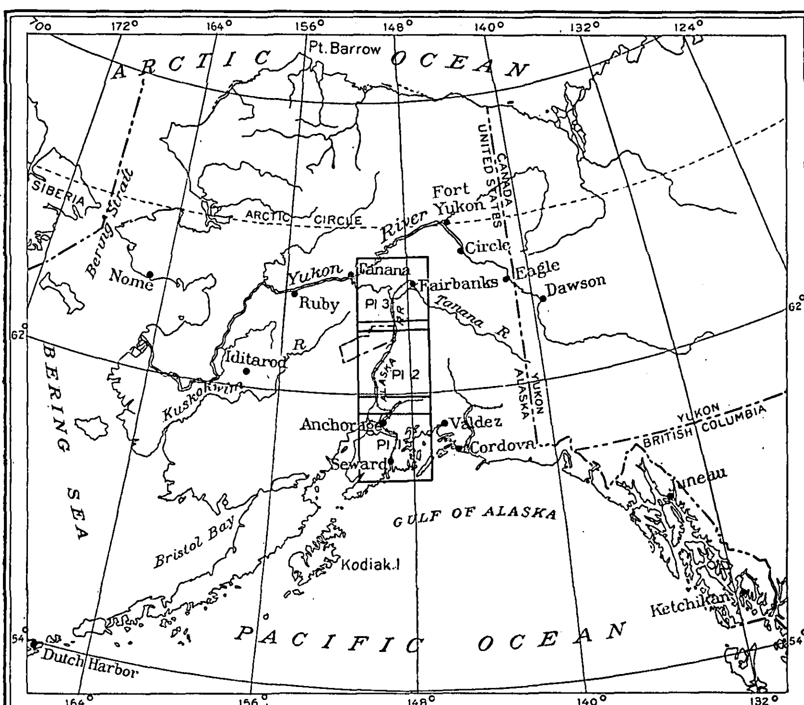


FIGURE 1.—Index map showing location of the Alaska Railroad region.

Tanana, Yukon, and Kuskokwim Basins that are connected by roads, by river transportation, or by air lines with the railroad and thus includes a large portion of central Alaska. In the present report, however, it has been necessary to confine the discussion of the geology and mineral resources to a more restricted area. The region here included is 380 miles long and 130 miles wide, lying for the most part between latitude 59°40′ and 65°10′ north and longitude 147° and 151° west. It includes the entire Government railroad from Seward to Fairbanks, and the branch to the coal field in Matanuska Valley, as well as the territory immediately tributary to the railroad on both sides. Figure 1 shows the position of this region and its relations to other parts of Alaska.

A measure of the economic importance of the railroad region is afforded by the following table, which lists the total mineral production for the several districts up to and including 1936:

Mineral production of the Alaska Railroad region up to and including 1936

Gold:	
Placers	$126, 188, 700
Lodes [1]	12, 517, 300
	138, 706, 000
Silver (mainly from alloys with gold)	845, 000
Coal	9, 835, 000
Miscellaneous,[2] including lead, antimony, tungsten, copper, and other products	225, 000
	149, 611, 000

[1] Does not include production from lodes of gold in Prince William Sound region nor Nuka Bay district.

[2] Does not include production of copper from deposits in Prince William Sound region.

Placer gold production from the Alaska Railroad region, by districts, up to and including 1936

Kenai Peninsula	$2, 213, 200
Willow Creek	46, 100
Yentna	2, 964, 500
Valdez Creek	720, 000
Bonnifield	494, 500
Kantishna	496, 100
Fairbanks	104, 406, 600
Rampart	1, 476, 100
Hot Springs	7, 526, 000
Tolovana	5, 844, 900
	126, 188, 700

HISTORY OF EXPLORATION

The story of the migrations of native tribes to Alaska and their settlements would be of great ethnologic and historic interest if the record could be obtained, but these natives are of primitive types and have no written language, and much of their early history is forever lost. Trustworthy records date back only to the first arrival of white men, and the most important historic events are here summarized briefly.

During the early days of colonial settlement on the Atlantic coast the northwestern part of the North American continent had never been seen by white men. In the early part of the eighteenth century, however, the Russian fur traders on the coast of Siberia learned that some land lay to the east, for trade had long been carried on between the Siberian natives and the Alaska Eskimos. The probabilities that this new land offered a promising area into which to extend the fur trade stimulated the Russians to seek it out, and to determine definitely whether or not there was a land connection between eastern Siberia and western North America. Accordingly, in 1724 Czar Peter the Great dispatched Vitus Bering to make the long journey overland to the Pacific coast and there build his ships. His first voyage, in 1728, proved that Asia and America were separated by water, though Bering failed to sight the Alaska coast. On a second voyage, in 1741, he approached the shore of the mainland near Mount St. Elias, landed on one of the islands, and thus is popularly credited with the discovery of Alaska. On his return trip to Siberia he probably caught sight of land near the mouth of Cook Inlet and so was the first white man to visit this portion of Alaska, though he made no landing there. Bering died on the return voyage to Siberia, and the official interest of the Russians in the newly found Alaska lagged, but the fur traders were prompt to see the possibilities for extending their outposts to this virgin territory. By 1763 they had pushed eastward along the Aleutian Islands and Alaska Peninsula to Kodiak Island, and in 1783 they established their first settlement at Three Saints Bay, later moving this settlement to the present site of Kodiak. Within the next 5 years other settlements were established at Kasilof and Kenai, on the east shore of Cook Inlet, and later on a trading post at Knik. The traders up to that time, as well as later, were interested mainly in the commercial exploitation of the country, and if they carried on important explorations and made any record of them, the records have been lost and their contributions to our geographic knowledge have been small.

The first important exploration in this region was carried out by the navigator Capt. James Cook, who was sent by King George III to search for a northwest passage around the north end of the continent. After following the coast northward from Oregon he entered the embayment now known as Cook Inlet in 1778 and, thinking himself in the mouth of a great river, followed it northward as far as the entrance to Turnagain Arm, which he called Turnagain River, for he then turned back to continue his explorations elsewhere.

In 1786, Dixon and Portlock, who had been officers with Cook on this earlier voyage, returned to Cook Inlet in charge of two trading vessels and extended our knowledge of its shores. By that time the fur trade was in the hands of a single powerful company, which had established posts on Kodiak Island and on the east shore of Cook Inlet but which had little interest in extending explorations inland. In 1793 an agricultural colony was established on the east shore of Cook Inlet, and in 1795 a ship built of Alaska timber was launched at a newly established shipyard on Resurrection Bay. The actual charting of the shore of Cook Inlet was completed in 1794 by George Vancouver, an English navigator who had been with Cook to this coast 16 years before. Vancouver was the first to mention the lofty mountains of the Alaska Range, culminating in Mounts McKinley and Foraker, which can be seen on a clear day from the head of the inlet.

For the next 50 years little exploration of interest has been recorded, with the exception of a trip by Malakoff, a Russian fur trader, who traveled by boat for some distance up the Susitna River in 1834. The first recorded mining venture in Alaska was made in 1848–50 by Doroshin, a Russian mining engineer, who sought and attempted to mine gold on Kenai Peninsula and recovered some gold, though he failed to find deposits rich enough to encourage further exploitation. Four years later, in 1854, the Russians produced the first coal mined in Alaska, from beds that crop out at Port Graham, and maintained a small output for several years. Russian maps of this part of Alaska published before the transfer of the territory to the United States show correctly the general position of the Susitna and Matanuska Rivers, but whether that information was based on reports by the natives or on first-hand knowledge gained by exploration is not known. Certainly in 1867, when the Russian occupation ended, the territory immediately back of the coast of Cook Inlet, except for the position of the main rivers, was largely unknown to white men. Meanwhile the Russians had extended their explorations for at least 400 miles up the Kuskokwim River, and had journeyed up the Yukon to the mouth of the Tanana. Thus, although in the region here considered they had explored only the seacoast, they had a knowledge of the general courses followed by the main rivers.

The failure of the Russians to explore and survey the region systematically should not be harshly criticized, for the first 25 years after the transfer witnessed an equal apathy on the part of the United States, and "Seward's folly" was largely left to take care of itself, so far as Federal appropriations were concerned. The venturesome prospectors and fur traders, however, asked no Government help and early began to find their way into remote parts of the Territory, in their search for gold and furs. As early as 1878 Arthur Harper and A. Mayo, who had descended the Yukon, made a trip up the Tanana as far as the present site of Fairbanks and found alluvial gold on the bars of the streams. About 1880 a trading post was established 20 miles above the mouth of the Tanana, but it was later abandoned. Frank Densmore and several companions in 1889 crossed from the Tanana to the Kuskokwim Basin, probably by way of the Kantishna River and Lake Minchumina, and their enthusiastic descriptions of a great mountain to the southeast, now known as Mount McKinley, led the prospectors of the interior to speak of it as "Densmore's Mountain."

The first systematic study of the geology of any part of this portion of Alaska was made on Kenai Peninsula in 1880 by William H. Dall, who was then a member of the United States Coast Survey. He returned in 1895 for the Geological Survey and in company with G. F. Becker made a study of the west coast of Kenai Peninsula, thus beginning the work of the Geological Survey in Alaska, a work that has continued to the present time.

For 12 or 15 years after 1880 public interest in Alaska gradually increased, for reports of gold discoveries fired the popular imagination, and many venturesome men penetrated into previously unexplored parts of the Territory. An expedition by the War Department in 1885, in command of Lt. Henry T. Allen, explored the headwaters of parts of the Copper River Basin and descended the Tanana from the mouth of the Delta River, adding greatly to our knowledge of the geography of interior Alaska.

The first discovery of gold in paying quantities within the Cook Inlet Basin is said to have been made in 1888 near Hope, but it was several years later before vigorous development work was carried on there.

An attempt in 1889 to exploit the lignitic coal of Kachemak Bay for export to the Pacific Coast States ended in failure. The next year gold-bearing beach placer deposits were discovered at Anchor Point, on Cook Inlet, and in 1894 the placer diggings on Bear and Palmer Creeks were found. These discoveries stimulated prospecting throughout Kenai Peninsula, and mining soon began in many localities. Gold quartz float was discovered in the Moose Pass district in 1896, and many quartz lodes were located in 1898 and 1899. Between 1896 and 1898 many placer claims were staked on the north side of Turnagain Arm, although a workable gravel deposit has since been developed there at only one locality. The first placer discoveries in the Willow Creek district were also made in 1897.

An exploration worthy of mention was that of W. A. Dickey, who in 1896, with three other men, took a boat up the Susitna River to the mouth of the Indian River and explored portions of the main valleys of the Susitna and Chulitna Rivers. He published the first description of Mount McKinley and gave it its name, and his estimate of the height of the mountain as 20,000 feet, made at that time without instrumental observation, has proved to be within 300 feet of the actual height.

In 1897 and later there were doubtless many prospectors who penetrated to different parts of the Susitna Basin, but those men left no written record of their wanderings, except where valuable minerals were found and small mining communities sprang up.

The attention of the world was drawn forcibly to Alaska in 1897–98, upon the discovery of the exceedingly rich gold-placer diggings of the Canadian Klondike, and the effects of that spectacular stampede of gold seekers were reflected throughout the entire Territory in greatly increased vigor in prospecting. A keen demand arose from the public for accurate information about the Territory, and the Government recognized the importance of that demand by empowering several agencies to carry out investigations there. The Coast and Geodetic Survey soon commenced the charting of the shore lines and navigable waters, and that work is still in progress. The Army and the Geological Survey, in cooperation or separately, sent several expeditions into the Territory in 1898, four of which reached the area here under discussion. Of these expeditions, one under the leadership of G. H. Eldridge and Robert Muldrow, of the Geological Survey, traveled by canoe up the Susitna River with the object of crossing the Alaska Range and descending the Tanana to the Yukon. Reaching the head of navigation at the mouth of the Indian River, the expedition proceeded overland as far as the Nenana River, but exhaustion of supplies compelled it to return by the same route. As a result of this journey a survey was carried from the coast to the Susitna-Tanana divide; the position and altitude of Mount McKinley were determined; and some information was gathered concerning the geology of this great basin.

That same year J. E. Spurr and W. S. Post, of the Geological Survey, made a remarkable journey by canoe up the Yentna and Skwentna Rivers to the summit of the Alaska Range, which they crossed, and descended the Kuskokwim to its mouth. They proceeded thence around to Bristol Bay by following a series of rivers and lakes and returned to the Pacific waters by crossing the Alaska Peninsula to a point opposite Kodiak Island. Throughout their journey they carried on topographic and geologic mapping and added greatly to our knowledge of the region they traversed.

Meanwhile a War Department expedition in charge of Capt. E. F. Glenn, to which W. C. Mendenhall, of the Geological Survey, was attached as geologist and topographer, was working in another part of this area. Preliminary to the main expedition Mendenhall crossed the pass from Prince William Sound to Turnagain Arm and returned by way of Portage Bay and Portage Glacier, and later traveled northward overland from Resurrection Bay to Turnagain Arm. The main expedition, which he then joined, journeyed by pack train up the Matanuska Valley and across the Copper River Basin to Delta River, which they descended nearly to the Tanana, returning by the same route. Throughout this journey Mendenhall carried on a topographic and geologic survey under difficult conditions and brought out a great amount of information about a previously unmapped area.

A fourth expedition in 1898 was that of W. J. Peters and A. H. Brooks, who ascended the White River from the Yukon, portaged across to the head of the Tanana, and explored that stream to its mouth. As a result of these explorations in 1898 the larger geographic features of this portion of Alaska were at least outlined, and a foundation was laid for the work that was to follow.

In 1899 an Army expedition commanded by Lt. J. S. Herron left Cook Inlet with the object of crossing the Alaska Range along the general route already mapped by Spurr and Post and proceeding northward on the west side of the range to the mouth of the Tanana. After many misfortunes the trip was accomplished, and at least some idea of the geography of that route was obtained. At the same time Sgt. William Yanert, acting under orders of Captain Glenn, made some reconnaissance surveys in the Susitna Basin, and George Van Schoonhoven, also of Glenn's command, proceeded by pack train up the Susitna River and across into the Nenana Basin. In 1899 also the Harriman Alaska Expedition, with a notable group of geologists and geographers that included G. K. Gilbert, W. H. Dall, John Muir, B. K. Emerson, Charles Palache, and Henry Gannett, made some studies in Prince William Sound and on the east shore of Cook Inlet. In 1902 preliminary surveys for a railroad from the Pacific coast to the Tanana River, by way of the Susitna Valley and Broad Pass, were carried over that entire route, and in 1903 railroad construction began at the newly established town of Seward and a great stimulus was given to prospecting along the projected railroad line. This road was eventually completed for a distance of 71 miles, reaching the north side of Turnagain Arm, and was expected to tap the Matanuska coal field, at that time known to contain high-grade coal, and to extend to the new placer camp at Fairbanks, discovered in 1902. Unfortunately the coal-land controversy arose at this time, and the uncertainty that arose concerning title to the coal lands delayed the development of the coal fields, and so discouraged the financial backers of the railroad that construction was stopped and was not resumed until 1915, when the old line was acquired as a part of the new Government railroad system.

The most fruitful trip of exploration that has been made in this region was that of the Geological Survey party in charge of A. H. Brooks, including D. L. Reaburn as topographer and L. M. Prindle as an additional geologist. In the spring of 1902 the members of this party landed at Tyonek with pack horses and supplies, proceeded overland to and up the valley of the Skwentna River to its head, crossed the Alaska Range by a pass they discovered, and followed the northwest flank of the range to the Nenana Valley, which they descended to its mouth and proceeded thence to the Yukon at Rampart. Topographic and geologic mapping were carried on throughout the journey, in a country much of which had been previously unexplored. These men were the first to set foot on the slopes of Mount McKinley, and their reports of its wonderful scenic beauty and of the most available routes by which it could be reached were in large measure influential in starting the series of mountaineering expeditions that culminated in the ascent of the highest peak in 1913.

The expeditions organized between 1903 and 1913 for the purpose of climbing Mount McKinley contributed largely to our knowledge of this part of Alaska, for narrative reports describing several of the expeditions were published, and all of them were given considerable publicity. At least one of those reports, that of the Parker-Browne exploration, included a comprehensive sketch map of the Mount McKinley region and contained a large amount of original geographic information. None of the mountaineering parties, however, except the second Cook expedition, made an attempt to conduct systematic instrumental surveys. The following is a brief chronologic account of the expeditions that made serious attempts to ascend Mount McKinley.

In 1903 James Wickersham and party proceeded from Fairbanks down the Tanana and to the head of navigation on the Kantishna River and thence traveled overland to the base of the mountain. They succeeded in climbing to an altitude of about 10,000 feet but were turned back by lack of provisions and other difficulties. That same year Dr. Frederick A. Cook, with a party including among others Robert Dunn, traveled by the route mapped by Brooks the preceding year to the northwest base of the mountain, and on the second attempt to climb the mountain was stopped by impassable cliffs at an altitude of about 11,000 feet. On the return trip this party proceeded eastward from the mountain, crossed the Alaska Range through a difficult pass they discovered at the head of the Teklanika River, and descended the Chulitna and Susitna Rivers by raft.

The second Cook expedition, in 1906, included among its members Herschel Parker, Belmore Browne, and a topographer, R. W. Porter. This time the attack on the mountain was made from the southeast, but again without success. The expedition resulted, however, in the topographic mapping of a considerable area along the southeast slope of the Alaska Range and so made a valuable geographic contribution.

Three mountaineering expeditions were carried out in 1910. Of these the most unusual was that organized in Fairbanks, including four Alaska pioneers and miners, Thomas Lloyd, William Taylor, Pete Anderson, and Charles McGonagal. These men were accustomed to the hardships of travel in low temperatures but had had little or no experience in alpine work. Ignoring the elaborate preparations and precedents of earlier expeditions, they sledded with dog teams to the base of the mountain in early spring, and after back packing their improvised outfit and provisions for several weeks to successively higher camps, two of them, Anderson and Taylor, in a single day's magnificent spurt, made the last climb of more than 8,000 feet and placed a flag on the northeast peak. They chose the northeast peak, although it is a few hundred feet lower than the southwest peak, because they thought a flag on that point would be more plainly visible from the lowlands to the north. The ascent to the highest peak was not attempted, though the route to it was said to present no difficulties; so the ultimate goal was still unattained.

In that same year, 1910, two attempts were made to scale the mountain from the south, one by a party organized by C. E. Rust and the other under the leadership of Herschel Parker and Belmore Browne. Neither of these expeditions succeeded in finding a practicable route to the summit. A second Parker-Browne expedition was started in 1912 for the purpose of making the climb from the north slope. The members of this party took supplies by dog sled from Seward and spent many weeks in ascending the Susitna and Chulitna Rivers and crossing the range to Muldrow Glacier by way of Ohio Creek and the glacier at the head of the West Fork of the Chulitna River. The ascent of Mount McKinley was begun in early June, and after more than 3 weeks spent in climbing and relaying outfit and provisions on their backs the climbers ascended to a point within a few hundred feet of the top of the mountain, only to be turned back by a blizzard. A second attempt for the summit was made a few days later, but bad weather and lack of proper food compelled them to abandon their purpose, after having so nearly achieved it.

Although in all but a technical sense Mount McKinley had been ascended both by Anderson and Taylor in 1910 and by the Parker-Browne expedition in 1912, still the highest peak remained unconquered until 1913, when Archdeacon Hudson Stuck and three companions, among whom Harry Karstens was the leading spirit, proceeded by dog sled from the Tanana and camped at the north base

77786—40——2

of the mountain. They began the actual climb in the middle of April and stood on the peak on June 7, 17 years after Dickey first described and named the mountain. Since that time the mountain has been scaled only once, on May 7, 1932, when a party that included Supt. Harry Liek, of the park; Erling Strom, and Grant Pearson made a successful ascent.

Although the ascent of Mount McKinley was a spectacular feat that appealed to the popular imagination, the year of Brooks' exploration in 1902 and those immediately following witnessed a series of events that were far more important in the industrial development of this part of Alaska. First of these in importance was the discovery of the rich placer gravel deposits of the Fairbanks district. The first actual discovery was made in 1902, but the fame of the new gold camp became widespread in 1903, and in that year and 1904 a gold stampede to Fairbanks took place. This not only established the most important interior placer camp of Alaska but directly stimulated prospecting throughout a wide area in the Yukon and Tanana Basins, and a number of minor gold camps were found, including the Bonnifield region and Valdez Creek in 1903, the Kantishna and Yentna districts in 1905, and the Willow Creek quartz lodes in 1906. Placer gold was first found on the West Fork of the Chulitna River in 1907 and was mined on a small scale in 1909. The first lode claims there were staked in 1909, but in 1911 and 1912 the district was actively prospected and many lode claims were staked. Active prospecting for gold lodes began in the Kantishna district about 1912 and has continued since.

Announcement was made in 1914 that the Seward-Fairbanks route had been selected for the Government railroad. Although at that time parts of the route selected had not been completely mapped by the Geological Survey, nevertheless the general character of the country, including the position and size of the rivers and the height of the mountain divides, had been well determined. The expeditions carried out between 1898 and 1902, already referred to, and the railroad surveys made in 1902–6 for the Alaska Central Railroad had yielded abundant preliminary information about the route, and this was of course supplemented by further location surveys made for the Government railroad in 1914–19. In 1915 construction was begun on Knik Arm, and increased activity followed throughout the region along the projected line. There was a great rush of people to Knik Arm, at the construction center for the Cook Inlet end of the railroad, and in June 1915 a canvas town of perhaps 1,500 tents sprang up almost overnight on the flat at the mouth of Ship Creek. That same summer a permanent town site was surveyed on a high terrace just south of the tent town, the lots sold at public auction, and by fall a substantial town, with wide, well-graded streets and a fine sanitary location, was rapidly growing on a spot that a few months earlier was a wilderness, while a dock, railroad yards, and buildings of the Alaska Engineering Commission had grown on the side of the earlier tent village. This town was named Anchorage, as it lay at the farthest inland point on Knik Arm to which ocean steamships could safely go.

In anticipation of the agricultural settlement of the public lands around Knik Arm and in the lower Matanuska Valley the General Land Office had for several years been actively engaged in making land surveys in that region, and this foresight was justified by the great influx of homesteaders that began about 1915. A large number of farms were taken up, land was cleared, and preparation for planting crops began. Mining and prospecting were also stimulated, and several projects were initiated for exploiting placer gravel by means of machinery, instead of by the more laborous and expensive hand methods. The first gold dredge in the Susitna Basin was built in the Yentna district in the fall and winter of 1915, several coal beds were opened in the Matanuska field, and vigorous prospecting resulted in the discovery of gold quartz veins in the Willow Creek district and of gold-copper and copper lodes in the Iron Creek district of the Talkeetna River Basin.

In 1916 active construction work was begun on the railroad from the interior. The town of Nenana, a construction center, was built at the confluence of the Nenana and Tanana Rivers, and railroad building was carried forward from that point both southward toward Broad Pass and eastward toward Fairbanks. The original plans and estimates contemplated the completion of the railroad from Seward to Fairbanks for a cost within the limits of the original appropriation, by the end of 1919. The World War, however, greatly interfered with those plans both by decreasing the supply of labor and by greatly increasing the cost of labor, supplies, and construction materials. Congress recognized the unusual conditions and so increased the appropriations that construction continued, and rail communication was established between Seward and Fairbanks in the winter of 1921–22, though it was then necessary to ferry passengers and freight across the Tanana River. In the spring of 1923 the great steel bridge across the Tanana River at Nenana was opened to traffic, completing the last link in the railroad between Seward and Fairbanks.

Since the several expeditions from the Geological Survey in 1898 there has been continuous activity of the Survey in Alaska. Many parties have made topographic and geologic studies in the area here considered, and it is from the results obtained on these expeditions that this report is compiled. Within the boundaries of the region shown on the accompanying maps (pls. 1–3) there are now only a few small areas that remain unsurveyed, and something is known of both the geography and geology of even these areas. The plans for a gradual completion of the map of Alaska are going forward year by year, and the blank spaces on the map are being rapidly restricted or eliminated. Coincident with the geologic and topographic mapping carried on by the Geological Survey during the last 38 years, other bureaus of the Federal Government have been engaged in surveys of other kinds within the same area. The Coast and Geodetic Survey is following its program of charting the shore lines and coastal waters of Alaska and in extending precise triangulation from the coast into the interior. The General Land Office has surveyed and subdivided many areas in which the agricultural or mining possibilities justified that work. The Bureau of Soils has made soil reconnaissances in various parts of the Territory, and the Biological Survey has made studies of the animal life throughout the Territory and recommended and enforced the game laws. The Alaska Road Commission and the Bureau of Public Roads have also made road surveys in the various areas in which they were engaged in road building.

For the purpose of permanently recording the date and locality of the various geologic and topographic investigations that have been made in this region, there follows a brief chronology from 1895 through 1936.

1895. W. H. Dall and G. F. Becker examined the coal deposits and gold lodes of southern Kenai Peninsula.

1898. J. E. Spurr and W. S. Post journeyed up the Skwentna River and down the Kuskokwim.

W. C. Mendenhall traveled across Kenai Peninsula and up the Matanuska Valley.

A. H. Brooks and W. J. Peters descended the Tanana River.

1902. A. H. Brooks, D. L. Reaburn, and L. M. Prindle ascended the Skwentna and Kichatna, crossed the Alaska Range, and followed its northwest flank to the Nenana River, proceeding thence northward across the Tenana to Rampart.

1903. T. G. Gerdine, in the course of an extensive survey in the Yukon-Tanana region, carried reconnaissance topographic mapping northward from Fairbanks.

L. M. Prindle began a study of the geology and mineral resources of the Yukon-Tanana region.

1904. F. H. Moffit examined the Sunrise placer district, and E. G. Hamilton did topographic mapping in the same region.

T. W. Stanton, G. C. Martin, and R. W. Stone were engaged in an investigation of the geology and mineral resources of the southwestern part of Kenai Peninsula.

1905. U. S. Grant and Sidney Paige made some brief studies on the east shore of Kenai Peninsula.

G. C. Martin made a reconnaissance of the Matanuska coal field.

1906. An expedition including T. G. Gerdine and R. H. Sargent, topographers, and Sidney Paige and Adolph Knopf, geologists, mapped topographically a large area around Knik Arm and in the Talkeetna Mountains.

L. M. Prindle made a reconnaissance in the Bonnifield and Kantishna regions.

R. W. Porter made a topographic map of a part of the west side of the Susitna Basin.

1907. C. C. Covert spent a part of the summer in making stream measurements in the Fairbanks district.

1908. U. S. Grant, assisted by D. F. Higgins, continued his investigations in the Prince William Sound region.

L. M. Prindle and F. J. Katz made a detailed study of the Fairbanks placer district; and C. C. Covert and C. E. Ellsworth studied the water supply of the region around Fairbanks.

1909. U. S. Grant and D. F. Higgins continued their studies in Prince William Sound and in the southern part of Kenai Peninsula.

R. H. Sargent made a detailed topographic survey of the lower Matanuska Valley.

L. M. Prindle and B. L. Johnson continued geologic mapping in the Yukon-Tanana region, devoting special attention to a study of the auriferous quartz veins near Fairbanks.

C. E. Ellsworth continued stream measurements in the Fairbanks district.

1910. G. C. Martin, F. J. Katz, and Theodore Chapin made a detailed geologic study of the lower Matanuska Valley.

F. J. Katz and Theodore Chapin made a reconnaissance of the Willow Creek gold district.

F. H. Moffit and B. L. Johnson made a geologic reconnaissance in the Gulkana-Susitna region, at the same time that D. C. Witherspoon and C. E. Giffin were engaged in mapping that area topographically.

J. W. Bagley made a topographic map of the Bonnifield region, and S. R. Capps carried the geologic mapping over that area.

R. H. Sargent and others made a land survey near Fairbanks.

C. E. Ellsworth and G. L. Parker studied the conditions of placer mining and the water supply of the Yukon-Tanana region.

1911. R. H. Sargent mapped a topographic survey from Kachemak Bay to Turnagain Arm.

J. W. Bagley made both detailed and reconnaissance topographic surveys in Kenai Peninsula.

G. C. Martin and H. Lewis made a geologic reconnaissance from Port Graham to the Kenai River and eastward to the Alaska Northern Railway.

B. L. Johnson studied the auriferous lodes of the north half of Kenai Peninsula.

S. R. Capps studied the geology and gold placer fields of the Yentna district.

H. M. Eakin made a geologic study in the Rampart district.

C. E. Ellsworth continued his studies of the water supply of the Fairbanks district.

1912. C. E. Ellsworth again made measurements of stream flow in the Fairbanks district.

P. S. Smith examined the auriferous gold lodes of the Fairbanks district.

1913. F. H. Moffit and J. E. Pogue made a geologic reconnaissance in the Broad Pass region.

J. W. Bagley made a topographic survey in the Broad Pass region.

C. E. Giffin made a topographic reconnaissance from Passage Canal to Turnagain Arm and later mapped the Willow Creek district in detail.

S. R. Capps studied the gold lodes of the Willow Creek district and mapped the geology of that district.

C. E. Ellsworth and R. W. Davenport investigated the water supplies of the eastern part of Kenai Peninsula.

B. L. Johnson studied the geology and mineral deposits of Port Wells and Latouche Island.

R. H. Sargent made detailed topographic surveys in Matanuska Valley.

G. C. Martin, J. B. Mertie, and R. M. Overbeck made a detailed study of the Matanuska coal field.

Theodore Chapin studied the gold lodes of the Fairbanks district.

1914. B. L. Johnson made a brief study of the Port Wells district.

J. W. Bagley made a reconnaissance topographic map of the Nelchina-Susitna region, and Theodore Chapin studied the geology of the same area.

A. H. Brooks studied the geology in the neighborhood of Fairbanks.

H. M. Eakin investigated mining developments at Hot Springs and Fairbanks.

1915. J. W. Bagley did reconnaissance topographic mapping in the Turnagain-Knik district and in the western Talkeetna Mountains.

S. R. Capps did geologic mapping in the Turnagain-Knik district, and investigated the mining developments of the Willow Creek district.

1916. J. W. Bagley made a topographic reconnaissance in the northwestern part of Prince William Sound.

B. L. Johnson studied the geology and mineral resources of Latouche and Knight Islands.

G. C. Martin, A. G. Maddren, and R. M. Overbeck made a detailed study of part of the Nenana coal field.

C. E. Giffin surveyed the Kantishna region topographically.

S. R. Capps studied the geology and mineral resources of the Kantishna region.

J. B. Mertie examined the gold placer deposits and studied the geology of the Tolovana district.

1917. J. B. Mertie studied the progress of mining in the Yentna district.

S. R. Capps studied the geology and mineral resources of the upper Chulitna district and the Western Talkeetna Mountains, and made a short visit to the Willow Creek district.

Theodore Chapin studied the mineral resources of the railroad region.

1918. D. C. Witherspoon carried on topographic mapping in an area extending northward from the Talkeetna River to the upper Chulitna region.

Theodore Chapin studied the mining developments in the Matanuska and Willow Creek districts.

1919. A. H. Brooks studied conditions in the railroad region.

S. R. Capps and S. H. Cathcart made a reconnaissance study of the geology of the eastern part of Mount McKinley National Park, and T. P. Pendleton did topographic mapping in the same area.

J. R. Eakin and R. M. Overbeck did topographic and geologic mapping in the area between the Talkeetna River and Broad Pass.

Theodore Chapin continued his studies of the mineral resources of the Susitna Basin.

1920. J. R. Eakin did topographic mapping in the vicinity of Broad Pass.
P. S. Smith made geologic investigations in the vicinity of Fairbanks and in the Salcha-Goodpaster districts.
1921. A. H. Brooks visited the Kantishna and Willow Creek districts.
J. B. Mertie, Jr., continued geologic mapping of the Fairbanks quadrangle.
1922. P. S. Smith made special investigations in areas adjacent to the Alaska Railroad.
J. B. Mertie, Jr., continued geologic studies in the Fairbanks quadrangle.
1923. S. R. Capps studied the metal deposits of the railroad region.
1924. S. R. Capps and K. K. Landes did detailed geologic mapping in the upper Matanuska Valley.
1925. P. S. Smith, together with B. D. Stewart and J. J. Corey, made studies of the Matanuska and Nenana coal fields.
K. K. Landes made a geologic reconnaissance of the area between the Knik and Matanuska Rivers.
1926. P. S. Smith studied the mineral resources of the region.
1927. P. S. Smith made geologic studies in the Alaska Railroad region.
1928. P. S. Smith collected information on mining activities in the region.
1929. P. S. Smith continued geologic investigations in the Matanuska and Fairbanks areas.
1930. P. S. Smith examined mining camps between Seward and the Willow Creek district.
F. H. Moffit examined metalliferous deposits in the Kantishna and Bonnifield regions.
S. R. Capps made geologic studies in the headward tributaries of the Susitna and Nenana Rivers.
1931. As a result of an appropriation made by Congress to the Alaska Railroad to stimulate mining in the railroad region, the Geological Survey was called upon to select projects and personnel and to administer the work. W. C. Mendenhall, P. S. Smith, and D. F. Hewett gave advice and supervision in the field. The field conduct of the following parties was under the direct oversight of S. R. Capps:
R. W. Richards and G. A. Waring made detailed geologic studies of the Anthracite Ridge coal field of the upper Matanuska Valley. L. O. Newsome did detailed topographic surveying.
J. M. Hill studied the gold lodes of the Fairbanks district.
J. C. Ray studied the gold lodes of the Willow Creek district.
Ralph Tuck studied the gold lodes of the Moose Pass-Hope area.
W. C. Carson and C. F. Park made detailed topographic and geologic investigations in the Girdwood district.
C. P. Ross did detailed geologic and topographic work in the Valdez Creek and West Fork of the Chulitna districts.
F. G. Wells and S. C. Cain did detailed geologic and topographic mapping in the Kantishna district.
S. N. Stoner and J. C. Reed did detailed topographic and geologic mapping in the Mount Eielson area.
G. A. Waring studied nonmetalliferous deposits along the railroad belt.
1932. P. S. Smith continued mineral investigations in the region.
Ralph Tuck and C. P. McKinley did reconnaissance geologic and topographic mapping in the district east of Curry.
G. A. Waring supervised core drilling in the Anthracite Ridge and Moose Creek coal fields.

1933. P. S. Smith studied the mining developments in the area.
S. R. Capps and Ralph Tuck studied the gold veins of the Willow Creek-Kashiwitna district.

1934. P. S. Smith examined mining developments in the region.
Ralph Tuck made detailed topographic and geologic studies of the Eska coal field.

1935. P. S. Smith studied mining conditions in the region.
Ralph Tuck continued geologic work in the Eska coal field.

1936. P. S. Smith studied mining conditions in the railroad area.
S. R. Capps and Ralph Tuck surveyed mining developments in the railroad region.

The following bibliography lists the more important publications that treat of this region, especially those that have contributed largely to the knowledge of its geography and geology. The list is admittedly incomplete, and no attempt has been made to include articles from the daily press or more than one or two from the periodicals. As regards the publications of the Geological Survey, where preliminary reports have been superseded by more complete final reports, only the latter have been included. In addition to the publications listed below there has been issued each year a report on current mining activities and production for the Territory as a whole, under the title "Mineral resources of Alaska." The arrangement here given follows roughly the chronologic order in which the publications appeared or the order in which the investigations upon which the reports are based were made.

Steller, G. W., Reise von Kamtschatka nach Amerika mit dem Commandeur-Captain Bering, St. Petersburg, 1793.

Cook, James, A voyage to the Pacific Ocean, 2d ed., vol. 2, pp. 386–402, London, 1785.

Dixon, George, and Portlock, Nathaniel, A voyage round the world, but more particularly to the northwest coast of America, London, 1789.

Vancouver, George, Vancouver's voyage, vol. 5, pp. 147-275, London, 1798.

Vancouver, George, Voyages of discovery, vol. 5, pp. 210–211, London, 1801.

Grewingk, Constantin, Beiträge zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nordwest Küste Amerikas, St. Petersburg, 1850.

Tebenkoff, Michael, Hydrographic atlas and observations, p. 17, St. Petersburg, 1848–52.

Tebenkoff, Michael, Hydrographic notes to the northwest shores of America, the Aleutian Island, and some other places of the north Pacific Ocean, St. Petersburg, 1852.

Dall, W. H., Remarks upon the natural history of Alaska: Boston Soc. Nat. History Proc., vol. 12, p. 144, November 4, 1868.

Schwatka, Frederick, A military reconnaissance in Alaska: 48th Cong., 2d sess., S. Ex. Doc. 2, 1885.

Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk Rivers, in the Territory of Alaska, 172 pp., 1887.

Petrof, Ivan, Alaska; its population, industries, and resources: Tenth Census, 1880, vol. 8, 1884.

Porter, R. P., Report on population and resources of Alaska: Eleventh Census, 1890, Washington, 1893.

Dickey, W. A., Discoveries in Alaska, New York Sun, January 24, 1897.

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

Eldridge, G. H., A reconnaissance in the Susitna Basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 1–29, 1900.

Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 265–340, 1900.

Brooks, A. H., A reconnaissance in the Tanana and White River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 425–494, 1900.

Wells, E. H., Up and down the Yukon, a compilation of narratives of explorations in Alaska, Washington, 1900.

Herron, J. S., Explorations in Alaska, 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.

Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

Brooks, A. H. Geography and Geology of Alaska, with a section on climate by Cleveland Abbe, Jr., U. S. Geol. Survey Prof. Paper 45, 1906.

Paige, Sidney, and Knopf, A., Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, 71 pp., 1907.

Dunn, Robert, The shameless diary of an explorer, New York, Outing Publishing Co., 1908.

Cook, F. A., To the top of the continent, New York, Doubleday, Page & Co., 1908.

Thompson, W. E., First account of the conquering of Mount McKinley: New York Times, June 5, 1910.

Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, 89 pp., 1910.

Moffit, F. H., Headwater regions of Gulkana and Susitna Rivers, Alaska: U. S. Geol. Survey Bull. 498, 82 pp., 1912.

Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 98 pp., 1912.

Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 64 pp., 1912.

Browne, Belmore, The conquest of Mount McKinley, New York, G. P. Putnam's Sons, 1913.

Grant, U. S., and Higgins, D. F., Coastal glaciers of Prince William Sound and Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 526, 75 pp., 1913.

Prindle, L. M., Katz, F. J., and Smith, P. S., The Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, 220 pp., 1913.

Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, 75 pp., 1913.

Railway routes in Alaska—Message from the President of the United States: 62d Cong., 3d sess., H. Doc. 1346, pts. 1 and 2, 1913.

Stuck, Hudson, The ascent of Denali, New York, Charles Scribner's Sons, 1914.

Johnson, B. L., The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 195–236, 1914.

Moffit, F. H., and Pogue, J. E., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, 80 pp., 1915.

Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 86 pp., 1915.

Ellsworth, C. E., and Davenport, R. W., Surface water supply of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Water-Supply Paper 342, 343 pp., 1915.

Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, 243 pp., 1915.

Reports of the Alaska Engineering Commission for the period from March 12, 1914, to December 31, 1915: 64th Cong., 1st sess. H. Doc. 610, pts. 1 and 2, 1916.

Capps, S. R., The Turnagain-Knik region: U. S. Geol. Survey Bull. 642, pp. 147–194, 1916.

Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, pp. 193–220, 1917.

Johnson, B. L., Mining on Prince William Sound: U. S. Geol. Survey Bull. 662, pp. 183–192, 1917.

Maddren, A. G., Gold placers near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 363–402, 1917.

Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351–362, 1917.

Mertie, J. B., Jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 403–424, 1917.

Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, 64 pp., 1917.

Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 116 pp., 1919.

Johnson, B. L., Mining on Prince William Sound: U. S. Geol. Survey Bull. 692, pp. 143–152, 1919.

Capps, S. R., Gold lode mining in the Willow Creek district: U. S. Geol. Survey Bull. 692, pp. 177–186, 1919.

Capps, S. R., The western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 187–206, 1919.

Capps, S. R., The upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 207–232, 1919.

Mertie, J. B. Jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 233–264, 1919.

Chapin, Theodore, Mining in the Fairbanks district: U. S. Geol. Survey Bull. 692, pp. 321–327, 1919.

Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

Capps, S. R., Geology and mineral resources of the region traversed by the Alaska Railroad: U. S. Geol. Survey Bull. 755, pp. 73–150, 1924.

Capps, S. R., An early Tertiary placer deposit in the Yentna district: U. S. Geol. Survey Bull. 773, pp. 53–61, 1925.

Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, 493 pp., 1926.

Capps, S. R., and Short, M. N., A ruby silver prospect in Alaska: U. S. Geol. Survey Bull. 783, pp. 89–95, 1926.

Capps, S. R., Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 791, 92 pp., 1927.

Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 219–300, 1930.

Moffit, F. H., The Kantishna district: U. S. Geol. Survey Bull. 836, pp. 301–338, 1930.

Richards, R. W., and Waring, G. A., Progress of surveys in the Anthracite Ridge district: U. S. Geol. Survey Bull. 849, pp. 1–27, 1933.

Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849, pp. 29–163, 1933.

Ray, J. C., The Willow Creek gold lode district: U. S. Geol. Survey Bull. 849, pp. 165–229, 1933.

Reed, J. C., The Mount Eielson district: U. S. Geol. Survey Bull. 849, pp. 231–287, 1933.

Ross, C. P., Mineral deposits near the West Fork of the Chulitna River: U. S. Geol. Survey Bull. 849, pp. 289–333, 1933.

Wells, F. G., Lode deposits of Eureka and vicinity, Kantishna district: U. S. Geol. Survey Bull. 849, pp. 335–379, 1933.

Park, C. F., Jr., The Girdwood district: U. S. Geol. Survey Bull. 849, pp. 381–424, 1933.

Ross, C. P., The Valdez Creek mining district: U. S. Geol. Survey Bull. 849, pp. 425–468, 1933.

Tuck, Ralph, The Moose Pass-Hope district, Kenai Peninsula: U. S. Geol. Survey Bull. 849, pp. 469–530, 1933.

Tuck, Ralph, The Curry district: U. S. Geol. Survey Bull. 857, pp. 99–140, 1934.

Waring, G. A., Core drilling for coal in the Moose Creek area: U. S. Geol. Survey Bull. 857, pp. 155–173, 1934.

Capps, S. R., and Tuck, Ralph, The Willow-Kashwitna district: U. S. Geol. Survey Bull. 864, pp. 95–113, 1935.

Waring, G. A., Geology of the Anthracite Ridge coal district, Alaska: U. S. Geol. Survey Bull. 861, 57 pp., 1936.

PRESENT REPORT

With the completion of the Alaska Railroad, in 1923, year-round communication was established between the open port of Seward, on the Pacific coast, and the mining regions of interior Alaska, and it became possible to develop mineral resources of parts of the Territory that without this cheaper and more reliable transportation could not have been profitably exploited. The coal fields of the Matanuska Valley began to supply fuel for the railroad and for domestic and other purposes south of Broad Pass, and the cheap fuel from the Nenana coal field made possible the development of power for mining the lower-grade gravel of the Fairbanks district. Mining of lode gold in the Girdwood, Willow Creek, and Fairbanks districts was stimulated; the placer operators in the Moose Pass, Yentna, Valdez Creek, Bonnifield, and Kantishna districts were able to obtain supplies more cheaply, and the many placer camps in the Tanana and Yukon Basins were benefited to a greater or less degree. The value of year-round rail transportation to all of this region cannot be measured directly by a comparison of the gold production before and after the railroad was completed, for by 1923 most of the richer placer deposits had already been mined out, and the gold that remained was largely in lower-grade deposits that could not have been mined at all under the old conditions of high freight rates and a short open season. For instance, without cheap coal for power development the large-scale dredging operations of the Fairbanks district would not have been undertaken, and the production of that camp would be this time have shrunken to a small fraction of its present value.

In the 38 years that the United States Geological Survey has been active in Alaska a large number of individual geologists and topographers have worked in the area here under discussion, and their work has resulted in a constantly increasing number of reports and maps that deal with portions of this area. In that time, too, each year has added new facts and permitted new interpretations, so that the later workers, by building on the foundations laid earlier and by extending their observations over wider areas, have been able to correct certain errors of interpretation made in the earlier reports and to reach broader conclusions as to the geologic history of the region. An examination of the list of important publications concerning this region, already given, shows that useful information is contained in at least 78 printed volumes or articles. Of these some are rare and difficult to consult. Others are out of print and can be found only in the larger libraries. Within the last 38 years the Geological Survey alone has published or has in press more than 55 volumes or special articles, most of them illustrated by maps, that discuss parts of this area. It is therefore easy to appreciate the difficulty that confronts the person who wishes to gain a comprehensive idea of the geology, geography, and resources of this region, for to find the facts he desires he must search through a large number of printed pages.

The present report has been prepared for the use of those who wish to learn the outstanding facts concerning the geography, geology, and mineral resources of the area without too great an expenditure of time. It is not based on special field work done for this purpose only but is admittedly a compilation of information already published or in manuscript. It so happens that the writer has spent 13 field seasons in this part of Alaska and so has first-hand familiarity with much of it. For the interpretation of the facts in those areas concerning which he has published his conclusions he alone is responsible. For other areas he quotes or summarizes from the reports of the many Federal geologists who have worked in this field. No attempt is here made to discuss in detail the sequence or structure of the rock formations in various parts of this region. For such discussions the reader is referred to the original publications, listed above, for the limitations of space alone would prevent such treatment here. The writer has found it necessary in the interest of uniformity for the geologic maps presented herewith (pls. 1–3) to use wide discretion in correlating the rock formations throughout the region. Frequently he found it necessary to group several subdivisions that had been made by one author, in order to correlate them with a single rock group elsewhere. All the age determinations that had been made by the original authors are here accepted except where earlier determinations have been superseded by later ones or where the authors themselves expressed a willingness to have certain formations grouped in a way differing from their published interpretations. For the material given in this report the writer has drawn largely upon all the earlier publications and has felt privileged either to use that material as direct quotations, in which reference is made to the source of information, or, where the original wording was not suited to the needs of this report, to rephrase sentences or paragraphs or to combine facts gathered from various sources, without making specific acknowledgment. Special emphasis has been placed upon the geography, mineral resources, and broad geologic features of the region, for the discussion of the more highly specialized phases of petrography, paleontology, the origin of the ore deposits, and detailed structural geology belong properly in the more detailed reports that treat of smaller areas.

GEOGRAPHY

GEOGRAPHIC PROVINCES

The area traversed by the Alaska Railroad is a north-south strip that crosses several of the distinct geographic provinces that occupy south-central Alaska. The Pacific coast margin of North America is bordered by a broad belt of mountainous country, comprising many more or less closely connected ranges, that has become known as the Pacific mountain system. As this great northwestward-trending mountain system crosses the east boundary of Alaska at the 141st meridian its trend becomes more nearly east and west, and it divides into two rather distinct ranges—the Chugach Mountains, the coastal division, and the Alaska Range, swinging farther inland, both ranges merging into and joining the intermediate mass of the Wrangell Mountains. West of the Wrangell Mountains the two ranges are sharply separated by the upper basin of the Copper River, but at the 148th meridian the intervening space is occupied by the Talkeetna Mountains and their northward extension. Thence westward the axis of each range is deflected in a great crescentic arc to the southwest, the Chugach Range being continued by the Kenai Mountains and the mountains of Kodiak Island, and the Alaska Range swinging southwestward past Mount McKinley to merge more or less closely into the Aleutian Range. The Kenai, Chugach, and Talkeetna Mountains are separated on the west from the Aleutian and Alaska Ranges by the Cook Inlet depression and the basins of the Susitna and Chulitna Rivers. North of the Alaska

Range the broad lowland of the Tanana Basin intervenes between that range and the Yukon-Tanana upland. Geographically, therefore, the region here discussed comprises seven natural subdivisions, which are described below.

Chugach-Kenai Mountains.—The north shore of the Pacific Ocean from the 141st meridian to Cook Inlet is bordered by a broad belt of rugged mountains that rise abruptly from the shore or are separated from it only by a narrow coastal plain. This range is called the Chugach Mountains from Mount St. Elias west to Turnagain Arm. South of the depression formed by Turnagain Arm and Passage Canal the term "Kenai Mountains" is used. Geologically and structurally, however, these two mountain masses belong together and they have been given separate names only because in their erosion history two glacial fiords and a relatively low pass between have formed a depression across the mountain range. East of the Copper River the Chugach Mountains trend a little north of west and have a width from north to south of about 100 miles. In the region of the western portion of Prince William Sound, which falls within the area here considered, the sound itself and its long fiorded arms penetrate deeply into the mountains, so that from the head of College Fiord it is only 40 miles north across the range to the Matanuska River. The mountainous islands that form the outer border of the sound, however, properly belong to the Chugach Mountains, and if they are so included the width of the range there is as great as it is farther east. Prince William Sound lies in the convexity formed by the range as its trend changes in a great crescentic curve from north of west through west to southwest. The Kenai Mountains are structurally continuous with the Chugach Mountains, trend southwest, and across the mouth of Cook Inlet are continued by the mountains of Afognak and Kodiak Islands.

Throughout their extent the Chugach-Kenai Mountains are approximately alike in topographic form. They consist of masses of rugged peaks of somber colors, rising generally to altitudes of 4,000 to 7,000 feet above sea level, but still higher in a few places, such as the head of College Fiord, where several peaks rise above 10,000 feet and the highest, Mount Marcus Baker, reaches 13,250 feet. They are composed dominantly of sedimentary materials, much folded and deformed. Their surface forms are conspicuously due to severe glacial erosion, although the glaciers doubtless only remodeled previously existing stream valleys. All the higher portions of these mountains nourish glaciers, many of which are vigorous and of large size. There are several large centers of ice accumulation, notably on the south and east sides of Kenai Peninsula and in the area north of Prince William Sound, from which distributary valley glaciers push out radially. In Prince William Sound and along the south coast of

Kenai Peninsula the scenic beauty of the region is enhanced by the many great ice tongues that push down into the sea in fiords whose steep walls and bordering ridges rise abruptly from the water. The mountains are peculiar in that they have few large, systematically developed river systems, the drainage in those areas that are not ice-filled flowing through relatively small and irregular stream valleys. The coast line is deeply embayed and sinuous, and in Prince William Sound there are scattered many mountainous islands whose topography is like that of the mainland. The railroad route from Seward starts at the head of Resurrection Bay, a beautiful fiord, runs northward through mountain valleys that follow the trend of the Kenai Mountains, and at Turnagain Arm, another great fiord, turns westward along the flank of the Chugach Mountains, which it follows to the Matanuska River. The Eska branch of the railroad lies along the boundary between the Chugach and the Talkeetna Mountains.

Talkeetna Mountains.—The Talkeetna Mountains form a great, rudely circular mountain mass that is bordered on its west side by the lower Susitna Valley, on the south by the Matanuska River, and on the east by the Copper River Basin and that fades out gradually northward beyond the westward-flowing portion of the Susitna River. Although these mountains border closely against the Chugach Range on the south and are separated from it only by the valley of the Matanuska River, they nevertheless are sharply in contrast to it in topography, in structure, and in the rocks of which they are composed and form a distinctive intermediate range between the coastal mountains and the Alaska Range. The rocks are dominantly of igneous origin and include great areas of granitic materials and lava flows of several ages, though in the east half of the mountains they comprise a considerable area of Mesozoic sediments. The present relief of the range is the result of a great domal uplift, rather than of close folding and faulting, and many of the formations are but little deformed. The drainage lines have a general radial arrangement, but most of the streams are tributary to the Susitna River, which, with its tributaries, borders the mountain mass on the east, north, and west sides. A small area drains southeastward to the Copper River, and most of the waters from the south slope find their way to the Matanuska River. The mountain mass is divided along a north-south line into two nearly equal portions by the northward-flowing headwaters of the Talkeetna River and by the Chickaloon River, a tributary of the Matanuska from the north. The valleys of these two streams form the first available route west of the Susitna Valley by which the range can be crossed from south to north.

The Talkeetna Mountains as a whole comprise a rugged area, for the hard rocks there tend to yield sharp, sawtoothed ridges and peaks, and the dissection of the range by streams and glaciers has produced deep valleys and high interstream ridges. Only a few of the larger stream valleys offer feasible routes of approach to the center of the range, and it is not easy to get from one valley to another, for passes across the ridges are few and difficult. The mountain crests average between 5,000 and 7,000 feet in altitude, although there is an area between the heads of the Sheep and Talkeetna Rivers where many peaks exceed 8,000 feet and one approaches 9,000 feet. These high parts of the range nourish many valley glaciers. All the important streams that drain from the center of the mountain mass are glacier-fed, and their silty waters flow over wide gravel bars of glacial outwash. The longest glacier, at the head of the Sheep River, has a length of about 12 miles.

Cook Inlet-Susitna lowland.—Cook Inlet is a long, narrow embayment in the south coast of Alaska, bordered on the east by Kenai Peninsula and on the west by the south end of the Alaska Range. Near its mouth high mountains rise boldly from the water's edge. North of Kachemak Bay the inlet is bordered by shore cliffs a few hundred feet high, the cliffs forming the wave-cut edge of a rolling lowland that extends eastward 30 to 40 miles to the base of the Kenai Mountains. This lowland is underlain, at least in part, by coal-bearing Tertiary beds that form conspicuous exposures along the shore. The surface is covered by glacial deposits and by stream and terrace gravel. Across the waters of the inlet similar lowlands, or piedmont plains, extend westward to the base of the Alaska Range. Northward they are found east and north of Point Campbell, between Turnagain and Knik Arms, and north of Knik Arm and the head of the Inlet, where they merge into the Susitna lowland.

All these lowlands have a common origin. They are at least partly floored by Tertiary sedimentary rocks and have been overridden by a great glacier that descended Susitna Valley and Cook Inlet and was fed by many glaciers from the mountains to the east and west. Their topography is due to the erosive action of these ice fields, the glacially modeled surface having later been modified by deposits of moraine and of gravel from the glacial streams. Upper Cook Inlet is shallow, and a filling of about 200 feet would completely exclude the ocean from that part above Kachemak Bay, and the lowlands east and west of the upper inlet would then be continuous with those of the Susitna Valley. Such a filling is now in progress. The deltas of the Susitna, Matanuska, and Knik Rivers and the head of Turnagain Arm are rapidly encroaching upon the area of tidewater, and the wide expanses of mud flats, visible at low tide in the upper inlet testify to the great volume of detritus that is being carried down by the glacial streams and deposited in salt water.

