GEOLOGY AND MINERAL RESOURCES OF THE REGION TRAVERSED BY THE ALASKA RAILROAD.

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INTRODUCTION.

On the completion of the bridge across Tanana River, in March, 1923, the Alaska Railroad, begun in 1915, was opened for direct traffic between Seward, on the Pacific coast, and Fairbanks, in the heart of central Alaska, a distance of 468 miles (fig. 1). Rarely has