The broad Susitna lowland, the landward continuation of the Cook Inlet depression, is a structural basin comprising the lowland basins of the Susitna River and its tributaries and of several other rivers that flow directly into the head of the inlet. It is bordered on the south by the waters of Cook Inlet, on the east by the Chugach and Talkeetna Mountains, and on the southwest and west by the Alaska Range. The main basin so bounded has a length from north to south of about 100 miles and a width of more than 50 miles in the latitude of the Kashwitna River, but narrows to the north. The entire Cook Inlet-Susitna lowland, extending from the mouth of Kachemak Bay into the Chulitna Valley, is over 200 miles long and averages about 60 miles wide, although within that area lie the waters of upper Cook Inlet and some mountains that project above the level of the rolling plain. From it branching arms project far into the surrounding mountains up the larger tributary valleys. The Susitna River flows east of the center of the basin, its course lying parallel to the west base of the Talkeetna Mountains at a distance of about 8 miles. The river itself occupies a flood plain that is from 1 to 6 or 8 miles wide, and the bordering lowland is surfaced with glacial deposits and stream gravel and is dotted with a great number of lakes. From the main river toward the bordering mountains the relief of the lowland increases, the tributary streams are more deeply entrenched, and the rolling topography of the lowland gives way to the steeper slopes of the foothills and the mountains.

Copper-Susitna lowland.—A part of the eastern border of the area here considered falls within the drainage basin of the Copper River. This region comprises a great rudely circular basin entirely surrounded by high mountains, including the Talkeetna Mountains on the west, the Alaska Range on the north, the Wrangell Mountains on the east, and the Chugach Range on the south. The term Copper River Plateau has frequently been used to designate this area, but, as has been pointed out,[1] the area stands below the bordering mountains, and therefore is a depression in which the streams have entrenched themselves. It is continuous to the northwest with the headward basin of the Susitna River, the whole depression being floored with a thick filling of glacial moraines and gravel through which isolated mountains of hard rock project. The divide between the tributaries of the Copper and Susitna Rivers is in many places low and inconspicuous, and it is likely that at a time not very remote geologically the entire upper basin of the Copper River drained to the northwest and discharged its waters to Cook Inlet through the Susitna Valley.

Alaska Range.—The Alaska Range comprises a great crescentic belt of rugged mountains that sweeps northward from the base of

[1] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, p. 48, 1918.

the Alaska Peninsula to Mount McKinley, extends thence northeast and east to the Delta River, and is continued in a southeasterly direction by the Nutzotin Mountains into Canada. As thus defined the range has a length of nearly 600 miles, is 50 to 80 miles in average width, and forms one of the major ranges of North America. Its south end merges to some extent into the Aleutian Mountains, thus forming a continuous mountain belt reaching from the Canada-Alaska boundary west and southwest throughout the Alaska Peninsula. In a general way this range forms the divide between streams that flow south by the Susitna and Copper Rivers to the Pacific Ocean and those that drain west by way of the Yukon and Kuskokwim Rivers to Bering Sea, although the tributaries of a few of the northward-flowing streams rise on the south flank of the mountain mass. Near the south end of the range, at the head of the Skwentna River, the peaks of the divide are comparatively low, ranging from 5,000 to 9,000 feet in altitude, and the crest is broken by several passes at a height of about 3,000 feet. Northward the mountain range becomes higher and more rugged, culminating at the northwest convexity of the arc in the two great peaks, Mount McKinley and Mount Foraker, 20,300 and 17,000 feet high, respectively. East of those mountains the divide peaks generally reach altitudes between 7,000 and 9,000 feet. It is an interesting fact that in this portion of the range, which contains North America's highest mountain, there are only two other peaks, Mount Foraker and Mount Hunter, that exceed 14,900 feet in altitude, and few others that reach 12,000 feet.

From the passes at the head of the Skwentna River to Mount McKinley the inland front of the range rises abruptly from the piedmont plain without foothills or outlying ridges. East of Mount McKinley, however, the main range as far east as the Delta River is separated from the lowland by one or two minor chains of mountains or foothills. The Kantishna Hills are the most conspicuous and massive of these minor ranges. The foothill belts are separated from the summit ridges of the range and from one another by a series of depressions and low passes, or by broad basins floored with Tertiary sedimentary rocks and Recent gravel that represent the remnants of an ancient drainage system. At present these low basins and passes are occupied only by minor streams, the trunk streams flowing northward from the crest of the range and crossing the basins to plunge into deep rock canyons across the belts of foothills. As an example, the Teklanika River, the first northward-flowing stream west of the Nenana River, leaves the high range to cross successively three broad basins separated from one another by ridges through which the stream has cut canyons from 1,200 to 2,000 feet deep. By following any one of these basins eastward to the Nenana River the Teklanika could have found an outlet hundreds or thousands of feet lower than by crossing the intervening ridges. It is evident that the present courses of these northward-flowing streams were established either before the transverse ridges had been uplifted, or more likely at a time when those ridges were covered by Tertiary sediments, and that the cross canyons were cut down during the removal of the Tertiary deposits, without displacing the plan of the drainage.

The Nenana River crosses the range north of Broad Pass, thus affording the first low pass across the mountains north of the Yentna Basin. East of Broad Pass the mountains are rugged, with altitudes of 5,000 to 9,000 feet, increasing to nearly 14,000 feet at Mount Hayes, beyond which they are again broken by a low pass through which the Delta River flows. Beyond the Delta the range terminates in the Nutzotin Mountains.

In that portion of the range between the head of the Skwentna River and Mount McKinley much the greater part of the mountain mass lies on the Susitna side of the divide. The asymmetric position of the divide has had a large effect upon the development of the great glaciers that now fill the mountain valleys on the southeast slope. The moist Pacific winds in blowing up the Cook Inlet-Susitna depression are chilled upon their passage over the surrounding mountains and drop their moisture as snow. The southeast slope offers great catchment basins for this snow, and valley glaciers of great size are formed there. These ice streams average much larger than those that are found on the northwest slope, where the catchment basins are smaller and the snowfall lighter. East of Broad Pass, in the high mountains surrounding Mount Hayes, the glaciers on the coastal side of the mountains are larger than those on the north, although the divide is in about the center of the mountain belt. The glaciers of the south slope are in that area favored only by a greater snowfall.

Tanana-Kuskokwim lowland.—The Alaska Range is bordered on the west and north by a broad, structural lowland basin that is continuous from Bering Sea by way of the Kuskokwim Valley northeastward across an almost imperceptible divide to the Tanana Valley and thence eastward across the Alaska-Canada boundary to the upper Yukon Basin. This lowland ranges in width from 30 to 60 miles, has a gentle slope away from the range, and is broken only by a few isolated hills that rise above its general level. It is floored by unconsolidated materials, prevailingly gravel, that have been supplied by the erosion of the Alaska Range. Beneath the gravel there are probably extensive Tertiary deposits.

In the upper Kuskokwim Basin the mountain edge of the lowland rises in a piedmont plateau to altitudes of 2,500 to 3,000 feet, where it abuts against the steep mountain front. This plateau slopes away toward the Kuskokwim with a grade that locally exceeds 100 feet to the mile and is dissected by the streams that cross it. In the Tanana Basin the piedmont plateau is less evident, the gravel plain sloping northward from the base of the foothills, at an altitude of about 1,000 feet, to the Tanana River, with an average gradient of 10 or 12 feet to the mile or less, and the transverse streams flowing in shallow valleys at the level of the plain. Only the larger streams maintain well-defined channels across the lowland, for the smaller tributaries sink into the gravel to emerge again as sluggish meandering creeks that drain the flat basin.

The lowland surface is flecked with patches of timber, open marshes, and lakes and is difficult to cross in summer. In the area here considered the Tanana River hugs closely the north border of the lowland, for the northward-flowing streams, many of which are glacier-fed, carry large quantities of gravel and silt and so have graded the lowland up with their detritus. The less vigorous streams flowing south from the Yukon-Tanana upland normally carry clear water and have thus been at a disadvantage as compared with the heavily loaded streams from the south. As a result, the valley axis of the Tanana has been shifted northward and now follows closely the sinuous line formed by the base of the bordering hills. It also seems likely that the actual level of the Tanana has been raised by this process, and this may account, in part at least, for the depth to bedrock in many of its tributary streams from the north.

Yukon-Tanana upland.—That part of the Yukon-Tanana upland that lies within the area here considered consists of smoothed and rounded ridges having a northeasterly trend, that rise from flat lowlands by which the separate ridges are entirely or partly surrounded. The lowland is that of the Tanana River and its sluggish northern tributaries, and its timbered and marshy surface has an altitude between 300 and 600 feet. Through this expanse of flat alluvial deposits the hard rock ridges project as islands or peninsulas with sinuous outlines. The crests of the ridges have altitudes between 1,000 and 3,000 feet, although farther north certain peaks and domes project above the level of the upland surface to heights of nearly 5,000 feet. This area falls within the limits of the Yukon Plateau. The topography is mainly that developed in a region of highly folded and metamorphosed rocks by the agencies of stream erosion and deposition, glaciers having existed only as small ice tongues around the higher domes. There is no evidence of even local glaciation in the area here discussed. The topography of the upland north of the Tanana River is therefore in sharp contrast to that of the entire region south of the Tanana lowland, for there extensive glaciers have more than once been developed and have been the controlling factor in producing the present topographic forms. North of the Tanana long-continued and uninterrupted stream erosion, influenced by the structure of the underlying rocks, has developed maturely dissected ridges and broad valleys that lie parallel to the prevailing trend of the bedrock. The surface is generally covered by a thick mantle of muck, soil, humus, and products of rock disintegration, and rock outcrops below the ridge crests are uncommon. The main stream valleys have wide floors and gentle gradients, and there is generally a thick filling of alluvium between the present stream beds and the underlying bedrock.

CLIMATE

The climate of the region here described varies greatly from one district to another, the temperature and precipitation at a particular locality being determined not alone by latitude but by the geographic surroundings. For example, two localities on the south coast of Kenai Peninsula and only a few miles apart may show striking differences in the amount of rainfall and in the mean annual temperature, for one may lie on the outer coast line and have heavy rainfall and a climate moderated by the waters of the Japan current, and the other may be at the head of a long fiord and have the severe climate and more moderate rainfall characteristic of the Kenai Mountains at a distance from the coast. Weather records kept for a period of years at any place are highly valuable as showing the average climate for that locality, but caution should be used in accepting such records as indicating the climate of other places, even though not far distant, unless the geographic conditions are known to be similar. Weather records have been kept for several years at a number of localities along the railroad route, but at a distance from the railroad this region between Cook Inlet and the Tanana River has few permanent residents, and records of the climate are not available. The following tables compiled from the records of the United States Weather Bureau, summarize such weather records as are available for this region and its immediate surroundings.

Mean temperature in Alaska Railroad region (°F.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Seward	21.4	26.6	31.0	37.3	44.6	50.8	55.3	53.9	48.5	39.7	30.9	24.7	38.7
Anchorage	10.1	17.4	23.4	34.3	44.7	53.0	56.8	55.4	53.6	35.7	22.0	12.5	34.9
Matanuska	11.9	17.5	23.7	35.4	46.3	55.0	57.5	55.6	47.2	36.1	22.0	12.4	35.5
Talkeetna	7.3	15.9	20.9	33.4	45.1	54.4	57.8	55.0	46.1	34.2	20.6	8.8	33.3
McKinley Park	1.7	4.4	12.0	25.5	41.5	52.2	54.7	51.8	41.3	27.0	11.8	2.6	27.2
Nenana	−11.4	−1.5	10.0	26.0	45.5	57.2	61.0	57.0	44.1	26.1	4.7	−8.7	25.8
Fairbanks	−8.3	.9	10.7	28.4	46.5	57.6	59.7	55.6	44.3	27.0	5.9	−37.0	27.1

Average precipitation in Alaska Railroad region (inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Seward	3.87	4.57	3.38	4.07	3.00	2.35	2.78	6.15	9.39	10.78	7.45	6.41	64.19
Anchorage	.94	.74	.52	.37	.42	.55	1.75	2.66	2.78	1.84	.97	.92	14.46
Matanuska	.88	.84	.64	.45	.69	1.09	1.88	2.78	2.70	1.73	.91	1.02	15.61
Talkeetna	1.85	2.54	2.25	1.06	.77	1.58	3.60	4.88	4.81	3.88	1.87	1.65	30.74
McKinley Park	.62	.67	.41	.61	1.10	2.09	2.05	2.54	1.71	.77	.46	.66	13.69
Nenana	.49	.64	.71	.29	.60	1.48	2.74	2.14	1.03	.81	.47	.53	11.93
Fairbanks	.86	.63	.44	.25	.64	1.40	1.93	2.13	1.75	.67	.49	.52	11.71

Highest recorded temperature in Alaska Railroad region (°F.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Highest
Seward	48	55	52	72	77	84	88	85	84	65	58	53	88
Anchorage	49	55	56	60	71	92	81	82	73	63	62	52	92
Matanuska	47	59	54	63	76	84	83	83	69	69	57	53	84
Talkeetna	45	48	55	60	79	88	90	88	71	68	52	41	90
McKinley Park	47	48	51	60	70	89	85	83	75	69	56	47	89
Nenana	38	46	52	60	81	87	94	88	76	64	47	40	94
Fairbanks	40	47	56	65	86	95	99	90	80	67	48	43	99

Lowest recorded temperatures in Alaska Railroad region (°F.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Lowest
Seward	−20	−14	−7	9	22	32	39	33	27	11	3	−12	−20
Anchorage	−33	−31	−19	−15	20	29	34	31	20	−5	−18	−36	−36
Matanuska	−36	−32	−22	−8	22	30	34	32	21	−2	−22	−34	−36
Talkeetna	−48	−33	−28	−23	20	25	31	27	18	−10	−30	−41	−48
McKinley Park	−52	−47	−34	−33	−4	20	30	24	2	−15	−32	−54	−54
Nenana	−63	−60	−50	−25	−9	29	37	26	15	−17	−48	−60	−63
Fairbanks	−65	−57	−56	−32	5	28	30	19	11	−21	−54	−59	−65

Although official weather records have been kept at only a few scattered localities, nevertheless certain general statements may be made about the climatic characteristics of the various geographic regions here described. The Pacific coast portion of Kenai Peninsula lies within the influence of the warm ocean currents of the north Pacific, and its climate, like that of all the northwest coast of America, is mild considering the latitude. The summers are cool, and the winters are long but moderate, zero weather being unusual. The rainfall is fairly heavy, being about 64 inches at Seward, but is not so great as in parts of Prince William Sound farther east. The central and northern parts of the peninsula have less rainfall and a wider range of temperature than the coastal areas. The Cook Inlet lowland is less affected by the warm ocean waters than the outer coast and has more severe winters and a smaller rainfall. The mean annual temperature ranges from 34° to 35° and the precipitation from 15 to 30 inches. The climate of Matanuska Valley and the lowland on both sides of Knik Arm differs both from that of Cook Inlet and from that of the surrounding mountain provinces.

The summers are warmer, and the precipitation is small, averaging only about 16 inches. The highest recorded temperature is 84° F. and the lowest −36° F.

In the lack of accurate records the Susitna-Chulitna Basin from Cook Inlet to Broad Pass and the bordering slopes of the Alaska Range and the Talkeetna Mountains may be considered to have a similar climate. There the summers are of moderate temperature and have a large number of cloudy days, with gentle rains. The winters are severe, and the snowfall is fairly heavy. The eastern Talkeetna Mountains and the basins of the Copper and upper Susitna Rivers are separated from the coast by high mountains, and the climate is characterized by severe winters, moderate summers, and a light rainfall.

The north slope of the Alaska Range has a markedly different climate from the Susitna slope. In summer the rainfall is light, and there is much pleasant weather, with clear, warm days. The winters are severe, but the snowfall is light. Similar conditions prevail in the Tanana lowland, with an even smaller rainfall. The Yukon-Tanana upland has a somewhat heavier rainfall than the Tanana lowland, though the precipitation is moderate. The summers are mild and the winters cold. The average annual precipitation at Fairbanks is only 11.71 inches, and the mean annual temperature is about 27° F.

VEGETATION

The vegetation of this part of Alaska is largely determined by the climate and local geographic conditions and so varies markedly in different parts of the region. In Kenai Peninsula and the area between Knik and Turnagain Arms the timber line lies at about 2,000 feet, and so in the mountainous regions only the valley floors and lower slopes of the bordering ridges have trees. The most abundant trees are spruce, hemlock, birch, aspen, and poplar. Patches of alders, willows, and dwarf birches grow for some distance above timber line and give way above to grasses. Still higher the slopes are clothed with heather and other low shrubs to about 5,000 feet, above which the surface is bare of vegetation. The Cook Inlet lowland is timbered with groves of the same varieties of trees, interspersed with open grassy or brushy meadows. Grasses for summer forage for livestock can be found throughout Kenai Peninsula except on the rocky coast. Especially good pasturage may be found in the Cook Inlet lowland, where there are wide areas of meadows. Grass is also commonly to be found on the mountain slopes near and above timber line. Native grasses have been cut for hay to a considerable extent around Kachemak Bay and at various localities on the east shore of Cook Inlet, as well as near the towns of Seward, Sunrise, and Hope and on many tide flats around Knik Arm, and these natural meadows have by no means been used to the extent of their possibilities.

The vegetation of the Susitna lowland and the bordering mountain slopes is similar to that of Kenai Peninsula, except for the absence of the hemlock, whose northern range is on Turnagain Arm. The river valley locally supports heavy forests of cottonwood, with many trees reaching a diameter of 4 feet. These trees are largely confined to the flood plain of the river, which also carries extensive spruce groves. The rolling lowland is dotted with open marshes and lakes, between which are patches of timber. Where the drainage is poor, scrubby spruce trees prevail. In better-drained areas the spruce trees reach a size of 2 feet or more and are interspersed with birches. In general the forests have a considerable growth of underbrush, so that trail chopping is necessary.

The characteristic vegetation of the mountain slopes to an altitude of 2,000 to 2,500 feet is a mingled assemblage of spruce and birch trees growing as small groves or scattered trees in widespread meadows of luxuriant grass. Above timber line dense alder thickets alternate with open meadows of grass, brakes, and other plants. The prevailing grass is a variety locally called redtop, which grows in thick stands and in many places sends its seed stalks to a height of 6 feet or more. The aggregate area in the Susitna Valley covered by this grass is very large, as it flourishes above timber line to altitudes of 3,000 feet and over, and many single meadows containing hundreds of acres are free from brush or rocks and could be easily mowed. This grass affords good forage for stock in summer and if cut and properly cured makes hay of a fair quality. If frozen on the stalk, however, it loses its food value and is worthless for winter grazing. The difficulty that has been encountered in much of this region is to get enough clear, dry weather to cure the hay after it is mowed, for the grass is so heavy that it cures slowly, and the average summer has frequent showers.

The vegetation of the parts of the basins of the Copper and Susitna Rivers that lie within the area of this report and east of the Talkeetna Mountains differs somewhat from that of the main Susitna Valley. The lowland, of swampy or poorly drained gravel flats, is covered with a growth of scrubby low spruce trees. In a few valleys the spruce trees grow larger, up to 2½ feet in diameter. Some birch is present, but it is not generally abundant, and alder grows only at scattered localities. Timber line is higher than in the main Susitna Valley, ranging from 2,500 to 3,000 feet. Redtop and bunch grass are both available for horse feed but are not abundant, and it is difficult in many places to find adequate forage for stock.

On the north slope of the Alaska Range the average altitude of timber line is about 2,500 feet, though there are wide areas below that altitude that have little or no timber. The commonest tree is the spruce, which grows as thick groves or as scattered trees in the main valleys within the foothills and throughout the Tanana lowland. The Tanana lowland has large marshy areas which are devoid of trees or in which scrubby spruce or tamarack are scattered. Birch and aspen grow on the well-drained slopes, and some cottonwood is found along the stream courses. Willow and alder bushes grow within the timber and for some distance above timber line. The most valuable forage grasses here, as elsewhere in the region, are redtop and bunch grass, and in places a vetch locally called pea vine is eagerly sought by horses and is highly nutritious.

In the Yukon-Tanana region, in the vicinity of Fairbanks, only the higher ridge tops rise above timber line, which lies at about 2,500 feet. Timber is fairly abundant on the slopes of the large valleys and in places on the valley floors. Spruce is the most abundant, but some poplar and birch are present, and tamarack grows in the poorly drained lowlands. Most of the trees are small, only at favored localities exceeding 2 feet in diameter. A ground covering of mosses and lichens is commonly present in both timbered and marshy areas, and mosses are common, especially in the spruce timber, through the entire area between the Pacific Ocean and the Yukon, except high on the mountain slopes, above timber line.

In summarization, it may be said that except in a few small areas on the Pacific coast of Kenai Peninsula and on Turnagain Arm, there is no timber in this region of sufficient size and of high enough quality to serve other than local needs, and the region cannot be expected ever to supply any large quantity of lumber for export. Forage for the horses of the traveler can generally be found throughout the region during the summer months, though it is locally scarce in the timbered and mossy lowlands. Edible berries, including blueberries, cranberries, raspberries, and currants, are in places abundant, the blueberries being especially valuable in the fall, for they are widely distributed and grow in profusion.

ANIMAL LIFE

The region between Seward and Fairbanks includes two areas that are noted for the abundance and variety of big game, though in other parts of the area game is difficult to find. The western portion of Kenai Peninsula is a famous district for the big-game hunter, as it is fairly easy of access and contains numerous herds of the white bighorn sheep; moose are abundant and attain exceptional size; and black, grizzly, and the great brown bear are found. Some white mountain goats are found in the coastal mountains throughout the peninsula, though they are much less numerous than the sheep. Caribou are rarely seen.

In the area northeast of Turnagain Arm and south of the Matanuska River moose are present in the lowlands, and both mountain sheep and goats range the higher mountains. The goats are largely confined to the mountains near Turnagain Arm and Prince William Sound, and the sheep are numerous in the areas near the larger glaciers, especially in the inland slope of the mountains. Black bears are here present throughout the areas that have timber or brush, and grizzly and brown bears range into the mountains, high above timber line.

The Talkeetna Mountains have varied conditions of climate and vegetation, and the variety and abundance of game animals differs from place to place. Mountain sheep may be seen occasionally in almost any part of the more rugged area and are fairly common in the headwater regions of the Matanuska and Talkeetna Rivers. On the west slope they are largely confined to the headward portions of Iron Creek and Sheep and Kashwitna Basins. There are a few in the mountains north of the east-west portion of the Susitna River. Moose range throughout the lowlands surrounding the Talkeetna Mountains and up the larger valleys. They are fairly numerous in the basin of the Kashwitna River. Caribou are rare in the southern and southwestern parts of this mountain mass but are more abundant in the Talkeetna Basin and may be found in large herds in the upper Susitna Basin. Here, as elsewhere throughout the region, black bears are numerous in the timbered country, brown bears may be found in either lowlands or mountains, and grizzly bears in the rugged, timberless areas.

Moose and black bear range throughout the Susitna lowland, and the great brown bear spends part of the summer and fall along the salmon streams. Caribou occasionally cross the lowlands, but their customary range is in the high valleys and on the ridges above timber line.

The southeast slope of the Alaska Range, from the Yentna River to Broad Pass, is poorly supplied with big game. A few moose live in the lowlands, and black, brown, and grizzly bears are fairly numerous. Rarely caribou range as far south as the Yentna Basin, but toward Broad Pass they become more plentiful. Mountain sheep are rarely seen, except in the vicinity of Broad Pass, where a few range on the south mountain slope. East of Broad Pass sheep are fairly numerous, and caribou are common.

The north slope of the Alaska Range, in the region here concerned, was naturally a prolific range for big-game animals. The mountains were the home of thousands of sheep and caribou, and moose were plentiful in the lowlands. In areas that are most easily accessible by railroads or highway, hunting has reduced the number of game animals somewhat. West of the Nenana, in the area now included within the boundaries of Mount McKinley National Park, the mountains teem with sheep and caribou, in great herds often numbering in the hundreds. Moose are abundant in the timbered areas, and bears are common. A day's travel in the mountains there in which many big-game animals are not sighted is unusual.

The Tanana lowland is the range of numerous moose and black bear, but is avoided by the sheep, and by the caribou except in their fall migrations. A few herds of sheep occupy the higher mountains of the Yukon-Tanana upland but rarely if ever are found in the area here discussed. Caribou, however, range over that entire area, sometimes in great migrations during which many thousand animals pass within a few days.

The smaller fur-bearing animals, including the fox, lynx, mink, marten, ermine, wolverine, and wolf, are present over much of the entire area of central Alaska, and the pelts of these animals are an important source of income to the natives and to many white trappers, although constant trapping has diminished their number. Beaver are locally abundant south of the Alaska Range and are fairly abundant in the Tanana lowland.

Perhaps the most important animal for human food is the rabbit, which at times is present in incredible numbers. The abundance of rabbits, however, varies greatly from year to year, and periods of exceptionally numerous rabbits are followed by other years in which they are rarely seen. The same is true of the ptarmigan, of which there are two varieties, and they, with the rabbits, furnish the main food supply for all the predacious animals and birds. Thus years of abundant rabbits and ptarmigan are followed by a great increase in the number of fur-bearing animals, and conversely the fur-bearing animals become scarce after the rabbits and ptarmigan have diminished in numbers.

Ptarmigan and spruce grouse are important as a source of food. Aquatic birds, including many varieties of ducks and geese and some swans, pass down the Susitna Valley during their spring and fall migrations and congregate in large flocks on the deltas and tide flats of Cook Inlet. Some of them find nesting places near the streams and lakes of this country.

Of the fish that live in the streams by far the most important economically are the salmon, of which there are several varieties. Cook Inlet supports a number of large salmon canneries, and these fish furnish the main item of diet for the natives of the region, both in the Cook Inlet basin and on the Tanana River. The salmon ascend nearly all the streams that have clear-water tributaries or lakes at their heads and are easily captured by seines, nets, or spears. After spawning, the salmon die, and the shores of their spawning places are at times lined with their bodies. The clear-water streams are generally well stocked with fish that can be taken with a fly. On the Pacific slope there are several varieties of trout, grayling, and, locally, whitefish. The rainbow-trout fishing of the Russian River, on Kenai Peninsula, and of Willow and Lake Creeks, in the Susitna Basin, is justly famous, and the abundance, size, and gameness of these fish attract devotees of rod and reel from far and near. The tributaries of the Tanana River are stocked chiefly with grayling. All these fish avoid the silty glacier streams and so are not abundant in the higher ranges.

POPULATION [3]

The population of Alaska, which was 64,356 in 1910, had by 1920 decreased to 55,036, owing to the call of a large number of men to the Army and to the increased cost of supplies and wages during the war, which rendered many once profitable mines unworkable and discouraged prospecting. The high wages paid to industrial workers in the States also attracted many men who had been prospecting or mining in a small way. By 1930, however, the population of Alaska had again increased to 59,278, and although no official figures are available it seems likely that by 1936 there were again nearly as many people in the Territory as in 1910. These figures of course represent the whole Territory, but it should be remembered that the population is very unevenly distributed. Some two-thirds of the people live on the coast, and only one-third in the interior. As the coastal population is confined to a very small proportion of the land area of the Territory, the actual density of population away from the coast is less than 1 person to more than 20 square miles, and even that figure gives an inadequate picture of the situation, for of the 20,000 or so persons in interior Alaska, at least three-quarters live in towns or villages of 50 or more people. It therefore becomes evident that great areas in the Territory are totally uninhabited, and in certain parts of the interior it is possible to travel for months at a time without encountering a single person, white or native.

The population of the area here under discussion is largely distributed in the towns and settlements along the Alaska Railroad, with some smaller outlying mining communities and native villages. The total population of the area was estimated to be about 18,000 persons in 1936, of which all but about 1,400 were whites. This is a very different proportion from that for the Territory as a whole, in which the population is about equally divided between whites and natives, and the difference is due to the facts that the most numerous and largest native settlements are on the coast and that most of this area lies inland.

[3] U. S. Census, 1930, Outlying Territories and possessions, pp. 8, 9, 25.

The following table gives the census figures for population of the various districts and the principal towns and settlements in 1930.

	Population in 1930		*Population in 1930*
Anchorage district	2, 736	Fairbanks district—Continued.	
Anchorage	2, 277	Fairbanks	2, 101
Eklutna	158	Garden Island	54
Seward district	1, 279	Kantishna district	151
Seward	835	Toklat village	44
Hope	44	Nenana district	768
Talkeetna district	388	Healy Fork	36
Curry	91	McKinley Park	49
Denali	52	Nenana	291
Susitna	39	Suntrana	61
Talkeetna	89	Tolovana district	217
Wasilla district [1]	460	Chatanika River	63
Knik	34	Livengood	22
Susitna Station	52	North Fork village	36
Tyonek	78	Hot Springs district	199
Wasilla	51	Hot Springs village	45
Fairbanks district	3, 446	Coskakat village	46
College	61		

[1] Since the 1930 census was taken the Government has sponsored an agricultural settlement at and in the vicinity of Palmer, in the Matanuska Valley. Some 160 families have moved in, and perhaps 1,000 persons have been added to the population of Palmer and the surrounding country.

The principal industries of Alaska are fishing, mining, agriculture, and trapping. The commercial fisheries are all operating on salt-water fishes, so the processing plants are found on the coast. In this region they are confined to the towns of Seward and Anchorage and to the shores of Cook Inlet. The population in the Alaska Railroad belt is primarily dependent upon mining, and gold is by far the most valuable product of the mines. The coal mines, now of considerable importance, depend for the greater part of their market upon the Alaska Railroad, which is operated mainly because of the mining activity, or upon the gold mines themselves. Only a small part of the coal mined is shipped outside of this region. Similarly the agricultural areas around Knik Arm and near Fairbanks depend for their market upon the mines and upon the population of the towns whose main support is derived from mining and from the operation of the Alaska Railroad. Without the gold mines neither coal mining nor agriculture could be profitably carried on here, and the future development of the region is certain to be controlled by the prosperity of the mining industry.

There is, in this region, a considerable shifting of population with the seasons, inasmuch as most of the gold now produced from this area is derived from placer deposits, and except for a few deep placers where winter drifting is done on frozen ground, placer mining can be carried on only during the open season, when water is available. The season for hydraulic mining is in most places limited to the period between late May and late October, or a maximum of about 5 months. The dredging season may be somewhat longer, for a gold dredge requires less water than a hydraulic operation and can be housed in to protect the riffles from freezing. A few of the lode mines are operated on a year-round basis, but most of them are shut down during at least the coldest part of the winter. Prospecting for lode deposits of the metals is mainly a summer occupation, and the same is true for shallow placer ground. Deep placer ground was formerly prospected by sinking shafts in the frozen ground in winter, but this method has now been largely superseded by the drill. This seasonal character of much of the mining and prospecting results in a corresponding shift in the distribution of the mining population, many of the miners moving to the towns for the winter or even going to the States. Conversely, miners and prospectors leave the towns for the summer, but the influx of tourists and summer visitors in some degree offsets this shift. Activity in the coal mines of the Matanuska field is continued throughout the year, as it is in the Nenana coal field, though there the demand for coal to supply power for the mining industry of the Fairbanks district requires a larger number of miners during the summer. In all such placer districts as the Moose Pass-Hope, Girdwood, Yentna, Valdez Creek, Kantishna, and Fairbanks districts the creeks are largely deserted during the winter.

ROUTES OF TRAVEL

In the years before the Alaska Railroad was built travel in this part of the Territory was largely confined to the coast or to those places that could be reached by river boats, for land travel was difficult and slow, and long land journeys were attempted by only a few of the hardier and more adventurous miners, prospectors, and trappers, or by a few more elaborately equipped pack-train expeditions sent out by the Federal Government or for railroad-exploratory work. Journeys by prospectors away from the main rivers were usually accomplished by dog sled, in winter. The coast of Prince William Sound and the shores of Kenai Peninsula and Cook Inlet were readily accessible by small boats, and a few of the larger rivers could be ascended for some distance by power boats or by poling boats and canoes. The Tanana River was known to be navigable from the Yukon to and beyond Fairbanks, and the Susitna River to the mouth of the Indian River.

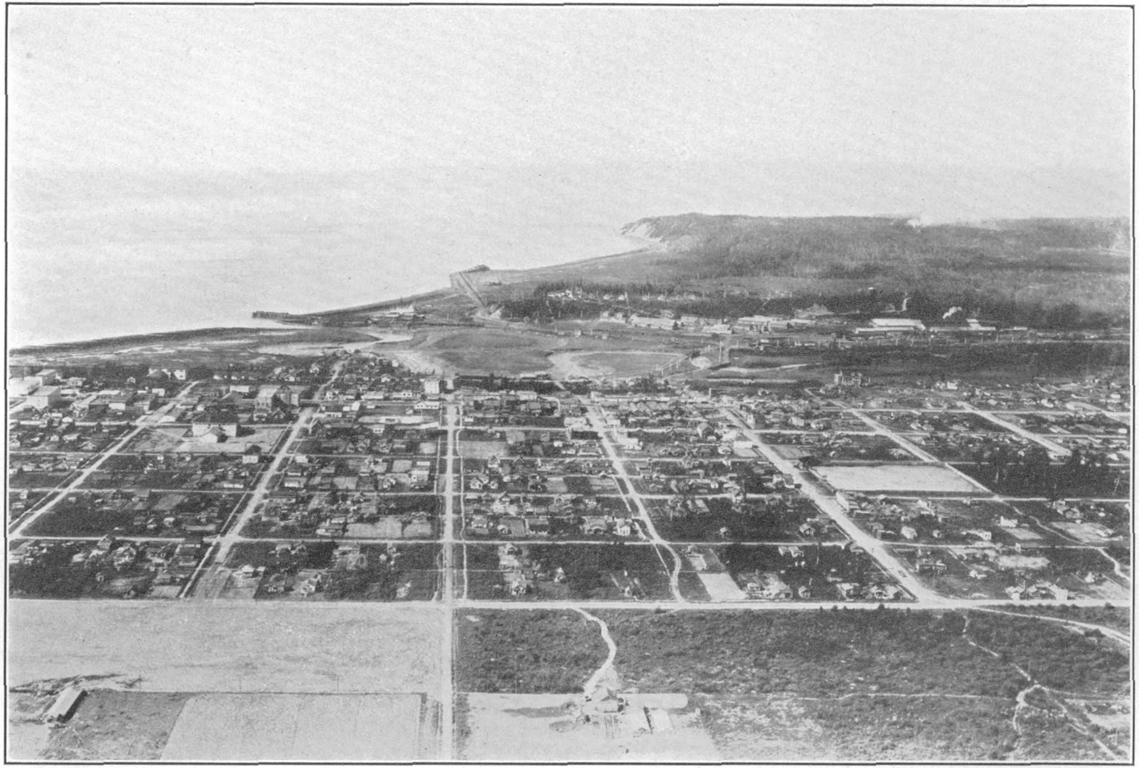
With the discovery and establishment of the placer mines of the Fairbanks district a regular boat service was operated to Fairbanks up the Tanana River during the open season, it being possible to reach that part of Alaska either by ascending the Yukon from its mouth, or by way of the White Pass & Yukon Railroad from Skagway to White Horse and thence down the Yukon. A trail later converted into an automobile highway was also built from Valdez, on Prince William Sound, up the Copper River Basin and across the Alaska Range through the valley of the Delta River to the Tanana, and down that stream to Fairbanks. In 1904 construction had been begun on the Alaska Central Railroad, later known as the Alaska Northern, and rails were later laid from Seward northward through Kenai Peninsula to Kern Creek, on the north side of Turnagain Arm, a distance of 71 miles. It was the early purpose to carry that railroad line north to Fairbanks along about the line of the present Government railroad, but financial difficulties and the uncertain status of the Matanuska coal lands brought construction to a standstill.

From 1906 to 1915 there was little change in the facilities for transportation in this region. The greatest improvements were the conversion of the Valdez-Fairbanks trail to a very fair wagon and automobile road; the completion of the Copper River & Northwestern Railroad from Cordova to Chitina; and the connection of the Fairbanks road with the railroad at Chitina. These changes improved summer and winter overland travel to Fairbanks from the coast, but stage charges were necessarily so high that all heavy supplies and freight went into the interior in summer by river boat. In the Fairbanks district the Tanana Valley Railroad, about 44 miles long, connected the more important mining localities with Fairbanks and Chena and so with the river steamboat lines, and an excellent system of wagon roads had been constructed there. In Kenai Peninsula a few short and unconnected stretches of wagon road had been built, one reaching from Sunrise to mile 34 on the Alaska Northern Railroad, and others from Girdwood up Glacier and Crow Creeks, from Hope up Resurrection Creek, and on Bear and Lynx Creeks. Some fairly good trails had also been established. From the end of the railroad at Kern Creek a winter dog-sled trail had been built by way of Glacier and Crow Creeks across a divide to the Eagle River and down that stream to follow around the head of Knik Arm to Knik. From Knik this trail led westward to Susitna Station and thence up the Skwentna, across the Alaska Range to the Kuskokwim, and to the placer mines of the Iditarod district. This trail was little used in winter and was traversed with difficulty in summer on foot. Within the great basin of the Susitna River very little work had been done on roads and trails. A wagon road had been built from Knik to and up the valleys of the Little Susitna River and Fishhook Creek to the mines of the Willow Creek district, and some trails had also been established in that district. From the wagon road a trail branched off eastward and ascended the Matanuska Valley to Chickaloon. From the Yentna River at McDougall a passable wagon road was built to the Kahiltna and a bridge constructed across that stream. The bridge was soon washed out, however, and the road beyond it was never completed. Beyond the Kahiltna a marshy trail led to the placer mines of the Cache Creek district.

The roads and trails above enumerated were, in the spring of 1915, the only important routes of land travel in the area here described. Exclusive of the Copper River & Northwestern Railroad, which lies entirely outside of this region, and the parts of the Chitina-Fairbanks wagon road that are beyond its limits, there were 115 miles of railroad, about 375 miles of wagon road, mostly in the Fairbanks district, and a few hundred miles of established trail passable for horses in summer in an area of over 57,000 square miles. The natural route from the coast at the head of Cook Inlet to the interior of the Territory, by way of the Susitna and Chulitna Valleys, Broad Pass, and the valley of the Nenana River, with its water grades and low gap across the Alaska Range, was entirely undeveloped to facilitate travel. The Susitna River is navigable for large river steamers only to a point a short distance above the mouth of the Yentna, and above that point it can be ascended only by small, shallow-draft high-powered boats, which may be taken to the mouth of Indian River. For land travel over that route the traveler with pack horses had no trail that could be continuously followed but had to use his own judgment in selecting his course, and was compelled to do much trail chopping in order to get through at all. No facilities were available for crossing the larger streams, such as the Kashwitna, Talkeetna, and Susitna Rivers, and those too deep to ford had to be crossed on rafts and the horses made to swim, at the risk of loss of both horses and supplies. As a result of these serious difficulties very few persons had traveled from Cook Inlet to the Tanana by land in the summer.

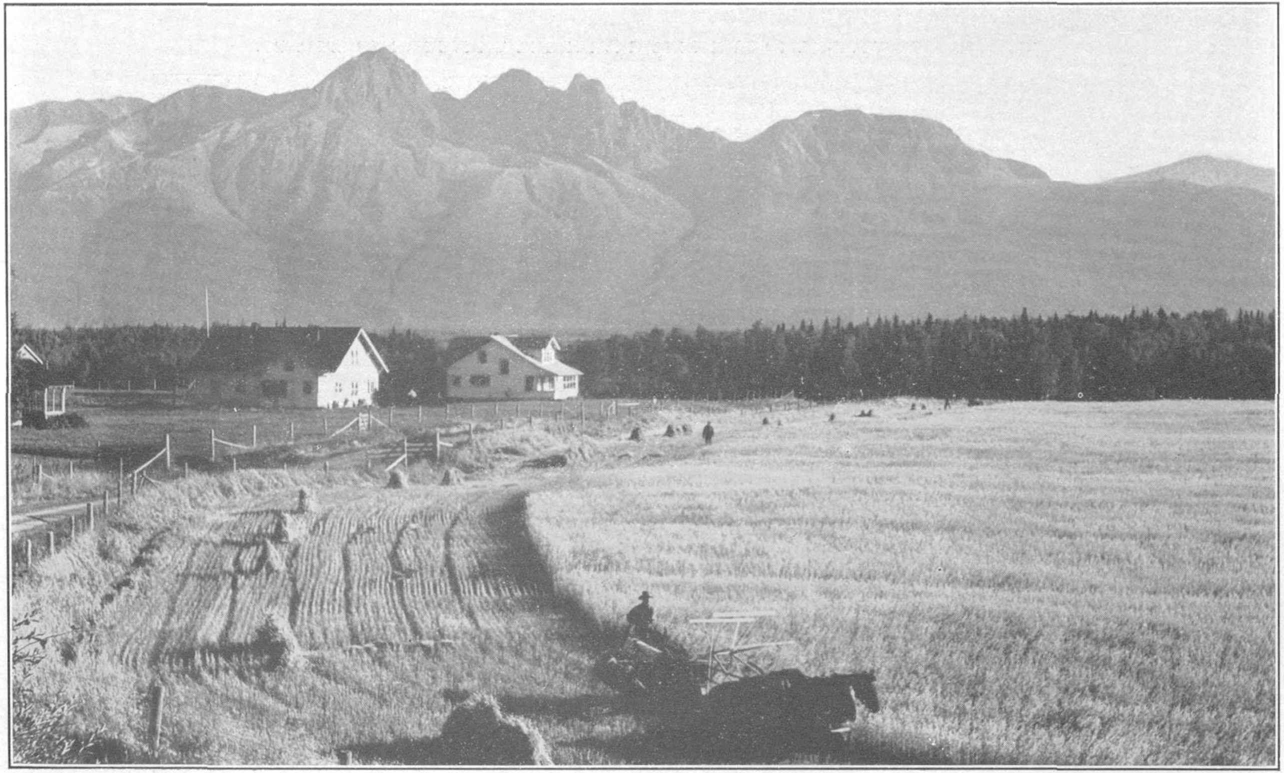
A new order of things for this region began in the spring of 1915, when active construction was started on the Government railroad from Seward to Fairbanks. (See pls. 4 to 7.) The Alaska Northern Railroad, which had fallen into such bad repair that much of it was impassable, was acquired and rehabilitated. The new town of Anchorage, on the east side of lower Knik Arm, was used as the center of construction for that part of the railroad south of the Alaska Range, and storage yards, repair shops, warehouses, and a dock were built there. Construction was carried on both southeastward to connect with the old Alaska Northern tracks and northward to the head of Knik Arm, whence the main line swings west and north to ascend the Susitna Valley, and the Matanuska branch runs northeastward to the Matanuska coal fields. In 1916 construction on

AIR VIEW OF SEWARD, THE COASTAL TERMINUS OF THE ALASKA RAILROAD.



AIR VIEW OF ANCHORAGE, LOOKING NORTH.

AIR VIEW OF FAIRBANKS, THE INLAND TERMINUS OF THE ALASKA RAILROAD.



AIR VIEW OF PALMER.

the inland section was begun at the new town of Nenana, at the point where the railroad crosses the Tanana River, and work was done both toward Broad Pass on the south and toward Fairbanks on the northeast. In connection with the surveying of the railroad line trails were cut and marked far in advance of construction, and passable wagon roads were built along those sections of the line where grading operations were in progress. Those trails and roads were necessary for carrying out railroad building operations, but they also greatly facilitated travel in general along the route, and parts of them have been and will continue to be useful to the public, though most of them were abandoned as soon as the railroad was in operation.

Important as the Alaska Railroad is to the region that it serves, it could fulfill only a part of its service if it were not supplemented by a comprehensive system of roads leading from it to the various centers of mining and agricultural activity along its route. In supplying these roads the chief agencies have been the Alaska Road Commission and in the national forests the Bureau of Public Roads. These agencies have already built hundreds of miles of automobile roads within this region and are actively engaged in extending and maintaining the road system as rapidly as funds are supplied to them. From Seward an excellent road extends northward to Kenai Lake and is soon to be connected with the road system that extends from Moose Pass to the Sunrise and Hope districts. From Girdwood a good road has been built up Glacier and Crow Creeks. From Anchorage, in addition to a network of roads leading to farms in that vicinity, there has now been opened a road roughly paralleling the railroad to Palmer, the new agricultural colony, and connected with the road system there, which includes branches leading to Wasilla and Knik, and to the lode mines of the Willow Creek district. From Talkeetna a 20-mile stretch of road leads toward the Yentna placer-mining district, and further construction toward that camp is in progress. A poorly developed road leads from Cantwell eastward to the Valdez Creek district. In Mount McKinley National Park an excellent highway has been constructed westward as far as Muldrow Glacier and will later be completed to Wonder Lake and Kantishna mining district. Fairbanks is well supplied with good roads which connect it with the mines in the vicinity of Ester Creek, with the University of Alaska, with the placer and lode mines on Goldstream and the Chatanika River and their tributaries, and with the many farms in the vicinity. This road net is continued northeastward by the Steese Highway, which leads to the Yukon at Circle, and southeastward by the Richardson Highway, which connects Fairbanks with Chitina and Valdez. Highway construction and mining and agricultural development go hand in hand. Without roads the development of mines is handicapped, and farm products cannot reach a market. Yet the undeveloped portion of Alaska is so vast that roads can be built only to those places where the promise of commercial development is best.

THE ALASKA RAILROAD

In the years between 1898 and 1912 many routes had been suggested as feasible for the construction of a much needed railroad from an open port on the Pacific to the interior of the Territory, and construction had been started on several of those routes. The White Pass & Yukon Railway was already performing a valuable service in furnishing rail transportation from Skagway to the navigable headwaters of the Yukon in Canadian territory and thus benefiting all the territory reached by the Yukon River boats. Construction had been carried northward from Seward to Turnagain Arm by the Alaska Northern Railroad (earlier the Alaska Central) but was there discontinued. The Copper River & Northwestern Railroad had in 1908 started construction from Cordova up the valley of the Copper River, with the avowed purpose of building to Fairbanks, and the road was eventually put into operation to Chitina, at the mouth of the Chitina River. From that point the great demand of traffic was from the copper mines of the Chitina Valley, and the road was completed to Kennicott, 196 miles from Cordova. No attempt was made to build northward from Chitina toward the Tanana Valley. Several other abortive projects were started to build to the interior from the coast, notably from Valdez, but none of them made any serious progress. The first step leading toward the construction by the Federal Government of a railroad in Alaska was taken in 1912, when Congress, by an act creating a legislative assembly for the Territory, called for the appointment by the President of a commission of four men to study the transportation problem in Alaska, to examine routes, to obtain surveys, and to make a report of their findings and recommendations in respect to the best and most available routes for railroads, for developing the country and its resources. This act was approved August 24, 1912, and that fall the commission was formed, examined a number of possible routes, and later submitted a report.

An act of Congress approved March 12, 1914, authorized the President to designate routes for railroad lines in Alaska, to be so located as to connect one or more of the open Pacific Ocean harbors on the southern coast of Alaska with the navigable waters in the interior and with coal fields. For this purpose a sum not to exceed $35,000,000 was authorized, and $1,000,000 was appropriated for immediate use. To carry out the provisions of the act the President conferred upon the Secretary of the Interior the necessary power and authority and created the Alaskan Engineering Commission, to have charge of field operations. The Alaskan Engineering Commission in 1914 carried out an extensive program of surveys and made detailed estimates of the cost of construction by the various routes, as a result of which the President, on April 10, 1915, by Executive order designated the route over which the Alaska Railroad was built. Naturally a great many factors required consideration in selecting one route from among a number that had been proposed, among the most important of which were the distance from the coast to Fairbanks, the harbor facilities at the ocean terminus, existing railroad lines, accessibility and coal resources of adjacent coal fields, the mining and agricultural resources of the country to be traversed, expense of construction, grades, and engineering difficulties. All these factors had to be carefully weighed, and the claims of rival communities and railway projects considered, but the question of the route once settled by Presidential order, the commission was free to direct its attention to construction, and the first construction party arrived at Anchorage on April 26, 1915.

In the meantime, however, the World War had broken out, and railroad construction was affected by mounting costs of labor and supplies, and later by the entry of the United States into the conflict. These factors delayed the project, but nevertheless it was continued, and in March 1923, upon completion of the bridge across the Tanana River at Nenana, the golden spike was driven that marked the opening of through rail service from Seward to Fairbanks, a distance of 470 miles.

Many optimistic predictions had been made that the opening of year-round rail service from the coast to the Yukon Basin would result in an immediate and rapid mining and agricultural development of all of interior Alaska. These predictions have not been borne out. It is true that coal mines were immediately opened in both the Matanuska and Nenana coal fields, but it was found difficult to enter any but local markets with this fuel. Furthermore, the search for rich placer properties in the region had been pretty thorough before the railroad was built. Interest in prospecting for gold lodes was stimulated, however, and a large number of lodes have been found and placed on a productive basis. Agriculture, like coal mining, found that its market was limited by the demands of the local population, and agricultural products were competitive with those of the Pacific Coast States, with the advantage of nearness to market but the disadvantage of a more severe climate.

Perhaps the greatest service that the railroad has rendered to the Territory has come as the result of lower freight charges, particularly on heavy supplies and equipment, which have rendered possible continued mining in many camps where the richest ground had been exhausted and where there was a narrowing margin between costs and the value of the product. The most notable example of this is to be seen in the extensive operations of the Fairbanks Exploration Co., in the Fairbanks district. There the deeply buried placer gravel that could be mined by the expensive process of underground drifting in frozen ground in the winter was about mined out, and the camp was facing the fate common to worked-out placer regions. With cheaper transportation, however, it was possible to build a central power plant supplied by fuel brought by rail from the Nenana coal field and to bring in heavy materials for dredges and pipe lines, thus extending greatly the life of the placer-mining operations there. All the other mining camps along the railroad and in much of the Yukon Basin have benefited in the same way, and mining is now and long will be profitably conducted on ground that under the old conditions would have been abandoned.

AGRICULTURE AND STOCK RAISING

Agriculture in Alaska has as yet made only a beginning, but there seems to be no room for doubt that each year will see an increasing acreage under cultivation. Although the high latitude gives a severe climate and a short growing season, the agricultural conditions are more favorable than in certain parts of northern Europe, where the people raise a large part of their foodstuffs. A rather complete discussion of the soil conditions, the climate as it affects agriculture, and an estimate of the agricultural possibilities of the region has been published.[3] The following summary of conditions throughout the Territory so far as they relate to the railroad belt is taken from a publication of the Department of the Interior.[4]

The area of Alaska capable of agricultural development has been estimated to be as much as 100,000 square miles. The principal areas of most promise are in the valleys of Yukon and Tanana Rivers, in the interior; the Susitna and Matanuska Valleys, the west side of Kenai Peninsula and the Copper River Basin. Much of these areas is rolling land or composed of gently sloping bench land, most of which is more or less wooded, and from which the timber and moss must be removed before agriculture is possible. In many parts of Alaska pioneer conditions still obtain, and the market for farm products is limited to those settlements which can be conveniently reached by road, railroad, or water transportation. Agricultural experiment stations have in the past been maintained at Matanuska, Fairbanks,

---

[3] Bennett, H. H., and Rice, T. D., Soil reconnaissance in Alaska, with an estimate of the agricultural possibilities, 202 pp., U. S. Bur. Soils, 1915.

[4] General information regarding the Territory of Alaska, ed. of June 1931.

and Rampart, and these have done much to demonstrate what crops can be successfully raised in the region and to develop hardy varieties suited to its climate.

Grains, such as oats, barley, and spring wheat, have been successfully grown year after year at Matanuska and Fairbanks. Hay is made each season from native grasses, or from grain sown for the purpose. Some difficulty may be encountered from rainy weather during the season for harvesting hay and grain.

Hardy vegetables have been raised throughout most of Alaska south of the Arctic Circle. Radishes, mustard, turnips, kale, and lettuce can be grown nearly anywhere, and if garden sites are selected with reference to shelter and exposure to the sun, carrots, parsnips, parsley, peas, cress, cabbage, cauliflower, Brussels sprouts, onions, spinach, beets, potatoes, rhubarb, and such herbs as caraway, mint, catnip, sage, and thyme may be grown. Corn, beans, cucumbers, tomatoes, eggplant, melons, etc., cannot be grown under ordinary garden conditions. Potatoes form an important crop in both the Fairbanks and the Matanuska districts.

Tree fruits have not been successfully grown in this region. Bush fruits, such as currants, gooseberries, blueberries, and raspberries, flourish.

In both the Fairbanks district and the Anchorage-Matanuska area farming has been carried on continuously for many years, and the local farms supply a considerable portion of the needs of these communities for fresh vegetables and poultry and dairy products. Stock raising has also been successfully conducted, and horses, cattle, sheep, and swine have been raised. Native grasses furnish luxuriant forage throughout the region from late May to late September, but for 7 or 8 months each year stock must be fed on grain and cured hay.

In 1935 the Federal Government sponsored an agricultural colony in the lower Matanuska Valley, and about 160 families were brought in from the States and placed on farms there. Help was extended to the settlers in clearing land, building houses and farm buildings, providing wells, and establishing credits for supplies until such time as they should become self-supporting. The time since the colony was established has been too short to determine what measure of success it will attain. It seems evident, however, that agriculture in this region will depend mainly for its market upon the population resident within the region itself. The mining industry is the underlying basis for the growth and development of this area, and any considerable increase in population is likely to result only from an expansion of mining activity. As to future prosperity, agriculture and mining are therefore inseparably related and interdependent.

MOUNT McKINLEY NATIONAL PARK

Early in 1917 Congress, recognizing the desirability of preserving for the people a region of unusual scenic beauty and of abundant wildlife, created the Mount McKinley National Park. The act establishing the park is as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the tract of land in the Territory of Alaska particularly described by and included within the metes and bounds, to wit: Beginning at a point as shown on Plate III, reconnaissance map of the Mount McKinley region, Alaska, prepared in the Geological Survey, edition of nineteen hundred and eleven, said point being at the summit of a hill between two forks of the headwaters of the Toklat River, approximate latitude sixty-three degrees forty-seven minutes, longitude one hundred and fifty degrees twenty minutes; thence south six degrees twenty minutes west nineteen miles; thence south sixty-eight degrees west sixty miles; thence in a southeasterly direction approximately twenty-eight miles to the summit of Mount Russell; thence in a northeasterly direction approximately eighty-nine miles to a point twenty-five miles south of a point due east of the point of beginning; thence due north twenty-five miles to said point; thence due west twenty-eight and one-half miles to the point of beginning, is hereby reserved and withdrawn from settlement, occupancy, or disposal under the laws of the United States, and said tract is dedicated and set apart as a public park for the benefit and enjoyment of the people, under the name of the Mount McKinley National Park.

SECTION 2. That nothing herein contained shall affect any valid existing claim, location, or entry under the land laws of the United States, whether for homestead, mineral, right of way, or any other purpose whatsoever, or shall affect the rights of any such claimant, locator, or entryman to the full use and enjoyment of his land.

SECTION 3. That whenever consistent with the primary purposes of the park, the act of February fifteenth, nineteen hundred and one, applicable to the location of rights of way in certain national parks and national forests for irrigation and other purposes, shall be and remain applicable to the lands included within the park.

SECTION 4. Nothing in this act shall in any way modify or affect the mineral land laws now applicable to the lands in the said park.

SECTION 5. That the said park shall be under the executive control of the Secretary of the Interior, and it shall be the duty of the said executive authority, as soon as practicable, to make and publish such rules and regulations not inconsistent with the laws of the United States as the said authority may deem necessary or proper for the care, protection, management, and improvement of the same, the said regulations being primarily aimed at the freest use of the said park for recreation purposes by the public and for the preservation of animals, birds, and fish, and for the preservation of the natural curiosities and scenic beauties thereof.

SECTION 6. That the said park shall be, and is hereby established as a game refuge, and no person shall kill any game in said park except under an order from the Secretary of the Interior for the protection of persons or to protect or prevent the extermination of other animals or birds: *Provided,* That prospectors and miners engaged in prospecting or mining in said park may take and kill therein so much game or birds as may be needed for their actual necessities when short of food; but in no case shall animals or birds be killed in said park for sale or removal therefrom, or wantonly.

SECTION 7. That the said Secretary of the Interior may, in his discretion, execute leases to parcels of ground not exceeding twenty acres in extent for periods not to exceed twenty years whenever such ground is necessary for the erection of establishments for the accommodation of visitors; may grant such other necessary privileges and concessions as he deems wise for the accommodation of visitors; and may likewise arrange for the removal of such mature or dead or down timber as he may deem necessary and advisable for the protection and improvement of the park: *Provided*, That no appropriation for the maintenance of said park in excess of $10,000 annually shall be made unless the same shall have first been expressly authorized by law.

SECTION 8. That any person found guilty of violating any of the provisions of this act shall be deemed guilty of a misdemeanor, and shall be subjected to a fine of not more than $500 or imprisonment not exceeding six months, or both, and be adjudged to pay all costs of the proceedings.

Approved, February 26, 1917.

The park, as originally established, had an area of about 2,200 square miles. It was enlarged by act of Congress in 1922 to 2,645 square miles, and again in 1932 to 3,030 square miles. At present its eastern boundary is along the west shore of the Nenana River, and the northwest boundary was made to include Wonder Lake.

Under the act establishing the park the rights of prospectors and miners in the park area were preserved. No mine has yet been put upon a producing basis within the park boundaries, but there are a number of promising prospects on lodes containing gold, silver, copper, lead, and zinc, and this area may yet yield its quota to the mineral output of the Territory.

As appears on the accompanying map (pl. 3), a large part of this park lies within the limits of the area here described. Its boundaries were well chosen, for they include the highest and most rugged portion of the Alaska Range, culminating in Mount McKinley (see frontispiece) whose peak towers 20,300 feet above sea level and is the highest point in North America. Mount McKinley and its companion peak, Mount Foraker, stand near the north front of the mountain mass, at the crest of the great arch formed by the crescentic curve of the range, and so dominate the broad lowlands of the Kuskokwim and Tanana Rivers on the west, northwest, and north. The view they present from those directions is perhaps unexcelled elsewhere for the sheer height of the mountain above its immediate base. On its north slope Mount McKinley rises from the terminus of Peters Glacier, at an altitude of 2,600 feet, to the summit, in a distance of 13 miles, and its perpetual snow line lies at about 7,000 feet, this mountain being said to offer the highest climb above snow line in the world. The setting of these two peaks is also unusual, for as seen from the interior they stand far above their surroundings, the next highest mountain visible from that direction being less than 12,000 feet above sea level.

The region of the Mount McKinley National Park offers exceptional attractions to the mountaineer. The highest peak of America's loftiest mountain has been scaled but twice, and only one accessible route up it has been found. The achievement of the climber who first finds another route to the summit will be scarcely less than that accomplished in making the first ascent, for the successful party traveled a route that had already been explored and demonstrated to be practicable. Mount Foraker has been ascended only once, and a multitude of lesser peaks are still unnamed and unexplored. The approach to these peaks from the north, heretofore requiring much time and labor, is much easier now that the railroad is completed and a good road built into the park to a point within a few miles of the base of Mount McKinley, and the climber will be able to camp in a delightful climate close to the base of his chosen mountain. For those who seek the difficulties and dangers and the accompanying pleasures of more difficult approaches into the heart of the mountains, the glacier-filled basins of the southeast flank of the range are inviting.

The attractiveness of this park, however, will appeal not alone to the mountaineer. The foothills and spurs of the outlying mountains on the north present wonderful scenery, a delightful summer climate, and an abundance of wildlife that cannot fail to make this park a vacation ground for those who love outdoor life in a region of unspoiled natural beauty. This part of the park is the chosen range of great herds of caribou and mountain sheep, which, having been little molested, are tame and easy of approach. Probably no other areas of North America have such a natural abundance of big-game animals. In certain mountain valleys many hundred white bighorn sheep may be seen in a day's travel, and caribou in herds containing hundreds of individuals may be encountered. Bears of several varieties are present, and moose are numerous in the timbered lowlands. Under the protection that these animals have within the park, they have become less wary of human approach and prove an endless source of pleasure to visitors.

At the time of writing (1936) the park is developed by a single road that leads from the railroad at McKinley Park station to Muldrow Glacier, and construction is under way to Wonder Lake, north of Mount McKinley, but even away from the road this is an easy country in which to travel, for most of it is above timber line, the north-south mountain ridges are broken by easy passes from one valley to the next, the stream valleys are natural highways, and the herds of caribou have already developed well-marked trails in many places.

During the open season, from mid-June to mid-September, accommodations are provided for tourists to visit the park. Cars and busses meet the trains, and travelers are taken 12 miles over the highway to the Savage River Camp, where a central lounge room, dining room, and kitchen and individual or two-person tents are provided. Special arrangements can be made for drives over the highway to scenic points in the park, for saddle horses, or for airplane trips. It is expected that upon completion of the road to Wonder Lake a permanent lodge for guests will be built there, in full view of Mount McKinley.

GEOLOGY

PRINCIPAL FEATURES

The areal mapping of the various rock groups as shown on the accompanying geologic maps (pls. 1–3) is the result of studies of the many geologists who have worked in this field since 1898. The earliest workers were pioneers and explorers, who had no foundations already prepared upon which to build and elaborate their conclusions but were compelled by necessity to lay their own foundations as they proceeded. Later workers have had the advantage of those earlier conclusions and have been able to extend the areas of the rock groups and formations that had already been recognized and from them to draw conclusions concerning the age and relations of other formations. In the very nature of the case, in a region of this size and geologic complexity, where fossils are unusually scarce, certain mistakes of interpretation have been made. It has already been possible to correct some of these misconceptions. Others, inherited from the pioneer geologists or due to mistaken conclusions of the later workers themselves, doubtless remain still undetected, or, if the proper interpretations have been suspected, they are not yet capable of definite proof. The facts accumulate year by year, and after a time certain missing pieces in the puzzle will come to hand and, being fitted to their proper place, reveal the picture as a whole in its true aspect. Fossils, those remains of ancient organisms that the geologist uses in determining the age of the rocks with which he deals, may after long search be discovered in a formation that has long been puzzling and thus at once clear up a whole group of problems concerning the rocks in which they are found and other associated formations.

The critic of the future, who views the mistakes of his predecessors in the light of the evidence available to him, must also remember that the work in this region was not done as a single study continuously pursued by a certain group of workers, but that it progressed in steps, first an area here and then a gap there being filled, and many of these studies were made by men to whom this region and its problems were new and whose field of study was isolated. In the past the difficulties of travel to and within parts of this area have been great, and a large part of the geologist's energies have been used up merely in getting about the country. Most of the work has been of exploratory or reconnaissance character, in which the attempt was made to cover a large area in a short field season. Detailed studies have been made at only a few localities. Since the railroad was completed it has been possible to increase notably the number of days of field work in a season, and one man is now able in a single summer to visit many localities of especial interest and to coordinate and correlate the facts over wider areas. The few unmapped parts of this region can be more easily reached, and as they are filled out and studied the solution of many unsettled problems will be found.

On the geologic maps (pls. 1–3) all the information available has been used, whether obtained as the result of exploratory, reconnaissance, or detailed surveys. In assembling this information in single maps it has not been possible to distinguish between those areas which have been studied painstakingly and in which the geologic boundaries are approximately correct, and those which have been only hastily explored and in which the geologic boundaries have been drawn between more widely spaced points of observation. In the following text, however, some attempt has been made to evaluate the conclusions reached in different parts of the field, giving proper weight to those that are based on more deliberate field work. It is believed that the geologic maps represent with considerable accuracy the larger features of the surface distribution of the various rock groups or formations. Field studies that are each year in progress will no doubt refine the work as time passes and correct such errors as may have crept in.

A study of the geologic maps at once discloses the fact that most of this region is occupied by rocks of only moderate geologic age. So far as is now known, pre-Cambrian rocks occur here only north of the Alaska Range and perhaps in a small area in the Willow Creek district. The great Paleozoic era is also rather scantily represented south of the Alaska Range, where only a few areas of undifferentiated metamorphic rocks that are possibly of Paleozoic age, a few small areas of Carboniferous sediments and tuffs in the Chulitna region, and some Devonian limestones and associated sediments are known. North of the range Paleozoic rocks are better represented, for there are extensive belts of mica schists, or metamorphosed sedimentary rocks, and of ancient lavas and associated sedimentary beds, all now greatly altered from their original state.

The prevailing rocks from Seward to Broad Pass are believed to be for the most part of Mesozoic age. They include great areas of slates, shales, and graywackes of somewhat uncertain age but in part Cretaceous; some fossiliferous sandstones and shales, a little limestone and quartzite, and great areas of basic lavas and tuffs. The Cantwell formation composed of hard mountain-building conglomerates and shales is now also believed to be of Cretaceous age. Conspicuous also are the masses of granitic intrusive rocks that have penetrated the earlier Mesozoic materials and now lie as great batholiths, such as that which forms most of the western Talkeetna Mountains, or as smaller and more widely scattered masses. Tertiary rocks are also present in abundance and include the generally unconsolidated sands, clays, and gravels of the coal-bearing beds. Widespread ancient gravels also belong with the Tertiary or early Quaternary. Quaternary deposits cover a large portion of the region and include the unconsolidated lowland deposits of the streams and shore lines and the glacially deposited materials. Both stream and glacial deposits and estuarine accumulations in the upper part of Cook Inlet are today being formed.

In an area so large and including so many distinct geographic and geologic provinces as the one here described, a systematic description of the rock formations, in chronologic order, would require the reader to focus his attention on first one locality and then on another far away, and by so doing to become confused as to the sequence of earth history and of formations at any one place. In the geologic history of the area the sequence of events was not the same for any two geologic provinces. It therefore seems desirable to describe the rocks by provinces rather than by geologic periods. The area is naturally divided into four major subdivisions, which include distinct mountain masses, as well as the bordering lowlands. These divisions are (1) the Kenai-Chugach Mountains, (2) the Talkeetna region, (3) the Alaska Range, and (4) the Yukon-Tanana Plateau. During the last great time division, the Quaternary, the mountain masses have all stood approximately in their present positions and at about their present altitudes, and the geologic events, including the shaping of the surface forms by erosion and deposition and the great ice invasions, have affected all this area to a greater or less degree. A special section of this report therefore deals with the Quaternary history as it has affected the area as a whole.

KENAI-CHUGACH MOUNTAINS

GENERAL SUCCESSION

The term "Kenai-Chugach Mountain region," as here used, includes the portion of the Chugach Mountains that falls within the area described in this report, the structurally continuous Kenai Mountains of Kenai Peninsula, the bordering islands of Prince William Sound, and the lowlands east of Cook Inlet and Knik Arm.

The region is therefore bounded on the south and east by the Pacific Ocean and its embayments, and on the west and north by Cook Inlet, Knik Arm, and the Matanuska River. It lies at the elbow or hinge where the coastal mountains of south-central Alaska change their trend from west to southwest, as they sweep from Prince William Sound toward Kodiak Island, their seaward continuation. For the last 40 years these coastal mountains, with their rugged relief, their hundreds of miles of wave-cut cliffs and deep fiords, have attracted a succession of geologists, for in many ways they seemed to present excellent opportunities to solve the riddle of their age and structure. Nevertheless, the problem has been found to contain many difficulties, and much still remains to be done. The chief difficulty arises from the fact that the mountains are composed in very large part of a monotonous succession of slates, shales, and graywackes many thousands of feet thick, in which no single formation or bed is of distinctive enough character to be certainly recognized over any considerable distance. The beds are generally much folded and faulted, fossils are generally lacking, and over wide areas no underlying, older rocks are exposed.

On the accompanying geologic maps these slates and graywackes of the mountainous portions of Kenai Peninsula are grouped as undifferentiated Mesozoic, except for certain areas of igneous rocks that have been separately classified. Along the northwestern flank of the Chugach Range and in southwestern Kenai Peninsula, however, the prevailing slates and graywackes are underlain by an older metamorphic complex. Martin [5] in discussing the geology of Kenai Peninsula mentions a complex situation at the southwest extremity of the peninsula, in Seldovia Bay, Port Graham, and along the southeast shore of Kachemak Bay, where he found ellipsoidal lavas, overlain by limestones and fine-grained tuffs of Upper Triassic age, and these succeeded by contorted cherts, lavas, tuffs, and agglomerates. He considered the ellipsoidal lavas to be of questionable Triassic age and grouped the limestones, fine-grained tuffs, and contorted cherts as Upper Triassic and the overlying tuff and agglomerate as Jurassic. He considered that all these rocks overlay the great series of slates and graywackes to the east and concluded that the slates and graywackes were chiefly of Paleozoic age.

As shown below, the slates and graywackes have now been found to include some beds that carry Cretaceous fossils. Furthermore, recent studies [6] along the strike of these rocks in Afognak and Kodiak Islands, to the south, have shown a strikingly similar association of

---

[5] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 33–36, 1915.

[6] Capps, S. R., Kodiak and adjacent islands: U. S. Geol. Survey Bull. 880–C, 1937.

formations, though the slates and graywackes are there separated from the ellipsoidal lavas, limestones, tuffs, and contorted cherts by a profound fault. Capps concluded that the slates and graywackes of Kodiak and adjacent islands are mainly upper Mesozoic, probably of Cretaceous age, and are in faulted contact with the older lavas, tuffs, cherts, etc. The whole association in those islands is so remarkably similar to that in southwestern Kenai Peninsula that the writer strongly suspects the presence in Kenai Peninsula also of a great fault that runs northward to Turnagain Arm and thence northeastward at least as far as the Knik River. At Turnagain Arm, however, the Triassic limestones, ellipsoidal lavas, and cherts have been cut out, and the Jurassic agglomerates are in direct contact with the slates and graywackes.

The rocks between Knik and Turnagain Arms are described [7] as occurring in an area that is widest at the south and narrows gradually northeastward toward the Knik River, and comprising a wide variety of materials that include altered igneous rocks that range from andesites and andesite porphyries to basic rocks that include peridotite, dunite, serpentine, pyroxenite, and gabbro, with tuffs and agglomerates of all these materials. Associated with these igneous materials and metamorphosed along with them there are varying amounts of shale and sandstone, indicating that the whole group was deposited in water. All these rocks are so much altered and weathered that determinable specimens are difficult to obtain. The same rocks were described and their position mapped in places by Tuck [8] on the south side of Turnagain Arm, and by Park [9] in the Girdwood district. Neither of these writers was able to determine definitely the structural relation of these rocks to the slate-graywacke group farther east, though all regarded them as probably older. The relationship of the two rock groups on Kodiak Island, however, and the straight line of the contact between two groups of highly deformed rocks in Kenai Peninsula strongly suggest a fault contact such as was definitely recognized on Kodiak and Afognak Islands.

Still farther east, along the south side of the Matanuska Valley, there are schists and foliated rocks associated with the slates and graywackes, but evidently older, as well as volcanic rocks that include lava agglomerate, breccia, and tuff, together with minor amounts of sandstone and shale. These volcanic rocks are in fault contact with the sedimentary rocks to the south. They carry plants and

[7] Capps, S. R., The Turnagain-Knik region, Alaska: U. S. Geol. Survey Bull. 642, pp. 153–154, 1916.

[8] Tuck, Ralph, The Moose Pass-Hope district, Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 849–I, pp. 478–480, 1933.

[9] Park, C. F., Jr., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849–G, pp. 388–389, 1933.

marine organisms of Lower Jurassic age.[10] Landis,[11] however, mapped an extensive area of greenstone and greenstone tuff in the region between the Knik River and the lower Matanuska Valley. He states that there the greenstones overlie the slates and graywackes but underlie the Cretaceous sedimentary rocks, and concludes that all the greenstones in the area in which he worked are probably of early Jurassic age. Since Landis' work was done Park [12] has shown definitely that in the Girdwood district, not far southwest of Landis' area, greenstone tuffs unconformably overlie sedimentary beds that carry Cretaceous, probably Upper Cretaceous fossils. On the other hand, it has been just as definitely shown by Martin and Katz [13] that in the lower Matanuska Valley there are similar volcanic rocks that carry Lower Jurassic fossils. It therefore appears likely that Landis found tuffs of both Lower Jurassic and Upper Cretaceous age, and on account of their similarity grouped them together and assigned rocks of both ages to the Lower Jurassic.

As has been stated, the bulk of the Chugach and Kenai mountain province is composed of a great series of dark-colored metamorphosed marine sediments that consist mainly of argillaceous materials, now altered to argillites and slates, and of impure hard sandstones, here referred to as graywackes. These rocks have been described at some length by the many geologists who have worked in this part of Alaska, but their uniform appearance through a great stratigraphic thickness of beds, their complex structure, the lack of continuity of single lithologic units, the absence of distinctive key beds, and the almost complete lack of determinable fossils have all combined to make the understanding of the succession and age of these beds a difficult problem that is still only partly solved.

UNDIFFERENTIATED MESOZOIC SLATES AND GRAYWACKES

Johnson [14] described the rocks in the northwestern part of Prince William Sound as consisting mainly of closely folded slates, argillites, and graywackes, with minor amounts of greenstones and some large, intrusive masses of granite. He also studied the geology farther south along the coast, where he mapped similar sedimentary rocks and large areas of greenstone.[15]

---

[10] Capps, S. R., Geology of the upper Matanuska Valley Alaska: U. S. Geol. Survey Bull. 791, pp. 19–23, 1927.

[11] Landis K. K., Geology of the Kni-Matanuska district: U. S. Geol. Survey Bull. 792, pp. 58–62, 1927.

[12] Park, C. F., Jr., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849-G, pp. 394–395, 1933.

[13] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 29–32, 1912.

[14] Johnson, B. L., The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, p. 203, 1914.

[15] Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, pp. 193–220, 1918.

In past years the rocks of the Chugach-Kenai Mountains have been variously subdivided, by different workers, into three divisions—the Valdez group, the Orca group, and the †Sunrise group[16]—and these names have been variously used to include parts of the great aggregation of rocks. It has proved exceedingly difficult, however, to define any of these groups so clearly that it could not be confused with the others. The Valdez group was long considered to be in part, if not mainly, of Paleozoic age, and to be overlain unconformably by the Orca group. Later work has raised a question as to the relative age of these two groups, and the possibility that the Valdez may be younger than the Orca must be considered. Fossils that are probably of Mesozoic age have been collected at several localities from rocks that had previously been classified with the Valdez group, thus requiring either that the enclosing rocks should be reclassified and placed with the Orca group, or that a probable Mesozoic age should be accepted for at least part of the Valdez group. The †Sunrise group of the area around Turnagain Arm presents similar difficulties. Its rocks are lithologically similar to those classified elsewhere as belonging to the Valdez and Orca groups, and it doubtless represents parts of one or both of those subdivisions.

Character.—Many pages of description of these rocks have been written by the various geologists who have worked in different parts of this field, but the rocks of this series as a whole are so uniform in character over wide areas that any one of the published descriptions would be fairly accurate for the whole region. The series as a whole consists mainly of alternating bands of fine-grained mudstone, now metamorphosed to argillite or slate, and coarser impure sandstone, now indurated to graywacke. The other constituents of the series—namely, conglomerate, grit, limy argillite or argillaceous limestone, and tuff—occur in minor amount and are entirely absent over considerable areas and through great stratigraphic thicknesses of the series. The most characteristic and perhaps the commonest phase consists of alternating layers of slate and graywacke from a fraction of an inch to a foot or so in thickness. In places the banding is so fine as to suggest seasonal varves, but elsewhere it is much coarser, with individual beds attaining several feet in thickness and here and there are exposures of either slate or graywacke in sections 100 feet or more thick. Mud cracks and ripple marks, as well as the character of the rocks themselves, indicate deposition in shallow water, yet in order to form a series of beds many thousand feet thick but all laid down in shallow water would have required a very delicate balance of conditions in which the collecting

[16] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the Geological Survey.

basin sank as fast as debris accumulated, but never either much faster or much slower.

The argillaceous rocks range from fairly massive, poorly cleaving argillites to slates and even schists, though fissile slates are most abundant.

Commonly the planes of cleavage are wavy, though locally so even that the rocks approach roofing slates in character. The materials of which the argillaceous rocks are composed are very fine and include particles of feldspar and quartz in a groundmass of sericite, chlorite, graphite, and clayey constituents. Near the margins of large granitic intrusive masses they have in places been recrystallized into hard rocks that contain quartz, biotite, iron oxides, and coarse cordierite crystals. Quartz veins and veinlets are common in both slates and graywackes.

The graywackes are composed of impure sand and range in coarseness from argillite at one extreme to grit and conglomerate at the other. They include materials derived from many sources, but the presence in them of grains of quartz, feldspars, hornblende, micas, and other minerals indicate that the land mass from which they were derived by erosion contained much igneous material. The graywackes also contain rock fragments, most common of which are argillite and graywacke.

The graywackes are hard dense rocks that have resisted both deformation and erosion much better than the mudstones. Massive, little-altered graywacke in beds separated by highly cleaved slate is common. In areas of intense folding and crumpling most of the movement has been taken up in the slaty layers, the graywacke beds showing little metamorphism.

Though conglomerates are not rare in this series of rocks, they form only a very small fraction of the whole. The most common conglomerates are composed of argillite pebbles in a sandy matrix, forming beds a few inches to a few feet thick. In places, however, thicker conglomerates that contain pebbles of a wide variety of rocks are found. None of these conglomerate beds have been found to be continuous over wide areas, and they are believed to be intraformational and of no great stratigraphic significance, representing local conditions that permitted the deposition of lenticular masses of coarser materials.

Structure and thickness.—Throughout the area in which they occur the slates and graywackes are highly tilted and folded, locally with intricate contortion and crumpling. In general, however, the beds stand at steep angles and strike parallel to the axis of the range. Over long distances the beds dip at angles of 60° to 90°, with no direct evidence of duplication by faulting or folding, but here and there is evidence that close folding has occurred, and there are many faults of unknown displacement. The high degree of fissility developed in the slates also indicates a tremendous amount of slipping parallel to the bedding.

No reliable estimates have been made as to the maximum thickness of beds involved in the coastal mountains that are composed almost exclusively of these slates and graywackes. All authors agree, however, that no figure of less than 5,000 feet is adequate, and the actual thickness may be much more than that.

Age and correlation.—As originally described by Mendenhall [17] these rocks were tentatively assigned to the upper Paleozoic. More recently fossils have been found in this group that showed a part of it, at least, to be of Cretaceous age.

In the Girdwood district of Turnagain Arm Park [18] made several fossil collections, all of the same organism, that were identified as of Cretaceous, probably Upper Cretaceous age. Furthermore, it is now known that at least a large part of the slates and graywackes of the Chugach Mountains and Kenai Peninsula are younger than the Jurassic volcanic rocks and older than the Eocene coal-bearing beds of the Matanuska Valley and western Kenai Peninsula. No unquestioned Paleozoic fossils have been found anywhere in this great series of sedimentary rocks. It is true that fossils of any kind are rare, but such as have been found invariably point to a Mesozoic age, and as paleontologic evidence has accumulated, the area of these rocks that might be classified as Paleozoic has shrunk. As the positive evidence so far obtained points to a Mesozoic age for the slates, argillites, graywackes, and greenstones of Kenai Peninsula and the Chugach Mountains, and as no unquestioned evidence of their Paleozoic age has been found, these rocks are mapped on plate 1 as of undifferentiated Mesozoic age.

MESOZOIC GREENSTONES

Large areas of greenstone flows are interbedded with the Mesozoic sedimentary rocks above described and therefore correspond with them in age. These greenstones are for the most part surface or subaqueous lava flows and tuffs of diabasic or basaltic composition and are economically important because locally they carry commercial deposits of copper minerals. The principal deposits in this region are on Latouche and Knight Islands and on the point between Resurrection Bay and Day Harbor. These have been described by Grant.[19]

---

[17] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 305–307, 1900.

[18] Park, C. F., Jr., op. cit. (Bull. 849–G), pp. 393, 394.

[19] Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 223–225, 1915.

The rocks that are commonly referred to in the literature as greenstones consist mainly of basic lava flows, though they also include minor amounts of basic intrusive material. Most of them are basaltic in composition, and they vary in appearance from massive flows that were extruded upon land surfaces to ellipsodial or pillow lavas that are generally considered to have been deposited under water. In places they have been so much altered by folding, faulting, and chemical changes that their original character is obscured.

The problem of determining the age of these greenstones at any particular place arises from the fact that basic lava flows of strikingly similar composition and appearance were extruded at various times during the Mesozoic era and that lithologic character alone cannot be relied upon as a basis for correlation. In southwestern Kenai Peninsula and on Kodiak and adjacent islands greenstones are present that have been rather definitely determined to be of Triassic age. In Prince William Sound very similar greenstones are found interbedded with slates, graywackes, and conglomerates that are believed to be of Mesozoic age but much younger than the Triassic. As the associated sedimentary rocks are generally unfossiliferous and therefore of somewhat uncertain age, and as the structural relation between greenstones and sedimentary rocks are in many places obscure, it is often difficult to determine whether the greenstones are of Triassic or much later Mesozoic age.

GREENSTONE TUFF

In the region between Turnagain and Knik Arms and extending from the upper basin of Ship Creek northeastward to and beyond the head of Eklutna Lake there is an area of some 200 square miles in which the rocks consist of greenstone tuff that unconformably overlies the Mesozoic slates and graywackes. These rocks have been described by Capps [20] and Park.[21] The tuff has a greenish color, due to the presence of dark-green chlorite, and is characterized by the presence of small fragments of black argillite, which are scattered throughout it from top to bottom. The tuff contains many small fragments of quartz and plagioclase feldspar and in places microscopic hornblende and pyroxene. The secondary minerals include quartz, chlorite, and zeolites, and the tuff is cut by veins and stringers of calcite and some prehnite. The matrix is commonly composed of carbonates and serpentinous material, though in places it is glassy.

The tuffs have been somewhat folded and faulted, but as a whole they are less deformed than the underlying formations. The beds

---

[20] Capps, S. R., The Turnagain-Knik region, Alaska: U. S. Geol. Survey Bull. 642, pp. 165–174, 1916.

[21] Park, C. F., Jr., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849–G, pp. 394–395, 1933.

are generally massive, interbedded clastic sediments are present only in small amounts, and in most places the jointing is more conspicuous than the bedding. Apparently the tuffs are in the form of a rather simple synclinal basin, in which the prevailing strike is parallel to the outer border of the tuff area, and the beds dip from the margins toward the center of the basin. The tuffs reach a maximum thickness of several thousand feet.

No fossils have been found in these tuffs. They lie with sharp angular unconformity above the slates and graywackes, which are, at least in part, of Cretaceous age, probably Upper Cretaceous. They are thoroughly indurated and are different from any Tertiary rocks that have been recognized in the region. Eocene beds nearby are much less indurated and consist of sandstones and shales, usually containing coal beds. Apparently the tuffs are older than the Eocene and younger than the Cretaceous rocks on which they lie. They are tentatively assigned to the Upper Cretaceous.

GRANITIC INTRUSIVES

Granitic intrusive rocks occur scattered throughout this region and include some rather large masses, such as those at the mouth of Aialik Bay, just south of the lower Matanuska River, and on Esther Island, as well as smaller areas. Similar rocks also occur as dikes and sills, which are particularly abundant on both sides of Turnagain Arm. In composition they are prevailingly diorites or quartz diorites, though locally granites and granodiorites occur. These acidic intrusives cut sedimentary beds that have been classified as belonging to the Valdez, Orca, and Sunrise groups and are younger than any of these rocks, for they were injected not only after the sediments were laid down but after a large part of their folding and faulting had been completed. North of Turnagain Arm acidic intrusives have been injected into rocks that have yielded fossils of Cretaceous age. Some of the intrusions are therefore certainly as young as Cretaceous, and probably Upper Cretaceous, and are apparently of pre-Tertiary age. The granitic intrusive rocks are of particular importance because they have a genetic relation to the gold lodes of the region. In many places this relation is evident, and elsewhere it is inferred.

TERTIARY ROCKS

The lowland portion of the Chugach-Kenai region, lying northwest of a line drawn from the head of Knik Arm to the upper end of Tustumena Lake, is strikingly different in both topography and geology from the mountainous portion to the east. In the lowland hard rocks are not exposed at the surface, and much of it is probably underlain by the loosely consolidated Tertiary sedimentary beds of the Kenai formation, though for the most part these beds are covered and concealed by Quaternary deposits. The Kenai formation is best exposed and has been carefully studied in the lowland southwest of the area here described, in Kachemak Bay and near Anchor Point. From sections exposed there the formation appears to be 1,800 to 2,000 feet thick, with neither the top nor bottom exposed. Martin,[22] who studied this area, describes the Tertiary beds as consisting of partly indurated fresh-water or estuarine sands and clays, probably of about equal volume, the individual beds of which are generally not more than 20 or 30 feet thick, though a few measure more than 100 feet. Interbedded with the sands and clays are a few inconspicuous conglomerates and many beds of lignite. The rocks are in general hard enough to stand in almost vertical cliffs several hundred feet high, yet they can be readily cut with the point of a pick or knife. The argillaceous beds are mostly blue or gray, rarely white, are soft and plastic when wet, and have imperfectly developed shaly fractures. Most of the sandy beds are composed of fairly well sorted, clean white quartz sand, with some ferromagnesian grains. Some beds are feldspathic.

The coal beds are numerous, but most of them are of only moderate thickness. Measured sections show that 3 to 5 percent of the total thickness of rock consists of coal beds 3 to 7 feet thick.

Structurally the beds are little disturbed, with dips usually of only 2° to 4° and maximum dips of 10° to 13°. They contain abundant plant remains, which have been determined to be of upper Eocene age. In the area between Turnagain and Knik Arms exposures of the coal-bearing Tertiary beds are known at only a few places, and those only in the lowland that lies west and north of the Chugach Mountains. Nevertheless occurrences of these rocks at Point Woronzof and at the railroad bridge across the Eagle River suggest that the Tertiary coal measures may occupy considerable areas in that lowland, though generally covered and concealed by glacial moraines and outwash gravel.

QUATERNARY DEPOSITS

Practically the entire lowland northwest of the Kenai Mountains and between Knik Arm and the Chugach Mountains is covered with Quaternary deposits, including glacial moraines and outwash, stream and terrace gravel, and beach and estuarine sand and silt. These materials are characteristically unconsolidated and have been spread over the underlying beds in sufficient thickness to give the surface its present mild relief. A fuller discussion of the Quaternary deposits of the entire region covered by this report is given on pages 150–169.

---

[22] Martin, G. C., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, p. 68, 1915.

STRUCTURE OF THE KENAI-CHUGACH MOUNTAINS

The Kenai-Chugach province includes two regions that are markedly different in structure, the mountainous portion being complexly faulted and folded, probably in several directions, and the lowland being of simple structure, with little important faulting and only broad, gentle folds. The mountain structure is so complex as to have defied all attempts to solve it. It is known, however, that there is a wide range in the complexity of the structure from place to place, and this may be related to the age of the rocks affected. Thus the highly metamorphosed materials southeast of Knik Arm underlie or are in fault contact with the younger, less altered sedimentary rocks. Similarly, near Seldovia and Port Graham, there are several types of materials, including schists, greenstones, cherts, and tuffs, which are thought to be older than the associated, less altered sedimentary rocks. Although there is evidence of cross folding and of faulting in many directions, a tendency exists for the rocks in any locality to strike parallel to the axis of the range at that locality and to dip at rather high angles. This tendency was especially noted along the excellent section across the range offered by Turnagain Arm, the Portage River, and Portage Glacier. Over a distance of 23 miles the rocks were observed to have a fairly uniform northeasterly strike and an average dip of about 70° either to the northwest or to the southeast. Faults are common in the slates and graywackes, but in the lack of recognizable key beds it is impossible to determine the amount of displacement. There is considerable evidence to support the belief that the older schists, greenstones, tuffs, and cherts in the Seldovia area, as well as the agglomerates and tuffs of lower Turnagain Arm and along the southeast side of Knik Arm, are separated from the slates and graywackes by a profound fault, and similarly that the greenstones and greenstone tuffs south of Matanuska Valley are also in fault contact with the sedimentary beds to the south.

No reliable estimates have been made of the thickness of the sedimentary beds and volcanic rocks that make up the Chugach and Kenai Mountains. In the southwestern portion of Kenai Peninsula, near Seldovia, there is a group of schists, of unknown age and undetermined but considerable thickness. These are overlain by some 5,000 feet of basic lava, slate, graywacke, chert, and tuff, of Triassic or earlier age, and these in turn by Upper Triassic limestone, chert, and tuff. These beds are in fault contact with the slates and graywackes that make up the bulk of the Kenai and Chugach Mountains. On Turnagain Arm also there are many thousand feet of greenstone tuffs, and there too the relation of the tuffs to the slates and graywackes is probably a fault contact. The thickness of the slates and graywackes is also unknown. The problem of estimating their thickness is immensely complicated by the absence of recognizable key beds from which the structure might be deduced and by the tremendous folding and faulting that have taken place. In view of the fact that this great belt of mountains, hundreds of miles long and averaging over 50 miles wide, and with a vertical relief of many thousand feet, is composed almost exclusively of slates, argillites, and graywackes, with only subordinate amounts of igneous material, it is difficult to believe that the aggregate thickness of beds is less than several thousand feet, and it may be several miles.

GEOLOGIC HISTORY OF THE KENAI-CHUGACH MOUNTAINS

Any account of the sequence of geologic events in this region that can now be written leaves much to be desired, for there are great gaps in the record that are not represented by recognized deposits, and of the rock formations that are present only a few have yielded fossils from which the age of the enclosing rocks could be determined. The record for Paleozoic time is largely undecipherable. No rocks of definitely proved Paleozoic age have been found, but certain schists in southwestern Kenai Peninsula were originally sedimentary rocks that were probably deposited, consolidated, and partly metamorphosed before the end of the Paleozoic era.

The earliest Mesozoic rocks of this region include lava flows and tuffs, probably of early Triassic age, that in part at least were deposited in water and include some interbedded sedimentary materials. Upper Triassic deposition is represented by limestones in the Port Graham district and by fragmental volcanic materials there and elsewhere.

In early Jurassic time coarse tuffs and agglomerates were laid down along the western and northwestern margin of the Kenai-Chugach province. Middle and Upper Jurassic rocks have not been recognized in this region, though this fact is difficult to explain in view of the fact that just west of Cook Inlet and in the eastern Talkeetna Mountains, to the north, there is a thick and highly fossiliferous section of Jurassic rocks. Possibly some part of Jurassic time is represented by a part of the great assemblage of unfossiliferous slates and graywackes that form the bulk of the Kenai and Chugach Mountains.

It has now been proved that at least a part of the slates and graywackes of the coastal ranges are of Cretaceous age and probably Upper Cretaceous. Diagnostic fossils have been found in only one district, but these prove that during Cretaceous time this province was submerged beneath the sea and received great thicknesses of shallow-water clastic sediments. Why that sea was so inhospitable to marine organisms is not known, but a few forms existed there, and evidence is accumulating that here, as in other parts of Alaska, tremendous thicknesses of Cretaceous muds and sands were laid down, and more and more of the unfossiliferous Mesozoic sediments are becoming recognized as of Cretaceous age.

After these Cretaceous beds had become indurated, folded, and elevated above sea level, volcanic activity was renewed in the area between Turnagain and Knik Arms, and several thousand feet of greenstone tuff was laid down. At about this time, too, there was extensive intrusion of granitic bosses, dikes, and sills into the earlier rocks, and these effected the gold mineralization of the region.

At the beginning of Tertiary time practically all of Alaska had emerged from the sea, and it has remained a land mass ever since. Certain of the major geographic divisions that are now recognized were already outlined, and there were even then lowlands which corresponded in a general way with the regions of low relief now known as the Cook Inlet depression and the Susitna and Matanuska Valleys, and these lowlands were bordered by regions of higher relief. During Eocene time great quantities of mud and sand were carried by the streams from the highlands and deposited as fresh-water or estuarine beds in the lowlands, to make up the Kenai formation.

In the lowlands conditions occurred from time to time that favored the accumulation of the remains of vegetation, now altered to lignite or coal. Locally thick deposits of gravel accumulated on top of the coal-bearing Kenai formation, and in places diabasic dikes and sills were intruded into it. The Eocene climate was warmer than the present climate, as is witnessed by the plant remains that include forms not now able to exist in this latitude.

From the end of the Eocene to the end of Pliocene time no sedimentary record was left in this region. The general distribution of mountain masses and of lowlands was about as it is today, and no important periods of folding, faulting, or mountain building have occurred since. Erosive processes of course were active, with continuing removal of detritus from the uplands to the sea.

Quaternary time was begun by a change of climate that brought glacial conditions to this area. The sequence of Pleistocene events, as we know them, and the results of glaciation upon the landscape are discussed in another section of this report (pp. 150–169).

TALKEETNA REGION

The Talkeetna Mountains constitute a roughly circular mountain mass that lies north of Knik Arm and the Matanuska River and is almost completely encircled on the west, north, and east by the Susitna River and its tributaries, the Tyone River and Tyone Creek. On the north the Talkeetna Mountains are more or less continuous with other ranges that extend beyond the westward-flowing portion of the

Susitna River, and for the purposes of this report the Talkeetna region is considered to include the entire mountainous tract that lies east of the Susitna and Chulitna Rivers, south of the Alaska Range, west of the Copper River lowland, and north of the Chugach Mountains. It thus includes the rugged country to which the name Talkeetna Mountains has been applied, as well as certain continuing ridges and isolated groups of mountains to the north. The region is separated topographically from the Alaska Range by the wide Susitna lowland, the valley of the Chulitna River, Broad Pass, and the wide basin of the upper Nenana River. On the east it is adjoined by the Copper River lowland. The topographic line of demarkation on the south is less evident, for only the valley of the Matanuska River separates the Talkeetna from the Chugach Mountains, but the structural and geologic difference is pronounced.

As shown on plates 1 and 2 the conspicuous geologic feature of the Talkeetna region is the great granitic batholith and its surrounding satellites that occupy so large a portion of this area. The geology of a part of the region north of the Talkeetna River has not yet been studied, but it is known that granitic rocks are abundantly represented there also. Only secondary to the granitic rocks in area are the extensive deposits of lavas and tuffs of various ages. The region is therefore prevailingly one of igneous rocks, in contrast to the Chugach-Kenai region, where sedimentary deposits greatly preponderate over igneous materials. As shown below, these mountains exhibit a profound difference in structure as well as in materials from the coastal mountains, for they were elevated, not as a result of intense folding and faulting, but as a massive uplift, with comparatively little deformation. The valley of the Matanuska River, lying along the border of these two mountain masses, presents a small geologic province of itself, for it was the hinge along which the mountain-building forces of both ranges acted, and so suffered correspondingly.

MICA SCHIST

Apparently the oldest rocks in the Talkeetna region are the mica schists that occur in the Willow Creek district. As they have been fully described elsewhere,[23] a brief description will suffice here. They occupy an area of 12 by 4 miles and doubtless extend westward and southward beneath the Tertiary beds and the surface covering of Quaternary materials. The rocks are prevailingly highly contorted, fissile mica schists and phyllites, the fissility depending to some degree upon the amount of weathering the rocks have under-

[23] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 26–30, 1915.

gone. Fresh unweathered material appears comparatively massive, but weathering reduces it to thin plates and slabs. The amount of mica varies locally, and the perfection of the cleavage of the schist depends upon its abundance. Associated with the typical mica schists and included with them are certain masses of more or less metamorphosed basic rocks that locally have been altered to serpentine. The schist is cut by numerous quartz veins, usually as irregular, sinuous bodies following the lines of schistosity. Only small amounts of gold have been found by assay in most of these veins, though one has been mined in a small way. At a few places the gravel of streams draining the schist has contained workable gold placer deposits, thus showing that the schist must contain small amounts of gold in veins or veinlets.

The structure of the schist is highly complex, and the original bedding planes of the sedimentary rocks are largely obscured by the secondary schistosity. It is apparent, however, that there is present a major series of larger folds striking northeast and with steeply dipping limbs, upon which are superposed the countless minute folds and contortions that are visible in all good exposures and even in hand specimens. The thickness of the schist series is not known, though these rocks crop out over a vertical range of 2,200 feet in a single mountain, and the schist belt averages about 3 miles in width at right angles to the direction of major folding.

The schists of this district contain no fossils, and their age can only be inferred from their relations to other formations of known age and from their degree of metamorphism. They are cut by or are in faulted contact with undeformed granitic intrusive rocks of Mesozoic age and are overlain by early Tertiary beds. The metamorphism they have undergone exceeds in degree that of any of the known Mesozoic rocks of this region, of the Devonian limestones of Broad Pass, and of the other rocks of the region that are presumably of Paleozoic age. The only rocks of similar appearance in this part of Alaska are the Birch Creek schists of the north flank of the Alaska Range and of the Yukon-Tanana region, which are believed to be of pre-Cambrian age. The schists of the Willow Creek district bear a striking resemblance in appearance and perfection of schistosity to the Birch Creek schist farther north, and in the absence of definite evidence of their age they are here classified with the Birch Creek and thus as of pre-Cambrian age.

SEDIMENTARY ROCKS OF QUESTIONABLE PALEOZOIC AGE

Within the Talkeetna region there are several areas occupied by metamorphosed sedimentary rocks concerning whose age there is little definite information except that they are apparently somewhat more metamorphosed than the associated Mesozoic and Tertiary materials. In the great bend near the head of the Susitna River, where its course changes abruptly from south to north of west, there are several isolated hills composed of rocks that are probably of pre-Carboniferous age. Chapin,[24] who studied these rocks, described them as including greenstones and schists, local beds of limestone, slate, and quartzose rocks, and dioritic and diabasic intrusives. He stated that though the rocks of this group differ widely in composition and character they are more or less related, and he grouped them together until more detailed studies of them could be made. That there may be considerable difference in age between some of the constituents of the group is suggested by the wide range in the amount of metamorphism observed in them. The lower part of the group appears to be dominantly sedimentary and the upper part igneous. The most prevalent rock type is greenstone, which includes several kinds of lava and intrusive materials. The lavas are prevailingly altered andesites and basalts. The principal intrusive rock was originally a diorite, now much altered. Limestone occurs only locally but has a maximum thickness of 500 feet. In its upper part it is interbedded with sheets of greenstone and metamorphosed sediments. With it in places are thin beds of black slate, quartzite, and fine-grained schist and phyllite, evidently of sedimentary origin.

The age of the rocks of this group is uncertain. Chapin correlates them with similar rocks east of the Susitna River which Moffit[25] tentatively regarded as pre-Carboniferous. They have yielded no fossils but seem to be more highly metamorphosed than the nearest Carboniferous beds. They are here included with the undifferentiated Paleozoic rocks.

No rocks of unquestioned Paleozoic age have been identified in the Talkeetna region. In their study of the lower course of the Talkeetna River Paige and Knopf[26] noted a series of slates and schists, cut by granitic intrusives. Similar slates had already been described by Eldridge[27] as extending from a point about 15 miles above the mouth of the Chulitna up the Susitna Valley to and beyond the mouth of Indian Creek. Only a part of this region has been mapped areally. The larger structural features of the beds of this group seem to consist of a succession of close folds striking northeast, parallel to the axis of the Alaska Range, with the beds dipping generally southward. Faults are not conspicuous but if

[24] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 23–25, 1918.

[25] Moffit, F. H., Headwater regions of Gulkana and Susitna Rivers, Alaska: U. S. Geol. Survey Bull. 498, p. 26, 1912.

[26] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 11–12, 1907.

[27] Eldridge, G. H., A reconnaissance in the Susitna Basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 15–16, 1900.

present would be difficult to detect in beds of such uniform composition. The thickness of the group is unknown but is probably several thousand feet. From Eldridge's description and from the description by Paige and Knopf of similar rocks in an adjoining area, it appears that these slates are somewhat more highly metamorphosed than the undifferentiated Mesozoic slates and graywackes of the Yentna district. Furthermore, it is now known, from studies by Moffit in the Broad Pass district, by Capps in the upper Chulitna region, and by Ross on the West Fork of the Chulitna, that Paleozoic rocks crop out along the southeast front of the Alaska Range. This suggests the possibility that at least a part of the Susitna slates of Eldridge may be of Paleozoic age, although there is even better evidence for correlating them with the Mesozoic rocks of the Yentna district, along the strike of which they lie. In the most recent geologic studies in this field Tuck [28] correlates the slates along the Susitna River near Curry with similar rocks in the Yentna, Tokichitna, and Eldridge Glacier areas and classifies them as of Triassic to Cretaceous age. The writer is inclined to agree with that correlation and to group these rocks with the undifferentiated Mesozoic sedimentary rocks, and they are so shown on plate 2.

MESOZOIC ROCKS

UNDIFFERENTIATED MESOZOIC SEDIMENTARY ROCKS

In the headwater region of the Nenana and Susitna Rivers Moffit [29] mapped three groups of Mesozoic sediments, one of which he classified as of questionable Triassic age, one as questionably Jurassic, and one as of undifferentiated Mesozoic age. The Triassic (?) group, which occupies a belt that crosses the Susitna River in a northwesterly direction in the vicinity of Valdez Creek, consists prevailing of dark-blue and black slates, with some interstratified beds of arkose and graywacke, and includes beds that may be several thousand feet in thickness. These beds are closely folded and locally have been altered to phyllite and schist. Moffit considered these beds to be the westward continuation of a formation well exposed east of the Susitna River from which he collected Upper Triassic fossils.[30] However, as the fossils were found only in a limestone which forms only a small part of the group, and as the group as a whole is very thick, it seems probable that beds of other than Triassic age may be included, and they are here grouped with the undifferentiated Mesozoic sedimentary rocks.

---

[28] Tuck, Ralph, The Curry district: U. S. Geol. Survey Bull. 857, pp. 117–123, 1934.
[29] Moffit, F. H., op. cit. (Bull. 498), pp. 39–40.
[30] Idem, pp. 31–33.

The second group of rocks, mapped by Moffit [31] as of questionable Jurassic age, occurs along the south side of Broad Pass and the Nenana River from the Middle Fork of the Chulitna River to Seattle Creek. It consists of closely folded dark-blue and black slates with interbedded graywacke and conglomerate and locally some impure limestone, and has a thickness of several thousand feet. The prevailing strike of the beds is N. 50°–70° E., parallel to the axis of the Alaska Range to the north. Moffit correlated these beds with the slates and graywackes of the Susitna and Chulitna Basins, to the southwest, and of the Prince William Sound and Kenai Peninsula regions, the age of which at that time was uncertain but which have since been shown to be in part, at least, of Cretaceous age. In this report this group is included with the undifferentiated Mesozoic sedimentary rocks. Still another group of strata in the Broad Pass region that extends from Wells Creek eastward to and beyond West Fork Glacier was classified by Moffit [32] as of undifferentiated Mesozoic (?) age. This group includes a complex of beds that consist chiefly of slate and limestone that strike northeast and that lie along the strike of slates and graywackes of the Jack River that Moffit regarded as of possible Jurassic age. Little detailed work was done on this group of beds, but Moffit considered that they were probably of Mesozoic age, and they are here classified with the undifferentiated Mesozoic sedimentary rocks.

Chapin [33] has described rocks somewhat farther south, in the Nelchina-Susitna region along Tsisi Creek, as consisting prevailingly of dark-blue and black slate and argillite and greenish-gray graywacke. The graywacke is composed of grains of quartz and feldspar and fragments of rock. The beds are closely folded and locally are considerably metamorphosed to mica schists and intermediate schistose rocks. Some thin beds of crystalline limestone are intercalated with the sedimentary rocks.

Structurally this group is closely folded, the beds having a general northeast strike and dipping steeply to the northwest. An incomplete section showed a thickness of at least 2,000 feet, although neither top nor bottom of the section was seen. No fossils were found in this locality, but Chapin tentatively correlated this group of rocks with the sedimentary beds of doubtful Triassic age that extend from the heads of Deadman and Watana Creeks eastward to Maclaren Glacier, and referred them with a question to the Upper Triassic. In view of the uncertainty of this correlation and the fact that only a part of the

---

[31] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 32–38, 1915.

[32] Idem, pp. 39–40.

[33] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 27–28, 1918.

beds with which they are correlated are known to be Upper Triassic, the sedimentary rocks on Tsisi Creek are here grouped with the undifferentiated Mesozoic rocks.

In the western Talkeetna Mountains a narrow, sinuous, and interrupted belt of sedimentary rocks crosses the basins of the Sheep River and Iron Creek in a northeasterly direction. The rocks of this belt include a massive limestone, locally altered to marble, and slate, shale, and quartzite. These materials occur in general as steeply dipping beds between the granitic rocks on the southeast and the greenstones on the northwest, although locally there are patches that are completely surrounded either by the greenstones or by the granitic rocks. Little is known concerning the original thickness of this series of beds, but in places the limestone is at least 600 feet thick. At other places the belt is a quarter of a mile wide and is composed of nearly vertical but much folded and much deformed beds. The age of these rocks is discussed by Capps,[34] who states that in all the localities that were examined the limestones and associated sedimentary rocks are strongly metamorphosed, and neither recognizable fossils nor even imprints or markings that suggested organic remains were found, though careful search was made for them. The only direct evidence as to their age, therefore, is obtained from their relations to the adjoining igneous rocks, for they are in contact with no other sedimentary beds. It is certain that if the sedimentary rocks are older than the andesite greenstones, and if the age of the greenstones has been properly determined, the sedimentary rocks are at least as old as pre-Jurassic. The nearest formations with which they might be correlated on the basis of lithologic similarity are the Triassic limestones and shales identified in the basin of the West Fork of the Chulitna River,[35] where the beds are generally less severely metamorphosed than those here described but have locally been altered to marble and slate. It is not unlikely that the limestone, marble, and associated sedimentary rocks of the Iron Creek and Sheep River Basins are of Triassic age, though that is the youngest period to which they can be assigned on the basis of present knowledge, and they may be considerably older than the Triassic.

For the purposes of classification, these beds, of uncertain age, are here tentatively assigned an undifferentiated Mesozoic age.

In the Matanuska Valley region, north of Castle Mountain, there are several small areas of blue-gray to white crystalline shattered limestone that in places is cherty. In at least one locality the limestone lies in a closely compressed overturned syncline and rests unconformably on volcanic rocks which are thought to be of Lower

[34] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, p. 195, 1919.

[35] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 216–217, 1919.

Jurassic age. Martin[36] provisionally refers these limestones to the Lower Cretaceous, but in the lack of positive evidence as to their age they are here grouped as undifferentiated Mesozoic.

JURASSIC ROCKS

LOWER JURASSIC VOLCANIC ROCKS

A group of volcanic rocks, with which some sedimentary rocks are locally interbedded, forms one of the prominent geologic units of the Talkeetna Mountains. Inasmuch as these rocks are more or less stratified and contain interbedded sedimentary rocks they are here described in their stratigraphic order along with the other bedded rocks. They occupy a belt that extends from the northern border of the Matanuska Valley northward and northwestward up the valley of the Chickaloon River and down the Talkeetna Valley to a point below the mouth of Iron Creek. Another belt runs diagonally across the Talkeetna Mountains in a southwesterly direction from upper Iron Creek to the basin of Montana Creek, and there is a considerable area of these rocks in the headward basins of the Oshetna River and Sanona and Tyone Creeks. A few smaller isolated areas of the same rocks also occur in the region. These rocks were first described by Paige and Knopf[37] as including andesite greenstones and quartz porphyries, with which are interbedded smaller amounts of tuffaceous sandstones, shales, and conglomerates. The great bulk of the greenstones are the products of explosive volcanic activity and occur in the form of stratified breccias in which angular fragments of dark-blue porphyry are enclosed in a matrix that is green from the abundant secondary chlorite that it contains. Some amygdaloidal flows are present, and in these the amygdules consist of chalcedony, quartz, calcite, chlorite, or zeolite. From the evidence available at that time Paige and Knopf assigned these rocks to the late Middle Jurassic, an assignment that has since been changed to Lower Jurassic.

Rocks belonging to this group occur extensively in the Matanuska Valley, where they consist mainly of volcanic breccia, agglomerate, and tuff. The rocks in an area north of Castle Mountain are described by Martin and Katz[38] as consisting of felsites of creamy-white and drab color, the former containing phenocrysts of small white feldspar and black decomposed biotite (?); brownish-green narrow-banded tuffs of fine angular clastic texture; dark fine-grained fragmental rocks studded with small white feldspar crystals; banded fossiliferous tuffs composed of angular bits of feldspar and horn-

---

[36] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 33, 1912.

[37] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 16–17, 1907.

[38] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 30, 1912.

blende or other dark minerals or fragments of dark rock; stratified breccias in which angular fragments of porphyritic or felsitic rocks are embedded in a matrix of only slightly different appearance, accentuated on weathered surfaces; and black aphanitic vesicular basalts. All these rocks are much weathered. The prevalent green color indicates general development of secondary minerals and decomposition products. Some of these rocks are severely crushed and shattered, and in them epidotization and chloritization are particularly pronounced. These rocks are intricately interlaced with small quartz and calcite seams.

Still farther to the northeast, in the basins of the Oshetna and Tyone Rivers, there are large areas of similar volcanic rocks, dominantly andesitic and rhyolitic in composition, that have been described by Chapin,[39] who found no positive evidence of their age and who correlated them with the similar group of materials already described by Paige and Knopf and by Martin and Katz.

The area of this great group of volcanic materials has more recently been found to extend southwestward from the Talkeetna Valley as a belt that crosses the basins of Iron Creek, the Sheep River, and Montana Creek and thus is shown to be continuous between two localities at which it had earlier been observed by Paige. In this belt, however, the rocks are prevailingly dark-colored lava flows, and the fragmental volcanic materials that are so abundant elsewhere are here entirely subordinate. The rocks in this area are described[40] as consisting almost exclusively of amygdaloidal greenstone flows, with small areas of intrusive greenstone, but the tuffs and breccias that seem to predominate farther east are almost completely lacking. Over most of this area a single rock type prevails—a dark-green porphyritic amygdaloidal greenstone, in which the amygdules consist of greenish-yellow epidote. Similar hand specimens of this rock might be collected anywhere from the Kashwitna Basin northeastward to the upper valley of Iron Creek, and it is in this rock that the ore deposits of Iron Creek occur. As studied in thin section the groundmass is seen to be diabasic, of medium grain, and much altered. It contains a little secondary quartz and feldspars that are too badly altered to permit close determination. Abundant chlorite is present and probably represents an alteration product of hornblende. The vesicles are filled with secondary epidote, whose radiating crystals form spherulites.

This group of volcanic rocks is in general not greatly deformed, though in the western Talkeetna Mountains the greenstone flows have

---

[39] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 29–32. 1918.

[40] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 195–196, 1919.

locally been folded and faulted. In the main the rocks are so massive that the structure is difficult to determine. In the Talkeetna and Chickaloon Valleys the beds locally show marked folding, though faults of small displacement are numerous. Still farther east, in the Oshetna Basin compression and subsequent tilting have developed a series of prominent eastward-trending folds. Faults are common but on a rather small scale.

As is to be expected in a group of rocks made up largely of lava flows and the material ejected from volcanoes, the series varies in thickness from place to place. In the western Talkeetna Mountains there are several thousand feet of rocks, mainly lava flows. In the Chickaloon and upper Talkeetna Basins the series in many places exceeds 1,000 feet in thickness, and in the Oshetna Basin the dominantly igneous portion of the series is at least 1,200 feet thick, in addition to which there are several hundred feet of tuffs, tuffaceous sandstones, and shales.

The age of this group has been determined on the basis of fossils collected from the Matanuska Valley. The earliest collections, made by Paige and Knopf, were thought to indicate a lower Middle Jurassic age for the enclosing rocks. When additional collections had been made by Martin and Katz the evidence was reexamined and reviewed, and the age of the group was determined as Lower Jurassic. No fossils have been found in this group in the Oshetna Basin or the western Talkeetna Mountains. In the latter region the correlation made by Paige and Knopf between the greenstone flows of Montana Creek and the beds in the upper Talkeetna Basin has been accepted, as the two areas are now known to be continuous. Similarly, the volcanic rocks of the Oshetna Basin have been correlated with the beds of like character in the Talkeetna-Chickaloon region. If these correlations are correct, then the age of the whole group seems to be definitely fixed as Lower Jurassic, and it appears likely that the volcanic rocks and associated sedimentary beds, already described, that extend almost continuously along the south side of the Matanuska Valley and along the northwest face of the Chugach and Kenai Mountains from the Knik River to and beyond Turnagain Arm are a part of this same group and are also of Lower Jurassic age.

MIDDLE JURASSIC ROCKS

In the upper basin of the Matanuska River and in the headwater area of the Nelchina River there are several areas of rocks of Middle Jurassic age that have been described [41] under the name "Tuxedni sandstone." The Tuxedni sandstone is composed of sandstones and

---

[41] Capps, S. R., Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 791, pp. 24–29, 1927. Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 32–33, 1918.

sandy shales that are at least several hundred feet thick and may be 1,000 feet or more. The formation contains marine fossils and abundant poorly preserved vegetable remains, mostly water-worn sticks and stems. It overlies the Lower Jurassic volcanic rocks and is overlain by the Chinitna shale. In general the beds are only slightly tilted, though locally there has been folding. Faults are common. The fossils show that this formation is of Middle Jurassic age.

UPPER JURASSIC ROCKS

Upper Jurassic rocks have been recognized in a small area near the head of Boulder Creek, in the upper Matanuska Valley, and in a much larger area on the headwaters of Billy Creek and the Nelchina River. They have been described as the "Chinitna formation" and the Naknek formation,[42] which includes the Chisik conglomerate member.

The Chinitna formation,[43] which was formerly considered to be Middle Jurassic but which is now believed to form the basal unit of the Upper Jurassic rocks, consists of shale and shaly sandstone, with a lesser amount of conglomerate and massive sandstone. Calcareous concretions are abundant in the shales, and the sandstone[44] in places is conglomeratic and contains angular fragments of shale and black minerals. The formation is probably several thousand feet thick and lies in synclinal troughs, in apparent conformity upon the Tuxedni sandstone. It is overlain unconformably by the Upper Jurassic rocks of the Naknek formation. Fossils found in these beds indicate an Upper Jurassic age, and they have been correlated with the Chinitna shale of Cook Inlet. The Chisik conglomerate member of the Naknek formation is well developed on the headwaters of the Nelchina River and Tyone Creek. It is composed of massive plates made up of dioritic and volcanic rocks set in a gritty matrix containing abundant fragments of mica and shale. The materials are coarsest near the base of the member. In the upper part of the section there are lenses of fine sandstone, shale, and fine conglomerate. The conglomerate locally has a thickness of at least 450 feet, and the section there is partly concealed. The beds are generally almost flat-lying or tilted at low angles. The structural relations show that this unit is of Upper Jurassic age.

The remainder of the Naknek formation consists of shales, sandy shales, and sandstones that conformably overlie the Upper Jurassic conglomerate in the Nelchina-Tyone district.[45] There the formation

[42] Martin, G. C., Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, pp. 227–232, 1926. Chapin, Theodore, op. cit. (Bull. 668), pp. 33–38.
[43] Martin, G. C., op. cit., pp. 227, 229.
[44] Chapin, Theodore, op. cit. (Bull. 668), p. 34.
[45] Idem, pp. 36–37.

occupies a shallow syncline, and the beds are more deformed than the underlying conglomerate and show many minor gentle folds and some small faults. On Boulder Creek[46] this formation rests unconformably upon the Chinitna formation and is overlain unconformably by Upper Cretaceous and Tertiary rocks. The formation is certainly more than 1,000 feet thick and probably several thousand feet.

On the basis of the contained fossils this formation is assigned to the Upper Jurassic.

CRETACEOUS ROCKS

LOWER CRETACEOUS ROCKS

Rocks of Lower Cretaceous age occur in the upper Matanuska Valley region on the headwaters of Billy Creek and in the upper basin of the Nelchina River. They consist of a group of tuffs or arkoses and conglomerates and the overlying Nelchina limestone. The tuff and conglomerate have not been mapped separately,[47] as their Cretaceous age was not recognized in the field. They were consequently included on plate 2 with Upper Jurassic rocks. They are probably uniformly present at the base of the overlying Lower Cretaceous limestone and occupy a narrow zone surrounding the areas of that limestone. The beds are between 100 and 200 feet thick and lie with apparent conformity upon the Upper Jurassic sandstones and shales of the Naknek formation, beneath the Nelchina limestone. These rocks include some highly fossiliferous beds, and on the basis of the fossils they have been assigned, with some uncertainty, to the Lower Cretaceous.

Lying conformably above the tuffs and conglomerates just described there is in the upper basin of the Nelchina River a limestone formation that has been described[48] as the Nelchina limestone. This formation occurs in several areas, most of which are small, and forms the tops of the hills on which it is found. It consists of massive, dark-colored, fine-grained unaltered limestone that is at least 100 feet thick, and may reach a thickness of 200 or 400 feet. It has been considerably faulted, so that its normal thickness is difficult to ascertain, especially as all the occurrences are on hilltops, where erosion has removed an unknown amount of the rocks. The Nelchina limestone overlies with apparent conformity the Lower Cretaceous tuffs and conglomerates above described. In most places occupying hilltops, it has no overlying materials, but locally it is covered unconformably by a Tertiary conglomerate. The Upper

[46] Capps, S. R., op. cit. (Bull. 791), pp. 31–33.
[47] Martin, G. C., op. cit., pp. 310–316.
[48] Idem, pp. 313–316.

Cretaceous strata were nowhere observed in contact with this limestone. Although some fossils have been found in the formation, it is generally unfossilifarous, and such forms as have been collected are not sufficiently characteristic to serve as a basis for an exact age determination. On account of its stratigraphic relations to the underlying tuffs and conglomerates, however, it is assigned with considerable confidence to the Lower Cretaceous.

UPPER CRETACEOUS ROCKS

Upper Cretaceous rocks, the Matanuska formation, are extensively developed in the Matanuska Valley, though elsewhere in the Talkeetna region they have not been recognized and are probably absent. They occur in irregular-shaped areas and belts extending from a point several miles below the mouth of Tsadaka (Moose) Creek up the Matanuska River to Sheep Mountain and north of Sheep Mountain. These rocks have been described [49] as consisting essentially of shale and sandstone, with subordinate amounts of conglomerate. The most complete section observed, in the gorge of Granite Creek, shows at least 4,000 feet of beds, of which the lower half is practically all shale, and the upper half consists of alternating beds of sandstone and shale, the sandstone predominating. The base of this series of beds has nowhere been observed, but it probably rests unconformably upon an erosion surface that truncates rocks ranging in age from Lower Jurassic to Lower Cretaceous. The beds are overlain unconformably by Tertiary arkose and conglomerates. In general these rocks in the Matanuska Valley have been so severely folded that the stratigraphic sequence cannot be recognized. Farther northeast, on Alfred and Billy Creeks and upper Boulder Creek, the beds are less disturbed and the structure is more gentle. On the basis of evidence obtained from numerous collections of fossils from this group of rocks, the beds are definitely assigned to the Upper Cretaceous.

In the Alaska Range, just north of the Talkeetna region, there is a great group of nonmarine sedimentary rocks including conglomerates, sandstones, and shales—the Cantwell formation, which heretofore has been assigned to the Eocene but which has recently been classified on the basis of its fossil leaves, as definitely of Upper Cretaceous age. These sedimentary rocks are in places associated with considerable igneous material, present as flows, dikes, sills, and fragmental volcanic accumulations. Their general state of induration and metamorphism and their structure and stratigraphic position indicate that they are younger than the slates and graywackes

[49] Idem, pp. 317–327. Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 34–39, 1912.

in the same region which are here mapped as undifferentiated Mesozoic but which have yielded marine fossils that have been determined as of Cretaceous age, and probably Upper Cretaceous. The implications of this reassignment of the Cantwell to the Upper Cretaceous are discussed in that portion of this report that deals with the stratigraphy of the Alaska Range (pp. 112–118), but this brief statement is necessary here because the hitherto accepted Eocene age of the Cantwell has required that certain intrusive and extrusive igneous rocks that either cut the Cantwell or are interbedded with it should also be assigned to the Tertiary. Among these igneous rocks there are several areas of lava flows on Tsusena Creek, north of the Susitna River, that were described by Chapin [50] as including dacite, rhyolite, and andesite of which the dacite flows are the oldest. Chapin thought that the dacite might be Mesozoic but regarded the other flows as Tertiary, probably because of their similarity to lavas that Moffit and Pogue had found interbedded with Cantwell sedimentary rocks which they assigned to the Eocene. The later correlation of the Cantwell as Upper Cretaceous requires that the lavas also should be regarded as of that age, and they are here mapped as undifferentiated acidic Mesozoic volcanic rocks, to differentiate them from the much younger basaltic lavas of the region. Moffit and Pogue [51] also described lavas that included rhyolite, trachyte, and andesite between the Nenana River and the head of the Jack River. Some of these lavas were interbedded with Cantwell sedimentary rocks, then considered to be Eocene. Owing to the reassignment of the Cantwell to the Upper Cretaceous, these lavas are here grouped with the undifferentiated acidic volcanic rocks of Mesozoic age.

MESOZOIC INTRUSIVE ROCKS

A study of the geologic maps of the Talkeetna region (pls. 1 and 2) discloses the fact that a very large part of the region is occupied by intrusive rocks, most of which are of granitic habit and which are prevailingly of the composition of diorite. It is likely that if the facts were known concerning the geologically unmapped area between the Talkeetna and Susitna Rivers, it would be found that almost or quite half of the Talkeetna region is underlain by granitic rocks. The largest single diorite body is that which forms the bulk of the Talkeetna Mountains west of the Chickaloon and upper Talkeetna Rivers, but there are great outlying masses, such as that in the lower basins of Sheep and Iron Creeks, the one in the basins of the Oshetna River and Kosina Creek, the large one in the area north of the east-

[50] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 38–40, 1918.

[51] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation by J. E. Pogue: U. S. Geol. Survey Bull. 608, pp. 60–63, 1915.

west portion of the Susitna River and south of Nenana River, which includes masses of granite, quartz monzonite, and granite porphyry, and numerous smaller satellites west of the Susitna River and south of the Matanuska River. It is quite possible that some of these masses, though portrayed as distinct bodies on the geologic map, have subsurface connections and were intruded at about the same time.

As the granitic rocks of the region have been described in some detail by the various geologists who have reported on different districts within the railroad belt, detailed petrographic descriptions are not necessary here. A medium to coarse gray quartz diorite seems to predominate, though granite and granite porphyry occur in places. By and large these rocks show little metamophism, though at many places gneissic phases in which dark minerals are more abundant than ordinary have been reported. This raises a question, still unsettled, as to whether or not the gneissic phases represent an older period of intrusion, with dynamic metamorphism before the injection of a later magma.

For many years it has been generally agreed that the diorites of the central Talkeetna Mountains were definitely shown to be of Middle Jurassic age, this determination being based on the facts that Lower Jurassic volcanic rocks are cut by granitic rocks and that Upper Jurassic rocks contain boulders of granite like that cutting the Lower Jurassic. Although these observations are significant, neither of them can be considered entirely conclusive. Granites cutting Lower Jurassic beds are certainly younger than the beds they cut, but they might be much younger. Furthermore, granitic boulders in Upper Jurassic beds only prove that somewhere in the region there were granites older than the Upper Jurassic. The determination of the age of intrusive rocks in this region offers great difficulties, for the contacts with other rocks generally lie in the alluvium-covered lowlands and cannot be seen. Furthermore, it is only under exceptional conditions that the stratigraphic and structural relations of large intrusive masses are such as to yield positive evidence of the age of the intrusives, and once such a determination is made, there is a tendency among geologists to refer other bodies of similar rocks, whose age is uncertain to the same period of intrusion. In this way many of the granitic intrusive masses of Alaska have been referred to a single great period of intrusion, in Middle Jurassic time. Perhaps that is the age of many of them, but it is known that granitic rocks have in places been injected at intervals from the early Paleozoic to the Tertiary, and more detailed work is likely to prove that some of the so-called Jurassic granitic rocks are older and some younger than those of the Talkeetna Mountains for which a Jurassic age assignment has been generally accepted.

Evidence from the Alaska Range, to the west and north, indicates that there most of the granitic intrusives were much younger than Middle Jurassic, for some of them cut rocks that carry Cretaceous marine fossils, and others cut the fresh-water sedimentary beds of the Cantwell formation, now believed to be Upper Cretaceous. It therefore seems unlikely that all the Mesozoic intrusives were of the same age. Some of the gneissic rocks may be pre-Jurassic or even older; some may be of Middle Jurassic age; some certainly cut Cretaceous slates and graywackes; and the youngest known granitic rocks intrude the Upper Cretaceous Cantwell formation.

TERTIARY ROCKS

In the Talkeetna region Tertiary rocks, of both sedimentary and igneous origin, are widely distributed. They have been most closely studied and are best known in the Matanuska Valley, where they contain coal beds that are of especial economic importance and where their areal extent is large. It is altogether probable, however, that the extent of Tertiary beds in the Susitna lowland is much greater than in the Matanuska Valley. The Susitna lowland and its northward continuation by way of the Chulitna Valley to Broad Pass are now largely covered by Quaternary unconsolidated materials, which conceal the underlying formations. The borders of this lowland basin have not been carefully examined, but already there are known to be many localities at which Tertiary beds crop out, and even far out in the basin, as at Susitna Station and at a point a few miles up the Yentna River and along the Cache Creek road west of Talkeetna, the Tertiary beds show through the mantle of later materials. The accompanying geologic map (pl. 2) shows that considerable stretches along the west side of the lowland are underlain by Tertiary beds that come to the surface at the lowland margin, and scattered occurrences have been observed up the Chulitna Valley as far as Broad Pass. Similarly, on the eastern border of the lowland Tertiary outcrops are known along the Susitna River near its junction with the Talkeetna, on lower Chunilna Creek, and near the railroad crossing of the Little Susitna River, and similar beds are reported on Willow Creek and the Kashwitna River, at the points where these streams enter the lowland. It will thus be seen that the great Susitna lowland is nearly encircled by scattered Tertiary outcrops, and it becomes evident that this lowland, continuous southward with the Cook Inlet depression and eastward with an extension up the Matanuska Valley, was a lowland also in Tertiary time and received as valley and estuarine deposits the detritus brought down from the then much lower surrounding hills. Thus it is possible that large areas of Tertiary materials are present in the lowland beneath the later gravel, though no doubt much Tertiary material was scoured out and carried away by the great glacier that later moved through the lowland.

In the Matanuska Valley it has been possible to subdivide the Tertiary sedimentary beds into three formations,—an unnamed lower one composed of arkose, conglomerate, and shale; the Chickaloon formation, which carries the coal beds in the Matanuska Valley; and the Eska conglomerate. Outside of the Matanuska Valley these subdivisions have not been made, and although coal-bearing beds occur that may be the equivalent of the Chickaloon, the evidence is usually insufficient to justify the correlation. For the purposes of this report, therefore, the Tertiary sediments of the Talkeetna region have been divided into only two groups—one of undifferentiated Tertiary rocks, including all those beds whose age has not been definitely determined, and the other including only the coal-bearing beds of the Matanuska Valley.

UNDIFFERENTIATED TERTIARY ROCKS

The sedimentary rocks here classified as undifferentiated Tertiary include arkose, shale, and conglomerate, some of which is probably as old as basal Eocene; sandstone, shale, and coal beds that may be of the same age as the Chickaloon formation; and post-coal conglomerates that may range in age from Eocene to Miocene. It thus includes all those areas of Tertiary sediments about which too little evidence has been obtained to justify a definite age assignment. These materials have been fully described in other reports,[52] and only a summary of their more important characteristics will be given here.

In Matanuska Valley and the upper basin of the Little Susitna River the basal Tertiary beds are composed prevailingly of arkose, with some shale, sandstone, and conglomerate. The lowest member of the arkose group is commonly a conglomerate containing boulders as much as a foot or more in diameter, with a matrix of arkose. This is succeeded above by a thick series of nearly pure arkose deposits. The arkose beds are composed of the disintegration products of the granitic mass that lies to the north of them and in places forms the surface upon which the arkose was deposited. As the igneous rocks that supplied this material were weathered largely by mechanical disintegration rather than by chemical decay, and as the disintegration products were deposited not far from their source, the arkose, though a sedimentary deposit, bears a remarkable resemblance

[52] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 39–55, 1912. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 24–31, 1907. Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 30–36, 1915; Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 791, pp. 40–45, 1927.

both in physical appearance and in chemical composition to the rock from which it was derived. In many places it would be difficult to distinguish sedimentary arkose from original granite or diorite were it not for the bedding of the arkose and the presence in it of scattered rounded pebbles and of plant remains. Toward the top of the arkose group there are interbedded layers and lenses of shale, impure sandstone, and conglomerate. At a few places basaltic lava flows are interbedded with the arkose.

Where the base of the arkose group could be observed it lies unconformably upon an erosion surface of the great granitic batholith that forms the core of the western Talkeetna Mountains or upon the ancient mica schists in the Willow Creek district. Elsewhere its relations to older rocks with which it comes into contact are largely due to faulting. It is apparent from the contact of the arkose with the underlying rocks that the surface upon which these beds were laid down was fairly level. The arkose was deposited in fresh water, presumably first in the lowlands but spreading laterally into regions of greater altitude as its thickness increased. The basal beds of the group are therefore not everywhere of the same age, for the overlapping edge of the deposits at one place was probably laid down after a great thickness of similar materials had already accumulated elsewhere. It is even possible that at the edge of the basin of accumulation arkoses were being deposited while the sands, shales, and organic materials of the coal-bearing series were accumulating not far away in the lowlands. In general, however, the arkoses form the base of the Tertiary rocks in the Matanuska Valley and are older than the Eocene coal-bearing formation that overlies them. They are therefore, in part at least, of Eocene age. They have, like all the other Tertiary sedimentary rocks, been indurated, tilted, and slightly folded. The beds generally dip southward, away from the mountains, at angles as great as 50°. Faults are common, and the displacement on some faults is great. The arkose series exceeds 2,000 feet in thickness at several places, and between the Little Susitna River and Moose Creek it appears to be over 6,000 feet thick.

Included here as undifferentiated Tertiary rocks are several small, scattered areas of materials from which no fossils have yet been collected and which are so separated from one another and from beds of definitely determined age that their place in the stratigraphic column can only be inferred. The Tertiary rocks as a whole are, however, so distinctive in appearance and differ so greatly from other rocks of this region that there can be little uncertainty in referring these isolated areas to the Tertiary. Among the occurrences of such rocks are the bluff at Susitna Station, where conglomerates crop out; the cut near the railroad crossing of the Little Susitna, where shale, sandstone, and coal beds are exposed; the coal-bearing shales and sandstones of Chunilna Creek and on the Susitna River a few miles above the mouth of the Talkeetna; several localities along the Chulitna Valley where typical Tertiary coal-bearing beds are known; the shale, graywacke, conglomerate, and sandstone on the Jack River, near Broad Pass; and extensive areas of conglomerate at the headwaters of Billy Creek and the Oshetna and Nelchina Rivers. As shown below, a characteristic feature of the Chickaloon formation, of Eocene age, is its coal beds. Coal-bearing Tertiary beds in the Yentna district, on the west side of the Susitna lowland, have, on the basis of their fossil plants, been definitely determined as of Eocene age, and the position of the scattered areas of Tertiary rocks around the borders of the Susitna lowland indicates that that entire lowland was probably receiving Tertiary deposits at the same time. It therefore seems highly probable that the coal-bearing beds at the various localities mentioned are of Eocene age, yet these areas have been so little studied, and so little is known of their extent or their stratigraphic range, that they are here classified as undifferentiated. For other localities at which coal beds do not appear the correlation is less trustworthy.

The large areas of massive conglomerate that have been mapped on the headwaters of Billy Creek and the Oshetna and Nelchina Rivers lie unconformably beneath Tertiary volcanic rocks and rest unconformably upon various formations that range in age from Lower Jurassic to Upper Cretaceous. The conglomerate consists of coarse well-rounded pebbles, largely of volcanic origin, embedded in a gravelly matrix. It varies in thickness from a knife edge to 2,000 feet and is generally little deformed. Its age is certainly Tertiary, but no more definite assignment can yet be made.

The Eska conglomerate of the Matanuska Valley is also included on the map (pl. 2) with the undifferentiated Tertiary rocks. This formation makes up such prominent features as Wishbone Hill and Castle Mountain. It consists of about 3,000 feet of predominantly coarse conglomerate in massive plates, interbedded with a very subordinate amount of coarse sandstone. The rocks are dominantly of a light tawny-red color and vary in grain from sandstone and fine conglomerate to beds crowded with pebbles as much as 6 inches in diameter. Individual beds of conglomerate reach 75 feet in thickness and are commonly structureless. This formation is in general only mildly deformed. It lies without observed unconformity upon the Chickaloon formation, of Eocene age, and is overlain by basaltic lavas and tuffs. No determinable fossils have been found in it, so that the only conclusion that can be reached concerning its age is that it is certainly Tertiary and is younger than the part of the Eocene represented by the Chickaloon formation.

CHICKALOON FORMATION

The term "Chickaloon formation" has been used to describe those coal-bearing Tertiary rocks that occur in the valley of the Matanuska River. There are other coal-bearing beds in the region, as described above, some portions of which are doubtless the time equivalent of parts of the Chickaloon formation, but too little is known about their exact age to justify assigning them to either the Kenai or the Chickaloon formation, and they have here been included with other undifferentiated Tertiary beds.

The Chickaloon formation occupies the greater part of the Matanuska Valley north of the Matanuska River and between the Kings River and Hicks Creek, two of its northern tributaries, with some small areas also south of the river. A part of the area here mapped (pl. 1) as undifferentiated Tertiary, on Eska and Moose Creeks, is also occupied by beds of the Chickaloon formation. This formation is described by Martin [53] as comprising a rather monotonous succession of shales and sandstones. The shales, which predominate over the sandstones in aggregate thickness, are gray to drab, rather soft and inclined to disintegrate on exposure, poorly bedded, and without well-defined joint planes. Most of the beds are rather gritty and vary in grain along the bedding. They contain many nodules of iron carbonate, in places in fairly persistent beds. The sandstones are yellowish, rather soft, of diverse grain in different beds and of varying grain in the same bed, and for the most part feldspathic. In general the individual beds are not very persistent. The thickness of the formation is doubtful but appears to be at least 2,000 feet.

There are numerous coal beds in the Chickaloon formation, and coal has been mined at various localities, including several on Moose Creek, on Wishbone Hill, on Eska Creek, on the Chickaloon River, and on Coal Creek. A characteristic feature of this coal field is the variation in thickness of individual coal beds within rather short distances, so that correlation of sections measured at different places is difficult. In the lower Matanuska Valley the beds of the Chickaloon formation are only mildly folded or tilted, but up the valley toward Anthracite Ridge the folding becomes progressively greater, and the formation is cut by numerous dikes and sills of diabase. Many faults of moderate displacement are present, and the whole coal field lies in a down-faulted block bordered on both the north and the south by highland areas of older rocks.[54] With this progressive increase in folding and intrusion from west to east along the valley there is a corresponding change in the character of the

---

[53] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 42–52, 1912.

[54] Capps, S. R., Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 791, pp. 41–44, 1927.

coal. In the nearly flat-lying and little-metamorphosed beds near the railroad crossing of the Little Susitna River the coal is lignitic. At Moose Creek and Wishbone Hill it is a noncoking bituminous coal. At the Chickaloon River there is coking coal, and at Anthracite Ridge there is locally some high-grade anthracite.[55] The difficulties of mining, however, increase with the complexity of the structure of the formation, and as the principal demand is for steaming coal at a reasonable price, most of the coal produced has come from the Wishbone Hill area, which yields a good noncoking bituminous coal. The character of the coal is described in the section on economic geology (pp. 193–196).

The Chickaloon formation has yielded abundant remains of fossil plants and has been shown to be definitely of Tertiary age and probably Eocene. It is the local equivalent of at least part of the Kenai formation of Cook Inlet and is the approximate equivalent of the Tertiary coal-bearing rocks that are present in many parts of Alaska.

On the accompanying geologic map the Chickaloon formation is included in undifferentiated Tertiary.

TERTIARY IGNEOUS ROCKS

Lavas and tuffs.—Effusive volcanic rocks of Tertiary age are widely scattered throughout the Talkeetna region and cover large areas, especially in the central Talkeetna Mountains, where they have been described by Paige and Knopf[56] as including a series of nearly horizontal basalt flows, which with the interbedded fragmental volcanic materials reach a thickness of 1,000 feet. These flows lie nearly horizontal and form the upper portion of the mountains, resting with angular unconformity upon the older rocks. Their basal portion is composed of tuffs and breccias. The flows display a wide variation in habit and texture and include glassy types, amygdaloids, porphyries, and dolerites. Their position in forming the upper portion of the mountains over wide areas indicates that they were formerly much more widespread than they are now and that they have been removed by erosion from great areas in which the older underlying rocks now appear at the surface. Apparently these basalt flows are the youngest hard rocks in this region.

Mertie,[57] in referring to the Tertiary lavas and tuffs, says that they reach a thickness of at least 2,500 feet and that the lava flows that cap Castle Mountain are part of a continuous area which formerly extended across the Chickaloon Valley, and has now been dissected by the Chickaloon River.

---

[55] Waring, G. A., Geology of the Anthracite Ridge coal district, Alaska: U. S. Geol. Survey Bull. 861, 1936.

[56] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 29–30, 1907.

[57] Mertie, J. B., Jr. (unpublished manuscript).

It is certain that the effusion of lavas took place several times during the Tertiary period and that all the rocks here classified as Tertiary igneous rocks were not contemporaneous, or even results of a single period of volcanism. In the Willow Creek district basalt flows are interbedded with arkose near the base of the arkose sedimentary series, and these flows therefore presumably were extruded in early Eocene time. By contrast, the great lava areas in the central Talkeetna Mountains are believed to be younger than the Eska conglomerate and may be as young as Miocene.

North of the Susitna River, on Tsusena Creek, there are several surface lava flows that Chapin [58] has described as including dacite, rhyolite, and andesite, of which the dacite is the oldest. The age of all these flows is somewhat uncertain, but Chapin concludes that they are probably Tertiary, though he admits the possibility that the dacite may be Mesozoic. They are all, however, older than the basaltic lavas that are so widely distributed in the Talkeetna Mountains south of the Susitna River. They are most closely related to lava flows near the head of the Jack River, formerly believed to be of Tertiary age but now determined to be in part Upper Cretaceous. The flows mapped by Chapin are therefore now assigned to the Mesozoic also.

In the Broad Pass region Moffit and Pogue [59] have mapped areas of Tertiary lavas between the Nenana River and the head of the Jack River, where there are acidic lava flows, mostly rhyolite and trachyte, but with some andesite, intimately associated with granite and granite porphyry that are also thought to be of Tertiary age. The age determination of these rocks was based on their relation to the Cantwell formation, then considered to be Eocene. Recently the Cantwell has yielded fossils that have been determined to be of Upper Cretaceous age, and that change in its age assignment necessitates the placing of the associated igneous rocks in the Mesozoic also, or at least in the time interval between the Cantwell and the Eocene coal-bearing beds.

Intrusive rocks.—The Tertiary intrusive rocks of the Talkeetna region include a large number of small irregular-shaped dikes and sills in the Matanuska Valley. These rocks, as described by Martin and Katz [60] and by Mertie,[61] include various types, of which the chief consist of diorite porphyries, trachytic rocks, diabases, gabbros, and basalts. The description of these rocks, just cited, is so

---

[58] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 38–40, 1918.

[59] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation, by J. E. Pogue: U. S. Geol. Survey Bull. 608, pl. II, 1915.

[60] Martin, G. C., and Katz, F. J., op. cit. (Bull. 500), pp. 55–67.

[61] Capps, S. R., Geology of the upper Matanuska Valley with a section on the igneous rocks by J. B. Mertie, Jr.: U. S. Geol. Survey Bull. 791, pp. 68–72, 1927.

complete that repetition here is unnecessary. There seems to be a general agreement that these intrusives are only locally faulted and folded, and their deformation is much less than that of the Tertiary beds they intrude. They are therefore considerably younger than the Tertiary sedimentary rocks and are probably of late Tertiary age.

In the Broad Pass region, south of the headwaters of the Nenana River, Moffit and Pogue[62] have mapped considerable areas as being occupied by Tertiary intrusive rocks. Their descriptions include granite, quartz, monzonite, and granite porphyry. These rocks have now been assigned to the Mesozoic and are described under that heading.

QUATERNARY DEPOSITS

Quaternary deposits, including such unconsolidated materials as glacial moraine and outwash gravel, river terrace gravel, the deposits of present streams, beach and estuarine deposits, talus, and soils, are widely distributed in the Talkeetna region. On the accompanying map (pl. 2) Quaternary deposits are shown only where they are sufficiently thick over considerable areas to conceal effectually the character of the underlying rock. These conditions are found principally in the lowlands, and the areas of Quaternary materials as shown are therefore practically coextensive with the lowlands and the valleys of the larger streams, although as a matter of fact there is a much more widespread mantle of soil and of the products of rock weathering. A discussion of the conditions under which the Quaternary materials were laid down and a description of those materials are given on pages 150–169, in a part of this report that deals with the Quaternary deposits of the whole Alaska Railroad region.

GEOLOGIC HISTORY OF THE TALKEETNA REGION

The early geologic history of the Talkeetna region is obscure, for many pages are missing from the record as it remains to be read from the rock formations and their relations to one another. Rocks deposited during those great eras of the earth's history represented by pre-Paleozoic and Paleozoic time are present here at the surface in only a few localities, where the stress of time and earth movements have so altered the rocks from their original aspect that the record is obscured and only partly legible. Probably the oldest rocks present are the mica schists of the Willow Creek district. These include materials that originally were normal water-laid sediments, as well as igneous rocks that were either laid down on the surface or were later injected into the sedimentary rocks from below. Both sedimen-

[62] Moffit, F. H., The Broad Pass region, Alaska, with sections on Quaternary deposits, igneous rocks, and glaciation by J. E. Pogue, U. S. Geol. Survey Bull. 608, pl. II, 1915.

tary and igneous materials were later deeply buried, altered, and closely folded, perhaps many times. Neither the age of the period during which their deposition occurred nor that of the times of their compression and distortion is known accurately, but it is believed that the rocks were laid down in either pre-Paleozoic or early Paleozoic time.

Other areas of what are presumably Paleozoic rocks occur between the Talkeetna and Susitna Rivers, but there also the beds have by later deep burial and by crustal deformation been so altered that they little resemble the original sediments from which they were derived, and neither their age nor the times during which they were deformed are now known. Similarly rocks whose age has not been determined, except that they are believed to be pre-Carboniferous, are found in the region of the great bend of the upper Susitna River, where their character and structure indicate great age.

It will thus be seen that our knowledge of the geologic events that took place in this region before the beginning of Mesozoic time is very scanty. Whatever record of past happenings has been preserved by the rocks themselves is difficult to decipher in localities where such rocks crop out, for the rocks have been severely metamorphosed. Elsewhere the evidence is concealed by the widespread cover of younger materials.

The record of Mesozoic events in this region is lacking in many details but is much more complete than that of the earlier periods of earth history. At least parts of the region were covered by the sea in Triassic time, and thick deposits of water-laid materials, including limestone, shale, and sandstone, were laid down. Limestone bearing Triassic fossils crops out near the head of the Susitna River and west of the Chulitna River, outside of but not far from the Talkeetna region. Limestones that may be of Triassic age occur in the western Talkeetna Mountains and in the Matanuska Valley. Thus we have definite evidence that in Triassic time the sea invaded this part of Alaska, and in it limestones were laid down. Other sedimentary rocks, of unknown age but presumably in part Triassic, are associated with the limestones, and beds of this age may be widely represented in this region, though concealed from view by younger overlying rocks.

The outstanding event of early Jurassic time in the Talkeetna region was vigorous and long-continued volcanic activity. At that time, especially in the eastern Talkeetna Mountains, volcanic materials, for the most part products of explosive volcanic activity, accumulated to a thickness of 1,000 feet or more. These materials comprise stratified breccias, with some lava flows, tuffs, and a minor amount of interbedded tuffaceous sandstones, shales, and conglomerates, showing that at least a part of this material was deposited in bodies of water. Farther west this fragmental material is less conspicuous, and the beds are composed largely of thick, massive lava flows, showing that the volcanic activity then was of a different type. The present surface distribution of these Lower Jurassic volcanic rocks by no means represents the areas over which the original lava flows and fragmental materials were deposited, for later granitic intrusions have displaced them from wide areas which they once occupied, and younger formations have covered and concealed them from view. It is certain that in early Jurassic time a large part of the region now occupied by the Talkeetna Mountains was buried beneath these materials.

Middle Jurassic time in this region was marked by the return to normal conditions of sedimentation, although whether the deposition of the sediments upon the volcanic materials took place without interruption, or whether there was an intervening period of erosion is not known. The earliest Middle Jurassic sedimentary rocks consist of sandstones deposited in comparatively shallow salt water. They contain abundant fossil remains of water-worn sticks and stems, indicating that land was not far distant. The conditions of deposition then changed, though without any notable time break or crustal movement, and a thick deposit of shale and shaly sandstone was laid down upon the sandstone until these materials accumulated to a thickness of several thousand feet.

Among the most notable geologic events that occurred in this region in Mesozoic time was the intrusion beneath the earth's surface of tremendous bodies of granitic rock. Such intrusions occurred at about this time in many parts of Alaska and western America, and in the Talkeetna region they were especially widespread. The single great batholith of the western Talkeetna Mountains has a surface area of about 1,400 square miles and is probably continuous beneath the surface with the granitic rocks to the southwest, across the Susitna River, and to the northeast, in the basins of Kosina Creek and the Black River. Probably at the same time other masses of granitic material, some large and some small, were being intruded into the regions now occupied by the Alaska Range and the Chugach-Kenai Mountains. The texture of these rocks, which are prevailingly coarse-grained, indicates that they were injected into the earth's crust but cooled slowly far beneath the surface. The mechanics by which such vast quantities of molten rock were emplaced are not well understood. In the Talkeetna Mountains alone their volume is certainly many hundreds of cubic miles. For this material to have made its way into the rocks of the region either the invaded rocks must have been absorbed into the molten mass, or they must have been displaced. Doubtless both absorption and displacement occurred, but the relative importance of the two processes is not yet known. If the earlier rocks were extensively displaced, however, either by being bulged or domed vertically or by being pushed aside laterally, there must have been notable surface expression of the movements of the deep-seated igneous materials, but our knowledge of the geography of that time is too scanty to show how greatly the surface relief was affected by the invasion of the granitic magmas.

It would be supposed that during a period of such widespread, deep intrusion at least some bodies of molten rock would find their way to the surface and be poured out as lava flows, yet lava flows or other materials that might represent the volcanic equivalent of the deep seated granitic masses are largely lacking, except in the youngest of the Mesozoic sediments. The only conclusion to be reached, therefore, is that for some reason the granitic magmas in general failed to reach the surface and cooled slowly beneath a fairly thick covering of other rocks.

After the Middle Jurassic sedimentary beds already referred to had been laid down, some warping of the surface brought them above sea level, and they were tilted and eroded. Later at least a part of their area was again submerged, and in Upper Jurassic time a deposit of conglomerate several hundred feet thick was formed, its pebbles and finer materials being derived from the igneous rocks of nearby land masses. The deposition of the conglomerate was followed without interruption by the laying down of shales, sandy shales, and sandstones that accumulated to a thickness of more than 1,000 feet.

Little is known of the events that took place at the end of the Jurassic period and the beginning of the Cretaceous period. The first recorded event of this period, probably in early Cretaceous time, was the laying down, in shallow ocean waters, of the conglomerates and tuffs that are now present in the upper Matanuska region and on the head of Billy Creek. These deposits indicate the presence of nearby lands on which volcanoes were active, and the tuffs represent the dust and fragments thrown out by the volcanic explosions. As the volcanic activity at length died out, limestone was laid down conformably upon the conglomerates and tuffs and in places accumulated to a thickness of 100 to 400 feet.

In the meantime a great thickness of muds and impure sandstones was being laid down in the border area between the Talkeetna region and the Alaska Range. These beds were deposited in an arm of the sea in which, for some yet unknown reason, conditions were unfavorable for the growth of marine shell-bearing organisms, and the rocks are almost devoid of fossil remains. For that reason the exact age of the beds is uncertain, but the best evidence is that they are Mesozoic and mainly of Jurassic and Cretaceous age.

So far as we know, all of this region except the Matanuska Valley had emerged from the sea by the end of Lower Cretaceous time and has remained land ever since. In the Matanuska Valley, however, a thick deposit of shale and sandstone was deposited during the Upper Cretaceous epoch. These beds apparently were laid down on the eroded edges of older formations, and they locally accumulated to a thickness of at least 4,000 feet. Later they were elevated above sea level, were greatly folded and faulted and then eroded, and at the beginning of Tertiary time occupied the floor of a broad valley that followed approximately the present course of the Matanuska River.

In the northern part of the Talkeetna region, between the Susitna and Nenana Rivers, late Mesozoic time was marked by the extensive intrusion of granitic rocks beneath the surface and by the outpouring upon the surface at several localities of acidic lavas, including dacite, andesite, rhyolite, and trachyte.

Toward the end of Cretaceous time, or in the beginning of the Tertiary epoch, the present Talkeetna Mountains formed a land mass of moderate relief, and a great lowland occupied about the same location as that now existing along Cook Inlet and up the Susitna, Chulitna, and Talkeetna Valleys. In early Eocene time a moderate uplift of the Talkeetna Mountains caused the streams to erode and transport southward toward the present Matanuska Valley a great quantity of arkose, the disintegration product of the granitic rocks. This arkose accumulated in the lowlands of the Matanuska Valley and north of the present position of Knik Arm until it formed a series of beds that were locally several thousand feet thick. It might be inferred that a similar deposit of arkose would have accumulated in the lowland west of the Talkeetna granitic mass, but so far as is now known such deposits were not formed there in amount comparable to that in the lower Matanuska Valley.

As the mountains were worn down by erosion and the lowlands filled with the detritus brought from the surrounding highlands, the stream gradients became more gentle, and the materials they could transport became less abundant and of finer grain. Apparently the arkosic sediments continued to accumulate around the margins of the lowlands, but at points farther away from the hills sand and mud were deposited. In these lowlands the laying down of fine sediments was no longer continuous but occurred spasmodically, with long intervening periods during which vegetation grew and died, the plants of each season successively forming a peaty deposit upon which other generations of plants grew, until vegetable remains accumulated to a great thickness. In this way the organic material now converted to coal originated. Periods of plant growth and peat formation gave place to other periods during which the organic materials were deeply buried by sands and clays, and by these alternating changes the coal-bearing formations of the lowlands were formed. The time required for the laying down of this coal formation was very long, for the slow erosion of the highlands supplied the sediments, and a foot of coal, as it now appears, required the accumulation of many feet of loose, uncompressed peat. Furthermore, it is unlikely that at any time peat was forming over the entire lowland, for certain areas were receiving the detritus brought down by the streams, while other areas were so free from sedimentation that the peat could accumulate to great enough depths to form later thick coal beds. It is therefore difficult to correlate either coal beds or sedimentary deposits at widely separated localities, for at one place at the lowland margin arkose may have been laid down, while elsewhere sands and muds were deposited, and at still other localities peat was in process of accumulation. It seems likely, however, that during much of Eocene time these three types of deposition were all operating throughout the lowlands at different localities. From time to time through this early Tertiary period there was mild volcanic activity in this region, and small areas of basaltic lavas were poured out upon the surface, to be later buried by further accumulations of sediments. This pouring out of lavas was apparently the feeble beginning of the much more intense volcanic activity that took place later in Tertiary time.

The deposition of the coal-bearing formation, at least in the Matanuska Valley, was ended by an uplift, in about middle Tertiary time, of the Talkeetna Mountains. The streams thus steepened began to erode their valleys more actively, and coarse gravel was carried to the lowlands to cover the great deposits of sand, clay, and plant remains there. The gravel deposits in places were built up to a depth of 3,000 feet, and by the increase in the altitude of the lowlands at the same time that the mountains were being lowered by stream erosion, the relief of the region once more became fairly gentle. A later event of importance in Tertiary time was the pouring out upon the surface of the central Talkeetna Mountains of extensive sheets of basaltic lavas with accompanying deposits of tuffs and breccias, the product of volcanic explosions, and the intrusion of igneous rocks as dikes and sills into many older formations, especially in the Matanuska Valley. Naturally the lavas, in pouring out from the vents, first flowed down the preexisting valleys and as these were filled spread laterally over the intervening ridges. The surface so covered was then much more extensive than that now occupied by these rocks, for the existing irregular areas (pl. 2) are largely confined to mountain tops and ridges. Inasmuch as flowing lavas by nature fill the lowlands first, the present distribution of this material is evidence that the region has since been elevated and deeply eroded, and the remaining mountain-top lava beds are only the remnants, separated by erosion, of former widespread and connected lava fields.

The basaltic lava flows of the Talkeetna Mountains are, so far as we know, the youngest Tertiary rocks present in this district, yet after they were laid down sufficient time still remained during the Tertiary period for the Talkeetna region to be uplifted bodily without great deformation, and for the highland so produced to be deeply dissected by streams, so that the country had approximately its present amount of vertical relief. Certainly the products of this extensive erosion of a great land mass must have been deposited somewhere, but they have not been recognized in this region and may have been largely carried out to sea or may later have been overridden by the Quaternary glaciers and in part disturbed or destroyed by them or covered by the glacial deposits.

The events of the Quaternary period in this region have been more largely destructive than constructive. At the beginning of the period this entire region was a land mass, as it had been since the beginning of Tertiary time. Streams and all the other agencies of subaerial weathering and erosion were active in reducing the highlands and aggrading the lowlands. The surrounding mountains had about their present altitude, but their surface forms were strikingly different, as the sculptured features were the result of weathering and of stream erosion in a temperate climate. The outstanding feature of Quaternary time was the accumulation, probably in several successive periods, of enormous bodies of glacial ice, with intervening periods of ice retreat, ending in the present condition of only moderate glaciation in the mountains. These events exercised a fundamental influence upon the surface features of mountains and lowlands, and to them in large part is due the appearance of the region as we see it today. A more complete discussion of the Quaternary happenings in the Talkeetna region is given in another section (pp. 150–169), in which the Quaternary history of the Alaska Railroad region as a whole is discussed.

ALASKA RANGE

The Alaska Range comprises a broad belt of mountains that extends from Yukon Territory northwestward to Broad Pass, beyond which it sweeps to the southwest in a great crescentic curve to the Alaska Peninsula. The portion of the range here considered lies at the crest of the arch, and in it the axis of the range veers in direction from northwest through west and southwest to nearly south. Near the apex of the crescentic curve lies America's highest peak, Mount McKinley. In this region the range is geographically and geologically distinct from other mountain masses, as it is sharply limited on the north and west by the broad lowlands of the Kuskokwim and Tanana Rivers and is bordered on the south and east by the lowlands of the Susitna and Chulitna Rivers, by Broad Pass, and by the headwater lowlands of the Nenana and Susitna Rivers. In general, the range forms the divide between the southward-flowing Pacific Ocean drainage and the westward-flowing tributaries of Bering Sea, although the Nenana River heads on the south flank of the range and then flows directly across it in a deep valley to join its waters with the Tanana.

From Mount McKinley eastward the portion of the Alaska Range here considered consists of a main rugged mountain mass flanked on the north by several parallel but less lofty and rugged subsidiary mountain ridges, separated from the main range and from one another by broad basinlike depressions. These ridges and the intervening troughs are the result of mountain-building forces and of erosion upon rocks of varying character and resistance. Normal stream erosion upon a mountain mass composed of rocks of uniform composition would have produced a very different result.

The geology of this portion of the Alaska Range is not perfectly known, for some areas still remain unexplored and unmapped, and others have been studied only in an exploratory way. The linear arrangement of the rock formations, however, parallel with the axis of the range, encourages the belief that cross sections of the unexplored portion of the range, as through Mount McKinley, to the southeast, and at the eastern edge of this region in the vicinity of Mount Hess, would show an assemblage of rocks similar to those found between them.

The general synclinal character of the Alaska Range in the latitude of the Skwentna River and Rainy Pass was recognized by Brooks[64] who traced that structure northward to the Broad Pass region, and showed that a broad synclinorium was the dominating structural feature between the Susitna Basin and the inland front of the range. Brooks recognized that on the western limb of this synclinorium, in the Kuskokwim Basin, there was a belt of closely folded Paleozoic sedimentary rocks, including beds of Ordovician and Devonian age. The older of these he classified as the Tatina group, made up of limestones and argillites, part of which carried Ordovician fossils, and the younger he called the Tonzona group, composed of unfossiliferous argillites in the lower part and limestone and slate containing Devonian fossils in the upper part. Brooks attempted to carry the mapping of these two groups northeastward to the Nenana River, far from the localities at which he obtained his fossils. In this report

[64] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 111, 1911.

these groups have been included with the undifferentiated Paleozoic sedimentary rocks. Brooks considered that the scantily fossiliferous slates and graywackes of the southeast flank of the range were Paleozoic. These beds have now been determined to be mainly of Mesozoic age. The Cantwell formation, considered by him to be probably of Carboniferous age, was later determined to be Eocene but recently, on the basis of new fossil collections, has been assigned to the Upper Cretaceous.

Confirmatory evidence of the general synclinal character of the range has been found by Moffit [65] and by Capps [66] in the region east of Mount McKinley, where the central part of the range is composed mainly of Mesozoic rocks underlain on both flanks by rocks of Paleozoic or pre-Cambrian age. The folding in this part of the range is complex, and faults of long extent and great displacement are present.

Granitic intrusive masses are present throughout the range but are most abundant near and south of Mount McKinley.

PRE-CAMBRIAN ROCKS

BIRCH CREEK SCHIST

Distribution and character.—On the north flank of the Alaska Range in this region there is an extensive and continuous belt of mica schist that is apparently the oldest group of rocks that occurs in this range. At the west edge of the region the belt is widest, as it expands northward to include a large part of the Kantishna Hills, a subsidiary mountain group. Between the Kantishna Hills and the Nenana River the schist appears at the surface as a belt only a few miles wide but no doubt is present beneath the unconsolidated Tertiary and Quaternary beds in the basin that borders it on the north. East of the Nenana River the mica schist is an important element in the higher mountains of the range, and between that stream and the Delta River it is the prevailing rock in a belt that ranges from 12 to 25 miles in width. This mica schist has been correlated with the Birch Creek schist of the Yukon-Tanana region. It has been described by several writers,[67] but its essential characteristics are much the same throughout the belt in which it is present.

The most prevalent phase of the Birch Creek schist is a quartz-muscovite schist composed principally of quartz. Where the rock is

---

[65] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 65. 1915; The Kantishna district, Alaska: U. S. Geol. Survey Bull. 836, pp. 301–338, 1930.

[66] Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 219–300, 1930.

[67] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 26–29, 1919. Moffit, F. H., The Kantishna district: U. S. Geol. Survey Bull. 836, pp. 306–307, 1933. Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 20–22, 1912. Wells, F. G., Lode deposits of Eureka and vicinity, Kantishna district, Alaska: U. S. Geol. Survey Bull. 849, pp. 343–347, 1933.

fresh the mica is inconspicuous on faces not parallel to the foliation, but parallel to the foliation the whole surface is covered with greenish mica flakes. Upon weathering the rock breaks down into thin slabs and flakes along the lines of schistosity, the cleavage being controlled by the parallel orientation of the cleavage planes of the muscovite, which weathers to gray, brown, and reddish colors. Although the quartz-muscovite schist is the commonest type, there are many localities where other phases predominate. These phases include mica-garnet schist, limestone schist, chlorite schist, and graphitic schist in an infinite variety of proportions and of great range in mineral composition. These phases are all believed to have been produced by the profound metamorphism of ancient sedimentary rocks, but intimately associated with them are masses of greenstone that represent the metamorphosed products of igneous rocks.

All the types of schist are cut by quartz veins of various ages. The older of these veins have apparently been deformed along with the enclosing rocks. Later veins, some of which are mineralized, are undeformed and evidently were deposited after the metamorphism of the schists had been completed.

The original structure of the sedimentary rocks from which the schists were derived is in most places obscure, for metamorphism has so destroyed the bedding that in most places it cannot be made out, unless certain faint color bandings represent bedding. The foliation of the schists has a general east-northeast strike, paralleling the axis of the Alaska Range, with dips both to the north and to the south. In many places close folding and even intimate contortion can be observed, with several sets of folds of different amplitudes visible in the same exposure. It is likely that the history of these beds, if known, would reveal intense folding at many recurring intervals, corresponding to periods of active diastrophism in this mountain region.

No reliable estimates have been made of the thickness of the Birch Creek schist, but as it occurs in compact areas containing mountains with a local relief of at least 3,000 feet, and with neither the top nor bottom of the schist series exposed, it seems certain that several thousand feet of beds are involved.

To summarize briefly, the schists were originally sedimentary rocks, chiefly sandstone and limestone, that were intruded by or interbedded with medium-basic igneous rocks. The whole assemblage then underwent severe dynamic metamorphism at recurring intervals, corresponding to the periods of mountain-building activity in this region. As a result of these mountain-building stresses the sedimentary rocks were altered to quartz, mica, and calcareous schists and the igneous rocks to greenstones, with the development of many secondary minerals. Quartz veins were deposited in the schists at various times, some before the metamorphism was completed, and some afterward.

Age and correlation.—The name "Birch Creek schist" was first used by Spurr [68] for a group of rocks in the basin of Birch Creek, a tributary of the Yukon River. Brooks [69] and Prindle, finding rocks of similar lithology in the Kantishna region, correlated them with the Birch Creek schist, and Capps [70] found no reason to change that designation. None of these writers found any direct evidence of the age of the schists except that they were older than any of the fossiliferous Paleozoic sedimentary rocks of the region. The schists were for a long time classified merely as pre-Ordovician. In eastern Alaska, near the international boundary, later workers have found convincing evidence that the Birch Creek schist is not only pre-Cambrian, but early pre-Cambrian. Mertie [71] has shown that a limestone containing early Middle Cambrian fossils not only lies above the Birch Creek but is separated from it by a thickness of 20,000 to 25,000 feet of sedimentary beds, the Tindir group, believed also to be pre-Cambrian and Lower Cambrian. Mertie therefore classifies the Birch Creek as early pre-Cambrian, and that assignment is based on the most recent and most conclusive evidence now available.

UNDIFFERENTIATED PALEOZOIC ROCKS

Within the Alaska Range geologic province there are extensive areas of rocks, mainly of sedimentary origin but including also some metamorphic igneous rocks, that, according to the best evidence available, are wholly or in part of Paleozoic age but are so highly metamorphosed that any fossils they may have once contained have been destroyed, and no accurate determination of their age has been possible. These rocks are here grouped together and, for the sake of simplicity, are mapped with a single pattern, although they include materials of many distinct types that have been separately mapped by the various geologists who have worked in this field. It is the aim and the custom of geologists, as observations are extended, more detailed studies made, and information accumulates, to subdivide rock groups into smaller and more precisely defined units, and the practice here followed of including in a single group rocks of diverse character and doubtless of great range in age may seem a backward step.

---

[68] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18 Ann. Rept., pt. 3, pp. 140–145, 1898.

[69] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 56–60, 1911.

[70] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 26–29, 1919.

[71] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: Geol. Survey Bull. 872, pp. 55–59, 1937.

The reason for adopting that procedure here, however, is that the age assignments of all the rocks here grouped as undifferentiated Paleozoic are based on scant direct fossil evidence, and that evidence was in many places obtained in areas far from the localities here described. In attempting to give some suggestion as to the probable age of a group of rocks, the geologist has often been forced, in the lack of direct fossil evidence, to make long-range correlations on the basis of rock type, structural relationship, or degree of metamorphism. Within a province that has been the site of mountain-building movements at recurrent intervals through great stretches of geologic time, long-range correlations on the basis of lithology, and particularly on the grounds of similar degrees of metamorphism, are subject to error. Within short distances in this region rocks as young as Upper Cretaceous range in character from normal, little-altered conglomerates to sheared and stretched conglomerate and even to schists. It has therefore seemed best, in a general report such as this, to group together all these rocks of somewhat uncertain but probable Paleozoic age. Later work will doubtless break this group up into many units, which may range in age from early Paleozoic to Permian.

The rock assemblages here classified as undifferentiated Paleozoic include the Tatina and Tonzona groups on the north flank of the range between the Sanctuary and Stony Rivers; a great series of altered sedimentary rocks that lie above and below a Middle Devonian limestone and that are present as isolated patches or as extensive areas from a point west of Hanna Glacier to the upper valley of the Nenana River; and certain metamorphosed sedimentary rocks that lie unconformably below Carboniferous beds in the valley of the West Fork of the Chulitna River.

The Tatina group, as originally described by Brooks,[72] includes a series of sedimentary rocks which are dominantly calcareous but in which there are also shales and sandstones. The type locality for this group is in the upper basin of the Kuskokwim River, but Brooks mapped their extension to the northeastward into the headwaters of the Kantishna River in the region here discussed. In the Kantishna region east of Muldrow Glacier the rocks of this group occur only in a narrow belt 2½ miles or less in width. The beds have been described by Capps [73] as consisting of black slates or slate schists, argillites, cherts, and black limestone, cut by many quartz and calcite veins and much contorted and folded. The only other stratified deposits with which they were observed in contact are those of the Upper Cretaceous Cantwell formation, beneath which they lie un-

---

[72] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 69–73, 1911.

[73] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 30–32, 1919.

conformably. The other observed contacts were with younger intrusive rocks.

At all the localities where they were studied these sedimentary beds are intensely deformed, the structure including large folds with smaller folds and close crumples superposed upon and parallel to them. This intense deformation has produced slates and schists. The distribution of these rocks in a long, narrow band, bordered for the most part by beds of the Cantwell formation, is due to their general anticlinal structure. They are estimated to be some thousands of feet thick, though no accurate measurements could be made.

The age of the rocks shown on the accompanying geologic map that were formerly classified as the Tatina group is uncertain. They have yielded no fossils in the region here described, though similar rocks in the upper Kuskokwim Basin, and along the same general strike, contain Ordovician fossils in their basal portion. Capps [74] advanced some reasons for questioning the relative ages of the Tatina and Tonzona groups, though at that time he accepted Brooks' determination of their Ordovician age. That may be a correct determination, but the proof is far from conclusive, and it seems best at present to group these metamorphic sedimentary rocks with the other undifferentiated Paleozoic materials.

The name "Tonzona group" was first used by Brooks [75] to designate a group of black slates and argillites that he found on the Tonzona River in the Kuskokwim Basin, west of the region here under consideration. What he believed to be the eastward extension of these rocks forms a narrow belt extending from the Stony River to the Sanctuary River, in the northern part of Mount McKinley National Park. North of that belt, and stretching from the Kantishna Hills eastward to the basin of the Little Delta River, there is another group of metamorphic rocks called by Capps [76] the "Totatlanika schist," which consists dominantly of rocks of igneous origin but contains also considerable metamorphic sedimentary material. Capps was unable, in the time at his disposal, to map the igneous and sedimentary phases separately, but he recognized the presence, especially near the base of the group, of black slates, carbonaceous slaty schists, limestone, and quartz conglomerate, all closely infolded and involved with the metamorphic igneous materials. He considered the sedimentary phases of the group to be the correlative of Brooks' Tonzona group, though in his map they were included with the Totatlanika schist.

The Tonzona rocks in this region are characteristically black slates and argillites and carbonaceous slates and schists, much metamorphosed and cut by multitudes of small quartz and calcite veinlets. In

[74] Idem, pp. 31, 32.
[75] Brooks, A. H., op cit. (Prof. Paper 70), p. 73.
[76] Capps, S. R., op. cit. (Bull 687), pp. 34–37.

places there is considerable black limestone, and locally quartz conglomerate is present.

The age of the Tonzona rocks is uncertain, no fossils having been obtained from rocks characteristic of the group. A small collection of imperfectly preserved corals from a limestone in the Shushana Basin that was associated with Tonzona rocks was pronounced to be of probable Triassic age, and this means either that some Mesozoic limestone was folded or faulted down into the Paleozoic rocks, or that some supposedly Paleozoic rocks are in reality of Mesozoic age. The high degree of metamorphism of these beds suggests an age older than Mesozoic. Much more detailed field work will be necessary before the distribution of the rocks of this group is fully known, and until that work is done there will be uncertainty as to the age of the beds. It seems best for the purposes of this report to include them with the other undifferentiated Paleozoic rocks.

On the southeast flank of the Alaska Range between the West Fork of the Chulitna River and Eldridge Glacier, Capps[77] and Ross[78] have mapped a belt of metamorphosed sedimentary rocks, much folded and faulted and apparently of great thickness, consisting of calcareous beds containing considerable siliceous and argillaceous material and in places full of chlorite, with locally some greenstone and greenstone tuff. These rocks are unconformably overlain by Permian (?) beds. Further evidence of their age is lacking, but Ross tentatively correlated them with sedimentary rocks north of Broad Pass that are associated with a Devonian limestone and suggested a Devonian age for them. As shown on page 101, the rocks north of Broad Pass include a group that contains many thousands of feet of beds, some of which lie above and others below a middle Devonian limestone, the only member of the group that has yielded fossils. The writer suspects that that group contains rocks of a considerable range in age, though all are probably Paleozoic. Too little is known about them to warrant a more definite age determination, and on the accompanying geologic map they are classified as of undifferentiated Paleozoic age.

From Hanna Glacier on the west to the upper basin of the Nenana River on the east, a very thick group of metamorphic sedimentary rocks that are associated with Middle Devonian limestone constitute a large element in the Alaska Range, and between Muldrow Glacier and the Nenana River they form a wide belt that comprises the highest portions of the range. That portion of the mountain mass is very rugged, and all the valleys that head against the divide contain

---

[77] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 215, 216, 1919.

[78] Ross, C. P., Mineral deposits near the West Fork of the Chulitna River, Alaska: U. S. Geol. Survey Bull. 849–E, p. 294, 1933.

glaciers in their upper courses, as a consequence of which the geologic section is difficult to study and is still imperfectly known. From Muldrow Glacier eastward to the Nenana River these rocks are bordered on the south by a great fault that brings them into contact with Mesozoic rocks. East of the Nenana River the throw of that fault is reversed, so that the south side is upthrown, thus bringing the Devonian and associated rocks up on the south side of the fault into contact with Mesozoic rocks on the north side.

This group of sedimentary rocks includes, in addition to a heavy Middle Devonian limestone that has been mapped separately, a great thickness of beds among which are thin-bedded limestones, graywackes, arkoses, conglomerates, argillites, and quartzites, with impure limestones and calcareous argillites predominating. These rocks have been described in various publications by Capps,[79] Reed,[80] and others. The most complete sections of these rocks that have been studied are to be found south of the crest of the range, in the headward basins of the West Fork of the Chulitna and Bull Rivers and Cantwell Creek. There the Paleozoic rocks have been brought up along a great fault, and lower portions of the series than have been recognized elsewhere can be examined. In general, the oldest exposed portion of the series, in any north-south section across the range, occurs at the south edge of its outcrop, adjacent to the great fault. The deepest beds are found in the area between Easy Pass and Windy Creek, where a basal group containing slate, schist, serpentine, and metamorphic limestone occurs. It seems likely that these rocks are much older than the less metamorphosed sedimentary beds immediately associated with the Middle Devonian limestone, and they may even be of pre-Paleozoic age, but in the absence of definite evidence on this point they are included with the undifferentiated Paleozoic rocks.

Above the basal schist, serpentine, slate, and limestone group the lowest member of the less metamorphosed beds is a dark-brown to black conglomerate that ranges from 200 to 1,000 feet or more in thickness. This is succeeded by a conspicuous white conglomerate 50 to 200 feet thick, in which the pebbles are mainly white quartz in a white or gray siliceous matrix. Above this conglomerate is a series several thousand feet thick composed mainly of alternating layers of black slate or of argillite and graywacke or quartzite that exhibit varying degrees of schistosity. They are characterized by a rusty red hue on weathered surfaces, though freshly broken surfaces fail to show this coloration. Intermingled with these rocks are some

[79] Capps, S. R., The Toklat-Tonzona River region: U. S. Geol. Survey Bull. 792, pp. 88–92, 1927; The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 251–255, 1933.

[80] Reed, J. C., The Mount Eielson district, Alaska: U. S. Geol. Survey Bull. 849–D, pp. 247–250, 1933.

hard siliceous conglomerates, thin-bedded black limestone, and in places black or gray limestone beds that reach a thickness of 20 or 30 feet. All these rocks are abundantly seamed with quartz veins that attain 3 or 4 feet in thickness and show reticulating veinlets of calcite.

Upward in the section there is a more or less gradual transition from argillite, slate, graywacke, and quartzite into a more limy phase. Thin-bedded limestone is interlayered with the clastic rocks, and the limestone beds become more and more abundant until in places they equal or surpass in bulk the associated clastic beds. Still higher in the section there is in places a massive gray recrystallized limestone that locally reaches a thickness of 1,500 feet, though it is generally not so thick. This massive limestone was found to be almost continuous from the head of the Bull River eastward to the west fork of Windy Creek. Farther west it was not observed on the south flank of the range, but as it everywhere lies near the crest of the range in areas still occupied by vigorous glaciers, it has not been mapped in detail.

On the north flank of the range from Hanna Glacier eastward to the basin of the Sanctuary River there are disconnected patches of massive limestone, probably separated from one another as a result of the severe deformation and faulting which these mountains have undergone, that may be the stratigraphic equivalent of the limestone on the south flank. The complex structure of these rocks is still to be worked out, and many details of the succession are still unknown.

It is considered probable, though not yet proved, that most of the Paleozoic rocks exposed on the north flank of the higher part of the range at Mount Eielson and in the headward basins of the Toklat, Teklanika, and Sanctuary Rivers lie stratigraphically above the Middle Devonian limestone. Like those south of the massive limestone belt, they include schists, slates, thin- to medium-bedded limestones, conglomerates, graywackes, argillites, and arkoses. They have been studied in the Mount Eielson district by Reed.[81] East of the Nenana River, according to Moffit,[82] the beds include limestone, slate, and conglomerate, all more or less metamorphosed and cut by granular intrusives. From the limestone he collected fossils that were determined to be either lower Upper Devonian or more likely Middle Devonian. He classed both limestone and associated beds as Devonian.

Structurally this whole series of rocks is so badly folded, faulted, and crumpled that of no single section which has been studied can it be confidently asserted that the normal succession of beds is known

[81] Reed, J. C., The Mount Eielson district, Alaska: U. S. Geol. Survey Bull., 849–D, pp. 247–250, 1933.

[82] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 24–26, 1915.

from top to bottom, or that the thickness of the series has been determined. Duplication of beds by close folding is known to have occurred in some places and has probably occurred at many others. Faults of unknown displacement occur. Much more detailed studies than have been made will be required before these facts can be satisfactorily determined. It can be safely said, however, that many thousands of feet of sedimentary rocks are included in this series, and that detailed mapping will result in breaking up the section into several formations.

As to the age of these rocks, all that is definitely known is that a limestone of probable Middle Devonian age is present and that this limestone lies in the midst of a thick section of clastic materials which have yielded no fossils and whose age is not accurately known. Some of the beds that are older than the Middle Devonian limestone lie upon a still older group of slates, schists, limestone, and serpentine. Other clastic beds above the Middle Devonian horizon are almost certainly of pre-Permian age. It is possible that rocks now included in this series may range in age from pre-Cambian to Carboniferous. For the purpose of this report and in the absence of more definite knowledge, all this heterogeneous assemblage of materials is here grouped together as of undifferentiated Paleozoic age.

MIDDLE DEVONIAN LIMESTONE

In the preceding description of the undifferentiated Paleozoic rocks, frequent mention has been made of a massive limestone of Middle Devonian age. In most places this limestone has been so altered, either by shattering, silicification, or even complete recrystallization, that any organic remains it once contained have been destroyed. At a few places, however, collections of well-preserved Middle Devonian fossils have been made. As the stratigraphic associations of this limestone are much the same throughout the area in which it occurs, and as the various patches all lie along the same general strike, it has been assumed that they represent a single formation, although now much broken and separated by folding and faulting and possibly even duplicated in certain cross sections of the range.

The longest continuous exposure of this limestone lies in the headward basins of the Bull River and Cantwell Creek, where it ranges in thickness from a few hundred feet to 1,500 feet, though the maximum figure may be the result of duplication by close folding. In that area the limestone is gray, weathering to light buff. It is partly recrystallized and has been much fractured, the fractures being healed by calcite veinlets. An intensive search failed to find determinable fossils in that area. In the same longitude, but somewhat to the north of the crest of the range and outcropping on the ridges between the glacier-filled valleys, there is another more or less continuous belt of limestone, somewhat interrupted and broken into isolated blocks by faulting and deformation. In the basin of the Teklanika River this limestone yielded Middle Devonian fossils. Disconnected patches of a limestone, in many places completely recrystallized, occur at intervals along the same general strike as far westward as Hanna Glacier. In the absence of evidence to the contrary, all those occurrences of massive limestone are assumed to be of the same age—that is, Middle Devonian—although this is not proved.

East of the northward-flowing portion of the Nenana River and south of the great fault Moffit[83] found a thick limestone formation, associated with slate and conglomerate. From it he collected fossils of probable Middle Devonian age. In his mapping he grouped the limestone with the associated clastic beds, which yielded no fossils, and classified them all as of Devonian age. On the accompanying geologic map (pl. 2) Devonian limestone is shown at only a few of Moffit's localities. Elsewhere this limestone and associated sedimentary beds are grouped with the undifferentiated Paleozoic rocks.

Structure.—The structure of the Devonian limestone in this region is highly complex, and its details have not yet been worked out. Deformation that included broad folding as well as crumpling and possibly close folding has certainly taken place, and faulting has interrupted the continuity of the limestone outcrops, particularly on the north slope of the range. During the deformation of the beds the limestone has been shattered, silicified, and in places completely recrystallized, so that its organic remains have been destroyed.

Age.—Invertebrate marine fossils, some definitely Middle Devonian and others of probable Middle Devonian age, have been found in this limestone at only a few localities. Elsewhere the rock is too much altered to have preserved identifiable fossils. The stratigraphic associations of the limestone outcrops throughout the region are so similar, however, that it appears likely that they all belong to a single formation, part of which is of known Middle Devonian age and part of probable Middle Devonian age. These limestones are therefore for the present all classified as of that age. Further studies may succeed in proving that limestone at more than one horizon is present, and that limestones either younger or older than Middle Devonian have been erroneously grouped together.

TOTATLANIKA SCHIST

Character and distribution.—The name "Totatlanika schist" has been applied to a series of quartz-feldspar schists and gneisses, with some metamorphosed sedimentary rocks, which are extensively devel-

[83] Moffit, F. H., op. cit. (Bull. 608), pp. 24–26.

oped in the foothills and higher mountains of the north flank of the Alaska Range between the Kantishna and Little Delta Rivers. For that distance the Totatlanika schist is in general the northernmost hard-rock formation of the range, though it is concealed over great areas by overlying Tertiary and younger materials. These rocks may also extend northward beyond the foothills, beneath the heavy filling of gravel in the Tanana lowland. The sedimentary rocks of Brooks' Tonzona group are in places so intimately associated with schists and gneisses of igneous origin that these components have not yet been separately mapped in the field, and the Totatlanika schist thus includes mainly materials derived from igneous rocks, but also some beds of sedimentary origin that if separated would properly belong in the Tonzona group.

The Totatlanika schist at various localities has been described by several writers, though that name has not always been used. The rocks include a great variety of materials of both igneous and sedimentary origin and vary widely from place to place in the degree of metamorphism they have undergone. The description of these rocks in the Kantishna and Bonnifield regions[84] is applicable throughout the region here discussed. The most characteristic phase of these rocks is a porphyritic schist or augen gneiss, with phenocrysts of quartz and white orthoclase feldspar, the feldspars forming the augen, which in places reach a diameter of over 2 inches and have sharply marked crystalline outlines. The matrix in which the crystals lie is a dark fine-grained groundmass composed chiefly of mica and quartz. The quartz phenocrysts reach a diameter of half an inch. The lines of schistosity are well developed throughout the rock, and in places the quartz and feldspar crystals are oriented with their long axes parallel with the foliation. From the coarse augen gneiss phase the rock grades through successively finer-grained materials with less conspicuous phenocrysts to a very fine-grained white or cream-colored sericitic schist, which shows little or no grit when broken and rubbed between the fingers. All gradations between these two extremes may be found. When fresh the groundmass of the augen gneiss is dark in color, spotted by the white feldspar phenocrysts, but upon weathering the rock becomes light gray or whitish. On weathered slopes and on the high ridges the surface is in places covered by fragments of feldspar crystals, left by the decay and removal of the groundmass.

This assemblage of gneisses and feldspathic schists is believed to have resulted from the metamorphism of rhyolitic rocks, presumably flows, with possibly some associated tuffs.

---

[84] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 35–37, 1919; The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 22–26, 1912.

Associated with the altered igneous rocks, especially in the lower part of the series, are commonly beds of carbonaceous shales and schist and some quartz conglomerate, which are certainly of sedimentary origin. At a few places beds of limestone have also been found. The carbonaceous schists are most abundant in the region east of the Nenana River and extend in a fairly well defined though discontinuous belt along the contact between the Totatlanika schist on the north and the Birch Creek schist on the south. They are interbedded with the quartz feldspar schists and are so closely folded and involved with them that it has been impossible in reconnaissance studies to separate the two. Indeed, it is probable that the deposition of the sediments was interrupted at times by the extrusion and ejection of igneous rocks, so that they properly belong to the same time period. The beds of clastic origin are prominent only near the base of the schist series; the quartz-feldspar schists in its upper portion contain little sedimentary material. The term "Totatlanika schist" has therefore been used to designate a series consisting mostly of metamorphosed rhyolites but in its lower part containing much material of sedimentary origin. In a few places a part of this schist series has been found to be impregnated with pyrite and to carry gold, so that the weathering of these rocks may have furnished some of the placer gold of the region, although most of it is supposed to have been derived from veins in the Birch Creek schist.

Both the clastic and the igneous beds of the Totatlanika schist have been cut by intrusive rocks at various times. Some of the dikes were injected when the rocks were comparatively young and have been folded with them. Other intrusives came in much later and are still comparatively massive and undeformed.

The complex structure of these rocks renders it difficult to gain a knowledge of their thickness. Valleys cut 3,000 feet below the peaks fail to show the base of the series, and much of its upper portion at these places may have already been eroded away. On the other hand, the apparent thickness at any particular place may be due to folding and repetition. Definite evidence of the real thickness is now lacking.

Age.—In the absence of fossils from the Totatlanika schist there is no certain evidence of its age. It overlies the Birch Creek schist, which is pre-Cambrian, and it was correlated by Brooks [85] with his Tonzona group, which he tentatively assigned to the Silurian or Lower Devonian. The Totatlanika schist is more metamorphosed than the sedimentary rocks associated with the Middle Devonian limestone of the Alaska Range. Nothing more definite can now be

[85] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 75, 1911.

said than that it is probably Paleozoic and earlier than Middle Devonian.

CARBONIFEROUS (PERMIAN?) ROCKS

The only rocks in this region that are definitely known to be of Carboniferous age occur on the southeast flank of the range in the vicinity of Broad Pass. As described by Ross[86] they include a wide range of materials of both volcanic and sedimentary origin, which have an aggregate thickness of over 10,000 feet. For convenience in description, Ross divided them into five units, of which four represent local lithologic phases of the first, with an additional sixth unit, a limestone, mapped separately. The general unit he described as characterized by tuffaceous beds of deep-rose and related shades, some beds moderately fine-grained and others coarser breccias, all composed for the most part of fragments of lava and of igneous materials, mainly plagioclase, with abundant quartz and calcite in the cement. Some of the coarser breccias also contain fragments, generally angular, of argillaceous rocks, quartz, and other materials. In other beds, however, the rock particles are fairly well rounded and form conglomerate. Interbedded with the reddish rocks is considerable green and black tuff composed of fragments of lava, devitrified glass, and other material, with abundant chlorite. Flows of gray, purple, and green andesite are widely distributed and are interbedded with the tuffs, though subordinate to them in volume. In a few places limestone beds 100 feet or more thick are interbedded with the tuffs, with small amounts of argillite and conglomerate also, but in general sedimentary materials form only a small proportion of this group of beds.

According to Ross' description, the Carboniferous rocks are much faulted, and the exposed section differs greatly from place to place. The lower portion of the section appears to consist of black chloritic argillite, conglomerate, and limestone, with some beds of coarse grit in a tuffaceous matrix and some lava flows of dacite and basalt. These beds are succeeded above by black to greenish chloritic argillite, followed by a heterogeneous assemblage of strata in which chert, cherty limestone, and chloritic argillite predominate, with locally andesitic lava, tuff, and tuffaceous breccia. Still higher in the section is a series of chert, cherty limestone, tuff, and argillite, with some conglomerate.

All the beds described above are assigned by Ross to the Carboniferous, and probably to the Permian. They lie stratigraphically above rocks of questionable Devonian age and below Triassic beds.

---

[86] Ross, C. P., Mineral deposits near the West Fork of the Chulitna River, Alaska: U. S. Geol. Survey Bull, 849–E, pp. 294–298, 1933.

MESOZOIC ROCKS

UNDIFFERENTIATED MESOZOIC ROCKS

A persistent though somewhat discontinuous belt of sedimentary rocks of Mesozoic age lies on the southeast flank of the Alaska Range in the region from the Yentna River to Broad Pass and forms a conspicuous element in the make-up of the range. Similar rocks, along the same general strike, also occur on the north slope of the range in the headward basins of the Savage and Sanctuary Rivers. A parallel belt of similar rocks also lies east of the Susitna River from the vicinity of Curry to Broad Pass, and its northeastern extension reaches into the Alaska Range in the headwater regions of the Nenana and Susitna Rivers. These rocks consist mainly of shallow-water marine sediments that as deposited were muds and impure muddy and feldspathic sands but that have been indurated and metamorphosed into argillites, slates, and argillaceous graywackes. They bear a striking resemblance in lithology and structure to the great group of sediments in the Chugach and Kenai Mountains that have been described above as undifferentiated Mesozoic rocks, and that description applies almost equally well to the great areas of Mesozoic rocks in the Alaska Range. They compose the major portion of the Peters and Dutch Hills, in the Yentna district, extend thence northeastward across the basins of the various southeastward-flowing tributaries of the Chulitna River to the Cantwell River Basin, though interrupted by granitic intrusive masses, and appear on the north flank of the range in the eastern portion of Mount McKinley National Park. Similar rocks also appear in a somewhat parallel belt that has its northeast end near the glacier at the head of the West Fork of the Susitna River, and a third belt with the same general strike crosses the upper Susitna River into the Alaska Range in the latitude of Valdez Creek. In all these areas the principal rock constituents are argillites, slates, and graywackes, with here and there some limestone and with subordinate amounts of conglomerate. Their most characteristic phase is an alternation of argillite or slate beds from a few inches to a few feet thick with graywacke beds of similar thickness, indicating frequent changes in the character of the sediments that were brought into the basins of sedimentation. In places, however, either the clayey or the sandy phases may predominate, and sections 100 feet or more thick may consist almost exclusively of one or the other of these types of material.

Included in this report with the undifferentiated Mesozoic rocks is a thick group of rocks in the Broad Pass region composed mainly of slate, graywacke, and argillite, which on the basis of fossils collected from its lower portion was assigned by Moffit[87] to the Triassic, and another group in the same area composed mainly of shale, argillite, and slate, with minor amounts of graywacke, conglomerate, chert, and a little limestone, which yielded a few fossils of Jurassic or Cretaceous age. Moffit was uncertain about the position of the boundaries between these two groups, and they are both included here as undifferentiated Mesozoic. In the region between the Chulitna River and Windy Creek Capps[88] found Triassic limestone associated with a thick series of slates and graywackes, and a thick group of black argillites and slates in which Jurassic fossils were collected at a single horizon. All these rocks are here grouped as undifferentiated Mesozoic, as are similar rocks in the Curry district, described by Tuck,[89] and in the Yentna district[90] and eastern Mount McKinley National Park described by Capps. Although in all these areas there are local phases which are somewhat distinctive, the rocks as a whole have many characteristics in common. They are almost everywhere steeply tilted and folded and have been sufficiently metamorphosed for the argillaceous materials to show some degree of slaty cleavage; the frequent alternation of thin beds of argillaceous rocks with coarse-grained materials is widespread; and ripple marks and mud cracks can commonly be seen, attesting their shallow-water origin. But perhaps the most distinctive feature of these beds, and one that is difficult to explain, is the extreme scarcity of fossil remains in them. Throughout this region the localities at which identifiable fossils have been found can be counted on one's fingers. Small collections from this group of rocks of definite or probable Triassic age have been made at three or four localities. Two localities have yielded Jurassic fossils, and one locality yielded two specimens of probable Upper Cretaceous age; all these are from rocks that range in age from Triassic to Cretaceous, that cover an area of many hundreds of square miles, that reach a thickness to be measured in thousands of feet, and that are much alike from top to bottom. As neither the lithologic character of the group nor the fossils obtained from it have so far yielded information that would justify its subdivision into smaller, well-defined units, its rocks are here all grouped as undifferentiated Mesozoic, although it is known

---

[87] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 29–31, 1915.

[88] Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 257–260, 1933.

[89] Tuck, Ralph, The Curry district, Alaska: U. S. Geol. Survey Bull. 857, pp. 117–123, 1934.

[90] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 24–28, 1913.

that beds of definite Triassic, Jurassic, and Cretaceous age are included in it. Detailed geologic work will be necessary before this group of beds can be satisfactorily subdivided, and that subdivision will in most places of necessity be made on lithologic grounds, for nowhere are fossils abundant enough throughout the section to give the geologist the information needed to separate the beds accurately on the basis of age, as determined by the organisms that lived in this region while they were being deposited.

TRIASSIC ROCKS

Although no Triassic rocks are separately shown on the accompanying geologic map, beds of that age have been recognized from their fossils at several places in the Alaska Range, but always as a subordinate part of a larger group of unfossiliferous sedimentary rocks, so that the upper and lower limits of the Triassic beds could not be accurately determined. In this report, therefore, the known Triassic beds have been included with the associated sedimentary rocks and mapped as of undifferentiated Mesozoic age. On a more detailed map the small areas of known Triassic age would be shown in a separate pattern.

Limestones carrying fossils of Triassic, probably Upper Triassic age have been recognized in the basin of the West Fork of the Chulitna River by Capps [91] and by Ross.[92] They have been definitely recognized in the valleys of Ohio, Copeland, and Long Creeks and are everywhere associated with argillites of presumably the same age. Where fully exposed the assemblage ranges from 1,500 to more than 2,000 feet in thickness.

In the Broad Pass region Moffit [93] collected Upper Triassic fossils from limestones and slates associated with dark-colored slates, arkose, and graywacke, the whole assemblage having a possible thickness of several thousand feet and forming a belt 5 or 6 miles wide. The fossiliferous beds were found in the lower part of the section, but Moffit tentatively classified the whole group as Upper Triassic. Inasmuch as a great thickness of these rocks yielded no fossils, and there is therefore some uncertainty as to their age, they are all here grouped with the undifferentiated Mesozoic sedimentary rocks.

Limestone associated with older metamorphic sedimentary rocks in the upper basin of the Sushana River in Mount McKinley National Park was reported by Capps [94] as containing a few imperfectly

---

[91] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 216–217, 1919.

[92] Ross, C. P., Mineral deposits near the West Fork of the Chulitna River, Alaska: U. S. Geol. Survey Bull. 849–E, pp. 298–300, 1933.

[93] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 29–31, 1915.

[94] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 33–34, 37, 1919.

preserved corals that are probably of Triassic age. Its area was so small and its stratigraphic relations so obscure that it was not mapped separately, and it is mentioned here only because it indicates the presence of Triassic rocks in a little-known area on the north slope of the Alaska Range.

JURASSIC OR CRETACEOUS ROCKS

Sedimentary rocks that have been assigned to either the Upper Jurassic or the Lower Cretaceous have been described by Capps [95] as occurring in the upper basin of the West Fork of the Chulitna River. They comprise at least 4,000 to 5,000 feet of beds, mainly mudstones now altered to shale, argillite, and slate, with a few thin limestone lenses. These beds overlie a series of sedimentary rocks that carries Upper Triassic fossils, and are succeeded unconformably by the Cantwell formation, long assigned to the Eocene but recently determined to be of Cretaceous age. In view of the age assignment of the fossils collected at a single horizon as "not older than Upper Jurassic and not younger than Lower Cretaceous," and in the absence of knowledge as to both the upper and lower limit of the beds containing those fossils, these rocks are here mapped as of undifferentiated Mesozoic age.

Farther east, in the Broad Pass region, Moffit [96] tentatively assigned a thick group of beds comprising slate, graywacke, conglomerate, and limestone to the Jurassic on the basis of similarity in lithologic and stratigraphic position to other beds both to the east and to the southwest. In the region here discussed, however, he found no fossils, and it is now known that some beds in the southwestward extension of the same belt are of Cretaceous age. This group is therefore also here classified with the undifferentiated Mesozoic sedimentary rocks.

The thick belts of Mesozoic sedimentary rocks, mainly slates and graywackes, that stretch southwestward from the upper basin of the Susitna River into the basin of the Yentna River have for many years been recognized as of Mesozoic age, but their almost complete lack of fossils has prevented a detailed subdivision. It has been shown that this group of rocks contains beds of well-established Upper Triassic age and overlying beds of Jurassic or Cretaceous age. At one locality on Long Creek, a tributary of the Tokichitna River in the Yentna district, fossils have been found that are probably Upper Cretaceous. It therefore appears that marine sedimentation was more or less continuous in this region throughout Mesozoic time, though the monotonous lithology and the astonishing paucity of fossil remains have left the details of the geologic history clouded in uncertainty. The geographic event of major importance that occurred in late Mesozoic

---

[95] Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 260–264, 1933.

[96] Moffit, F. H., The Broad Pass Region, Alaska: U. S. Geol. Survey Bull. 608, pp. 32–38, 1915.

time was the final emergence of this province from the sea, probably in Upper Cretaceous time, and the resulting cessation of marine deposition. No marine deposits later than Upper Cretaceous are known in this part of Alaska.

CRETACEOUS ROCKS

CANTWELL FORMATION

Distribution and character.—The Cantwell formation is a group of terrestrial or fresh-water beds that have a wide distribution on both flanks of the Alaska Range. It has been recognized as far westward as the headward basin of the Tonzona River, in the Kuskokwim drainage area, occurs in scattered patches from that point eastward to Muldrow Glacier, and from Muldrow Glacier eastward to the vicinity of Mount Hayes is perhaps the most widespread single group of rocks in the make-up of the Alaska Range.

The Cantwell formation was recognized by the earliest geologic expeditions into this part of Alaska and has been described in some detail by several authors.[97] Except for some significant facts concerning its distribution, structural relations, and age the earlier descriptions are adequate and will be briefly summarized here. Recent information in regard to the age of both the Cantwell and of the next younger group of beds, the Tertiary coal-bearing formation, has reopened the question as to the age of these two sets of fresh-water deposits and is sufficient justification for a somewhat fuller description of the Cantwell and discussion of its age than would otherwise be given at this place.

The Cantwell formation was first described and named by Eldridge, who found conglomerates and coarse sandstones along the Nenana River between Windy Creek and Yanert Fork. He had no information and made no suggestion as to the age of the formation. Four years later, in 1902, Brooks saw and mapped these rocks from Muldrow Glacier eastward into the basin of the Yanert Fork. Brooks recognized the fact that this formation included, in addition to Eldridge's conglomerate and sandstone, a thick series of associated sandstone and shale, and he found in shale closely associated with the Cantwell plant remains that were later diagnosed as of Eocene age. Brooks had reached the conclusion from other lines of reasoning, however, that the Cantwell formation was of pre-Mesozoic age, and

[97] Eldridge, G. H., A reconnaissance of the Susitna Basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 16, 1900. Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 79–83, 1911. Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 40–49, 1915. Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 28, 1912; The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 38–44, 1919; The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 264–272, 1933.

he therefore inferred that the fossil plants he had collected had somehow been faulted into the position in which he found them and tentatively assigned the Cantwell to the Pennsylvanian series. In 1910 the writer observed firmly cemented sandstone, shale, and conglomerate in the headward basin of the Wood River, but he correlated those beds with the coal-bearing Tertiary beds, for the Cantwell was then still considered Carboniferous. In 1913 Moffit extended the known area of Cantwell rocks eastward into the upper Nenana Basin, collected fossil plants that were at that time determined to be of Eocene age, and showed that the rocks in the upper Wood River Basin, which the writer had earlier thought were a part of the Tertiary coal-bearing formation, really belonged to the Cantwell. In 1916, 1917, and 1919 the writer extended the known areas of Cantwell rocks into the headward basins of the Savage, Teklanika, and Toklat Rivers, on the north slope of the range, and into the upper basin of the West Fork of the Chulitna River, on the south slope. In 1930 he showed the presence of a nearly continuous belt of Cantwell rocks on the south slope of the range, bordered on the north by a great fault from Windy Creek westward to Anderson Pass, and extending thence westward an unknown distance into unexplored areas.

The shapes of the areas of Cantwell rocks shown on plate 3 have been determined in a variety of ways. In places the position of the margins is due to erosion, glaciers, and streams having cut through the Cantwell to expose older underlying rocks. In other places the Cantwell is in contact with post-Cantwell intrusive rocks. Over considerable areas lava flows of Cantwell or younger age have covered the sedimentary rocks, and elsewhere the younger Tertiary coal-bearing formation, the Nenana gravel, or glacier or stream deposits conceal the Cantwell strata. Faulting in many places has brought the Cantwell against a great variety of older materials.

The Cantwell formation consists almost exclusively of clastic sedimentary rocks ranging from coarse, massive conglomerate containing pebbles 6 inches or more in diameter through finer conglomerate to coarse gritty sandstone, and this into finer sandstone and shale. In many places the lowest part of the Cantwell is a coarse conglomerate 200 feet or more thick, including well-rounded cobbles and pebbles that represent most of the older formations of the region. This basal conglomerate is not everywhere present, however, and in places, particularly in the upper basin of the West Fork of the Chulitna River, it has not been possible to locate certainly the plane of contact between the fresh-water Cantwell rocks and the underlying massive Jurassic and Cretaceous beds. Above the basal beds of the Cantwell there is a succession of interbedded sandstone, grit, shale, and conglomerate, in which individual beds range in thickness from a few inches to many hundreds of feet. The succession is probably not the same at any two places, for a single bed may vary along the strike, being fine-grained at one place and coarse-grained not far away. Furthermore, it has been observed at many places that the beds are lenticular, a conglomerate several hundred feet thick thinning out and disappearing within a distance of a few miles, perhaps to be replaced by another conglomerate a little higher in the section. In a general way, however, the proportion of conglomerate decreases and that of shale increases upward in the section, though conglomerate recurs in the formation from bottom to top. In certain parts of the region, particularly in the valleys of the Sanctuary, Teklanika, and Toklat Rivers, along the route of the park road that leads from the railroad to Wonder Lake, there are large quantities of igneous rocks, occurring both as intrusive dikes and sills and as lava flows interbedded with the sedimentary rocks. They include rocks of a considerable range in texture and composition, among them rhyolite porphyry, rhyolite flows and tuffs, andesite, dacite, diabase, basalt, and amygdular greenstone, as well as coarser-grained intrusive rocks including granite, monzonite, diorite, and gabbro. The flows interbedded with the Cantwell sedimentary rocks are especially vivid in coloring and include hues ranging from white, cream, and light tints of pink, red, green, and purple to darker shades of brown, red, and green. These varicolored lavas and intrusive rocks in the Cantwell give the brilliant coloring seen in the mountains of the Teklanika Basin and Polychrome Pass.

The sedimentary beds of the Cantwell range in color from light-gray sandstone and conglomerate to dark, nearly black conglomerate, sandstone, and shale. They include some buff and reddish beds, but the colors are prevailingly somber, in contrast to the brilliant colors of the associated igneous rocks. The rocks are well indurated throughout and weather into bold, rugged forms. The peaks of many high mountains are composed of these materials, and the coarser beds, particularly the hard conglomerate, produce many fantastic and picturesque forms. The shale and argillite are generally less resistant to erosion than the sandstone and conglomerate, and where the formation is largely composed of the finer beds the relief is less bold and the slopes are smoother than where coarse materials prevail. In many exposures the hard, coarse-grained beds stand out in parallel plates of high relief, the shale having weathered into deep troughs between them.

In a few places the Cantwell formation contains coal beds. Along the railroad at mile 341 an attempt was made some years ago to mine coal, but displacement of the bed by faulting caused difficulties, and the project was abandoned. At other places coaly shales containing very thin beds and lenses of coal have been observed, but at present no coal is being mined from the Cantwell.

In the area just south of the great fault that extends from Anderson Pass eastward through the upper basins of the West Fork of the Chulitna River and the Bull River to the Nenana River, and north of that fault thence eastward to Nenana Glacier, the Cantwell strata have been shown [98] to exhibit a progressive change from little-altered sedimentary rocks at a distance from the fault zone through materials that show increasingly the effects of metamorphism to highly metamorphic rocks that include mashed and stretched conglomerate, black slate, and mica schist in the immediate vicinity of the fault. These highly metamorphosed phases are confined to the vicinity of the fault zone and are attributed to stresses set up by the faulting itself. A series of specimens may be collected that shows a complete graduation between slates and schists, on one hand, and little-altered argillite, conglomerate, and sandstone, on the other, and leaves little doubt as to the contemporaneity of the whole assemblage. The downthrown side of the fault was on the south in the area west of the Nenana River and on the north in the area east of that river, which accounts for the presence of the Cantwell rocks on different sides of the fault in those two areas. No study of the geology of the Alaska Range has been made in the region west of Anderson Pass and south of Muldrow Glacier, but abundant blocks of conglomerate, sandstone, and shale that are identical in appearance with Cantwell rocks are scattered over the surface of Muldrow Glacier, and these indicate that Cantwell sedimentary rocks form a considerable element in the high ridge of which Mount McKinley is the culmination. Neither the source from which the Cantwell sediments were derived nor the area originally covered by them is known. It is certain, however, that the area of deposition was much larger than the area now occupied by this formation, for the margins of the areas, as mapped on plate 2, everywhere show that they have been reduced by erosion, or covered by younger materials.

Structure and thickness.—The structure of the Cantwell formation in this region is complex, though less so than that of the rocks on which it lies unconformably. On the south flank of the mountains, south of the great fault, the prevailing structure of the Cantwell is a monoclinal dip of 15°–20° N., though the structure is by no means so simple as such a general statement indicates. Faults of various displacement are common, and there are large open folds,

[98] Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 266–267, 1933. Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 40–49, 1915.

great isoclinal folds, and local areas of intense crumpling and crushing. Along the zone of the great fault the beds are greatly sheared and mashed, the conglomerate is stretched and schistose, and the shale is mashed to fragments or reduced to a formless mass of clayey material. North of the great fault the beds exhibit a wide range in degree of deformation. West of the Nenana River the Cantwell lies in a broad synclinal trough, the south limb of which is upturned against the Paleozoic rocks along the crest of the range, and the north limb bordered by the Paleozoic and pre-Paleozoic rocks of the foothill ranges. Within this trough the Cantwell strata rest unconformably upon all the older formations there present. East of the Nenana River the Cantwell is probably bordered on the north by the pre-Cambrian Birch Creek schist and on the south by the great fault.

The folding, faulting, and deformation which the Cantwell has undergone took place during the period of mountain-building processes that acted along the site of the present Alaska Range but that preceded the last upward movement of the mountains. Certainly no mountains existed in late Mesozoic time in the area now occupied by the Cantwell, for its materials were of necessity deposited in low-lying areas, though they were deposited on land, for this region had already finally emerged from the sea. A part of the deformation preceded the deposition of the coal-bearing Tertiary beds, for the Cantwell was indurated, tilted, and eroded before these coal-bearing beds were laid down. Whether or not the great fault along the south flank of the range preceded or followed the deposition of the coal-bearing Tertiary beds is not certainly known, for those beds have not been observed immediately adjacent to the fault. Nevertheless it may be reasoned that the fault is older than the last uplift, which gave the range its present height. In the area west of the Nenana River the fault certainly has a displacement of at least 10,000 feet, and the south side was downthrown. Yet from Anderson Pass westward the highest portions of the Alaska Range are on the downthrown side of the fault. These facts suggest that the topographic relief of the surface due to this fault was reduced by the erosion that followed the deposition of the Cantwell and preceded the deposition of the coal-bearing Tertiary beds, and that the present relief of the range is the result of regional uplift and folding after the coal-bearing formation was laid down. A considerable part of the uplift of the present range is known to have been later than the coal-bearing formation, and that uplift was accompanied by compression and folding that involved both the Cantwell and the younger coal-bearing beds.

In no one place is the original uneroded thickness of the entire Cantwell formation exposed, and it is therefore not yet possible to state what the maximum thickness is. On the south side of the range the Cantwell formation is cut off on either its north or its south margin by the great fault, and its thickness where exposed has been diminished by erosion, yet in the ridge north of the head of the West Fork of the Chulitna River, where the beds are not folded and only moderately tilted, an incomplete section shows 4,000 feet of Cantwell strata. On the north side of the range the remaining portion of the formation is 2,000 to 3,000 feet thick. Moffit[99] calculated a thickness of about 2,700 feet in a single mountain in the Broad Pass region, near the mouth of Jack Creek, and believed that that measurement represented only a part of the section. From evidence now at hand it appears that the maximum observed thickness of the Cantwell formation is at least 4,000 feet, and that there the section was incomplete. The original thickness of the formation may have been much more than that amount.

Age and correlation.—Eldridge, who wrote the original description of the Cantwell formation, expressed no opinion as to its age. The name he took from what was then called the Cantwell River but is now called the Nenana, the valley of which is cut in this formation from the mouth of the Jack River to the mouth of Riley Creek. These beds were first assigned to a definite stratigraphic position by Brooks[1] as the result of studies made in 1902, during which he traced the formation from a point near Muldrow Glacier eastward to the Nenana River and for 25 miles up the Yanert Fork. He found the Cantwell formation lying unconformably upon beds of probable Middle Devonian age, and expressed the opinion that it was pre-Eocene, although recognizing its structural and lithologic resemblance to Eocene beds in other parts of Alaska. Brooks even found plant remains, later identified as of Eocene age, in Cantwell shales, but the beds were faulted, and from other considerations he concluded that the Cantwell formation was pre-Mesozoic, and that if so, it would most likely be Carboniferous. Moffit, however, as the result of his field work in 1913 in the Broad Pass region, assigned the Cantwell to the early Tertiary (Eocene) on the basis of fossil plants he collected. These plants were at that time identified by F. H. Knowlton and Arthur Hollick as Eocene. In 1916 the writer collected a few fragmentary leaves from the valley of Big Creek, a tributary of the Teklanika River, and these also were assigned to the Eocene. For many years, therefore, the geologists were confronted by a puzzling anomoly, for their field studies convinced them that the Cantwell was much older than the coal-bearing Tertiary beds, that it was much more indurated, more highly folded and faulted, and that it probably lay unconformably beneath the coal-bearing Tertiary,

[99] Moffit, F. H., op. cit. (Bull. 608), p. 47.
[1] Brooks, A. H., op. cit. (Prof. Paper 70), p. 81.

though such an unconformable overlap had not been directly observed. But in spite of this convincing field evidence that these two groups of fresh-water sedimentary rocks were separated by a considerable time interval, the plants from both had been assigned to the Eocene. There was therefore no alternative for the geologists but to accept that age for both groups of rocks, though they were well aware that the two formations were not identical and had repeatedly stated that fact.

During the summer of 1936 the writer was so fortunate as to meet Dr. Ralph W. Chaney, a paleobotanist, in Mount McKinley National Park, and was able to accompany him to a locality at which fossil leaves had been collected from the Cantwell formation 20 years earlier. There new and fuller collections of fossil leaves were made, and after careful study Chaney definitely pronounced those plants to be of Cretaceous age. Apparently the last word concerning these fresh-water sedimentary rocks cannot be said until the evidence from the fossil plants has been reviewed and until the paleobotanic findings are brought into accord.

TERTIARY ROCKS

TERTIARY COAL-BEARING FORMATION

Distribution and character.—Coal-bearing Tertiary fresh-water or terrestial sediments that heretofore have all been regarded as of Eocene age occur at many places along both flanks of the Alaska Range within the region here considered and indeed are known at intervals along the north slope from the Kuskokwim Basin eastward to the international boundary, a distance of 400 miles, and along the southeast and south slope from lower Cook Inlet to the head of the Susitna Basin and thence eastward into the basin of the Copper River. In spite of this wide distribution, however, the occurrences are sporadic, and it is unlikely that the beds, even as deposited, were continuous between these areas. This patchy distribution is in some degree due to the removal of these only moderately indurated materials by erosion but is mainly the result of the conditions under which they were laid down. The Tertiary coal-bearing formation is composed of little-consolidated or only moderately indurated gravel, sand, shale, and lignitic or subbituminous coal, all of which were deposited by streams or in lowland areas in which there were no large bodies of standing water. There is no evidence that any of this formation was laid down in marine waters, and the only fossils are plant remains or fresh-water organisms that indicate deposition under subaerial conditions or in small, shallow lakes. It is believed that these beds were originally confined to relatively narrow, open stream valleys or to somewhat broader lowlands into which streams flowed from highland areas of moderate relief, located in about the position of the present mountains of this part of Alaska. In certain favorably situated lowlands, notably the one now occupied by Cook Inlet and the Susitna River and its larger tributaries and another on the interior slope of the present Alaska Range, extending from the Sanctuary River eastward into the upper basin of the Totatlanika River, there were fairly broad areas that received these materials, and possibly they occur in still another broad basin, that of the Tanana lowland, though the later deposits of alluvial material conceal any Tertiary beds that may be present. Elsewhere the areas occupied by these beds are small, and they were probably never connected with one another.

The Tertiary coal-bearing formation in the Cook Inlet, Susitna, and Tanana Basins has been studied and described by several authors,[2] some of whom have visited the region here under consideration. West of the Nenana River the Tertiary coal-bearing deposits are scattered and of small area, and except for a few localities where the coal has been mined in a small way for local use, none are of present commercial value. Four miles east of the Alaska Railroad at Healy station, however, a remarkable section of these beds is exposed, and there a large coal mine has been operated continuously for many years. These exposures on Healy Creek give the most complete and best known section of this formation in the Alaska Range region, with a stratigraphic thickness of 1,900 feet of coal-bearing beds consisting of gravel, shale, sand, and lignite or subbituminous coal, of which 220 feet is coal in 23 separate beds. The stratigraphic relations at this locality are typical of the formation in many other places. The basal beds consist of several hundred feet of smoothly rounded pebbles of chert and white quartz in a matrix of white sand and kaolinic material, lying with angular unconformity upon the pre-Cambrian Birch Creek schist. The conspicuous white color of this part of the formation is characteristic over wide areas and is of great value in identifying the base of the formation. Above the white basal gravel are alternating beds of shale, clay, sand, lignite, and some fine gravel. The lignite beds, some of which have locally been burned out near the outcrop, are thickest and most numerous in the lower half of the section, where there are seven beds that aggregate 174 feet of coal. In the upper half of the section the coal occurs in thinner beds, and fine gravel is more abundant. The formation is succeeded above conformably by a thick deposit of gravel, the Nenana gravel. The Healy Creek section contains more known coal than any other section that has

[2] Brooks, A. H., op. cit. (Prof. Paper 70), pp. 94–103. Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 26–29, 1912; The Kantishna region, Alaska: U S. Geol. Survey Bull. 687, pp. 44–51, 1919; The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 272–278, 1933. Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 pp., 1919.

been examined, though at other places much of the formation is not exposed, and the amount of coal present below the lowest exposure is not known.

The relationship of the coal-bearing formation, occurring as it does in lowland areas and in narrow valleys between more rugged areas, is the direct result of the fact that the beds as originally laid down were confined to lowland areas and of the weakness of the beds themselves as compared with surrounding harder rocks. The coal-bearing beds consist largely of unconsolidated or easily eroded materials that were more readily removed by streams and glaciers during the general erosion of the region than the associated more resistant formations, and the position of valleys and low passes where these beds occur was in part determined by their easy erosion. The economic importance of this formation is much greater than its area would indicate, for almost everywhere that it is present it contains coal beds and so provides a source of fuel for local use in many places where other fuel would be difficult or expensive to obtain. The Healy Creek-Hoseanna Creek field, east of the railroad, is estimated to contain many billion tons of coal, and active mining is now being carried on there. It is unlikely that the smaller and more remote fields will be exploited commercially in the near future, or until the more accessible fields are depleted, but they form a large fuel reserve that sometime may prove valuable to the Territory.

Structure and thickness.—The Tertiary coal-bearing formation in this region occurs only as small scattered patches, or in basins of moderate area, and the structure and lithology within each of these localities have been determined by the conditions of sedimentation and of subsequent deformation. The sediments that make up the formation were deposited by streams, or locally in shallow lakes, in low, basinlike areas at a time when the present site of the Alaska Range was yet a region of low or only moderate relief, a fact indicated by the character of the beds themselves, for they are dominantly sand, fine shale, and clay, with only minor amounts of gravel. The deposition of the organic materials that make up the coal beds must have taken a long period of time, during which little detrital material was introduced, for these coal beds were formed by the slow growth and accumulation of vegetation, and while they were being built little stream-borne debris was brought in. The detrital material was much finer than the sediments now being handled by the streams in the same areas and points to low gradients and comparatively sluggish streams during the growth of the formation. Apparently the drainage lines on the north side of the range then followed a general east-west direction, in contrast to the present northward-flowing drainage, whereas on the south side there was apparently a lowland in about the same position as Broad Pass and its extensions to the east and southwest.

Much of the deformation and uplift of the present Alaska Range has been accomplished since the coal-bearing Tertiary beds were laid down, and the mountain-building processes of folding and faulting have affected these deposits as well as the older rocks of the region. The compression and warping of the crust during the growth of the range was comparatively slight in the foothills and on the lower flanks of the mountains, where the coal-bearing beds are most abundant, but in the higher mountains it was severe, and the small areas of this formation that occur there are more highly deformed than those on the borders of the range.

Little is known concerning the maximum thickness of this formation. In view of the conditions under which these beds were deposited, it is obvious that the formation, laid down by streams in a region of moderate relief, should vary greatly in thickness from place to place, and that as the lower basins were filled and the deposit thickened, the area it covered would increase, and the beds in basal contact with the older rocks would be younger than those deposited earlier on lower ground. For this reason, the lowest beds of the formation at different localities do not necessarily represent contemporaneous deposits, but are more than likely not to do so, and because individual beds are generally lenticular and the fossil leaves are not closely diagnostic, it has so far been impossible to correlate closely the beds at separate localities. The thickest and most complete section yet studied is that near the Suntrana mine, on Healy Creek. There the formation is about 1,900 feet thick, its base rests unconformably upon the pre-Cambrian Birch Creek schist, and its top merges conformably into the overlying Nenana gravel. Whether or not the base of the formation at that place represents the oldest portion of the formation in this region is not known, nor is it known whether the deposition of the coal-bearing sediments was here interrupted by the laying down of the Nenana gravel at an earlier or at a later time than elsewhere in the region.

Age and correlation.—Until the summer of 1936 the only fossils found in this formation were plant remains. From these and from its stratigraphic relations to overlying and underlying formations, and by correlation with other beds of similar lithology, the age of the Tertiary coal-bearing formation had for years been accepted as Eocene. Collections of fossil plants from this region have not been as abundant as is desirable, for although plant remains in the form of lignite or subbituminous coal and carbonaceous imprints of leaves and twigs are common, most of them have been so completely altered that the plant forms can no longer be identified. Furthermore, the enclosing sediments are but slightly consolidated, and most of the plant remains will not stand the handling incident to their collection and transportation for identification. In the Nenana field, however, certain shale beds have been hardened by the burning out of adjacent coal beds, and in these burned shales excellently preserved leaf prints have been found. From these and from other scattered collections throughout the region, the paleobotanists have stated the age of the beds to be Eocene and have correlated them with the Kenai formation of lower Cook Inlet. The similarity of the lithology of the coal-bearing formation of the Alaska Range to that of the Cook Inlet region, as well as the evidence from the fossil leaves, strongly suggests that at least some of the coal-bearing beds of the Alaska Range region are the correlative of some parts of the Kenai formation. It has not yet been demonstrated, however, that the entire age range of the coal-bearing series is the same throughout the Territory, and until more evidence on this point is available it has seemed wise not to apply the term "Kenai formation" to beds so far from the type locality on Cook Inlet.

In the summer of 1936 new evidence as to the age of part of the coal-bearing formation in the Nenana coal field was discovered by Eric Schlaikjer, who found fossil fresh-water fish in these beds on Healy Creek, a few miles above the Suntrana coal mine. Schlaikjer unqualifiedly pronounced these fish, and therefore the containing beds, as of Miocene age. This opens up the whole question of the validity of age determinations on the basis of fossil plants as compared with vertebrate remains. As has been stated, the Cantwell formation, which underlies the coal-bearing formation unconformably, has also yielded plants which for years had been regarded as of Eocene age but which recently have been assigned by Chaney to the Upper Cretaceous. The new evidence thus separates beds, all of which had been considered Eocene, into portions as far separated in age as Upper Cretaceous and Miocene. Although the geologist must rely upon the paleontologist for the determination of the age of fossils, he is able to determine the relative age of formations from his field observations. In this region the geologists have long recognized that the Cantwell formation is much older than the coal-bearing formation. This conclusion is fortified by the recent studies of both plant and animal remains. The true age of the beds, however, must remain in some doubt until the differences in age assignments made on the basis of organisms of different kinds are reconciled.

NENANA GRAVEL

Character and distribution.—The term "Nenana gravel" was first used by Capps [3] for a series of elevated gravel beds that reach a widespread development on the north flank of the Alaska Range and are particularly well exposed just east of the Nenana River. These gravel deposits were first described by Brooks and Prindle [4] as a result of their exploration in 1902. They considered them to be of glacial origin and Pleistocene age and grouped them with the other Pleistocene deposits. In 1906 Prindle [5] again visited this region and noted that wherever their structural relations could be observed these gravel deposits lay conformably upon the underlying Tertiary coal-bearing formation, whether in horizontal or tilted strata. He also made a distinction between gravel deposits of various ages, some of which were younger than the Nenana gravel. In 1910, 1916, and 1930 and at other times the writer [6] has studied the gravel deposits on the north side of the Alaska Range both east and west of Nenana River, outlining the areas in which they occur and arriving at the conclusion that they are of Tertiary age.

The Nenana gravel forms a thick series of unconsolidated or only loosely cemented materials consisting mainly of rather coarse, well-rounded gravel, with only subordinate amounts of interbedded sand. It has been shown on the geologic map only where its character is evident and where it has not been covered by later materials. Most of the pebbles in it range in diameter from 1 to 3 inches, though in places cobbles and boulders, evidently weathered from this deposit, are found in the bottoms of gulches cut in the formation. The pebbles include a great variety of rocks, among the commonest of which are quartz, quartzite, schist, conglomerate, and igneous rocks of a wide range of composition. As would be expected, the proportion of the various constituents differs from place to place, depending upon the character of the bedrock in the basins from which the pebbles were derived, for it is unlikely that these coarse materials were transported any great distance from their bedrock source. The deposition of the Nenana gravel probably began soon after the beginning of the pronounced uplift of the Alaska Range that followed

[3] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912.

[4] Brooks, A. H., op. cit. (Prof. Paper 70), pp. 105–106, 108–109.

[5] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 222, 1907.

[6] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912; The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 51–57, 1919; The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, pp. 279–284, 1933.

the deposition of the coal-bearing Tertiary beds, and the gravel is the product of erosion by vigorous, rejuvenated streams that drained from the recently elevated highlands. In some places the gravel is sufficiently cemented to stand in steep cliffs, but on weathering the sandy matrix crumbles and frees the pebbles. A characteristic feature of this gravel is its yellow or buff color, due to the oxidation of iron-bearing minerals in the sandy matrix and the pebbles, and indicates that the deposit is older than the blue and unoxidized gravel of the present streams and than the morainal materials left during the last great ice advance. At many places the Nenana gravel has been cut into by the present streams, and within these younger valleys the streams have formed terraces and flats of gravel that was in part at least derived from the Nenana gravel. In those places the younger deposits may either lie with apparent conformity upon the older gravel where it is flat-lying or be obviously unconformable upon the Nenana gravel where it is tilted. Where there is no obvious angular unconformity between the gravel deposits, it is easy to mistake younger terrace gravel for the Nenana gravel, particularly if the younger beds are composed mainly of reworked material from the bordering Nenana gravel ridges and in consequence have inherited the yellowish color of the parent formation. Normally the color of the gravel deposit under examination is an important criterion in determining whether it is Nenana gravel or younger, but in some places the physiographic form and relationships must be relied upon. The confusion on these points has led some observers to conclude that the Nenana gravel is commonly unconformable upon the coal formation, whereas according to the writer's observations there is in most places conformity between them. There are, however, a few localities in which the Nenana gravel is known to lie unconformably upon the coal-bearing beds.

In most of the areas in which the Nenana gravel is present the topographic features formed by its erosion are smoothly rounded, and the gravel is so deeply covered by loose surface material and by vegetation that its structure cannot be made out. Only where vigorous streams have cut into the gravel hills and formed bare bluffs can sections showing the character and structure of the formation be found. The present topography is due in part to the structure of the material, but the deposits are so loosely cemented that they break down readily, and in the absence of any hard, resistant beds, the gravel yields slopes of smooth outlines and subdued topography.

Structure and thickness.—All the Tertiary formations in this region, including the coal-bearing formation and the Nenana gravel, were deposited by streams in lowland areas under subaerial conditions. There is no evidence that this region has been generally submerged in either salt or fresh water since the beginning of Tertiary time. The Nenana gravel is stream-deposited, as is indicated by the character and composition of its material and by the distribution of the formation; and its coarseness, in contrast to the finer grain of the sedimentary rocks that make up the coal-bearing formation, points to a rejuvenation of the streams by an uplift of the area from which they flowed. This is believed to have been the first of the upward movements that formed the present Alaska Range, for during the deposition of the finer sediments and coal of the coal-bearing formation the relief of the region must have been relatively low. The earliest uplift is thought to have affected only the axial portion of the range, while the bordering areas now occupied by the Nenana gravel remained lowlands and received the detritus brought down by the invigorated streams. After the deposition of the gravel, locally to a thickness of nearly 2,000 feet, the region affected by the upward growth of the range broadened and included areas earlier covered by the gravel deposits. The processes involved in the growth of the range included bodily uplift, faulting, and folding. The folding was parallel to the trend of the range, and some of the folds affected the coal-bearing formation and its cover of Nenana gravel. Farther out on the flanks of the range these beds were only tilted, and in many places they escaped deformation almost completely. During the later stages of uplift, and since the elevation of the range to about its present height and area, erosion by streams and glaciers has been active, and the loosely coherent gravel has been deeply dissected. From some areas which it formerly covered it has been entirely removed.

In general the Nenana gravel is believed to lie conformably upon the coal-bearing formation where both are present. Where the coal-bearing beds are absent the gravel lies unconformably upon some older formation. At a few places what appears to be normal Nenana gravel is unconformable upon the coal formation, but this can be explained if the gravel so found is considered to represent not the equivalent of the oldest Nenana gravel, but some higher portion of the formation, deposited later as the gravel thickened and spread over increasingly wide areas. If in such local areas the underlying coal formation had become involved in folding and was later eroded before the edges of the thickening Nenana gravel lapped over it, an unconformable relation would appear, whereas in most places no such unconformity would exist. Certainly in most places there is conformity between the coal formation and the overlying Nenana gravel, even where both have been folded and tilted together. It may be said that in general the Nenana gravel is deformed equally with the coal-bearing formation where both occur.

Age and correlation.—No identifiable fossils, either plants or other organisms, have been found in the Nenana gravel, and its age is still somewhat uncertain. In the lack of fossils any appraisal of its age must be based on its stratigraphic relations to other formations, its physiographic position and form, its general structure, and its resemblance to other formations of less doubtful age. As first described by Brooks[7] the gravel was considered to be directly related to the Pleistocene glaciers and was grouped with the Quaternary deposits. Prindle[8] and Capps,[9] both of whom studied the gravel over considerable areas on the north flank of the range, observed that in most places it lies conformably upon the coal-bearing formation, and that in those places both have been deformed in equal degree, whereas the glacial deposits and associated outwash gravel are little or not at all deformed. Since these writers first published their observations many other localities have been found where both the Nenana gravel and the coal-bearing formation are exposed in the same section, and in nearly every such exposure the two have been folded and tilted together. On the other hand, at one or two places the undeformed gravel lies with angular unconformity upon the upturned and beveled edges of the coal formation. It seems likely that at such places the coal formation was uptilted by an early uplift of the range, was eroded while elsewhere the earlier part of the Nenana gravel was being laid down, and was later covered by the constantly thickening and broadening sheet of the later part of the Nenana gravel. In other words, the basal portion of the Nenana gravel, deposited over a rolling land surface, would have accumulated first in lowland areas, but as it grew in thickness its area would also have increased, and toward the margins of the basins of sedimentation the younger portions of the formation would be found in unconformable overlap upon older rocks. It is believed by the writer, however, that in most of the basins in which the coal-bearing formation was laid down sedimentation was continuous and uninterrupted from the top of that formation into the Nenana gravel, and that the boundary between those two formations is not marked by a break in sedimentation but only by a change from finer to coarser materials.

If the above-stated assumptions concerning the prevailing stratigraphic relations between the Nenana gravel and the coal-bearing formation are correct, then the oldest Nenana gravel is younger but only a little younger than the youngest beds of the coal formation. Just what that age is, however, is still open to some question. For years all the fossil leaves from the coal formation have been assigned to the "Kenai flora," and the age given as Eocene. As has

[7] Brooks, A. H., op. cit. (Prof. Paper 70), pp. 108–109.
[8] Prindle, L. M., op. cit. (Bull. 314), p. 222.
[9] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 33, 1912.

been stated, however, in the discussion of the age of the coal formation, recently fossil fish of Miocene age have been found in it. If a Miocene age is accepted for the coal-bearing beds, the Nenana gravel must be late Miocene or Pliocene. Certainly it is of pre-Pleistocene age, or at least it is older than any Pleistocene glaciation of which we know in this region. Brooks regarded the Nenana gravel as representing outwash from Pleistocene glaciers, but that idea is now discarded, for it is known that at least during the last great ice advance the glaciers moved down valleys that had already been deeply eroded into the Nenana gravel. As the Nenana gravel had already been uplifted, tilted, and deeply eroded before that ice advance, it is certainly much older than that glacial stage, which was probably of Wisconsin age. Our knowledge of the glacial history of Alaska before the last great ice advance is scanty, but it is definitely known that there have been at least two glacial stages, one much older than the last, and there may have been several. Many large boulders occur on top of the Nenana gravel on both sides of the Nenana River near the northern face of the foothills and in localities that are beyond the limits reached by the last great glaciers. These boulders are believed to be of glacial origin and to represent an ice advance, earlier than the last, in which the glaciers were thicker and pushed farther out from the mountains than the glaciers of the last stage of Pleistocene glaciation. All such boulders, however, lie on top of the Nenana gravel, which must have been present before the ice advanced to it, in order to have received glacial boulders upon its surface. The physiographic development of the gravel, which, after its uplift and tilting, was eroded into mature topographic forms, with deep intersecting valleys, indicates a considerable age for the gravel. So also does its advanced oxidation, for the gravel is oxidized to a buff color to a depth of many hundreds of feet, whereas the only known glacial deposits nearby are blue or gray and are oxidized scarcely at all. The general stratigraphic conformity of the gravel with the underlying coal-bearing formation, where both have been steeply tilted and deformed, as compared with the undeformed glacial deposits, also points to a Tertiary age for both formations.

In summary, the Nenana gravel, as observed for a long distance along the north flank of the Alaska Range, appears to be generally conformable with the coal formation, though local unconformities are present. Its deformation, advanced oxidation, and mature topographic forms indicate that it is of considerable age. It is certainly much older than the superposed and unoxidized deposits of the last stage of Pleistocene glaciation, which lie in valleys deeply eroded into the gravel. Boulders of glacial origin lie on its surface outside of and above the limits reached by the last great glaciers, but these boulders are found only on the surface of the gravel and not interbedded in it, thus indicating an age for the gravel greater than that of an earlier (pre-Wisconsin) glacial advance.

The gravel is superposed upon and so definitely younger than the coal-bearing Tertiary beds, though the writer believes that the deposition of the oldest Nenana gravel immediately succeeded the deposition of the coal formation without a time break. The precise placing of the Nenana gravel in the stratigraphic column must therefore depend upon the age determination of the coal formation, for no fossils have been found in the gravel. For many years the coal formation has been assigned to the Eocene on the basis of its contained plant remains. Recently fossil fishes found in it have been declared to be Miocene. Until an agreement is reached between the determinations based upon the plants and that based upon the fishes, it can only be said that the Nenana gravel is preglacial and therefore Tertiary, and that it is younger than the coal formation, which is of still earlier Tertiary age.

IGNEOUS ROCKS

Igneous rocks occurring as intrusive masses or as lava flows are associated with all the sedimentary formations in this region from the pre-Cambrian Birch Creek schist to the Tertiary coal-bearing formation. They have almost as wide a range in age as the sedimentary rocks. Thus the Birch Creek schist contains basic greenstone that apparently represents lava flows extruded on and interbedded with the water-laid sedimentary rocks of which the formation is largely composed. If the greenstone is actually interbedded with the sedimentary rocks, it is, of course, of the same age. The Birch Creek schist is also cut by intrusive masses of a wide range of materials, but the age of these masses is not known except that they are younger than the rocks they cut. The Totatlanika schist, the age of which is not accurately known but which is probably early Paleozoic, is made up mainly of metamorphic rocks that originally were rhyolites and rhyolite porphyries, with perhaps some tuff and some interbedded clastic sedimentary rocks. This group is many thousands of feet thick. The pre-Devonian schists on the south slope of the range west of Broad Pass are cut by dikes of various sorts and contain some basaltic materials that are now in places altered to serpentine. The great series of Middle Devonian and associated beds, though in the main quite free from interbedded igneous materials, is cut by a great variety of dikes and sills that range from diabase, gabbro, and basalt to dacite, andesite, monzonite, and granite. Nothing is known of the age of any particular intrusive rock in this series except that it is younger than the beds it cuts. In the upper basin of the Chulitna River the Carboniferous (Permian?) rocks include a considerable thickness of volcanic tuffs, which though stratified and deposited in water are of igneous origin, as well as some chloritic beds that may be altered lava flows.

What appears to be the oldest Mesozoic igneous rocks in the region are basaltic greenstone flows that reach a thickness of at least 2,000 feet in the Toklat Basin and near Muldrow Glacier and that overlie the Devonian beds and underlie the Cantwell formation. The beds are prevailingly dark green, brown, or purple, and are commonly amygdular, and in some flows show ellipsoidal structure. These characteristics indicate that the greenstone was poured out as lava flows upon the surface of the land, or perhaps in part beneath water. It appears to be quite free from associated sedimentary material and contains no fossils. Its age can therefore be determined only by its stratigraphic relations and by correlation on the basis of lithologic similarity to like beds elsewhere. Within this region the only evidence of the age of the greenstone flows is that they are younger than the Devonian sediments and older than the Cantwell formation, which is of Upper Cretaceous age. In the Broad Pass region, somewhat south of the Alaska Range proper, Moffit [10] found basaltic and andesitic flows that he tentatively assigned to the Triassic. In many other parts of Alaska there are extensive basalt flows that are in part Permian and in part early Mesozoic, and the greenstones in Mount McKinley National Park may well belong to that same period of volcanism. No closer age assignment can now be made for them.

Recently found evidence indicates that the Cantwell formation is of Upper Cretaceous age, and the deposition of the Cantwell was in places interrupted from time to time by the pouring out of lava flows of a considerable range in composition, including rhyolite, andesite, and diabase, and both sedimentary rocks and lavas were later cut by intrusive stocks, dikes, and sills that range in character from diabase and basalt through andesite and dacite porphyry to diorite, monzonite, and granite. Naturally some of these intrusive rocks cut all the formations of Cantwell or greater age, and the age of any particular intrusion can be certainly dated only as being younger than the rocks that it cuts. Certainly many of the intrusive rocks are as young as the Cantwell. On the other hand, the earliest Tertiary beds, those of the coal-bearing formation, are relatively free from intrusive rocks, though in a few localities cut by dikes. It therefore seems safe to say that by the end of Mesozoic time igneous activity in this region had almost ceased, and that throughout Tertiary time the injection of intrusive rocks and the pouring out of lava flows upon the surface were rare events and of small volume.

---

[10] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 26–28, 1915.

The larger masses of granitic rocks in this region have heretofore generally been considered to be of Mesozoic age and have commonly been assigned to the Jurassic period. More recent studies have developed the fact that many such masses cut rocks as young as Upper Cretaceous, though all seem older than the Tertiary coal formation. In the Broad Pass region Moffit and Pogue [11] recognized and mapped granitic rocks, including monzonite, diorite, granite, and granite porphyry, that range in age from post-Triassic to post-Eocene (?), the latter age assignment being based on the fact that those rocks cut the Cantwell formation, then considered to be Eocene but more recently determined to be Upper Cretaceous. In the Mount McKinley National Park region also there are granitic intrusives that cut the Cantwell but are probably older than the Tertiary coal-bearing formation. It seems certain, therefore, that there was considerable intrusion of granitic material in post-Cantwell time, perhaps at about the end of the Mesozoic era, but that intrusion of such rocks ceased before the coal-bearing formation was laid down.

QUATERNARY DEPOSITS

During Quaternary time the Alaska Range was subjected to at least two and probably several episodes of glaciation, which by the severity of the ice scour profoundly altered the surface aspect of the mountains and by the deposition of the materials so removed also greatly changed the appearance of the lowlands in which the glacial moraines and outwash gravel were laid down. Upon the final shrinkage of the glaciers to their present dimensions the present drainage lines were reestablished, and the ordinary processes of erosion and deposition in a subarctic climate were resumed. The events of Quaternary time and their geologic effects are more fully discussed in a section that deals with the whole of the railroad belt (pp. 150–169).

SUMMARY OF GEOLOGIC HISTORY OF THE ALASKA RANGE

Our knowledge of the main geologic events that affected the part of the Alaska Range that falls within the scope of this report may be briefly summarized as follows:

In pre-Cambrian time there accumulated a great thickness of sedimentary rocks that included limestone, sandstone, shale, with which some basic lava flows were interbedded. The source of these clastic materials is not known but they covered wide areas in central Alaska and in the region now occupied by the Alaska Range. After they were deposited these beds were probably buried to considerable depths by other materials and were then intensely deformed and metamorphosed by heat and pressure to such a degree that their original

[11] Moffit, F. H., The Broad Pass region, Alaska, with a section on igneous rocks by J. E. Pogue: U. S. Geol. Survey Bull. 608, pp. 54–65, 1915.

characters were largely lost. The original minerals were recrystallized to form many new minerals, mica was abundantly developed, and the whole mass became schistose, giving rise to what we now know as the Birch Creek schist. These rocks probably underwent regional and dynamic metamorphism at intervals during the long time that elapsed before the next younger rocks of this region were laid down, for they are much more highly metamorphosed than any of the succeeding formations.

It is probable that after the alteration and deformation of the Birch Creek schist were far advanced it was elevated, its cover was stripped off, and great quantities of the schist itself were removed by erosion, and that a very long time interval is represented by the unconformity between the Birch Creek schist and the next younger rocks in this region.

Next younger than the Birch Creek schist, in the Alaska Range area, is a group of beds that contain a wide variety of materials, among which may be deposits of various early Paleozoic ages, all of which are here grouped as undifferentiated Paleozoic. Among these are included the calcareous shales and sandstones that occupy a belt extending from Stony Creek eastward into the Teklanika Basin and that were early described by Brooks [12] and by Capps [13] as the Tatina group and tentatively assigned to the Ordovician; another group comprising argillites, slates, and phyllites, with some graywacke and chert, that lie along the north flank of the range in Mount McKinley National Park, and were described by Brooks [14] as the Tonzona group and on uncertain grounds assigned to the Silurian or Lower Devonian; a great series of altered lava flows, the Totatlanika schist, which with some associated carbonaceous schists was described by Capps [15] and tentatively correlated with the Tonzona group as of Silurian or Lower Devonian age; certain schists and serpentines on the south flank of the range north of Broad Pass that lie beneath sedimentary rocks of various types, among which is a limestone carrying Middle Devonian fossils, that occupies the crest of the range from Muldrow Glacier eastward to the Nenana River. It is probable that all these rocks are of Paleozoic age, though fossils in them are scarce or lacking, and present interpretations of their age relationships are subject to considerable change when more detailed studies are made. In view of these uncertainties it is at present impossible to outline the geologic history of this province in Paleozoic time with any confidence. It appears certain, however,

---

[12] Brooks, A. H., op. cit. (Prof. Paper 70), pp. 69–73.

[13] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 29–32, 1919.

[14] Brooks, A. H., op. cit., pp. 73–76.

[15] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 34–37. 1919.

that through early Paleozoic time the Alaska Range region was repeatedly the site of mountain-building stresses, with deformation, uplift, and erosion succeeded by subsidence and deposition. The details of that history remain to be deciphered.

Carboniferous time is represented in this area by deposits in the basin of the West Fork of the Chulitna River, which as described by Ross[16] include tuff, lava, limestone, chert, and argillite, all of probable Permian age, and indicate marine sedimentary conditions that were frequently interrupted by lava flows and the ejection of fragmental volcanic materials. The end of Paleozoic time was marked by an erosion interval during which at least parts of this province stood above sea level.

Perhaps the earliest Mesozoic event of importance in this region was the local pouring out of great thicknesses of basic lavas, particularly in the area near Muldrow Glacier and the Toklet Basin and in the headwater region of the Susitna River. These lavas may represent a continuation of the late Paleozoic volcanic activity into the Triassic, as is true in other parts of Alaska. The lavas were extruded into or under water, in part at least. Apparently this region was above sea level during much of Triassic time, or else the deposits laid down then have since been eroded. In late Triassic time limestones with some associated argillites were laid down in the upper Chulitna Basin, and in the upper Susitna Basin thick deposits of mudstone, now much altered, may also be of Triassic age, though these rocks are here grouped as undifferentiated Mesozoic. Marine conditions probably prevailed in much of this region during the Jurassic period and much of the Cretaceous, though the fossil evidence is scanty. Tremendous thicknesses of muds and impure sands, with a little limestone, were deposited over great areas, particularly on the southeast flank of the range, and these beds range in age from Triassic to Cretaceous. Their deposition was interrupted from time to time by deformation and erosion, but the evidence upon which to date these events is still too scanty to yield an accurate chronology.

Apparently in Upper Cretaceous time this region emerged finally from the sea, and portions of the region were sufficiently elevated to yield the coarse gravel of the Cantwell formation as well as great quantities of sand and mud. This subaerial sedimentation was interrupted from time to time by lava flows and the ejection of volcanic tuffs, and these Cantwell sediments, as well as all the older formations, were intruded by extensive masses of granitic material.

The events of early Tertiary time are not accurately known. After the completion of Cantwell sedimentation that formation was in-

---

[16] Ross, C. P., Mineral deposits near the West Fork of the Chulitna River, Alaska: U. S. Geol. Survey Bull. 849–E, pp. 294–298, 1933.

durated, folded, and uplifted and then deeply eroded, much of the detritus evidently being carried by streams to some point beyond the region here considered. After the mountains had been reduced to moderate elevation and smooth slopes, the deposition of the Tertiary coal-bearing formation began on the flanks of the upland region, sands and muds being laid down at some places, while at others thick deposits of plant remains, later to be altered to coal, were accumulating. The age of the coal-bearing beds has from different lines of evidence been stated as Eocene and Miocene.

The Pleistocene epoch witnessed a series of glacial expansions in the Alaska Range, evidence of a pronounced change in climate from that which had prevailed during the deposition of the Tertiary coal-bearing formation. At least twice, and possibly several times, the glaciers grew and pushed outward from the mountains. The entire Susitna Basin was ice-filled by a converging mass of mountain glaciers that reached from Broad Pass and the upper Copper River Basin out to sea by way of Cook Inlet. On the inland front of the Alaska Range the glaciers were smaller, but many of them pushed out from the mountain valleys to the lowland. During these stages of ice expansion the streams that drained from the glaciers were heavily charged with debris and built great valley trains out into and through the lowlands, and upon the retreat of the ice morainal deposits were left behind. At present the moraines that are still visible are mainly those left during the last glacial stage, for during each advance the deposits of earlier glaciers were overridden and in large part destroyed.

Since the final shrinkage of the glaciers to their present size the normal processes of erosion and weathering have been resumed over those parts of the region that are free of glaciers.

YUKON-TANANA REGION

The great region lying between the Yukon and Tanana Rivers, a part of which falls within the area considered in this report, comprises a geologic province of complex structure, in which rocks that range in age from pre-Cambrian to Recent are present. Most of these rocks have been strongly metamorphosed, and in general the exposures are much poorer than in the glaciated mountains farther south, so that there is less opportunity to observe directly the structural relations between the various components. Reconnaissance geologic studies have, however, been carried out in this region for more than 30 years, and sufficient data have been accumulated to reveal the major events of its geologic history. Inasmuch as a comprehensive report on the Yukon-Tanana region,[17] including that portion of it that is concerned in this

[17] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, 276 pp., 1936.

report, has recently been published, there will here be given only a brief digest of the geology of that part of the region that is shown on plate 3 of this report, taken largely from Mertie's paper. Inasmuch as many of the rocks are unfossiliferous, and their exact age and relations are not known, they are here discussed mainly by groups, rather than by named formations. These groups include, among rocks of sedimentary origin, the pre-Cambrian Birch Creek schist, a group of Paleozoic rocks that are older than Middle Ordovician, a middle Silurian limestone, undifferentiated Paleozoic rocks that are younger than middle Silurian, and a group of Cretaceous beds. Among the igneous rocks there are a group of volcanic rocks of Ordovician age, a group of basic rocks of Upper Devonian age, granitic intrusives mainly of Mesozoic age, and Tertiary intrusive rocks.

PRE-CAMBRIAN ROCKS

BIRCH CREEK SCHIST

Character.—The Birch Creek schist includes a great assemblage of pre-Cambrian rocks of sedimentary origin that have been repeatedly metamorphosed to produce micaceous and quartzose fissile schists and that are the oldest rocks in the area here under consideration. Rocks that are assigned to this formation in the Willow Creek district of the Talkeetna Mountains and in the Alaska Range are described above. In the part of the Yukon-Tanana region here under discussion they occur in a triangular area stretching from the town of Nenana northeastward and eastward and including most of the Fairbanks district (pl. 3). Included within the Birch Creek schist area are certain gneisses and schists derived from rocks of igneous origin, which, while not considered to be an integral part of the Birch Creek, have in reconnaissance studies not been separately mapped. The most complete published description of this formation is that by Mertie,[18] who described it as consisting of quartzite, quartzite schist, quartz-mica schist, mica schist, feldspathic and chloritic schists, and a minor proportion of carbonaceous and calcareous schist and crystalline limestone, with quartzite schist and quartz-mica schist the commonest types. Most of these rocks are completely recrystallized, though in some evidences of their sedimentary origin can still be recognized. In general they are highly foliated and in many places show evidences of later schistose structures superposed on earlier ones. The basal portion of this group is thought to be more quartzose than the higher portion.

Quartzite schist is perhaps the most massive rock in the group and occurs in beds a few inches to several feet thick. It is generally

[18] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 47–59.

more resistant to weathering than the more fissile phases and on the higher ridges produces prominent topographic forms. In general it contains enough mica to give it a definite cleavage, though in places mica is scarce and the rock is massive. An abundant component of the Birch Creek schist is quartz-mica schist, commonly interbedded with quartzite schist and showing all gradations from quartzite schist with little mica to mica schist with little quartz. These phases are incompetent and, having taken up most of the stresses during folding and compression, are now intricately crumpled and crenulated, so that the original bedding is difficult or impossible to distinguish. Upon weathering they break down readily and so produce smooth topographic forms.

Calcareous schist and limestone constitute only a small proportion of the Birch Creek schist and are present only locally, in lenticular masses of no great area. They are completely recrystallized and locally are siliceous.

The essential minerals in the Birch Creek schist are quartz, biotite, and sericite, with albite or oligoclase, chlorite, calcite, garnet, iron oxides and hydroxides, apatite, and zircon as the more common accessory minerals. Vein quartz, of course younger than the schist itself, is abundant throughout this formation, and although most of it is barren of metallic minerals, some of the veins carry such sulphides as pyrite, arsenopyrite, and stibnite, as well as free gold, and these veins are the bedrock source of the gold now found as placer deposits in the Fairbanks district.

Structure and age.—The structure of the Birch Creek schist is so complex that its history is almost undecipherable. In most places the bedding planes have been completely destroyed, and the observable structural features are the planes of schistosity. This cleavage has a general strike of N. 60° E., though many divergences from that trend may be noted. Mertie states that the distribution of the more quartzitic phases of the schist, which he believes to represent the lower portion of the formation, indicates that the general structure is anticlinal, with a plunge to the southwest.

For many years the closest age assignment that could be made for the Birch Creek schist was that it was pre-Devonian, pre-Silurian, or pre-Ordovician, depending upon the age of the oldest overlying rocks in the particular district studied. Later it was found beneath beds carrying Cambrian fossils, and more recently Mertie believes that a great group of rocks, the Tindir group, consisting of dolomite, limestone, shale, slate, quartzite, red beds, and basic lavas of pre-Cambrian and Lower Cambrian (?) age, intervenes between the Middle Cambrian and the Birch Creek. He therefore classifies the Birch Creek as of early pre-Cambrian age.

UNDIFFERENTIATED PALEOZOIC ROCKS EARLIER THAN MIDDLE ORDOVICIAN

Two great belts of sedimentary rocks of earlier than Middle Ordovician age that are present in the Yukon-Tanana region project into the area shown on plate 3. The northern belt extends from the junction of the Tatalina River and Washington Creek northeastward in a gradually widening belt to and beyond the edge of the region here under discussion. This belt also has a southwestward continuation in the low hills west of the lower Tolovana River. Only the western tip of the southern belt projects into this area, in the basin of the Chena River some 25 miles east of Fairbanks. As Mertie [19] has recently described these rocks in some detail, only a brief mention will be made of them here.

According to his tentative interpretation the sequence is as follows:

Slate and quartzite (top of section).
Black argillite, slate, and chert.
Red and green slates, quartzose sandstone, and a little limestone.
Quartzose sandstone and grit, in part feldspathic arkose and graywacke, all interbedded with slate.
Phyllite and quartzite, overlain by somewhat less altered quartzitic rocks.

The structure of these rocks is not well known, but Mertie considers it probable that the oldest rocks lie along the south side of the belts and that northward the beds are increasingly younger. The older beds have a cleavage that strikes about northeast and dips northwest, about the same as that of the underlying Birch Creek schist, but whereas the rocks of the Birch Creek schist are almost completely recrystallized, the overlying sedimentary rocks are not, and a structural unconformity between the two is indicated by their differing degree of metamorphism. Furthermore, the lithologic character of the overlying rocks indicates that they were derived from the erosion of the Birch Creek schist. The presumably higher beds in the group have the same general strike as the lower beds, but the dips are steeper and are generally to the southeast, and there is some evidence of the presence of appressed folds overturned to the northwest. In general, therefore, these rocks are believed to comprise a great thickness of beds that are overturned toward the northwest and dislocated by strike faults. Individual beds are thus probably repeated several times at the surface across the strike of the belt, and alternately older and younger beds are exposed. No true measure of the thickness of the group has been made, but Mertie believes that the thickness is not less than 10,000 feet, and it may be two or three times that figure.

[19] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 65–76.

The only fossils that have been found in these rocks are a single small collection taken from beds that are believed to be well up in the section. These fossils have been identified by different paleontologists as of Lower Ordovician or Upper Cambrian age. From various lines of evidence and reasoning Mertie concludes that the group includes rocks that range in age from late pre-Cambrian to Lower Ordovician or early Middle Ordovician. They are underlain by the pre-Cambrian Birch Creek schist and are overlain by Middle Ordovician lavas. No more precise age determination is possible at present.

ORDOVICIAN VOLCANIC ROCKS

In the basin of Beaver Creek, near the northeast corner of the area shown on plate 3, there are several small patches of igneous rocks which for the most part consist of stratified basic lavas, tuffs, breccias, and agglomerates of greenstone habit, together with a small proportion of granular basic intrusives. Inasmuch as these rocks have a definite position in the stratigraphic column and are interbedded with sedimentary rocks they are here described in stratigraphic order. Mertie described these rocks as the Fossil Creek volcanics [20] and stated that the lower part of the sequence consists mainly of bedded lavas and interbedded pyroclastic rocks, the lavas being diabasic and basaltic and of greenstone habit and in places ellipsoidal, whereas the fragmental rocks consist of laminae and beds of fine-grained tuffaceous material now consolidated into dense rocks that look much like the fine-grained basalts. Both lava flows and tuffs have been mashed and deformed and in places have developed a slaty cleavage. The intrusive rocks of this group are greenish gabbroic rocks and are believed to be the intrusive equivalents of the lavas.

The upper part of the sequence contains an increasing proportion of volcanic conglomerate and tuff, the conglomerate consisting of rounded pebbles and cobbles, most of which are of greenstone but including also granite and various sedimentary rocks. The youngest member of the group is a reddish calcareous rock which is probably a tuffaceous limestone, itself overlain by Silurian limestone. This member has yielded the fossils from which the age of the group has been determined.

The Ordovician volcanic rocks have been closely folded, so that in the belt in which they occur individual strata have been several times repeated. The general structural trend is about N. 50° E., but closely compressed anticlines and synclines and recumbent folds have been recognized, as well as thrust faults. Although no structural unconformity is apparent between the top of this group and

[20] Merite, J. B., Jr., op. cit. (Bull. 872), pp. 81–86.

the overlying Silurian limestone, nevertheless the great disparity in age between the fossils of the two formations indicates a time break between them. No precise measurement has been made of the thickness of this group of highly deformed strata, but Mertie concludes that they cannot well be less than 2,000 feet thick and may be considerably more.

Several small collections of fossils from the uppermost member of this group have yielded in the aggregate a considerable fauna. These fossils were originally considered to be of Upper Ordovician age, but more recent studies of them have resulted in their classification as Middle Ordovician, and that age is now accepted for the Fossil Creek volcanics.

SILURIAN ROCKS

TOLOVANA LIMESTONE

A middle Silurian (Niagaran) limestone, described by Mertie[21] as the Tolovana limestone, crops out in this region in the White Mountains, in the basin of Beaver Creek; on a spur between the lower Tatalina River and the Tolovana; and in the low hills west of the lower Tolovana River. This formation is composed almost entirely of carbonate rocks without any considerable amount of other clastic sediments. Both limestone and dolomite are present, but they have not been mapped separately, and the generic term "limestone" is used to cover both. In the White Mountains the rocks are light to dark gray in color, are of medium texture, and upon weathering are generally conspicuously white, though in places they have a surficial yellowish or buff color. This formation weathers into rugged and picturesque forms in the mountainous regions. It is generally so massive that no bedding is apparent, though locally it is thin-bedded. West of the lower Tolovana River the limestone appears in low hills as yellowish-brown outcrops, though upon freshly broken surfaces it is seen to be crystalline and of blue-gray color.

In the White Mountains the structure of the Tolovana limestone is similar to that of the underlying Fossil Creek volcanics. It is folded into closely compressed anticlines and synclines, is thrust-faulted, and is infolded with the Ordovician volcanic rocks, the folds striking northeast and pitching steeply to the southwest. Mertie estimates the thickness as possibly as much as 3,000 feet. Near the mouth of the Tatalina River the limestone strikes about N. 75° E. and dips steeply southeast. It disconformably overlies the Fossil Creek volcanic rocks in the White Mountains, and west of the lower Tolovana River the disconformity is still greater, for

[21] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 86–91.

there the Fossil Creek volcanics are missing. North of the White Mountains the next younger rocks that have been definitely identified are of Devonian and Carboniferous age, and these rocks trend nearly east and probably overlap the Tolovana limestone with a great unconformity.

The age of the Tolovana limestone has been determined from its contained fossils, which have been collected from many localities. These have always been considered to be of Niagaran age and are now believed to represent a late part of the Niagaran epoch, of middle Silurian age.

UNDIFFERENTIATED PALEOZOIC ROCKS LATER THAN MIDDLE SILURIAN

The sedimentary rocks here discussed as undifferentiated Paleozoic rocks later than middle Silurian comprise several groups of rocks and formations that have been differentiated in the field and described separately. However, inasmuch as the writer has little personal familiarity with this part of the area, and as Mertie [22] has recently prepared a comprehensive report on this region, these upper Paleozoic sedimentary rocks are here grouped together, with brief mention of their lithologic character and references to more complete descriptions elsewhere. This group, as shown on plate 3, includes sedimentary rocks of definite Middle Devonian age, limestones of Devonian age, and differentiated and undifferentiated rocks of Carboniferous age.

A belt of rocks that are considered to be largely of Devonian age crops out in the low hills west of the lower Tolovana River and extends N. 60° E. into the valley of Beaver Creek. These rocks include clay slate, siliceous slate, chert, sandstone, quartzite, conglomerate, and some thin beds of limestone, associated with and probably intruded by serpentine and other basic igneous rocks.[23]

The structure of this group of rocks is intricate, and details are still to be worked out. Cleavage is more prominent in most of them than bedding, and such structure as has been recognized includes generally steep dips. Apparently the beds have been closely folded and in considerable part overturned toward the north, so that individual beds are duplicated at the surface across the belt in which they occur.

Two faunas have been recognized from fossils collected from these rocks, one of which is clearly of Middle Devonian age and the other older. Mertie concludes that the older fauna is probably also of Devonian age, though admitting the possibility that part of it may

[22] Mertie, J. B., Jr., op. cit. (Bull. 872).

[23] Mertie, J. B., Jr., op. cit., pp. 91–153.

be upper Silurian. No Upper Devonian beds are known in this region.

Within this region there are Carboniferous sedimentary rocks, the Livengood chert, which for simplicity in mapping is also here included with the undifferentiated upper Paleozoic rocks. This chert formation, as described by Mertie,[24] extends from the Sawtooth Mountains eastward past the settlement of Livengood into the basin of Beaver Creek and forms a belt that has a maximum width of 8½ miles. It has also been recognized at several localities north and east of the area here under discussion. The formation consists dominantly of light-gray to black chert, with which are interbedded minor proportions of limestone and argillaceous rocks. Within the area there are also numerous small bodies of basaltic and diabasic greenstone, but these are thought to be intrusive and therefore younger than the chert. The formation is much brecciated. A prominent member near the base is a conglomerate that is composed essentially of chert pebbles in a chert matrix. The origin of this conglomerate is obscure, but for various reasons Mertie concludes that both pebbles and matrix are nearly contemporaneous, and that the pebbles were not derived from an older formation. Minor amounts of limestone are locally interbedded with the chert.

The structure of the Livengood chert is somewhat obscure, but it apparently has a general strike of N. 60° E. and steep dips to the south. The rocks are closely folded, however, and the beds are probably duplicated several times in crossing the belt from north to south. The best evidence indicates that this formation overlies the older rocks to the south and is overlain by younger rocks to the north and that its general structure is that of a closely folded sequence, overturned from south to north. Mertie suggests that the formation may be several thousand feet thick. The age of the chert formation, based on rather unsatisfactory fossil evidence, is Carboniferous, and Mertie suggests that it probably represents the base of the Carboniferous sequence in this region and is therefore of Mississippian age.

The area here mapped as undifferentiated upper Paleozoic sedimentary rocks also includes a group of sedimentary beds in the Rampart district that Mertie[25] describes as undifferentiated Mississippian rocks. This group includes many varieties of materials, which probably represent several horizons in the Carboniferous, but the structure in the Rampart district is so complex that the detailed stratigraphy has not yet been worked out. Among the rocks included in this group are shale, slate, phyllite, sandstone, quartzite, several varieties of schist, chert, chert conglomerate, limestone, greenstone, and

[24] Mertie, J. B., Jr., op. cit., pp. 105–111.
[25] Idem, pp. 111–122.

the metamorphic equivalents of all these rocks. Most of the rocks are so highly metamorphosed that their fossils have been destroyed. Mertie has given details of many sections in this belt but concludes that the rocks in most places have been so closely folded and overturned that it is impractical to attempt to give the stratigraphic sequence. A large number of fragmental fossil collections have been made from this belt of rocks, however, and all have been tentatively assigned to the Mississippian.

MISSISSIPPIAN ROCKS

RAMPART GROUP

The Rampart group comprises an assemblage of bedded volcanic and sedimentary rocks that border the Yukon River along the northwest portion of the area shown on plate 3. Inasmuch as the group consists of sedimentary rocks and interbedded lava flows, all of which have a definite place in the stratigraphic sequence, it is here described along with the other bedded rocks rather than in the section that deals with igneous rocks.

The stratigraphy of the Rampart group as a whole is imperfectly known, for the structure is complex and the exposures are discontinuous. The lithology, however, is distinctive, and descriptions of the rocks at various localities have been reviewed by Mertie.[26] From these it appears that the group consists in part of bedded greenstones, tuffs, and breccias and in part of a variety of sedimentary rocks that include chert, shale, slate, argillite, sandstone, and minor amounts of limestone and calcareous grit. Some coarse-grained basic intrusive rocks are mapped along with the bedded rocks, and these may be in part considerably younger than the bedded materials. All the greenstones and many of the sedimentary rocks have a greenish color on freshly fractured surfaces, due to the presence of secondary chlorite and serpentine.

The rocks of the Rampart group are structurally complex, and all exposures show close folding, faulting, and brecciation, with abundant slickensided surfaces. The general strike is N. 70° E., and the beds dip at moderately steep angles to the north or the south. No estimate of the stratigraphic thickness has been made, and such a measurement would require a more detailed knowledge of the structure than now exists. These rocks are present over a belt that reaches a width of 20 miles, and Mertie suggests that the group may have a thickness of as much as 5,000 to 10,000 feet.

Although this group consists dominantly of bedded igneous rocks, from one-third to one-half of it is composed of interbedded sedi-

---

[26] Idem, pp. 122–129.

mentary rocks, some of which are scantily fossiliferous. The fossils so far collected are imperfect and not closely diagnostic, but they have been assigned to the Mississippian. Inasmuch as these rocks have been closely folded, and no doubt in part infolded with both younger and older formations, the question arises as to whether the beds in which fossils have been found are really a part of the Rampart group or whether they may be older or younger beds infolded with the Rampart group. Mertie discussed this question in some detail and reached the tentative conclusion that the group is of Mississippian age.

CRETACEOUS ROCKS

Cretaceous rocks occur in the Hot Springs and Rampart districts (pl. 3) in a broad band that extends from the western edge of the region here under discussion northeastward into the headward basins of Troublesome Creek and the West Fork of the Tolovana River. This area includes such prominent topographic features as Wolverine, Elephant, and Roughtop Mountains, Eureka Dome, and Bean Ridge. In all these localities the Cretaceous sedimentary beds have been cut by granitic intrusive masses, which by their resistance to erosion have yielded mountains or ridges that stand up above their surroundings. These granitic bodies have also by the heat and pressure of their intrusion produced marked metamorphism in the enclosing sedimentary rocks, particularly near the intrusive contacts. Where least altered the sequence consists mainly of massive quartzite beds, four of which have been recognized. They range in color from creamy white to dark gray, the gray color being most common. Between the quartzites are beds of argillite and slate, but, being less resistant to erosion, they occupy depressions and are poorly exposed. Locally some conglomerate is present. In general the Cretaceous rocks, though showing effects of contact metamorphism, are not recrystallized, but in places a slaty cleavage that cuts across the bedding has been developed in argillaceous rocks, and elsewhere there are well-developed phyllites. Near the intrusive contacts with the larger bodies of granite more intense alteration has occurred, with the development of nodular schists containing andalusite.

In a few places plant-bearing beds have been observed that carry a flora that has been assigned to the Cretaceous. Near Wolverine Mountain beds of black carbonaceous sandy argillite and shale carry both plants and invertebrates of Upper Cretaceous age. The scarcity of fossils in this group of rocks has prevented a general separation of the Lower from the Upper Cretaceous, and the rocks have all been mapped together as a single group.

The structure of the Cretaceous rocks in this region is complex, particularly in the vicinity of the granitic intrusives. In general the beds seem to show broad anticlines and synclines, with a northeast strike, but this simple interpretation is more apparent than real, for the rocks have been generally folded, faulted and sheared, and intruded. Mertie [27] considers it likely that the folding took place before the shearing and intrusion, and that the axial planes of the anticlines became zones of weakness along which later movements took place. He considers that at least 5,000 feet of Lower Cretaceous rocks are present in this district and possibly much more.

A considerable number of fossil collections made from beds of this group indicate that most of it is of Lower Cretaceous age, though some Upper Cretaceous beds are also present.

TERTIARY ROCKS

Sedimentary rocks of early Tertiary age occur in the portion of the Yukon-Tanana region shown on plate 3 only in its northwest corner, near the Yukon River, in several small areas near the mouth of Minook Creek, and in one area opposite the mouth of Morelock Creek. The lithology, structure, and age of these beds, as well as of others of similar character and age throughout the Yukon-Tanana region, have been discussed in some detail by Mertie.[28] A section exposed on the east bank of the Yukon River above the mouth of Minook Creek showed at the base a coarse conglomerate, above which are finer conglomerate, grit, and shale. The basal conglomerate contains pebbles from 2 to 3 inches in diameter, derived from the underlying Paleozoic rocks. The beds in the upper part of the section are similar in lithologic character to those at the base, but are much less completely indurated and in places consist of little-consolidated sand and gravel. In places impure lignite is present in these beds.

In general these early Tertiary rocks are folded, and locally they are greatly deformed. The fossil plants that they contain are not sufficiently diagnostic to warrant close correlation between horizons within the formation, and such a correlation cannot be made between the beds exposed in the many isolated areas within the region, so that it has not been possible to construct a complete stratigraphic section for the formation as a whole. Furthermore, these beds were deposited under fresh-water or subaerial conditions, and as a consequence individual beds are lenticular and their lithology changes within short distances. Mertie states that these sediments apparently have a stratigraphic thickness of 3,000 to 5,000 feet. The linear distribution of the outcrops suggests that the beds as originally deposited followed old drainage lines, and those old valleys were perhaps the remote ancestors of the present major streams.

With one exception, a river mussel, all the fossils that have been found in the early Tertiary beds in this region are plant remains.

---

27 Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 156–172.
28 Idem, pp. 172–180.

These have been assigned to a late Eocene age. They include a large number of temperate-climate plants, as well as some subtropical forms, all of which indicate a much more temperate climate in Alaska in early Tertiary time than that now prevailing and a considerably heavier annual rainfall.

In addition to the early Tertiary sedimentary rocks just described there are in the region certain high terraces that now lie from 500 to 1,000 feet above the present drainage levels and that are believed to be of late Tertiary age. These terraces are rock-cut, but most of them still retain some of their original gravel covering. They are best developed in this region on the ridges east of lower Minook Creek. The deposits of ancient gravel on these terraces are inconspicuous, but fortunately they are gold-bearing, and prospecting and mining have given much information concerning their character and extent. Locally they are known to reach a thickness of 100 feet or more. The gravel is frozen and contains a variety of materials including quartz, quartzite, chert, diabase, and metamorphic rocks. Some of the boulders are as large as 2 feet in diameter. The bedrock surface is locally irregular, with abrupt rises and drops.

Mertie,[29] on the basis of his interpretation of the physiographic evidence in the district, concludes that these gravel deposits are of late Tertiary age. The altitude of the terraces on which they lie, some 1,000 feet above the level of the present streams, indicates a long period of erosion since they were deposited. Furthermore, more than 900 feet below these high terraces there is a set of lower terraces in which the remains of Pleistocene mammals have been found. The high terraces are therefore believed to be pre-Pleistocene. Inasmuch as the early Tertiary sedimentary beds are highly folded and deformed, whereas the high terraces show no such deformation, it is concluded that a period of severe folding took place after the early Tertiary (late Eocene) sediments were deposited, but before the high terraces were cut and the gravel deposited on them. The high terrace gravel is therefore assigned to late Tertiary time.

IGNEOUS ROCKS

The igneous rocks of the part of the Yukon-Tanana region shown on plate 3 have been divided into five groups, as follows, all of which have recently been described by Mertie:[30]

5. Tertiary intrusive rocks.
4. Granitic intrusives, mainly of Mesozoic age.
3. Rampart group, of Mississippian age.
2. Basic rocks, mainly intrusive greenstones of Upper Devonian age.
1. Fossil Creek volcanics, of Ordovician age.

[29] Idem, pp. 182–183.
[30] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 198–226.

Of these rocks, groups 1 and 3 are bedded volcanic rocks, interbedded with a considerable amount of sedimentary material. Inasmuch as these two groups have a definite position in the stratigraphic sequence, they are discussed above in their proper order along with the sedimentary rocks.

UPPER DEVONIAN BASIC GREENSTONE INTRUSIVES

The oldest group of igneous rocks that are mainly intrusive includes ultrabasic and basic materials, mainly intrusive greenstones, that occur in two distinct belts. The largest and most persistent of these belts begins at the Tanana River between the months of the Salcha and Chena Rivers and extends intermittently N. 75° E. to the head of the Salcha. In the other belt these rocks are present in small bodies both east and west of the Livengood mining camp. Near the Salcha River the rocks consist of serpentine, greatly brecciated along the borders, the fracture zones filled with secondary minerals, such as calcite, quartz, and chalcedony. This mass of serpentine is probably derived from some ultrabasic intrusive, such as dunite. Farther northeast a serpentinous rock derived from olivine diabase was observed.

In the northern belt near Livengood also there are serpentinous rocks with some magnetite, that are probably secondary after some basic or ultrabasic rock. There are also in this belt a variety of materials that are grouped under the general designation "greenstone," some of which are altered diabases and diorites, and some of which may be altered ultrabasic lava flows.

In general these rocks are largely of intrusive origin, but they include both basic and ultrabasic materials both of which are partly or wholly altered to serpentine and chloritic products. In their vicinity small quantities of chromite and traces of nickel and platinum have been found, facts which suggest that commercial deposits of ores of those metals may be present.

The age of these basic intrusives in the southern belt is uncertain, for they lie in contact only with ancient crystalline schists. In the northern belt, however, the serpentine intrudes rocks of Middle Devonian age but does not appear in the nearby beds of Mississippian age. From these facts the basic intrusives are referred to the Upper Devonian.

MESOZOIC GRANITIC ROCKS

Although granitic rocks are widely distributed in the Yukon-Tanana region, most of the larger bodies lie east of the area here considered, and in the region shown on plate 3 there are only relatively small, scattered bodies of such materials. Mertie[31] has di-

[31] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 210–216.

vided the granitic intrusives into two groups. Those east of the Tolovana River he considers to be mainly of Mesozoic age, though possibly including some Tertiary intrusives. All the granitic rocks west of the Tolovana he believes to be Tertiary, and they are so shown on plate 3.

The granitic intrusives, though of irregular shapes, tend to have their longest dimensions in a northeast-southwest direction, parallel to the structure of the enclosing rocks. They are relatively competent rocks and are so resistant to weathering that from them have been produced many of the highest mountains of the region.

The granitic rocks are mainly granite, biotite granite, and quartz diorite, with some monzonite and various differentiates of the original magma. Most of them are coarse-grained, and some are porphyritic. The usual constituent minerals are quartz, potash, and soda-lime feldspars, biotite, and hornblende. These granitic rocks occur mainly in areas of Paleozoic and pre-Cambrian rocks, where they are obviously the younger. Certain Tertiary rocks in the region contain abundant granitic cobbles and pebbles, probably derived from the granitic intrusions here under discussion. From this stratigraphic evidence it is safe to say that these intrusives are post-Paleozoic and pre-Tertiary. No more definite statement as to their age can be made from evidence obtained in this region. From other lines of reasoning, however, Mertie suggests that these rocks may have been intruded in late Jurassic or early Cretaceous time.

TERTIARY GRANITIC ROCKS

In the region that extends westward from the basin of the Tolovana River, there are more than a dozen areas that are occupied by granitic rocks. The largest of these areas lie between Idaho Creek and the Tolovana River and along the southeast slope of Hot Springs Dome. Others form such prominent topographic features as Sawtooth, Wolverine, Elephant, and Roughtop Mountains, which stand above their surroundings as a result of the greater resistance to weathering and erosion of the granitic intrusives of which their tops are composed. Besides these larger intrusive masses that are shown on plate 3 there are many dikes, sills, and small intrusive bodies, particularly around the margins of the larger intrusives, that are mostly too small to be shown on a map of this scale.

These granitic rocks are of gray color and in the larger bodies are of medium to coarse grain and consist of three general types—monzonite, quartz monzonite, and granite. Granite is least abundant of the three, and the monzonites show all gradations from monzonite to quartz monzonite. Mertie [32] has recently summarized what is known of the petrographic and chemical character of these rocks.

[32] Mertie, J. B., Jr., op. cit., pp. 219–226.

All these rocks whose geologic relations are clear cut sedimentary beds whose fossils show them to be of Lower or Upper Cretaceous age. It is therefore evident that some if not all of them are at least younger than the Upper Cretaceous. They have not been found to cut Tertiary beds, but none of them occur in contact with Tertiary sedimentary rocks. Near two of the intrusive masses there are now hot springs, which may indicate a relatively late age for the intrusions. Cinnabar has been found in the placer gravel near some of these granitic bodies, and that mineral is characteristic of many such intrusives in southwestern Alaska that are recognized as being of Tertiary age. From these and other considerations Mertie concludes that the granitic intrusives of the Yukon-Tanana region that lie west of the basin of the Tolovana River are of Tertiary age.

GEOLOGIC HISTORY OF THE YUKON-TANANA REGION

The geologic history of the portion of the Yukon-Tanana region here under discussion as recorded in the rocks is long and complex, and only a part of the record is preserved, for many formations that are represented farther east are here absent, either because they have been removed by erosion or because they were never deposited. Furthermore, in a region in which profound deformation has taken place repeatedly throughout geologic time the record is obscured and requires for its interpretation much more detailed studies than have so far been made. Certain facts are known, however, and are here briefly summarized. The reader is referred to a recently published much more complete summation of the history of this great province.[33]

The oldest rocks that have been recognized in this region are the metamorphic sedimentary rocks of the Birch Creek schist. These materials were originally laid down as sand, mud, and limestone, but by repeated dynamic metamorphism they have been in large part recrystallized and now appear as quartzite, quartzite schist, and mica schist. They contain no fossils, but from their relation to overlying rocks are known to be of early pre-Cambrian age. While the upper portion of this sedimentary series was being laid down there was a period of volcanism during which basic lavas were poured out, and intrusives were injected into the sedimentary rocks. These igneous materials were later metamorphosed along with the enclosing sedimentary rocks and are now basic schists. This long period of sedimentation and volcanism was ended by the intrusion of great masses of granitic rocks.

The portion of pre-Cambrian time that elapsed after the deposition of the rocks of the Birch Creek schist and the succeeding intrusion of granitic materials and before the deposition of the next

[33] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 229–237.

younger group of rocks in this region was very long and is here represented by a profound unconformity. During that time elsewhere on the continent great thicknesses of sediments were laid down, and periods of subsidence and deposition succeeded periods of elevation and erosion. In the northeastern portion of the Yukon-Tanana region the Tindir group, which comprises a great thickness of continental sedimentary rocks as well as of volcanic materials, was laid down in later pre-Cambrian and possibly early Cambrian time, to be followed by a subsidence of the land and the beginning of Paleozoic sedimentation, with a spreading ocean that reached its greatest size in Upper Ordovician time. The earliest Paleozoic rocks that are represented in the area here under discussion are the undifferentiated Paleozoic sedimentary rocks earlier than middle Silurian, which include a wide variety of materials. The history of this part of the Paleozoic era is not clear, but materials of this group were probably laid down at intervals from late pre-Cambrian to Middle Ordovician time. The Middle Ordovician was characterized in this region by the outpouring of a great thickness of basic lavas, tuffs, and breccias and the intrusion of similar basic rocks. Upper Ordovician rocks are lacking.

Apparently this region was above the sea during early Silurian time, but by the middle Silurian it was again submerged, and a heavy deposit of limestone was laid down. In the upper Silurian the region was once more elevated above the sea, and it apparently remained as land throughout the Lower Devonian epoch. Another subsidence and transgression of the sea took place in Middle Devonian time, and the movement was accompanied by widespread and severe folding of the rocks. In the late Middle Devonian there occurred another period of great volcanic activity with the extrusion of basic lava flows into the ocean basins, where they were interbedded with marine sediments. This period of volcanism may have extended into Upper Devonian time, though this is not certainly known.

Though the evidence is somewhat obscure, it appears that there is a break in the sedimentary record between the Middle Devonian and the Carboniferous, probably recorded by a stratigraphic unconformity. The earliest Carboniferous deposit is the Livengood chert, of Mississippian age, the deposition of which was at first interrupted and later terminated by the outpouring of a great thickness of lavas and volcanic fragmental material, the Rampart group, as submarine flows and accumulations. These volcanic rocks were succeeded, in other parts of central Alaska, by other Carboniferous sedimentary deposits, including the Calico Bluff and Tahkandit formations, but those formations have not been recognized in the region here under consideration.

It is believed likely that central Alaska stood above sea level during the Lower and Middle Triassic, but in Upper Triassic time sediments were laid down east of the region shown on plate 3, though no beds of that age have been recognized within its borders. Another general regional uplift followed the Upper Triassic, with the land above sea level during Jurassic time. During that period great masses of granitic materials were injected into the crust in this region, and particularly east of it, with regional metamorphism of the host rocks and extensive contact metamorphism along the borders of the intrusives. The formation of the gold-bearing veins of the Fairbanks district probably took place at this time.

By Lower Cretaceous time another subsidence had brought this region below sea level and a thick series of sediments was deposited in the Rampart district. The events of Upper Cretaceous time are obscure, though some sedimentary rocks that are apparently of that age are present. Certainly no such widespread submergence and heavy sedimentation as that of the Lower Cretaceous took place in this area, though farther southwest extensive areas were receiving Upper Cretaceous sediments.

As far as can be learned from the geologic record central Alaska emerged finally from the sea in late Upper Cretaceous or early Tertiary time and has never since been invaded by marine waters. The earliest Tertiary sedimentary rocks that are present include materials such as accumulated in broad valleys under fresh-water conditions in Eocene time, in a region of moderate relief. The sandstones, shales, and conglomerates of that time were interbedded with peaty deposits from which the Tertiary coal beds have since been derived.

Some time after the Eocene terrigenous sediments were laid down the region was again uplifted, the rocks were folded, and granitic materials were injected into the crust. The intrusions gave rise to a period of mineralization during which gold quartz veins and deposits of cinnabar and tin were formed.

Since the intrusion of the Tertiary granitic rocks and the accompanying uplift and deformation the geologic events in this region have been less spectacular. Erosion has predominated over deposition, and most of the products of that erosion have been carried by the streams beyond the borders of this region.

A discussion of the geologic events of Quaternary time throughout the railroad region as a whole is given in the following pages.

PLEISTOCENE AND RECENT GEOLOGY OF THE ALASKA RAILROAD REGION

PREGLACIAL CONDITIONS

As has been stated in discussing the different geologic provinces already described, it appears that by the end of the Tertiary period the mountain-building processes in this general region here discussed had in large part ceased, and the greater topographic features, including the Kenai and Chugach Mountains, the Talkeetna Mountains, the Alaska Range, and the Yukon-Tanana upland, had been elevated to approximately their present altitudes. Likewise the present great depressions, most notable among which are the Cook Inlet-Susitna Basin, the Copper River Basin, and the Tanana Basin, and their many minor tributary valleys, existed and have since been affected by only relatively feeble elevations or depressions. It must not be understood, however, that the general appearance of the country was like that which we now see. The mountains had been sculptured only by those agencies that are operative in a temperate climate, chief of which are streams, frost, and wind, and their topography was that characteristic of a stream-eroded country. It is possible that in the higher mountains then, as now, relatively small alpine glaciers were active, as they are in any latitude where the mountains rise high enough above the snow line, but these glaciers probably had not stretched down to the main valleys and had carved their characteristic valleys only among the higher peaks. The appearance of the lowlands, too, must have been in notable contrast to that of today. The area occupied by Cook Inlet was somewhat narrower, and its bordering lowlands were better drained, had fewer lakes, and probably presented a series of somewhat equally spaced stream valleys, separated by low rolling hills and ridges. Turnagain Arm was then in all likelihood the valley of a mountain stream, and Knik Arm was perhaps also a stream valley above the reach of the tides. At its north end Cook Inlet may have extended northward many miles over the area now occupied by the lowland delta. The lowlands of the Susitna and Copper River Basins had not yet received the large quantities of glacially brought gravel and till with which they are now generally buried, and the Tanana Valley also was strikingly different in appearance.

It is still impossible to reconstruct with accuracy the courses of even the main rivers as they flowed at the end of the Tertiary period, but certainly the drainage was then very different from that of the present. The south and east coasts of Kenai Peninsula were much more regular than now and lacked the fiords that are now so remarkably developed. The shape and size of Cook Inlet differed considerably from that shown on present maps. A great river there emptied into the sea at some point along what is now Cook Inlet, but that ancient stream was much larger than the present Susitna, for it received the waters not only from the area now tributary to it but in all likelihood drained also all of the Copper River Basin above Woods Canyon and that portion of the south slopes of the Alaska Range the waters from which now find their way by the Nenana and Delta Rivers to the Tanana.

The basin of the Tanana River at the end of Tertiary time was in many respects different from that of today. Instead of hugging the base of the hills along the north edge of its basin, the Tanana River probably flowed westward somewhere near the middle of its wide depression and at an altitude considerably lower than that of the present stream. It is possible, too, that instead of joining the Yukon at their present confluence, it flowed southwestward across what is now the Kantishna Basin and found its way to the sea along the course now followed by the Kuskokwim, or southward along what is now the general course of the Nushagak River to Bristol Bay.

None of these great changes in drainage has yet been worked out in detail, for the evidence lies in a country imperfectly explored and difficult of access, but the evidence at hand suggests strongly that the streams once followed some such courses as those outlined. In addition to these major changes, there has accumulated a mass of evidence to show that many of the secondary and smaller streams followed different preglacial courses. Some of these changes have been large and represent important shifts of drainage. Others are small and of less consequence. But in spite of the facts that point to large and small drainage changes, the drainage plan bore a close relation to that shown on maps of today, and the main valleys, both in the mountains and in the lowlands, were valleys then also and carried their waters to the ocean along the general routes that now drain this region.

GLACIAL EPOCH

The beginning of the Pleistocene or glacial epoch was brought about by a change in climate that included a decrease in the mean annual temperature of the region and possibly also an increase in the precipitation. The snow line on the mountains crept down to lower altitudes, such glaciers as already existed increased in size, and other valley heads that had been free of glaciers received a filling of ice and snow that grew in size and thickness from year to year. As in most such events in earth history, this change must have been gradual, normally warm years alternating with more frequent and increasingly cold years. Perhaps had there been people living in the region at that time the change during any one man's lifetime might have been scarcely noticeable, yet in the course of centuries a great change came about. Each mountain range became the nourishing ground of a multitude of alpine glaciers, one of which formed in the head of each high valley. These grew slowly larger, lengthened downward, and joined in the larger valleys, until the water streams were replaced by ice streams, differing from the ordinary rivers in that instead of flowing only along the valley floors, they filled the basins brim-full. This process continued until a very large part of the area here considered was buried beneath a great mass of slowly moving ice hundreds and even thousands of feet thick. The direction of movement of the ice was controlled, as is that of streams, by the shape of the surface over which it moved. In the mountains the ice currents generally followed the preexisting valleys, and a typical glacier consisted of a main ice lobe in the larger valley, nourished by many branching glaciers from the tributary valleys. In many places, however, where there were low passes or gaps in the valley walls the brimming ice flowed through these outlets from one valley to the next, thus giving a much more complex drainage pattern than that of ordinary streams.

EXTENT OF GLACIATION

As the mountain glaciers slowly grew larger and longer they pushed out beyond the mountain fronts into the great lowlands. This was especially true of the glaciers on the Pacific slope, where the precipitation was heaviest and the growth of the glaciers was therefore most rapid. Glacial tongues from the Kenai Mountains, the Chugach Range, and the Talkeetna Mountains pushed westward into the Cook Inlet-Susitna lowland to meet and join similar ice lobes coming from the Alaska Range to the west and north. At the same time the upper basin of the Copper River was similarly supplied by ice from the surrounding Chugach, Wrangell, and Talkeetna Mountains and the Alaska Range, until it was filled to overflowing with a great glacier that had a multitude of vigorous tributaries. This great Copper River glacier found outlets for its overflow in many directions. One portion moved down the present valley of the Copper River southward to the sea. Other tongues pushed northward into the Nabesna Basin, and through Suslota, Mentasta, and Delta Passes to drain to the Tanana, but a larger part of the ice movement must have been westward to the Susitna Basin by way of the pass to the head of the Matanuska River, and an even larger part, across the lowland to the head of the Susitna River. The Copper River Glacier thus formed an ice field that was continuous with that of the Cook Inlet-Susitna depression.

The Susitna-Cook Inlet glacier at the time of the greatest glaciation was limited in size only by the margins of the basin. It extended from a point near the crest line of one bordering range almost to the summit of the opposite mountain mass. On the west and north it was margined by the summit line of the Alaska Range, and it was continuous eastward with the Copper River glacier. The Talkeetna Mountains sent down radiating glaciers in all directions, and these contributed their ice to the Susitna glacier either directly or by way of the Copper River Basin or the Matanuska Valley. Similarly the Chugach Mountains sent ice to it through the Matanuska Valley, and down what are now Knik and Turnagain Arms, and many large ice streams flowed to it from the Kenai Mountains. Just how far southward down Cook Inlet this glacier was able to advance has not yet been determined, but it certainly reached the Forelands and probably extended all the way to the mouth of the inlet. Evidence recently obtained on the islands of the Kodiak group strongly suggests that those islands at the height of Pleistocene glaciation were tied to the mainland on the Alaska Peninsula by a continuous ice field that filled Shelikof Strait, and that the glacier descending Cook Inlet pushed south and southeast to a point east of the Barren Islands.[34] At any rate tidal glaciers extended into the lower inlet from the mountains on both east and west, and these may have joined from opposite sides or coalesced with a main lobe pushing downward from the north. At the time of the greatest glaciation, therefore, the entire area south of the crest of the Alaska Range was flooded by a tremendous mass of glacial ice, and only the highest peaks and ridges appeared as land above the glacier surface. Evidence has been found at several places to indicate the height to which the edges of this ice field reached. Thus along the west flank of the Talkeetna Mountains near the Kashwitna River the Susitna glacier at one time reached a height of about 4,000 feet, and the main southward-moving lobe was over 50 miles wide and had a thickness in the center of the valley of nearly 4,000 feet. If one can imagine all the lowlands below 3,000 or 4,000 feet completely buried beneath a broad, nearly level ice plain and the mountain valleys all brim-full of more steeply sloping tributary glaciers, so that only those ridges and peaks too steep and sharp to retain snow projected above this immense white ice sea, he will have some idea of the bleak and forbidding appearance that this region must have presented during the height of the glacial period.

Like the Copper River Basin, the Susitna Basin was full of glacial ice to overflowing, and while most of the ice moved southward toward the sea in the direction now followed by the rivers, at one point, at least, the glacial flood poured over a low gap in the surrounding

[34] Capps, S. R., Kodiak and adjacent islands: U. S. Geol. Survey Bull. 880-C, p. 161-166, 1937.

mountains. It is very likely that in preglacial time the crest line of the Alaska Range formed the watershed between the waters flowing to the Tanana River and to the Susitna River. The thick glacier, however, found an outlet northward across the range from Broad Pass into the Nenana River Valley and flowed through that gap in sufficient volume to wear down the divide and leave upon its retreat the low pass through which the railroad crosses this mountain barrier and through which the headwaters of the Nenana River now flow from the southern slope of the range into the Yukon Basin. It is only because of the great altitude of the Alaska Range elsewhere that other points of escape into the interior lowlands were not found by the Susitna glacier, as well as by the Copper River glacier.

On the north or inland slope of the Alaska Range the development of Pleistocene glaciers was much more moderate than on the south slope. This was due to several factors, first of which was probably the lesser precipitation on the inland slope. The present annual precipitation is 64.9 inches at Seward and 30.74 inches at Talkeetna, but only between 11 and 14 inches for points north of the crest of the Alaska Range. It is fair to presume that during Pleistocene time there was a similar discrepancy between the rainfall on the two sides of the range. Another important factor was the smaller average size of the portions of the northward-draining stream basins that lie in the high mountains as compared with those on the south slope, the areas of ice accumulation thus being smaller on the inland slope than on the seaward slope. Still another influence that prevented the growth of a glacier in the Tanana Valley that would compare in size with those of the Copper and Susitna Basins was the fact that the Tanana Valley is bordered, and that somewhat remotely, by high rugged mountains only along the southern margin, the country on its other margins being of too low relief to afford gathering grounds for vigorous glaciers. Whatever may have been the causes, however, the fact remains that few of the northward-flowing valley glaciers from the Alaska Range pushed their fronts beyond the base of the foothills, and probably no single glacial lobe reached as far north as the present course of the Tanana River. In a few of the larger valleys, such as those of the Chisana, Nabesna, Delta, Wood, Nenana, and Toklat Rivers, the ice moved to the north edge of the foothills and spread out a little onto the plains beyond, but not far. In most of the smaller northward draining valleys the glacial tongues never emerged beyond the mountain front. The Tanana Valley, therefore, has never been invaded by a single great glacier, and the entire Yukon-Tanana upland has remained unglaciated except for a few small and short valley glaciers that developed around one or two of the highest prominences in that area.

EVIDENCES OF MORE THAN ONE GLACIAL ADVANCE

The limits of glaciation in this region, outlined in the preceding paragraphs, are, so far as we now know, those reached by the ice during its greatest development and the most readily recognizable evidences of glaciation are those left during the last great glacial advance. That advance is probably to be correlated with the Wisconsin stage of glaciation in the northern United States, during which the continental glacier moved southward from Canada as far as the south edges of Lakes Michigan and Erie. In the Mississippi Valley, however, at least five major stages of Pleistocene glaciation have been recognized, and those were separated from one another by long periods of deglaciation. No such complete series of glacial stages has been worked out in Alaska, but it seems reasonable to suppose that any climatic change great enough to cause glacial ice to move hundreds of miles southward into the central United States should have been operative in Alaska also and should have been reflected there, to some extent at least, in an increased growth of the glaciers.

In a few places in Alaska evidence has been found of at least two ice advances, one much earlier than the last. Near the Alaska-Canada boundary, on the inland slope of the St. Elias Mountains, ancient glacial deposits occur that were indurated and uptilted before being overridden by the ice of the last great glacial advance. In the valley of the Nenana River also, close beside the railroad line at the point where it emerges from the foothills onto the Tanana lowland, there are great erratic boulders of glacial origin that lie far north of the outermost moraines left by the last glaciers at their most northerly stand. Still farther southwest, in the basin of one of the tributaries of the Mulchatna River that drains from the Alaska Range, a deposit of ancient oxidized glacial till lies beneath the younger, unoxidized moraines of the last glacial stage. These meager bits of evidence at least prove that there have been recurrent glacial advances in Alaska. Further evidence is most likely to be found at similar localities along the north front of the Alaska Range, for there the glaciers advanced toward an ice-free region, and glacial deposits left during one period of glaciation would in favorable places be preserved for future study. South of the Alaska Range such evidence is likely to be much more difficult to find, for the last glaciers covered the entire country, and removed, buried, or confused the deposits left by their predecessors.

EFFECTS OF GLACIATION UPON LAND FORMS

To the trained observer who travels from an unglaciated, stream-eroded mountain region into another mountain region where glaciation has been vigorous and prolonged, the difference in the appearance of the land forms produced by these two agencies of erosion is striking. In the stream-carved mountains the valleys are broadly V-shaped in cross section, and the streams flow over gradients adjusted to their volume and load along somewhat devious courses as they swing past the points of spurs projecting into their valleys, first from one side and then from the other, so that the view along the valley of one standing by the stream is cut off by these interlocking spurs. The outlook in an area of strongly glaciated mountains is quite different. There the broad-floored valleys are U-shaped in cross section, the valley walls rising precipitously from the edges of the stream plain. The great, troughlike valleys are straight, or bend only in great sweeping curves so that the view is generally open for miles up and down stream. Tributaries join the main streams from hanging valleys, with great lack of adjustment in their gradients, so that each tributary is likely to have rapids or falls where it plunges from the mouth of its hanging valley to the more deeply eroded trough of the main stream. In all the minor details of sculpturing, too, the ice-carved mountains contrast with those cut only by flowing water. Cirques, truncated spurs, hanging valleys, tarn lakes, and great bare rock walls free from accumulations of the products of rock weathering and decay all proclaim the resistless force and intense severity of the erosive power of thick, slowly moving ice streams, shod with an abundance of rock fragments.

In the region here described all the high mountains show these effects of intense glacial erosion. The deep valleys and fiords of Kenai Peninsula were carved in large part by great glaciers that were the ancestors of the still large ice streams there. The physiographic features of the ice-free portions of the Chugach and Talkeetna Mountains and of the Alaska Range are the same as those to be found in the basins of active glaciers, but little modified by postglacial stream erosion. These features are in sharp contrast to those of the Yukon-Tanana upland in the vicinity of Fairbanks, for there glaciers have never existed, and the land forms have been developed by other processes.

The effects of glaciation upon the lowlands and in the broad, open valleys of the major streams have been altogether different from those in the mountains, but nevertheless they have altered the appearance of the lowlands profoundly. In the mountains the tendency of ice erosion has been to accentuate the relief by deepening the valleys, sapping the bordering ridges, and so developing steep cliffs and sharp, ragged ridges and peaks. In the lowlands, however, especially in those valleys that were filled thousands of feet deep by moving ice streams, the effect of the ice invasion was to smooth out irregularities of the glacier beds by rasping down projections and filling hollows.

Thus those lowland areas that were submerged by glacial ice tend to show smoothed and rounded hills and ridges and broad, gently undulating lowlands with few conspicuous prominences. This is well exemplified in the lowlands in the headwater region of the Susitna River, where all the ridges less than 4,000 to 4,500 feet in altitude are smoothed and rounded, while those that rise a few thousand feet higher are sharp and rugged. The imposing on the lowlands of a smoothed and rolling topography is due no less to glacial deposition than to glacial erosion. The vast quantities of rock debris torn from the mountain valleys and from projecting and overriden ridges must of necessity have been deposited somewhere, and the lowlands, as the route over which this burden of ice-brought material was carried, received abundant deposits of it as glacial till and morainal matter. It is generally difficult to ascertain how thick this layer of glacial material is, for deep clean exposures of it are rare. Yet in places in the Copper River Basin there are stream cuts several hundred feet deep that fail to show the bottom of the glacially deposited material, and the aggregate amount of glacial till now present in the lowlands of the Copper and Susitna Basins must be many hundreds of cubic miles. To this must be added a large part of the tremendous amount of stream gravel that occurs along the valleys of those streams that head in glaciers, for such streams are heavily burdened by mud, sand, and gravel that have been supplied to them in large part by the glaciers in which the streams have their sources. Likewise the deltas of such streams as the Copper, Susitna, Matanuska, and Knik Rivers are largely made up of glacial outwash, as are the broad tide flats of upper Cook Inlet. The agricultural lands of western Kenai Peninsula and the Matanuska and Susitna Valleys are in the main floored by materials deposited directly by glaciers, or by glacially burdened streams.

As has been explained, the Tanana lowland has for the most part never been covered by glacial ice, but its present surface forms and the material with which it is paved are nevertheless principally of glacial origin. Most of the water of the Tanana River is received from streams that drain the north front of the Alaska Range, and those streams flow from valleys which were once ice-filled and many of which still harbor vigorous glaciers at their heads. The present heavy load of gravel and silt that the Tanana River carries is received almost entirely from these glacial streams. It takes little imagination to realize that the streams that flowed from the former much greater glaciers were even more heavily charged with glacial debris. These streams, burdened with all the gravel, sand, and silt they could carry, emerged from their relatively steep mountain valleys upon a lowland of lower slopes. With diminished gradient a part of the load was deposited, the coarser gravel being dropped nearest the mountains and progressively finer materials being laid down as the distance from the mountains increased and the stream gradients lessened. In this manner, during periods of severe glaciation, great alluvial fans, of low slope, were built out northward from the Alaska Range and its foothills into the Tanana lowland. These fans grew laterally to the east and west, as well as to the north, and the deposits built by a great number of rather closely spaced northward flowing streams finally merged to form a continuous alluvial apron along the entire north foot of the mountains.

By contrast to its heavily burdened tributaries from the glaciated mountains to the south, the streams that drained to the Tanana from the unglaciated Yukon-Tanana upland to the north were relatively clear and carried little solid material. As a consequence the aggrading gravel fans on the south side of the Tanana gradually caused a northward shifting of the axis of the broad valley, until finally the river flowed, as it does now, at the extreme north edge of its lowland, cutting against the rock bluffs of the valley on that side. The asymmetric position of that stream in its lowland, however, while showing definitely the influence of valley aggradation from the south, gives little measure of the actual amount of outwash filling in the lowland. Once shifted to the north side of its valley, the river would remain in that position if its erosive action were just balanced by the supply of new material from the south. If, however, the glacial tributaries for a considerable time brought down more detritus than the Tanana could remove, no great amount of lateral shifting of that river being possible, the whole valley would have been aggraded, and the level of the stream bed at any point would have become higher as aggradation went on.

There are several obvious tests that could be applied to determine whether or not the entire floor of the Tanana lowland has been raised to any appreciable extent by aggradation from the glacial tributaries. Observation that the alluvial cones from the Alaska Range extend into the lowland and slope downward to its north edge is conclusive in showing that the process has been and still is operative. Direct evidence of the thickness of this filling of glaciofluvial outwash in the lowland could be obtained by drilling, but unfortunately no such borings have yet been made, and evidence of that sort is still lacking. A third line of evidence can be obtained by a study of the valleys of the unglaciated tributaries of the Tanana from the north, for if the lowland to which they drained has been filled to any appreciable extent, this would result in the damning back of those other streams, and would cause them too also to aggrade their valleys, so that the bedrock valley floors should lie below the level to which the streams now cut. The filling in the valleys of these lightly loaded streams should also differ in character from the coarse glacial outwash from the south and should consist of such finer silts as a clear sluggish stream can transport, together with such remains of plant growth as would accumulate in the marshy valleys of partly obstructed streams. On the buried rock floor, however, there should still remain the coarser stream gravel that constituted the normal stream-channel deposits before the damming occurred, and at intervals higher in the filling there should be layers of fine gravel, or sand, brought down at times of flood, when the current was for a short time swift enough to handle material coarser than silt.

Fortunately, much information has been obtained concerning the conditions of the valley filling and the depth to the bedrock floor of those unglaciated streams in the Fairbanks region, for the rich placer-gold deposits there have caused the sinking of a great number of shafts to bedrock in search of the precious metal. In places shafts have shown the filling to have a thickness of over 300 feet. The placer gold generally occurs in a layer of coarse gravel that lies directly on bedrock. It seems likely that this layer represents the normal stream wash of the valleys during the gradual wearing down of the country by streams in preglacial and early glacial time, and it has retained the heavy concentrates from an immense amount of rock detritus that was moved along the valleys during the age-long erosion of the country. Above the auriferous gravel there is commonly another layer of coarse gravel in which there is no noteworthy concentration of gold. This may represent the detritus carried down by the streams at a time when the filling of glacial outwash in Tanana Valley had begun to hamper the free discharge of materials from the north, but while the gradients of the southward-flowing streams were still steep enough to permit the moving of coarse materials. The upper part of the filling in the southward-draining valleys, the so-called muck of the miners, consists largely of fine sediment and organic materials, all more or less completely frozen. This portion of the filling accumulated under conditions much like those that now prevail, where such streams as the Tolovana, Chena, Salcha, and their tributaries, impounded by the great glacial-outwash fill of the Tanana lowland, flowed sluggishly through broad marshy lowlands in which remains of vegetation, wind-blown dust, and the meager silt burden of the streams were laid down. Prospecting has shown that the depth to bedrock decreases gradually up any of those streams, and in the headward portions the valley fill is no deeper than in similar valleys elsewhere, and the normal processes of stream erosion in high latitudes are in operation.

The observed facts in the Fairbanks region thus seem to meet the conditions that would be expected as the result of a great aggradation of the Tanana Valley by glacial outwash from the south. Just how far the effects of glaciation have caused the filling of the northern tributary valleys and to what degree glaciation has indirectly caused the deep burial of the gold placer gravel in the Fairbanks region are as yet by no means known. Other influences, such as a general subsidence of the Fairbanks region, may have been and probably were in operation, yet the simple explanation advanced above—that is, the aggradation of the Tanana lowland to a minimum depth of several hundred feet by glacial outwash from the mountains to the south—will satisfy many of the requirements of the case and has certainly been an important factor in causing the deep burial of much of the placer gold of the Fairbanks region.

Deposits of glacial morainal material are much less widespread on the Tanana slopes of the Alaska Range than on the Pacific slope, for at only a few places were the glaciers able to push out beyond the mountain front on to the piedmont plains, where conditions were favorable for the laying down and preservation of the glacial deposits. In general, therefore, the glaciers on the north slope of the range were of the alpine type, were confined to narrow mountain valleys, and dropped their burdens of detritus in valleys in which stream erosion was active, so that much of the material has now been removed, reassorted, and added to the filling in the Tanana lowland.

RETREAT OF THE ICE

After the glaciers of the last period of ice advance had reached their greatest development the climate gradually became milder, so that conditions were less favorable for the accumulation of ice, and the glaciers of this region began to retreat. The retreat, like the advance, probably consisted of a series of oscillations of the ice edge, but in general the periods of withdrawal were longer than those of increase, and the ice fields shrunk both in area and in thickness. On the Pacific slope this retreat was first evident by a lessened discharge of ice into the ocean and a shortening of the distance that the tidal glaciers pushed out to sea. At a later stage many glaciers ceased to reach tidewater and shrunk back into their deeply eroded valleys. The great Cook Inlet-Susitna glacier, less abundantly supplied by ice from its multitude of mountain tributaries, shrunk northward until Cook Inlet was uncovered and invaded by salt water. Still later the Susitna lowlands were bared, the tributary ice streams from the surrounding mountains became detached, and each shrank slowly into the mountains. Similarly the Copper River lowland was bared, streams resumed their old courses across the lowland or found new ones, and the only glaciers left were of the alpine type, lying in deep gorges within the higher mountains.

The glaciers on the north slope of the Alaska Range probably experienced vicissitudes similar to those on the Pacific slope, but as they were smaller the magnitude of the oscillations was less. No single great glacier formed in the lowlands there, and few ice tongues pushed north beyond the mountain front. Nevertheless, many of the glaciers at their maximum were 25, 30, or 50 miles long, and upon their withdrawal a great area of mountainous country was freed from ice and exposed again to processes of atmospheric and stream erosion. Throughout the railroad belt there was a tremendous shrinkage of the glaciers. Many valleys that had once contained large glaciers became free of ice, and such of the glaciers as persisted were greatly shrunken. The present glaciers of the region are much-diminished remnants of the Pleistocene glaciers, and the ice withdrawal that marked the end of Pleistocene time is believed to have brought about the retreat of the glaciers to approximately the positions they now occupy.

PRESENT GLACIERS

The present glaciers have been referred to as the remnants of the greater Pleistocene glaciers, and such indeed they are, but in spite of the fact that they are only a fraction as large as they once were, there are few areas in the world where larger mountain glaciers exist than those in the region here described. In sailing along the east and south coasts of Kenai Peninsula, valley after valley is seen to contain a great glacier that pushes down almost or quite to tidewater, and the Kenai Mountains west and southwest of Resurrection Bay support a great ice cap some 75 miles long, from which great lobes project radially down all the larger valleys. The Chugach Mountains north of Turnagain Arm and Prince William Sound and south of the Matanuska River contain many glaciers of great size and exceptional beauty, whose heads lie in unexplored and unmapped country. The glaciers of the Talkeetna Mountains are numerous, but they are small compared with those of the belt of heavier precipitation along the coastal mountains. The Alaska Range, however, although outside of the coastal region of exceptionally heavy precipitation has, as a result of its great height and area, a number of valley glaciers of the first magnitude. No exact figures of their area can be given, for their headward portions are still unmapped, but Kahiltna Glacier is nearly 4 miles wide at its terminus and is probably between 40 and 50 miles long. Tokichitna Glacier is about half as large; Ruth and Eldridge Glaciers, which drain from the slopes of Mount McKinley to the Chulitna River, are probably nearly as large as Kahiltna Glacier; and Muldrow Glacier, on the inland front of the range, extends northeastward from Mount McKinley for a total distance of 39 miles. In addition to these there are a multitude of glaciers, many of them unnamed and unexplored, that range in length from a fraction of a mile to 25 miles and would be famous in their own right in any country less lavishly supplied with these impressive ice streams.

No general statement can be made that will apply to the present stability of all the glaciers of the region. Without doubt some of them have shown a considerable shrinkage in the last 100 years. Mature forests within a short distance of the distal ends of others indicate that the present stand of the ice front is about as far forward as at any time during the existence of the forests. Glaciers everywhere are subject to advances and retreats, as they depend for their nourishment upon snowfall in the mountains. A few years of less than the average snowfall or of higher than the average summer temperature will result in a general retreat of the glaciers in the region so affected, but a return to normal or higher than normal precipitation and cooler summers will bring about a readvance. If these minor oscillations are ignored it seems likely that the glaciers of this region have maintained their size and position without great change since the end of Pleistocene time.

RECENT DEPOSITS

TERRACE GRAVEL

Throughout the Alaska Railroad region there are extensive areas covered with deposits of stream-laid gravel that are related to the present topography but that lie above the levels reached by the present streams, even at flood stage. These gravel deposits form terraces along the stream valleys and occupy much of the interstream areas in the Susitna lowland, the Tanana lowland, and the basins that lie between the foothill ranges on the north slope of the Alaska Range. They may lie upon any of the older formations and are locally found upon the old hard-rock formations, on the less well indurated Tertiary beds, and on the glacial deposits. The term "terrace gravel" is applied to all materials of this class to distinguish them from the much older and generally deformed gravel and from the deposits of the present streams.

The terrace gravel is stream-laid and resembles the deposits of the present streams in composition, structure, and degree of assortment. It consists primarily of well-rounded pebbles, varying considerably in coarseness from place to place, and of considerable sand and silt, both intermingled with the pebbles and as irregular beds and lenses. In general the terrace gravel is undeformed and its surface slopes are the slopes of deposition, somewhat modified by later erosion. The character of its material and its topographic position indicate that the terrace gravel was laid down by streams whose courses ran along the present valleys, but the gravel has since been left in its present elevated positions by the deepening of the adjacent stream valleys by stream erosion. The terrace gravel in general shows little oxidation and is prevailingly of a blue or blue-gray color, thus contrasting sharply with the deeply oxidized and yellow Tertiary gravel. The thickness of the deposits is commonly not great, ranging from 1 to 20 feet or more, but there are broad areas over which they are sufficiently thick to conceal the underlying deposits. Their surface is commonly covered with vegetation. Locally the character of the terrace gravel is strongly influenced by the character of the nearby materials from which it was originally derived. Thus along the east bank of the Nenana River below the mouth of Healy Creek and at many other places there are terrace remnants that, as shown by their physiographic position and form, obviously belong with the terrace gravel, but are composed of oxidized and yellow materials that closely resemble the adjacent Nenana gravel in appearance. In such places the distinction of one type of gravel deposits from the other must be based on the physiographic and structural evidence, and not alone on the character and appearance of the composing materials, for the terrace gravel there has been derived wholly or in large part from nearby ridges of Nenana gravel and reveals the oxidized character and the composition of the ancestral deposit, but has taken on the physiographic and structural characteristics of the much younger terrace gravel with which it must now be classed.

The general physical condition and form of the terrace gravel and its relations to the glacial moraines indicate that in part at least it is composed of the outwash materials laid down beyond the ice border at the time of the last great ice advance. In origin, therefore, it is little different from the present broad gravel plains now found along so many of the rivers of this region that head in glaciers. The present stream gravel, however, is only in part directly of glacial origin and contains a considerable admixture of the products of normal stream erosion, together with reworked materials derived from older glacial deposits. The terrace gravel probably contains a larger percentage of debris supplied indirectly by the ice, but it too in places contains much material of local derivation that has been rehandled and reshaped into new physiographic forms but moved no great distance from its source.

The fact that in a single stream valley there may be a series of terraces, one above another, shows conclusively that the materials composing the terraces vary considerably in age, the lowest being the youngest and the highest the oldest. Such stream terraces have probably been continuously in process of formation from glacial time until today, and the terrace gravel, therefore, ranges in age from Pleistocene to the present. Placer gold has been found in encouraging amounts at several places in the terrace gravel in the Kantishna and Bonnifield regions, and at a few places a considerable amount has been recovered by mining. It is entirely possible that more intensive prospecting and the cheaper mining that has resulted from improvements in transportation and mechanical equipment will make it possible to mine the terrace gravel at a profit in many places where mining has so far not been attempted.

THE "MUCK" PROBLEM

The problems of the origin of the "muck" and of the deeply buried placer deposits in the Fairbanks, Tolovana, and other interior gold-mining camps and of the deep ground frost and the remarkable ice dikes and sills in those deposits are still far from solved and deserve much fuller study and discussion than can be given to them in a general paper such as this one. The writer believes that the alluviation of the master stream, the Tanana River, is one of the causes for the deep muck fill in the valleys of the southward-flowing streams of the Yukon-Tanana region, but many other causes have also been in part contributory. Many drainage anomalies in the Yukon Basin show that without doubt there has been gentle crustal warping in central Alaska in late Tertiary or early Quaternary time. This is indicated also by the fact that in the lower valleys of Goldstream Creek and the Chatanika River, where the present surface is less than 400 feet above sea level, there is a filling of muck of as much as 200 feet or more, and that the bedrock floor of those valleys is therefore less than 200 feet above sea level. The bedrock floor at the axis of the Tanana Valley is doubtless still deeper. The master stream of the region at the time these bedrock valleys were cut would therefore have had a gradient of no more than half that of the present Yukon River, and probably much less than half as much, if no warping had taken place. But warping is definitely indicated by such drainage anomalies as the passage of the Yukon River from a broad basin at the Yukon Flats into the narrow canyon of the Ramparts, and again by its passage from the wide alluviated basin above Tanana into the narrow valley at Ruby.

The origin of the material in the muck itself is also a problem which has been much discussed but concerning which various opinions prevail. The great age of much of it is indicated by the presence of fossil remains of long extinct animals such as mammoth, mastodon, horse, a giant bison, and other animals which are generally believed to have lived during Pleistocene time. A list of the vertebrate fossils collected by the Geological Survey and by the Smithsonian Institution, as well as of fresh-water invertebrates and plants from these deposits, has recently been given by Mertie.[35] The mate-

[35] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 190–193.

rial itself consists, besides the abundant partly decayed plant remains, mainly of a very fine silt or loam, almost free from sand, gravel, coarse grit, or rock fragments. The writer is of the opinion that much of this fine material is loess—wind-blown dust that was carried from the broad flats of the many-branching glacial streams and deposited widely over the hills and valleys in the unglaciated area of interior Alaska. This windblown material naturally lodged wherever there was a mat of vegetation to hold it and is therefore now found most abundantly only below such altitudes as the upper limit to which the Pleistocene vegetation grew freely. Recently mining excavations on Cripple Creek, near Fairbanks, show sections of well over 100 feet of fine buff comminuted rock material that contains no trace of any particles as coarse as sand and that resembles and probably is wind-blown loess.

The generally frozen condition of the muck to depths of 200 to 300 feet and the presence in it of dikes, lenses, and wedges of clear ice are problems that deserve fuller discussion than can be given here. Opinion still varies as to whether the muck became frozen from the surface down, or whether the frozen surface rose as the muck thickened by annual accretions. Some of the lenses of clear ice in the muck may be fossilized ponds or small lakes. The irregular dikes and wedges, on the other hand, were certainly formed after the muck was in place. The depth and character of the muck and the underlying gravel, their generally frozen condition, and their origin are matters of great economic importance in the gold placer camps of interior Alaska, for the gold-bearing gravel lies on bedrock beneath a cover of variable thickness of these materials, and to reach the pay gravel it is necessary either to sink shafts through these frozen deposits and remove the pay dirt by thawing and drifting, or in the larger mechanically equipped mines to thaw the entire deposit of muck and gravel, sluice off the muck, and mine the pay gravel by dredge, by mechanical scraper, or by hydraulic methods. Scores of millions of cubic yards of this material have already been thawed and mined in the Fairbanks district, and definite plans have been made to continue these operations for many years.

PRESENT STREAM GRAVEL

The present stream gravel includes only the gravel that occupies the flood plains of the existing streams and that may be overflowed in periods of high water. It has been laid down under conditions essentially like those that now prevail in the region. As a result of the way in which they were formed the deposits of stream gravel occur as long, comparatively narrow bands that follow the windings of the stream valleys. The present stream deposits are almost continuous along the entire course of each stream, but at places where there are narrow rock canyons the streams may cover the whole valley floor, and the stream deposits are there narrow and thin. They vary in width from place to place as the valleys widen or are constricted and with the amount of material that each particular stream carries. On such streams as receive little or no glacial water and are therefore comparatively clear the gravel deposits are likely to be narrow. There are few important rivers of this type south of the Tanana River, for all the major streams that drain from the Alaska Range and the Talkeetna, Chugach, and Kenai Mountains are glacier-fed and carry heavy loads. The rivers that drain to the Tanana from the ice-free Yukon-Tanana upland, however, are clear, and their gravel deposits are small in area. Streams mainly of glacial origin, on the other hand, are usually burdened to capacity with glacial debris during the summer season of high waters and have extensive gravel flats below the glaciers. These deposits are characterized by the coarseness of the gravel near the glaciers, and in a stream receiving glacial drainage only at its head the gravel deposits become progressively finer downstream. The heavily loaded streams deposit a large part of their burden within 10 or 20 miles of the glacier and spread in numerous branching channels over wide, bare gravel bars. Many of the large trunk streams of this region are by no means of this simple type, however, for they are joined at intervals by heavily loaded glacier-fed tributaries and their broad gravel plains therefore extend for long distances along the valleys. The Susitna River is of this complex type. At its head it is fed by two large glaciers and flows in many branching channels over a wide gravel flat. Below the great bend, where it flows in a westward direction, it has already deposited most of its coarse debris, the gravel plain narrows, and the stream flows in a single channel most of the way to its confluence with the Talkeetna and Chulitna Rivers. These streams, however, discharge great quantities of glacial outwash, and below their mouths the main Susitna has again developed a broad gravel plain. Below the Yentna the Susitna has left behind most of its coarse gravel and follows a fairly definite channel to the sea.

The Tanana River is heavily loaded with gravel along its entire course within this area, for it receives at rather short intervals such glacially burdened streams as the Delta, Little Delta, Wood, Nenana, and Kantishna Rivers and is unable to entrench itself deeply into its gravel fill.

The ability to distinguish between these two types of streams—that is, those that are aggrading, or building up their valley-floor deposits, and those that are eroding, or constantly deepening their valleys—is a most important matter to one prospecting in this area for placer gold, for aggrading streams have little ability to concentrate the particles of heavy metal into workable placer deposits, as the containing gravel is constantly receiving additions rather than being concentrated by the removal of the lighter materials. On such streams it is only at especially favorable localities, such as rock canyons where the restricted channel enables the stream to scour to bedrock or on certain bars where the current so flows as to cause local concentrations of gold, that workable placer deposits are likely to be found. Eroding streams, on the other hand, pass great quantities of material down their valleys but by periodically cutting down to bedrock and shifting their valley deposits around they are able to concentrate upon bedrock the heavy metallic content of the entire mass of detritus that they are moving, and if the detritus contains sufficient gold a continuous pay streak is likely to be developed on bedrock below the point from which the gold comes.

SOIL FLOWS

In regions of subarctic climate certain processes of erosion, by which the products of rock weathering are shifted slowly down slopes, are operative over great areas, and the aggregate amount of material transported in this way is enormous. These slow processes of erosion are here grouped under the general term "soil flow." They are operative generally throughout those parts of the railroad region in which there is permanently frozen ground. In the lowlands of the Cook Inlet-Susitna depression, the Matanuska Valley, and other valleys of low altitude on the south side of the Alaska Range there is little permanently frozen ground, and soil flowage there is not conspicuous. In the adjacent mountains, however, above an altitude of about 3,000 feet, there is much permanent frost and much soil flowage. North of the Alaska Range there is permanent frost even in the lowlands, and in the foothills generally the ground thaws to a depth of only a few feet even in midsummer and soil flowage is very active.

The phenomena here included under the general term "soil flows" are confined to those areas where permanent ground frost exists and are therefore operative at low altitudes only in subarctic areas or at high altitudes in areas at lower latitudes. In those areas, wherever the surface slopes are moderate and there is a soil cover of any kind, the ground is covered with a tough mat of alpine plants that include sphagnum and other mosses, many varieties of grass, and such low-growing shrubs as blueberry and heather. This mat of vegetation effectually retards the removal of rock waste by the ordinary processes of rill and gully wash. In those regions, too, the ground remains permanently frozen a short distance below the surface in places where the surface cover of plants affords effective insulation from summer melting, so that stream cutting is further retarded by frozen ground. The vegetative mat also acts as an absorbent medium for such precipitation as falls on the ground, and that moisture is prevented from sinking into the earth by the tightly frozen subsurface layer, so that the water table, as it exists in temperate climates, is absent, but the surface layer of soil remains surprisingly wet in view of the low annual precipitation in most of this region. Under such conditions the products of rock disintegration and weathering are removed by soil creep or flow. Many types of soil flow or rock-waste movement have been recognized, varying in rate of movement from landslides and sudden flows of soil and mud to soil creep and flowage in which the movement is much too slow to be visible but which yields large results in the amount of transportation accomplished. At many places, particularly on moderately steep slopes, the landscape is scarred by shallow depressions left where the semifluid soil has broken loose and flowed suddenly downhill, and such mudslides, still wet and sticky, are frequently encountered. These flows range in length from 100 to 500 feet and generally show an expanded, spatulate shape at the upper end, a rather narrow main body, and a lobelike heap of mud and turf at the point where the material came to rest. An examination of such a fresh flow shows that the material is saturated with water and that all the material above the level of ground frost, a distance of 3 or 4 feet below the surface, had moved. The writer has seen no such flow in actual movement but believes that the controlling factors are the declivity of the slope, the toughness of the mat of vegetation, the water content, and the depth of thawing. Vegetation promptly establishes itself on any favorable slope and by forming a tenacious fibrous mat almost completely inhibits the removal of loose material by surface water. The insulation afforded by the vegetation also favors the permanent freezing of the ground within a few feet of the surface, and this frozen zone prevents the penetration of surface water below the frost level. During the summer, when melting lowers the ground frost level a few feet, frost action brings about the disintegration of the underlying rocks, some chemical decay takes place, wind-blown material is trapped in the mat of vegetation, and soil and fragmental rock materials accumulate. This mass is saturated with water, and the intermittent growth and melting of ice crystals within the mass makes it porous and spongy, so that its water content is very high. During the long warm days of early spring and summer the surface portion of this mass thaws, and melting snows and rains saturate it. As it thaws it becomes semifluid but is held in place by the felt-like cover of roots and moss. As thawing proceeds still further the mass of water-soaked soil may become too heavy for the vegetation to hold, and a sudden parting of the turf may release a great quantity of mud, rock fragments, and slabs of turf which together flow down the slope to flatten out in the valley bottom, and the scar above is later re-covered by a new growth of plants.

The origin and movement of the slow types of soil flows are due to much the same causes as those of the sudden flows, but in them the turf stretches rather than breaks, and the flows assume various shapes and sizes, depending upon local conditions. Upon high slopes where the altitude is unfavorable to the rapid growth of vegetation soil flow may take place uniformly over considerable areas as a thin sheet, which moves slowly under the impulse of gravity and the heave of crystal growth during repeated freezing and thawing. In such areas the surface slopes are smooth, and the active movement of the soil may be recognized by the striped arrangement of rock particles and of vegetation along the lines of downward movement. In general such flows bear only a scanty and incomplete plant cover.

A second general type of slow soil flow that in the aggregate produces a vast amount of transportation has as variant forms terrace-like ridges and lobate or mammillary flows. In these flows the fairly steep surface slopes, the mantle of soil and muck, the permanently frozen subsoil, the matted plant cover, and the complete saturation with water are all present. When the superficial layer of muck and soil has thawed the semifluid mass tends to sag down the hillside, stretching the turf into flat bulbous forms or into ridges. The tenacious and feltlike turf, however, stretches but fails to rupture, and by the continued growth of the plants its strength is maintained as the stretching slowly proceeds. In this way a hillside may be entirely covered by mammillary lobes, closely grouped, each summer creeping downhill a little farther, or by long wavelike terraces which in moving retain fairly level fronts.

Though several distinct types of soil flows occur, there are gradational phases between all of them. Thus at one place the upper slope of a hill may be covered with mammillary flows; farther down the slope the turf may be torn into irregular patches that have been separated from one another by sheet creep; still farther downhill the surface may be nearly free of vegetation, the soil movement may be nearly uniform over the bare slope, and the rock particles and scanty plants arranged in linear, ribbonlike bands. In places too the vegetable mat on mammillary or terraced flows may rupture, and the mud move out as a small, sudden flow.

In addition to the types of soil movement mentioned above there are large areas near the upper limit of vegetation in which the surface is covered with small hillocks or ridges a foot or so high. Some such areas look as if they had been furrowed with a plow; others as if the soil had been hilled up in low mounds in cultivation of some crop. In these areas the appearance of soil movement is not conspicuous, but the surface forms are doubtless due to the interrelation of vegetation, soil, frozen ground, water content, and frost action, and all these phases are part of the general phenomenon of soil movement under subarctic conditions, a type of erosion that deserves much more intensive study than has so far been given to it.

ECONOMIC GEOLOGY

GENERAL FEATURES

The mineral resources of the region served by the Alaska Railroad from Seward to Fairbanks comprise a great variety of metallic and nonmetallic minerals. Some of these have been for years and are now being actively exploited. As is true in most frontier countries, the earliest prospecting was primarily a search for the precious metals, and especially for placer gold, for gold placer mining can be conducted with simple and portable tools, and the metal produced can be easily taken out from even the most remote regions. The first attempt to mine gold in Alaska was made in this region on the west side of Kenai Peninsula by the Russians in 1848, but without much success, though a little gold was recovered. Since the early nineties, however, there has been continuous prospecting, and many gold placer camps have been established. The next stage to follow the search for and exploitation of the gold-bearing stream gravel is the attempt to find the bedrock source of the gold which by erosion and transportation has been concentrated in the stream beds, and there are now several districts in this region in which gold quartz mining is being carried on, and the Willow Creek and Fairbanks districts have for years maintained a considerable output of lode gold. As has been stated, gold placer mining can be pursued even though rail or water transportation is almost wholly lacking. Gold lode mining, too, can be carried on in rather inaccessible regions, for although the cost of carrying to the mine such supplies as powder, steel, and machinery is often very high, the product, if the ore is free-milling, can be recovered and taken out without great difficulty. Deposits of gold ore in which the gold cannot be recovered by amalgamation and of such other desirable metals as silver and copper, which commonly occur as sulphide ores, cannot be profitably exploited without fairly good transportation, for not only must all supplies be brought to the ore deposit, but the heavy ore or concentrates produced must be transported to smelters to be reduced. It is obvious that to be profitable ore mined must contain sufficient valuable minerals to pay not only the cost of mining but also the cost of reducing the ore and of getting the product to the market, as well as yield a profit to the miner. The value of an ore deposit thus depends in great measure upon its location in respect to routes of transportation, and an inaccessible ore deposit that would have great value, if transportation to it were available, may be worthless.

The completion of the Government railroad from Seward to Fairbanks has greatly improved the transportation facilities to a large number of mines and prospects in this region and has made possible the production of metal from many lodes that otherwise could not be worked. The area tributary to the Alaska Railroad is preeminently a gold-mining region. The Fairbanks district, at the interior terminus of the railroad, has long been and still is one of the world's major gold placer camps. By the end of 1936 it had produced more than $100,000,000 in placer gold, and sufficient ground has been explored to assure continued large-scale mining operations for many years and an additional output from placer operations that may even exceed the production to the present time. By comparison with the placer output of the Fairbanks district the gold production from lodes has been small, but that industry is growing, and the probable reserves of lode gold are large.

The Willow Creek district is the second largest producer of lode gold in Alaska and is likely to maintain that position for some time. There is increasing evidence that the gold content of its lodes goes to depths much greater than have so far been exploited and that the camp should have a long life. The placer districts of Kenai Peninsula and the Yentna, Valdez Creek, Rampart, Hot Springs, Tolovana, Bonnifield, and Kantishna districts have produced from about $500,000 to more than $7,500,000 each. Development work is now under way on at least two large low-grade gold-lode deposits, one in the basin of the West Fork of the Chulitna River, and one in the Kantishna Basin, either or both of which may be developed into large mines.

One of the most valuable mineral resources of the region is its coal. Extensive fields of bituminous coal in the Matanuska Valley are already being mined, though on a rather moderate scale. Deposits of fairly good lignite or subbituminous coal are found at a great number of localities in the Susitna Basin. On the interior slope of the Alaska Range the Nenana coal field contains a great quantity of subbituminous coal, and similar deposits are scattered along the north flank of the range from the Kantishna River eastward to and beyond the Delta River. All these fields of mineral fuel are potentially valuable, but their value depends on good transportation and on accessible markets. At the present time the principal users of coal in the Alaska Railroad belt are the railroad itself for the operation of its trains and the Fairbanks Exploration Co. to furnish power for its extensive mining operations. There is also a considerable consumption of coal for domestic purposes in the towns adjacent to the railroad. A small market has also been developed in the towns and at mines and canneries on Prince William Sound and in southwestern Alaska,

77786—40——12

but only a small percentage of the coal mined moves out of the area directly served by the railroad.

The service of geology to the mining industry lies largely in recognizing and pointing out the relations of the various rock formations to the ore deposits and thus determining what additional areas give promise of reward to the prospector, and in searching out the probable extensions of such ore bodies as have already been found. Such information is gained largely by a study of the known ore deposits and of their geologic relations. It is therefore pertinent to summarize at this place such salient facts as are known in regard to the distribution of the ore deposits and the rocks with which they are associated. This summary is given in the general geographic order of the deposits from Seward into interior Alaska. Inasmuch as detailed descriptions of the geologic setting and the mining activities in all the camps in the railroad belt in which active mining is now in progress have recently been published, no attempt will be made here to describe individual operations unless such enterprises are characteristic of conditions throughout a camp. References are given to the most recent and complete published descriptions of detailed mining operations.

KENAI PENINSULA [36]

The central and northern portions of Kenai Peninsula, which lie within the area here considered, and the adjacent portion of the same geologic province north of Turnagain Arm and in the vicinity of Port Wells are composed predominantly of a great series of Mesozoic rocks, chiefly slates, argillites, and graywackes, with very minor amounts of granitic materials and greenstones. In that region there are a large number of placer mines and prospects, and many lode prospects on both gold and copper deposits, though only a small number of mines are producing metal from the lodes. Placer mines recover gold that has been concentrated in the stream beds from some bedrock source, and their relation to the rock formations is purely accidental after the metal particles have been delivered to the streams. If the prospector can learn the relation of the gold veins to their country rock, however, he is aided by both in the search for the original veins, and for the stream placers derived from them.

Gold lodes.—A study of the accompanying geologic maps shows a striking relation between the type of country rock and the type of the ore deposits in this area. The greatest number of lodes are gold

[36] Johnson, B. L., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 113–208, 1915. Tuck, Ralph, The Moose Pass-Hope district, Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 849–I, pp. 469–527, 1933. Park, C. F., Jr., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849–G, pp. 381–424, 1933.

lodes, and they occur almost entirely in areas in which the country rock is the slate and graywacke that predominates in this region.

The veins are generally of small size and irregular shape and may either cut across the structure of the enclosing rocks or lie parallel to their bedding planes. Many of them are genetically related to dikes or stocks of acidic intrusive rocks, and this relationship is probably true of other lodes in which it has not been demonstrated. The most common type of vein has a gangue that is mainly quartz but carries also some calcite. The commonest metallic minerals are native gold, arsenopyrite, galena, sphalerite, pyrite, chalcopyrite, and more rarely molybdenite and pyrrhotite. Free gold occurs in the quartz in many of these veins and in many places is closely associated with galena and sphalerite, minerals that usually indicate a favorable gold content. Silver occurs in all the veins, but most of it is alloyed with the gold, though some probably occurs with the galena. In general the metallic minerals form only a small percentage of the total vein material. In places the ore is very rich and yields fine specimens, but in even the better veins the gold content is irregularly distributed, and the yield from all the gold lodes of the region together has so far not been large.

In the Port Wells district one gold lode mine, the Granite mine, that has yielded a considerable production lies entirely within a small intrusive mass of granitic rock.

Gold placers.—The gold placers of the Kenai Peninsula-Turnagain Arm region are the result of the erosion and concentration by streams of the gold from the lodes, and their ultimate origin is therefore the same. The occurrence of placer gold, however, depends on physiographic processes, most important of which is long-continued erosion and stream concentration into a single restricted channel of the gold particles contained in the rock debris removed.

In this region normal stream erosion was long and perhaps frequently interrupted by the invasion of glacial ice. Probably much richer and more widespread placer deposits existed here in preglacial time, but these were in great part removed and scattered by the glacial ice. It is only in especially favorable localities that workable placers now exist, either in places that by chance escaped severe glacial scour or in places where postglacial concentration either of gold from the lodes or of gold contained in the glacial deposits has been especially rapid. It is only by close and intelligent prospecting that such places are likely to be discovered.

The exploited gold placer ground on Kenai Peninsula has been confined almost entirely to Resurrection and Sixmile Creeks and their tributaries, an area that has been continuously productive for over 40 years. North of Turnagain Arm the valley of Crow Creek, a tributary of Glacier Creek, has yielded in the aggregate a considerable placer-gold production.

Copper lodes.—The geologic relations of the lodes that are chiefly valuable for their copper content are strikingly different from those of the gold lodes. They occur either entirely in areas of greenstone or in sediments near such greenstone masses. The principal copper-bearing areas lie on the islands at the southwest side of Prince William Sound and on the east side of the entrance to Resurrection Bay. The area on the east side of Resurrection Bay has not been actively mined, though copper prospects have been found there. The rather meager information that is available concerning those prospects,[37] most of which have long been inactive, indicates that the copper occurs in veins in basic igneous rocks, particularly in flows of ellipsoidal greenstone. The veins occur as shear zones, as brecciated zones in which there has been little shearing, and as brecciated zones parallel with the enclosing greenstone flows. The copper-bearing mineral in these deposits is chiefly chalcopyrite, associated with pyrite and pyrrhotite. Locally at or near the surface the chalcopyrite has been altered to the carbonates malachite and azurite.

A copper-bearing district of considerable importance is found on the islands of southeastern Prince William Sound, though no active mining was being done there in 1937. The geologic conditions in that area have been described by Bateman[38] and summarized by Moffit.[39] The Beatson mine of the Kennecott Copper Corporation, at Latouche, was actively operated on a large scale for many years and produced a notable output of copper. The mine was abandoned when ore of commercial grade was exhausted. The country rock in the vicinity of the ore body consists of slate and graywacke, with which are associated a green chloritic schist and a flinty alteration product. The ore body itself occurred as a thick lenticular mass about 1,000 by 400 feet, in maximum dimensions, which lay on the footwall of a pronounced fault zone. The ore consisted of veinlets and disseminated sulphides scattered through the fault zone and in the adjacent country rock. The principal mineral of value was chalcopyrite, which in addition to copper carried also a little silver. Pyrite and pyrrhotite were also abundant.

On the islands of southwestern Prince William Sound several bodies of sulphides carrying a small percentage of copper have been actively prospected, but no mining has been done on them. Most of

---

[37] Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 236–37, 1913.

[38] Bateman, A. M., Geology of the Beatson copper mine, Alaska: Econ. Geology, vol. 19, no. 4, pp. 338–368, 1924.

[39] Moffit, F. H., The occurrence of copper on Prince William Sound, U. S. Geol. Survey Bull. 773, pp. 141–158, 1925.

them lie entirely in country rock of basic lava flows, commonly known as greenstones, and in practically all of this area the copper deposits are more or less closely related to bodies of basic igneous rocks.

TALKEETNA REGION

The Talkeetna Mountain region as the term is here used embraces all of the area that lies between the Matanuska River and the Alaska Range in the railroad belt. In that area there is one active gold lode mining camp, the Willow Creek district; one district in which there are numerous copper prospects, the Iron Creek district; an important coal field in the Matanuska Valley; several relatively small gold placer camps, including the Nelchina district and Gold Creek, a tributary of the Susitna River near the mouth of the Indian River; and numerous scattered prospects including lodes bearing gold, silver, copper, and antimony and gold placer claims. The Matanuska coal field is described in a separate section of this report dealing with the coal resources of the region.

GOLD LODES

The gold lodes of the Willow Creek district constitute by far the most important mining center of the Talkeetna region, and the production of lode gold from this camp exceeds that of all the other lode mines of the entire region here described. The most complete descriptions of the geology of the district and of the character and geologic associations of the veins are those by Capps[40] and Ray.[41]

The essential geologic elements of the Willow Creek district are an ancient mica schist, in probable fault contact with a massive intrusion of quartz diorite of Mesozoic age, which is in part overlain by early Tertiary sedimentary rocks, including arkose, arkosic conglomerate, and a series of coal-bearing sandstones and shales. Glacial morainic material and still younger stream gravel partly fill the valleys to varying depths.

The productive gold-bearing veins of the district, with a single exception occur in the quartz diorite. This diorite, which forms the greater part of the Talkeetna Mountains, is cut by dikes of various sorts, and flow structure in it and the position of its margin along a fault suggest that the ore deposits are largely confined to a zone around the border of the intrusive mass. All the producing mines and most of the promising prospects lie within a zone that is some 8 miles long and that extends in a northeasterly direction across the quartz diorite mass. The fractures in which the veins occur are shear

[40] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 55–60, 1915.

[41] Ray, J. C., The Willow Creek gold lode district, Alaska: U. S. Geol. Survey Bull. 849–C, pp. 165–230, 1933.

zones produced by tension. Many of the producing veins coincide with a northwestward-dipping set of joints. Postmineral faults cut the veins and have an important bearing on the economic development of the district, as they displace many valuable ore shoots, and the locating of the offset portions involves uncertainty and expense.

Four distinct types of veins have been recognized in the district, but all the productive veins were deposited under conditions of medium temperature (mesothermal veins). These veins attain a maximum thickness of 14 feet and have undergone reopening and movement during and since the several periods of quartz deposition. The average tenor of the ore that has been mined in the district is high. The larger mines have operated for long periods on ore of an average gold content of $30 to $60 or more to the ton. Most of the ore so far extracted has come from shallow depths and has been recovered by overhead stoping from adit tunnels, but there is reason to believe that ore of the character of that so far mined will continue to depths much greater than have yet been reached.

The principal producing mines in 1936 were the Lucky Shot and War Baby mines of the Willow Creek Mines, Ltd., on Craigie Creek, and the Fern mine, on Archangel Creek.

GOLD PLACERS

Willow Creek district.—The first mining in the Willow Creek district was done in 1897, when placer gold was found in Grubstake Gulch and on Willow Creek near the mouth of Grubstake Gulch. For several years that ground was mined profitably by hydraulic methods, but the best of it was soon worked out, and for many years the placer output of this camp has been insignificant. An interesting fact in this connection is that this, the only productive placer ground in the district, lies in a valley cut into the ancient mica schist, whereas most of the gold produced in the district has come from veins that lie entirely in the quartz diorite. Some small gold-bearing quartz veins have been found in the schist, and one or two attempts have been made to mine them, but up to the present time no successful lode mine has been found in this district except in the diorite.

Nelchina district.—A gold stampede of some magnitude took place in the fall of 1913 and the spring of 1914 into the headwaters area of the Little Nelchina River, a tributary of the Copper River, by way of the Tazlina River, which drains the southeastern portion of the Talkeetna Mountains, and resulted in a large amount of prospecting there. The results of this prospecting were disappointing, for although it was found that gold could be washed from nearly every stream in the district, it was present in encouraging amounts only in a small area on Tyone Creek and the Oshetna River, tributaries of the Little Nelchina, and even on those streams there was no well-defined and profitable pay streak.

Chapin,[42] who studied this region, expressed the opinion that the gold of the stream deposits has been concentrated from older gravel, derived from many sources and containing an abundance of rocks foreign to this region, which had evidently been moved a great distance. The bedrock source of the placer gold is therefore unknown, as are its geologic relations. The total amount of gold recovered from the gravel of the Nelchina district has been small, and only a few individuals are now engaged in mining there.

Gold Creek.—Placer mining in a small way has been done at intervals for many years on Gold Creek, a westward-flowing stream that joins the Susitna River some 2 miles below the mouth of the Indian River. This district has not been examined by a geologist, but it is known that the bedrock consists mainly of black slate and graywacke of probable Mesozoic age, cut by granitic rocks. The placer production of the Gold Creek Basin has so far been small.

Susitna Valley.—Since the earliest prospectors penetrated this region it has been known that gold is present nearly everywhere in the stream gravel of the Susitna River, though generally in quantities far too small to justify mining. At some places, however, exceptionally favorable combinations of gold supply, direction of the stream currents, and character of the alluvium have resulted in small shallow patches of bar gravel from which the gold may be recovered at a profit. This "bar sniping," as it is often termed by the miners, is usually done by small parties of keen prospectors who, having discovered such a favorable place, mine it out without the expense of elaborate or permanent equipment and move on in search of other placer fields. Such bars have been found near the mouth of Gold Creek and near Curry, but their aggregate production has been small. The sources of this bar gold and of the small quantities of gold that are found generally in the stream gravel of the Susitna River are distributed throughout the basin of that river itself. The gold no doubt is in part contributed to the stream gravel by such gold lodes as are now undergoing erosion, but the bulk of it has been concentrated from the glacial deposits of the valley, for those deposits contain the placer gold and the detritus swept from the stream beds by the great glaciers during the last great ice invasion of this region. It is likely that in late Tertiary time there were considerable gold placer deposits in many places in this region, but those placer concentrations were for the most part dispersed by glacial erosion

[42] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, p. 60, 1918.

and the gold scattered far and wide. In few places has a sufficient concentration of this scattered gold occurred since the retreat of the glaciers to afford well-defined and continuous pay streaks.

COPPER LODES

There are copper-bearing lodes at several places in the Talkeetna region, but so far there has been no production from them. Little interest was taken in the search for copper until the beginning of construction on the Government railroad, for all parts of the Talkeetna region were so remote that there was little possibility of profitably mining any ore that required smelting for its reduction and therefore good transportation. With the beginning and progress of railroad building, however, interest in the search for copper increased. In one copper district on Iron Creek many claims were staked some 20 years ago, but no property was developed to the producing stage.

Iron Creek district.—Iron Creek is a tributary of the Talkeetna River, which it joins from the southwest some 30 miles above its mouth. A brief history of mining developments there up to 1917 and of the geologic relations of the ore bodies is given by Capps.[43] The copper prospects all occur in a belt of andesite greenstones, some of which are amygdular lava flows and some are coarser-grained rocks that are probably intrusive. Many of the copper prospects show abundant copper carbonates and bornite near the surface as oxidation products, but beneath a shallow zone only a few feet thick the original minerals are pyrite, arsenopyrite, chalcopyrite, specular hematite, and quartz. The ores occur as vein fillings along shear zones or replace the sheared greenstone. Some assays show a gold content of several dollars to the ton. No active prospecting or development work has been done in the Iron Creek district in recent years, most of the claims having been abandoned.

Moose Creek.—A single group of claims has been staked on a copper-bearing lode on Moose Creek, a stream that flows southward from the Talkeetna Mountains to join the Matanuska River about 10 miles northeast of the town of Matanuska. This property was examined in 1917 by Capps,[44] who reported that the prospect lies on the west side of Moose Creek, near the divide between that stream and Little Susitna River, at an altitude of about 3,800 feet, 1,600 feet above Moose Creek. The bedrock is a gneissic phase of the great intrusive diorite mass of the Talkeetna Mountains. The ore body is conspicuous on account of a rusty-red gossan and has replaced the gneissic diorite by massive sulphides, chiefly pyrrhotite, pyrite, and chalco-

---

[43] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 189–205, 1919.

[44] Capps, S. R., Gold lode mining in the Willow Creek district: U. S. Geol. Survey Bull. 692, pp. 183–184, 1919.

pyrite. Sphalerite is also reported, and assays are said to show the presence of both gold and silver and some nickel. Each of the three principal sulphides—pyrite, pyrrhotite, and chalcopyrite—occurs in places in large, nearly pure aggregates, but more commonly the three are intermingled. So far as is known no important development work has been done on this property in recent years.

Other copper prospects.—Copper-bearing lodes have been staked in the valleys of Montana Creek and the Kashwitna River, two adjacent westward-flowing tributaries of the Susitna River from the Talkeetna Mountains. Little information has been obtained about these prospects, but both lie within an area in which the prevailing country rock is diorite. Samples reported to have been taken from the prospect in the Kashwitna Basin consist of nearly pure bornite, said to contain also specks of visible free gold.

Upper Susitna Basin.—Copper-bearing lodes have been reported by prospectors at several localities on tributaries of the Susitna from the north above Indian Creek. These prospects have not been examined by a geologist, and their geologic setting is not known.

ANTIMONY LODES

A lode valued principally for its antimony content was staked several years ago on Antimony Creek, a small tributary of the East Fork of the Chulitna near the junction with the West Fork. It has been described by Capps [45] as a vein cutting argillite and graywacke, with lenses or kidneys of stibnite within and parallel to the vein. The antimony occurs both as finely granular stibnite and as a mixture of granular stibnite with acicular crystals. Some specimens show a considerable admixture of granular quartz through the stibnite, but much of the ore is massive stibnite almost entirely free from other constituents. There has been no commercial production from this property.

SILVER LODES

Considerable interest has been attracted by a silver prospect of unusual type, called by the owner the Mint mine, that lies on Portage Creek 9 miles east of Chulitna station on the Alaska Railroad. This property has been described by Capps and Short.[46] The bedrock consists of black slate, probably of Mesozoic age, that is cut by altered acidic dikes that are andesitic in character and that are believed to have caused the mineralization. The ore is a mixture of sulphides, among which the ruby silver minerals pyrargyrite and

[45] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 229–230, 1919.

[46] Capps, S. R., and Short, M. N. A ruby silver prospect in Alaska: U. S. Geol. Survey Bull. 783, pp. 89–95, 1926.

miargyrite carry the silver. Arsenopyrite, chalcopyrite, galena, pyrite, and probably tennantite are also present. The ore occurs mainly in a slate breccia along both sides of the dike and in cracks and joints in the dike itself, the sulphides appearing in a gangue of quartz. Underground exploration on this lode failed to disclose ore of profitable tenor, and there has been no commercial production from the property.

ALASKA RANGE

YENTNA DISTRICT

Gold lodes.—The southernmost gold camp of importance in that portion of the Alaska Range that lies within the railroad belt is the Yentna district, containing the placer mines of the Cache Creek district, the Mills Creek-Twin Creek district, and the Kichatna district. No lode deposit in the Yentna district has been brought to a productive stage, though a few gold-bearing quartz veins have been found in the Cache Creek Basin and some development work has been done on some of them. The origin and geologic relations of the gold are discussed more fully below in connection with the description of the gold placers, and it is enough to state here that the bedrock source of the gold is believed to be the quartz veins that cut the slates and graywackes, of probable Mesozoic age, in the neighborhood of granitic intrusive masses and their associated dikes. No gold lodes of proved value have been found in either the Mills Creek-Twin Creek district or the Kichatna district.

Gold placers.—The gold placers of the Yentna district may be divided into two distinct geographic groups—those in the vicinity of Cache Creek and those of the Mills Creek-Twin Creek district. The origin, distribution, and genesis of the placer gold, and of the gold-bearing gravel in the Cache Creek district have been rather fully described by Capps [47] and Mertie.[48]

The placer deposits so far mined include the gravel of the present streams; various types of terrace or bench gravel; unassorted or little-assorted glacial morainal deposits; and early Tertiary residual placer concentrations. Most of the production, however, has come from the present stream gravel and from low benches or terraces.

The gold of all the placers of the district is believed to have been derived from quartz veins that cut the prevailing Mesozoic slate and

---

[47] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 48–51, 1913; An early Tertiary placer deposit in the Yentna district: U. S. Geol. Survey Bull. 773, pp. 53–61, 1925.

[48] Mertie, J. B., Jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 233–264, 1919.

graywacke bedrock of the district, the quartz veins being genetically related to nearby granitic intrusive masses and to the dikes and sills that are offshoots from those intrusives. The history of the concentration of the gold from that source into the present workable placer deposits is, however, very complex. Normal erosion of the bedrock and the quartz veins since the retreat of the last great glaciers has in most places been of too small amount to accomplish a workable concentration of placer gold, as is shown by the scarcity of paying ground in those valleys in which the glaciers scoured down to the slate and graywacke bedrock. The bedrock at most of the placer mines is composed of the Tertiary (Eocene) series of coal-bearing sandstones and shales. At the base of that series there is a great accumulation of angular and partly rounded quartz fragments and pebbles that lie on a deeply decomposed surface of the slates and graywackes. This quartzose basal portion of the Tertiary series has been shown to carry gold in minable amounts at several places. It is the writer's opinion that in late Mesozoic or early Tertiary time this district was subjected to a long period of erosion and weathering, with the breaking down of the Mesozoic sedimentary rocks and the release of the contained gold-bearing quartz veins. This quartz and gold accumulated on the surface and was incorporated into the earliest of the Tertiary sedimentary beds. These beds were later somewhat uptilted along the margins of the basins in which they occurred, and the basal beds were dissected by the streams that flowed from the hills of older rocks out into the Tertiary basins. During the Pleistocene epoch glaciers also occupied those valleys and incorporated the gold derived both from bedrock and from the basal beds into the debris they carried. In a few places the moraines formed from that debris are rich enough in gold to be mined.

Since the final retreat and disappearance of most of the Pleistocene glaciers from the basin of Cache Creek the streams have entrenched themselves into the easily eroded Tertiary beds, have removed a large volume of them, and have concentrated in their terraces and the present stream beds the gold that had earlier been contained in the basal Tertiary beds and in the morainal deposits.

Most of the placer mines in the Cache Creek district are operated by hydraulic methods. For many years a dredge was operated on Cache Creek, but it has now been dismantled. One property on Bird Creek has recently been equipped with a bulldozer and a dragline scraper. The total production of the district from its discovery in 1905 to 1936 has been nearly $3,000,000.

Within the past few years considerable placer platinum has been found associated with the placer gold in the Cache Creek district and the Kahiltna Valley. In the dredging operations on Cache Creek the platinum metals equaled 0.003 percent of the gold by weight,[49] whereas on Poorman Creek the percentage was somewhat higher. The platinum metals occur as small grains, most of them thin and flaky. There appear to be two kinds of these flakes, the more common of which is of dark-gray to bronzy color and probably carries the main content of platinum. The other variety consists of bright silvery grains, believed to be mainly iridosmium. No place has been found in this district where there was enough of the platinum metals to justify mining of them alone, but in a few places there is enough platinum to give hope that commercially valuable deposits of that metal may be found. So far the small amount produced has been recovered as a byproduct of placer-gold mining. No lodes containing those metals have been found, and their bedrock source is unknown, as is that of the tin mineral cassiterite and the tungsten mineral scheelite, which also occur in small quantities in the sluice-box concentrates.

Placer mining in the Mills Creek-Twin Creek area has been carried on intermittently for some 30 years, but on a small scale. Development has been retarded by the difficulty of bringing a water supply adequate for hydraulic mining to the most promising ground. Both Mills and Twin Creeks are small streams that flow through valleys eroded entirely into gravel and sand of Tertiary age, so that there is no apparent bedrock source for the gold in the stream gravel, and it must have been derived by the reconcentration by these streams of small amounts of gold dispersed through the Tertiary deposits.

CHULITNA REGION

Lode deposits.—The first prospecting in the basin of the Chulitna River of which there is any record was the result of the discovery of placer gold in the Valdez Creek district, to the east. It is reported that placer claims were staked in 1907 on Bryn Mawr Creek, a small tributary of the West Fork of the Chulitna River from the south, and that a small amount of placer gold was mined on this creek in 1907. This is the only gold-placer mining that has been done in the Chulitna district, but it resulted in the prospecting for and discovery of gold-bearing lodes. Several lodes were staked in the years 1909 to 1912, and some of these have been held continuously since that time. The district experienced a mild boom in 1915, when construction began on the Government railroad, for it was then realized that this area would soon be made accessible to rail transportation, but most of the claims

[49] Mertie, J. B., Jr., op. cit. (Bull. 692), pp. 246, 268.

staked at that time were later abandoned. Developments in the camp in 1917 were described by Capps,[50] and those in 1931 by Ross.[51] The bedrock of the district includes a wide variety of materials, among which are ancient chloritic rocks containing silicified limestone; tuff, lava, limestone, chert, and argillite of Permian (?) age; Triassic limestone, argillite, pyroclastic rocks, and lava; later Mesozoic argillite, slate, and graywacke; Cretaceous sandstone, shale, and conglomerate; and Tertiary sandstone, shale, and coal. All the rocks older than the Tertiary are cut by bosses, dikes, and sills of silicic porphyritic material.

Most of the lodes that have been staked from time to time are valued for their gold and silver content, but others have been staked as valuable mainly for copper or antimony, and many contain copper, lead, and zinc.

The lodes of the district are all genetically related to the porphyritic intrusive masses and their associated dikes, the metallic content of any particular lode having been determined by the chemical and physical character of the country rock and the distance from some intrusive body. Apparently the most promising ore body of the district is that known as the Golden Zone, now actively under development. This lode is a large body of biotite-quartz diorite porphyry intruded into argillite and breccias. Most of this stock is discolored through the oxidation of pyrite, which is disseminated through it. Locally the altered porphyry has been greatly fractured, and quartz stringers and sulphides are most abundant in such areas. Assays of this material range from a trace of gold and a fraction of an ounce of silver to the ton to 2 ounces or more of gold, and 4 to 8 ounces of silver. Development work was in progress in 1936 to determine the amount and grade of ore present, and plans were maturing for the installation of a power plant and mill.

No active developments were under way in 1936 on any of the other lodes of the district, and there has been no production from any of them.

In past years considerable prospecting for lodes has been done on Ohio Creek, the Hidden River, and other eastward-flowing tributaries of the Chulitna River.[52] Lodes carrying gold, silver, lead, and zinc have been staked, but no recent active development work has been done on any of them, and there has been no commercial production.

---

[50] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 207–232, 1919.

[51] Ross, C. P., Mineral deposits near the West Fork of the Chulitna River: U. S. Geol. Survey Bull. 849–E, pp. 289–334, 1933.

[52] Tuck, Ralph, The Curry district: U. S. Geol. Survey Bull. 857, pp. 99–140, 1934.

VALDEZ CREEK DISTRICT

Gold placers.—Placer mining has been conducted with varying degrees of activity in the Valdez Creek district since 1904. Valdez Creek is a tributary of the Susitna River from the east, joining that stream some 20 miles below the terminus of the glacier in which the Susitna River heads. The general geology of the region in which Valdez Creek lies has been described by Moffit,[53] as well as the mining developments that had taken place at the time of his visit, in 1913. More recently the progress of both placer mining and lode prospecting up to 1931, has been described by Ross,[54] and up to 1936 by Tuck.[55] The bedrock of the district in which the mines and prospects occur includes Triassic greenstone, limestone, schist, tuff, and argillite, all of which are cut by stocks of diorite or diorite gneiss, and coal-bearing Tertiary beds that are younger than the intrusive masses and the metal-bearing veins. Overlying the hard rocks are glacial morainal material, terrace gravel, and the deposits of the present streams.

The earliest placer mining in this district was in the stream gravel of Valdez Creek. In following the pay streak upstream, its tenor was found to decrease abruptly, and prospecting disclosed the fact that the gold had been supplied to the stream by its erosion of an old, buried stream channel. For many years the pay gravel in this old channel was mined by drifting and stoping to a distance of 1,000 feet from the gorge of Valdez Creek. In later years the old valley filling left by the drift mining was removed by hydraulic methods, leaving a great cut over 1,000 feet long and 80 to 100 feet or more deep. At the present time open-cut mining on this channel has been abandoned and drift mining renewed. It is estimated that this old channel has yielded well over $400,000 in placer gold.

Gold lodes.—There has been considerable activity in prospecting gold lodes in the Valdez Creek district in recent years, and many claims have been staked. Practically all the lodes on which development work has been done are valued mainly for their gold content. Some of these lodes show promise of developing into mines, but so far there has been no commercial production from any of them.

BONNIFIELD REGION

Gold placers.—The northward-draining portion of the Alaska Range from the Nenana River eastward to the Delta River has long been known as the Bonnifield region. In that area placer mining has

[53] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 80, 1915.

[54] Ross, C. P., The Valdez Creek mining district, Alaska: U. S. Geol. Survey Bull. 849–H, pp. 425–468, 1933.

[55] Tuck, Ralph, The Valdez Creek mining district in 1936: U. S. Geol. Survey Bull. 897–B (in press).

been carried on at a number of localities for more than 30 years. The bedrock geology of the region is diverse,[56] the principal types of rock including very ancient mica schists, the Birch Creek schist; somewhat younger but still highly metamorphosed lavas and sedimentary rocks, the Totatlanika schist; a great series of only moderately altered conglomerates, sandstones, and shales, the Cantwell formation; Tertiary coal-bearing sandstones and shales; later Tertiary gravel deposits, the Nenana gravel; and the still younger glacial morainal deposits, terrace gravel, and the deposits of the present streams. The older metamorphic rocks and locally the Cantwell rocks are cut here and there by granitic intrusive stocks and by related dikes and sills. The bedrock source of the placer gold is not certainly known, but it was probably derived from gold-bearing quartz veins that cut the older schistose rocks. From that source it was removed by erosion and sparsely distributed through the sedimentary beds of the Tertiary formations. The present placer concentrations are the product of reconcentration by the present streams of the gold distributed through the Tertiary deposits and the terrace gravel.

All the placer mining that has been done in this region has been carried on as small operations with simple equipment. No rich, long, and continuous pay streaks have been found, and the total placer production through more than 30 years of mining has not greatly exceeded $500,000.

Gold lodes.—Prospecting for gold lodes in the Bonnifield region has been carried on since the earliest discovery of placer gold there,[57] though the scarcity of promising lodes has been somewhat discouraging. Lodes of various types have been staked from time to time, but on most of them developments have been confined to little more than shallow surface openings. Most of the lodes are quartz veins that occur either in the altered sedimentary and volcanic rocks of the Totatlanika schist or in the Birch Creek schist. Granitic intrusive stocks, dikes, and sills are prevalent in these metamorphic rocks, and the mineralized lodes are presumed to be genetically related to them.

The only gold lode in the region on which systematic development and mining have been done is the property on Eva Creek known as the Liberty Bell mine of the Eva Creek Mining Co.[58]

---

[56] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 64, 1912. Maddren, A. G., Gold placers near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 363–402, 1918.

[57] Capps, S. R., op. cit. (Bull. 501), pp. 52–54. Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351–362, 1918. Moffit, F. H., Mining development in the Tatlanika and Totatlanika Basins: U. S. Geol. Survey Bull. 836, pp. 339–345, 1933.

[58] Moffit, F. H., op. cit., pp. 339–345.

This lode consists of lenses and stringers of sulphides with some quartz lying along the foliation planes of the schist country rock, and of disseminated sulphides scattered through the schist, in the neighborhood of granite porphyry intrusives. The schists in the ore body lie nearly horizontal and are highly sericitized and altered. The principal metallic minerals in the lode are arsenopyrite and pyrite, with a little chalcopyrite. In 1931 and 1932 a mill was built on this property and active mining commenced, but mining difficulties were encountered, the gold recovery was less than had been anticipated, and the venture was abandoned.

A few carloads of lead-silver ore has been produced from a lode on California Creek, a tributary of the Totatlanika, but no description of the lode or its geologic associations is available.

KANTISHNA REGION

The Kantishna region, as the term has commonly been used, embraces all of the north slope of the Alaska Range from the Nenana River westward to and including the headward basin of the Kantishna River. The principal tributaries of the Kantishna are the McKinley Fork, the Bearpaw, and the Toklat, with their various branches. The Teklanika River, in the eastern part of the Kantishna region, flows from the high mountains directly to the Tanana.

Most of the Mount McKinley National Park falls within the Kantishna region as thus defined. For many years during the early period of mining in this district the Kantishna diggings were remote from the ordinary routes of travel, and communication was difficult and infrequent and was maintained mainly by dog sled to Fairbanks in the winter. With the completion of the Alaska Railroad through the valley of the Nenana River this condition was greatly improved, and more recently the construction of a fine highway from the railroad through the park to Wonder Lake has brought the camp within a few hours' travel of the railroad during the open season.

A description of the geology of this great area would be a repetition of most of that part of this report that deals with the geology of the Alaska Range. The geology and mineral deposits of this region have been described from time to time by various authors, to whose reports the reader is referred for detailed descriptions.[59]

Gold placers.—Active placer mining in the Kantishna district has been limited almost entirely to a small area in the Kantishna Hills, where the geology is relatively simple.

---

[59] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 116 pp., 1919. Moffit, F. H., The Kantishna district: U. S. Geol. Survey Bull. 836, pp. 301–338, 1933. Wells, F. G., Lode deposits of Eureka and vicinity, Kantishna district, Alaska: U. S. Geol. Survey Bull. 849–F, pp. 335–379, 1933.

Moore and Caribou Creeks and the productive tributaries of Stony Creek all head in a group of mountains in which the bedrock is the ancient Birch Creek schist, and the placer gold has been derived by the erosion of that schist and its enclosed quartz veins. Locally there are remnants of the Tertiary coal-bearing formation. Most of the gold has been recovered from the gravel of the present streams, though some mining of low terraces has been done. Much of the gold is rough and little worn, giving evidence that it has travelled only a short distance from its bedrock source. Mining has been conducted in small units of a few men each, using simple equipment. No large-scale mining with mechanical equipment has been attempted. The total placer production of the camp in more than 30 years of mining has been about $500,000, and the richest ground is about exhausted. The future of this area as a placer-mining district will depend upon the possibility of large-scale mechanized mining of gravel of too low gold content to be profitably mined by hand methods.

Lode mines.—Lodes bearing a variety of metals and occurring under diverse geologic conditions have been staked in the Kantishna district, and some mining of them has been done. Considerable prospecting by open cuts and adit tunnels has been done on gold-bearing quartz veins that cut the Birch Creek schist, but no gold lode mine has been developed to the producing stage.[60] It is believed that the mineralization was due to the influence of intrusive rocks that cut the schist. Several years ago some 1,400 tons of picked ore was mined from several different claims on the ridge between Friday and Eureka Creeks and yielded well over $200,000 in silver, lead, and gold. No ore has been mined from those claims recently.

Another lode in the schist that has attracted considerable attention is the antimony lode on Stampede Creek. Too little work had been done on this property at the time it was visited by the Survey geologists to disclose its size or shape, but it appeared to be a large lens of nearly pure stibnite, containing only minor amounts of the precious metals. Active mining on this lode was commenced in the fall and winter of 1936, and ore was being shipped by sled to the railroad.

A group of claims on lode deposits on Mount Eielson[61] has been held for many years, and open cuts and adit tunnels have been made. The bedrock is composed of limestone, calcareous shale, and gray-

[60] Capps, S. R., op. cit. (Bull. 687), pp. 99–106. Moffit, F. H., op. cit. (Bull. 836), pp. 325–335. Wells, F. G., op. cit. (Bull. 849–F), pp. 335–379.

[61] Reed, J. C., The Mount Eielson district, Alaska: U. S. Geol. Survey Bull. 849–D, pp. 231–286, 1933.

wacke of probable Devonian age, cut by stocks, dikes, and sills of granodiorite. The lodes are replacement deposits, in which the principal metallic minerals are sphalerite, galena, chalcopyrite, and pyrite, the sphalerite being much the most abundant. The ore also contains small amounts of silver. No commercial mining has been done on these lodes.

West of Muldrow Glacier and on the north flank of the Alaska Range lodes that are valuable for their content of gold, silver, copper, or antimony have been staked.[62] These lodes occur in a belt of sedimentary rocks that are cut by many dikes and sills of light-colored granitic rock. Some of the lodes are reported to form very large ore bodies of low to moderate grade. Preparations were under way in the fall of 1936 to carry out extensive exploration of one of them in the hope that ore of minable grade would be blocked out.

FAIRBANKS DISTRICT

The Fairbanks district is one of the major gold-mining camps of the continent. Its history includes the events common to so many gold-mining districts—a stampede of historic proportions in the early days of discovery of rich placer gravel; a large production from those placers during the days of bonanza placer mining; the gradual decline of production as the richest and most easily exploited gravel was mined out; the slower prospecting, discovery, and development of the gold lodes; and the consolidation of many placer claims no longer profitable under the old methods of mining and their development and exploitation by more elaborate mechanical equipment. The latest phase, in which the Fairbanks district now finds itself, is less spectacular than the exciting times of sudden changes in individual fortunes, but it assures a long life of rather steady production to the camp and the mining of vast quantities of gravel of moderate gold content at low cost. The lode mining of the district has probably not yet reached its peak. Difficult conditions of prospecting have delayed the discovery of many lodes not yet found, and it is to be expected that the production of lode gold will continue for many years, probably on an increasing scale. Up to the end of 1936 the Fairbanks district had produced over $104,000,000 in placer gold and over nearly $3,700,000 in lode gold. There is reason to believe that the district will produce more gold in the future than has so far been mined.

The bedrock of the Fairbanks district consists exclusively of the various types of schist that make up the Birch Creek schist, of pre-Cambrian age, and of intrusive acidic igneous rocks that cut it. The granitic intrusive rocks are of Mesozoic age and are believed to have

[62] Moffit, F. H., op. cit. (Bull. 836), pp. 319–325.

introduced the gold-bearing quartz veins into the schist, and thus indirectly the gold placer deposits. The geology of the district and the gold placer and lode deposits have been studied and described by several geologists of the Geological Survey,[63] and their descriptions will not be repeated here.

Gold placers.—The history of the formation of the placer deposits of the Fairbanks district is complex, and much still remains to be learned about it. The placer deposits may be roughly divided into two general types—the gravel deposits of the present streams, now in process of formation by the concentration of gold derived from the veins in the schist bedrock, and the more ancient, deeply buried placer deposits, laid down under conditions different from those of today. Even this division is somewhat arbitrary, for the present stream placers pass imperceptibly under a thickening cover, to merge into the deeply buried gravel. The placers of the present streams are easily understood, for in this unglaciated area normal erosion has long been in progress, probably since late Tertiary time, and the gold from the veins that cut the schist was left behind in the stream beds as the lighter and more fragile enclosing rock was removed. The deeper placer deposits, however, are much less simple. Their burial was probably brought about by a combination of causes that included crustal warping and the raising of the baselevel of erosion of the Tanana River, the controlling stream, by a filling of glacial outwash gravel from the Alaska Range. Elements in the problem also include the permanently frozen condition of the ground; the introduction into the valley fill of lenses, dikes, and sills of ice; and the accumulation of great quantities of wind-blown material from the outwash plains of the glacial streams. The relative importance of these and other factors has not yet been adequately weighed.

Whatever may have been the reasons for the burial of the old placer deposits, the fact remains that an unusual condition now exists in this region. Many of the streams are now flowing on the surface of a valley fill which ranges from a few feet to 200 feet or more in thickness and much of which is permanently frozen. A typical section in this area shows a sluggish stream flowing in a mud channel through a swampy valley floor. A boring into the valley fill may penetrate as much as 100 feet or more of frozen "muck," a black deposit of fine, silty inorganic material commingled with much plant detritus and the remains of extinct mammals. Many recurrent zones show a series of old surfaces on which moss and other plants grew,

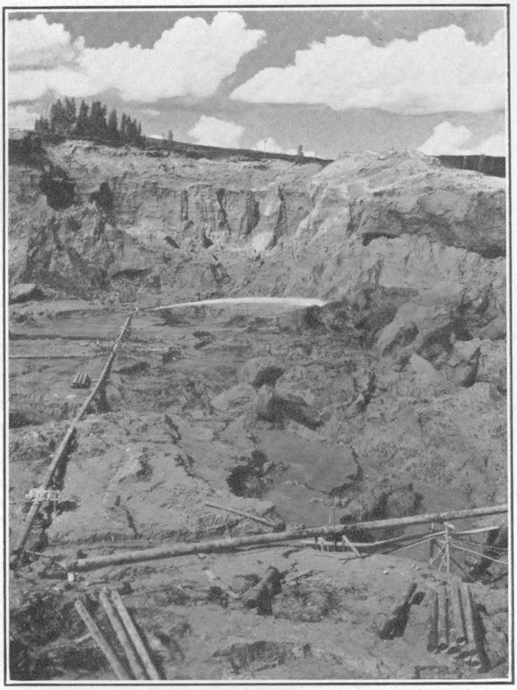
---

[63] Prindle, L. M., Katz, F. J., and Smith, P. S., A geologic reconnaissance of the Fairbanks quadrangle, Alaska : U. S. Geol. Survey Bull. 525, 220 pp., 1913. Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849-B, pp. 29-163, 1933. Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 276, 1937.

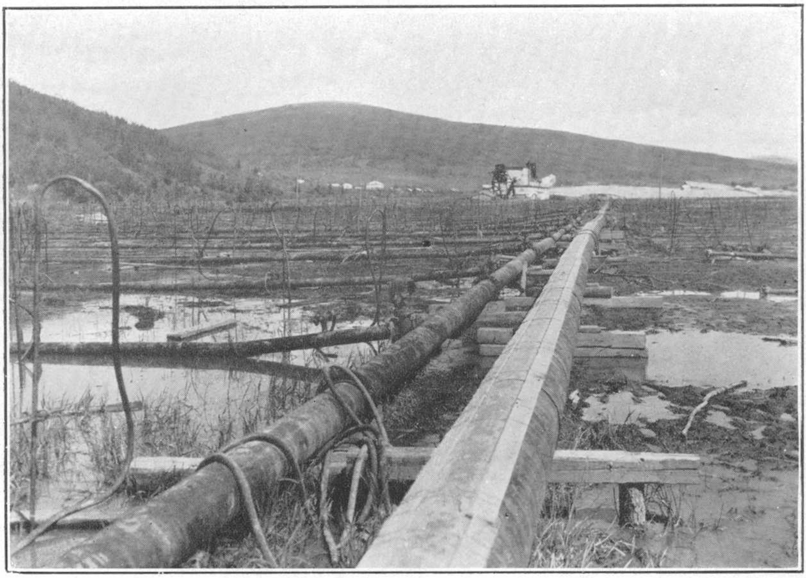
indicating that the muck accumulated as terrestrial deposits through a long period of years, and the moderate amount of decomposition of both plant and animal remains indicates that the level of ground frost rose as the muck thickened. The writer believes that a large proportion of the fine, silty inorganic material in the muck is windblown dust. Beneath the muck, gravel of varying thickness is encountered down to bedrock. In general this gravel contains a little placer gold throughout, but by far the greatest concentration of gold is found near, on, or in the crevices of the bedrock itself. Some of the gravel layers may be unfrozen, and if so, they made impossible the older method of drift mining from shafts sunk through the frozen-muck overburden. It is obvious that these deeply buried deposits of pay gravel were laid down at a time when the baselevels of erosion were at or near the present bedrock floors of the valleys. Crustal warping, filling of the master streams, or other causes have decreased the gradients of those old streams and allowed the accumulation in the valleys of a great thickness of gravel and muck above the old placer deposits. Modern mining methods (see pl. 8) involve the stripping and thawing of the muck by hydraulic methods and by atmospheric melting during the summer; the thawing of the underlying gravel by forcing water through hollow steel points down to the surface of the frozen layer and the intermittent driving of the points deeper as thawing progresses; and finally the removal and washing of the thawed gravel and its contained gold by means of gold dredges. A very large part of the present placer production of the district comes from the five dredges operated by a single company, though a few plants are operating by means of mechanical scrapers and hydraulic methods and a few drift mines are still found profitable. (See pl. 9, *B*.)

Gold lodes.—The lodes of the Fairbanks district have recently been described in some detail by Hill,[64] and his report supersedes the many preceding descriptions of lode-mining activity in that area. Most of the lode mining has been done on veins in which gold was the metal of principal value, though during the war period of high prices some tungsten (scheelite) concentrates were shipped, and at that time and later there was some production of antimony (stibnite) ore. The gold lodes are all fissure veins or lodes that cut various phases of the pre-Cambrian Birch Creek schist, and they are usually not far from some body of intrusive acidic igneous rock. Most of them are single veins from a few inches to 3 feet or more wide, though a few consist of lodes from 8 to 12 feet wide in which closely spaced quartz veinlets ramify through silicified schists. There are also present in the district several broad zones of silicified, sericitized

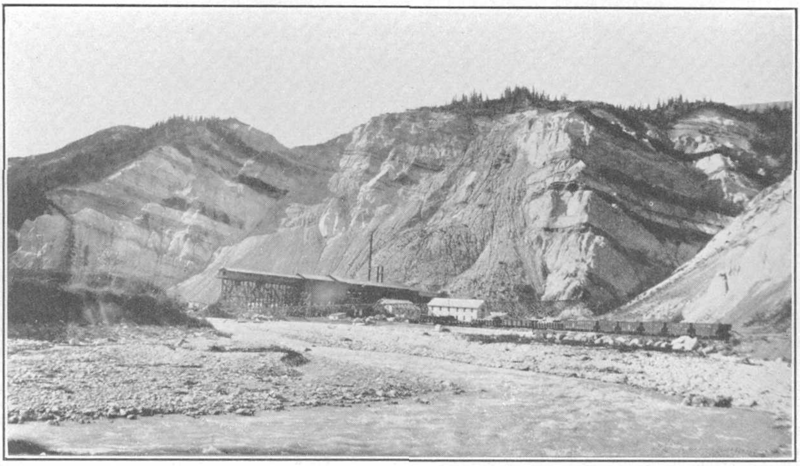
[64] Hill, J. M., Lode deposits of the Fairbanks district, Alaska: U. S. Geol. Survey Bull. 849-B, pp. 29-164, 1933.



A. STRIPPING "MUCK" OVERBURDEN ON CRIPPLE CREEK, FAIRBANKS DISTRICT.



B. THAWING FROZEN GROUND WITH COLD WATER IN PREPARATION FOR DREDGING ON GOLDSTREAM, FAIRBANKS DISTRICT.



A. THE SUNTRANA COAL MINE AND THE EOCENE COAL-BEARING SERIES, HEALY CREEK.

B. A GOLD DREDGE IN THE FAIRBANKS DISTRICT.

schist that carry some gold and that have been considered as possible low-grade gold lodes, though none of these have yet been mined. In the mining that has so far been done on the narrow fissure veins the expense of extracting the ore is high, and Hill gives figures to show that the average tenor of the ore mined up to 1930 was $27.44 a ton, calculated on the value of gold at $20.67 an ounce.

Antimony lodes.—The antimony lodes of the Fairbanks district, like the gold lodes, cut the Birch Creek schist and are related to nearby stocks or dikes of granitic intrusive rocks. Many of the lodes that are mined for gold contain some stibnite, and the antimony ore that was mined in former years carried some gold and silver. The district is the potential source of considerable antimony ore, but present prices for that metal and high mining and shipping costs prevent the exploitation of antimony mines, and no antimony ore is now being produced. Descriptions of the properties that have produced in the past are given by Hill [65] and Brooks.[66]

Tungsten lodes.—Under the stimulus of very high prices for tungsten during the World War several properties in the Fairbanks district that contained tungsten minerals were opened, and some tungsten concentrates were produced. Those lodes have been described by Mertie [67] and Hill.[68] The tungsten-bearing mineral scheelite occurs in disseminated deposits, in mineralized zones, and in quartz veins in silicified limestone or mica schist. Some of these ore bodies are obviously related to nearby acidic intrusive rocks, though in others that relationship is not established. Some of the tungsten-bearing veins carry gold also, but in the portions of the veins in which scheelite is most abundant the gold content is low. No scheelite lode is now being operated in this district, and there has been no production since the drop in the price of tungsten that followed the World War.

RAMPART DISTRICT

The Rampart district is one of the older placer-mining districts of the Yukon, gold having been discovered there as early as 1893. The bedrock source of the gold is believed to consist of quartz veins that cut the metamorphosed volcanic rocks and associated sedimentary beds. The various types of placer deposits in the district include the gravel of the present streams and terrace deposits of various ages, the oldest of which are thought to be late Tertiary. Although this camp has yielded nearly $1,500,000 in gold in the last 40 years, the richest ground was exhausted by 1909, and the production has now declined to a few thousand dollars a year.

---

[65] Hill, J. M., op. cit. (Bull. 849–B), pp. 156–157.

[66] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, 67 pp., 1916.

[67] Mertie, J. B., Jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 418–424, 1918.

[68] Hill, J. M., op. cit. (Bull. 849–B), pp. 157–159.

HOT SPRINGS DISTRICT

The Hot Springs mining district includes several smaller camps, among which are the placer mines of American Creek, of Sullivan and Cache Creeks, and of the northern tributaries of Baker Creek. The bedrock in this district includes slate, quartzite, and schist of Cretaceous age, cut by stocks of Tertiary granitic intrusive rocks. The placer gold is believed to have been derived from quartz veins that cut these rocks. No lode mining has been done in this district.

The placer deposits include the gravel of the present streams and certain older benches and deeply buried deposits of stream gravel that have little relation to the present drainage lines. These placer deposits have been described by Eakin,[69] Mertie,[70] and others. The district reached its peak of production in 1916, and then declined until 1931. Since that time, however, the increased price of gold and the greater use of mechanical equipment brought an increased interest in mining, and the value of the gold produced took an upward trend. It is probable that with the present gold price the life of this district will be considerably lengthened.

TOLOVANA DISTRICT

The placer mines of the Tolovana district are all on Livengood Creek or its tributaries from the south and east, or on tributaries of the Tolovana River that drain the ridge between that stream and Livengood Creek, the total productive area therefore being compact and small. These placer deposits have been described in some detail by Mertie,[71] who also attempts to explain the complex physiographic conditions under which the various types of placer deposits were laid down. The bedrock of the ridge from which the gold-bearing streams radiate is composed of Devonian and Carboniferous sedimentary rocks that include chert, silicified limestone, and carbonaceous shale, cut by granitic intrusives, and the gold is believed to have been derived from quartz veins that are related to the intrusive rocks.

Two general types of deposits are exploited. The bench placers on an old buried channel of Livengood Creek have an average depth of 80 feet, of which only the lower 10 to 15 feet is gravel and the rest is overburden composed of silt or muck with minor amounts of slide rock and of fine gravel and sand. The ground is permanently and solidly frozen, and the pay gravel is removed by drift mining. The other type of placer deposit includes the gravel of the present streams,

---

[69] Eakin, H. M., A geologic reconnaissance of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, p. 38, 1913.

[70] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 251–268.

[71] Mertie, J. B., Jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 221–278, 1918.

in which the pay gravel and bedrock lie at shallower depths, ranging from 4 or 5 feet to 25 feet or more. These deposits are for the most part mined by open-cut methods, though some drifting has been done on them.

The Tolovana district reached its peak of production in 1917, when the value of the gold output was over $1,000,000. Since that time the richest ground has been exhausted, and for the last 6 or 8 years the annual output has averaged about $100,000. The total production of this camp since mining began in 1915 has been nearly $6,000,000.

COAL RESOURCES OF THE RAILROAD REGION

The coal fields of the portion of Alaska served by the Alaska Railroad constitute one of the important mineral resources of the Territory, and the value of the coal produced in the railroad region is next to that of gold. Indeed, the present route of the railroad from the coast to interior Alaska was chosen largely because of the fact that it would open the Matanuska and Nenana coal fields to exploitation. At the time that the railroad was projected an important argument for its construction at Government expense was the great need for an American source on the Pacific coast of high-grade steaming coal for the Navy, which at that time was powered mainly by coal-burning boilers. It happened, however, that between the time that the Alaska Railroad was planned and the date of completion the Navy vessels were almost all converted to the use of oil fuel, as were also a great many merchant and passenger vessels, and the export market for Alaska coal has remained small. The Matanuska and Nenana coal fields, however, had a far-reaching influence upon the development of the railroad region. Fuel for the operation of the Alaska Railroad itself is obtained exclusively from the Moose Creek and Jonesville portion of the Matanuska field, although in the past a considerable tonnage was mined for railroad and domestic uses from the Chickaloon district. The railroad is by far the largest consumer of this coal, although a secondary market is found for domestic fuel, principally in Anchorage and Seward, and some is shipped to coastal ports to supply canneries and for other uses. It has long been known that in the upper Matanuska field there is some high-grade anthracite, but recent studies [72] of that portion of the field indicate that the available tonnage of anthracite is too small to justify its development at present.

The following table presents analyses of coal from different parts of the railroad region. Some of these analyses are composite analyses representing a large tonnage of coal and are believed to be

[72] Richards, R. W., and Waring, G. A., Progress of surveys in the Anthracite Ridge district, Alaska: U. S. Geol. Survey Bull. 849–A, pp. 5–27, 1933. Waring, G. A., The Anthracite Ridge coal district, Alaska: U. S. Geol. Survey Bull. 861, p. 54, 1937.

representative of the quality of coal that can be obtained from some certain part of the field. Others are averages of only a few representative analyses or single analyses.

Analyses of coal from various parts of the railroad region

	Air-drying loss	Form of analysis [1]	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value: Calories	Heating value: British thermal units	Remarks
Beluga River	------	A	19.45	34.36	29.81	16.38	0.22	4,428	7,990	
		B	11.87	37.59	32.61	17.92	.24	4,843	8,752	
Evan Jones mine	4.4	A	6.6	38.4	43.1	11.9	.3	6,469	11,645	Composite sample of 8,270 tons of washed steam coal, 1935.[2]
		B	2.3	40.1	45.1	12.5	.3	6,767	12,180	
		C	-------	41.1	46.2	12.7	.3	6,928	12,470	
		D	-------	47.0	53.0	------	.4	7,937	14,285	
Eska Creek	2.7	A	4.85	34.56	37.12	23.47	.32	5,605	10,090	Composite analysis of 12,800 tons of run of mine coal, 1923.[2]
		C	-------	36.32	39.01	24.67	.34	5,891	10,604	
		D	-------	48.21	51.79	------	.45	7,819	14,076	
Chickaloon	------	B	-------	20.11	69.86	9.84	.78	7,787	13,804	Average of analyses of samples from five different faces: U. S. Navy Alaska Coal Commission Mine.
Coal Creek	------	B	-------	18.27	73.24	7.96	.54	7,873	14,171	Average of 4 samples from workings of U. S. Navy Alaska Coal Commission Mine.
Anthracite Ridge	------	B	-------	8.6	83.6	5.2	.45	7,561	13,610	Average of two outcrop samples from big bed on Purington Creek.
Costello Creek Basin.	------	B	7.00	46.60	40.90	5.50	.41	------	11,190	Prospect on Coal Creek.
East Fork of Toklat River, Mount McKinley National Park.	------	A	21.8	36.9	35.6	5.7	.5	5,028	9,051	Alaska Road Commission mine.
		B	13.9	40.6	39.2	6.3	.5	5,539	9,970	
		C	-------	47.1	45.6	7.3	.6	6,433	11,580	
		D	-------	50.9	49.1	------	.6	6,944	12,500	
Nenana field	------	A	20.7	43.6	28.2	7.5	.1	4,820	8,645	Monthly composite of shipments to Alaska Railroad, Nov. 1931.
		B	12.9	47.9	31.0	8.2	.1	5,296	9,530	
		C	-------	55.0	35.6	9.4	.1	6,078	10,940	
		D	-------	59.6	40.4	------	.1	6,907	12,430	

[1] A, As received; B, air dried; C, moisture free; D, moisture and ash free.
[2] Tuck, Ralph, The Eska Creek coal deposits, Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 880-D, pp. 202-203, 1937.

In 1936 the only portions of the Matanuska field where mining was being done were on the property of the Evan Jones Coal Co. at Jonesville, on Wishbone Hill, from which most of the coal was produced, and some smaller operations on Moose Creek. This field had produced through 1935 a total of about 1,000,000 tons of coal.

An interesting and unusual condition is shown by the analyses of coal from different parts of the Matanuska field and from neighboring parts of the Susitna basin. The coal-bearing beds throughout this region are believed to be of approximately the same age, though the coal shows wide variations in chemical and physical characteristics in various parts of the field. In the Susitna Valley and along the shores of Cook Inlet the Tertiary (Eocene) coal-bearing series is made up of sandstone, shale, and coal, has been little deformed, and is entirely free from intrusive rocks, and the coal is of subbituminous rank. Eastward from the broad Susitna-Cook Inlet Basin up the Matanuska Valley, however, the coal-bearing series is strongly faulted, intrusive rocks have invaded the series in increasing abundance, and folds and crumples of the beds are more pronounced. These evidences of metamorphism and of intrusion are accompanied by an increase in the rank of the enclosed coal beds. In the table of coal analyses a single analysis of coal from the Beluga River is given. That locality is well out in the broad Cook Inlet Basin, the coal series is there little deformed, and the coal is believed to be of about the average rank of the coal that is found at intervals from the mouth of Cook Inlet to Broad Pass. Comparison of that analysis with those of coal from Jonesville, Eska, Chickaloon, Coal Creek, and Anthracite Ridge shows a striking though not quite systematic decrease in the volatile matter and an increase in the fixed carbon—a range in the fixed carbon percentage from 29.81 at Beluga River to 83.6 for some of the anthracite at Anthracite Ridge.

Altogether the Matanuska field contains a large reserve of bituminous coal, and smaller amounts of anthracite.

Coal has been mined in a small way at several localities throughout the region, but except for the two major fields—the Matanuska and Nenana—the coal recovered has been sold for local uses only, and none of it has been shipped far from the mine. Small amounts have been recovered from shafts or adits at Susitna Station and on the lower Yentna River. In the Cache Creek district coal was mined at the rate of a few thousand tons a summer for several years to operate a gold dredge there. Other bank mines have supplied a little coal for domestic use, and a small mine has been opened near the East Fork of the Toklat River, in Mount McKinley National Park, to supply coal for the camps along the road through the park. A little coal has been recovered from shallow workings in the basins of Moose and Stony Creeks, in the park, for the use of the mines of the Kantishna district. Coal is known at a large number of localities in the basin of the Susitna River and its tributaries and on the north slope of the Alaska Range, but the mines now in operation are capable of supplying the available markets, and none of these scattered outcrops are likely to be mined extensively in the near future.

The most productive coal field in 1936 was the Nenana field, in which the Healy River Coal Corporation was the only producer. (See pl. 9, *A*.) That mine produced over 70,000 tons of coal in 1935, practically all of which was shipped to Fairbanks, where the largest consumer, the Fairbanks Exploration Co., used it as fuel in its power plant for the operation of dredges, pumps, and other uses. The coal is of subbituminous rank, is of Eocene age, and occurs in a series of astonishingly thick and numerous beds. In a section of beds exposed on Healy Creek the coal-bearing formation is 1,900 feet thick and contains 220 feet of coal in 23 separate beds, with seven beds in the lower part of the section aggregating 174 feet of coal. Mining is carried on from an adit, all the coal that has been mined so far having been taken from above the adit level. This field has produced over 750,000 tons in the last 15 years and has a reserve of many billions of tons.

INDEX

The use of the subjoined mailing label to return this report will be official business, and no postage stamps will be required

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFFICIAL BUSINESS

This label can be used only for returning official publications. The address must not be changed.

PENALTY FOR PRIVATE USE TO AVOID PAYMENT OF POSTAGE, $300

GEOLOGICAL SURVEY,

WASHINGTON, D. C.

77786—40——14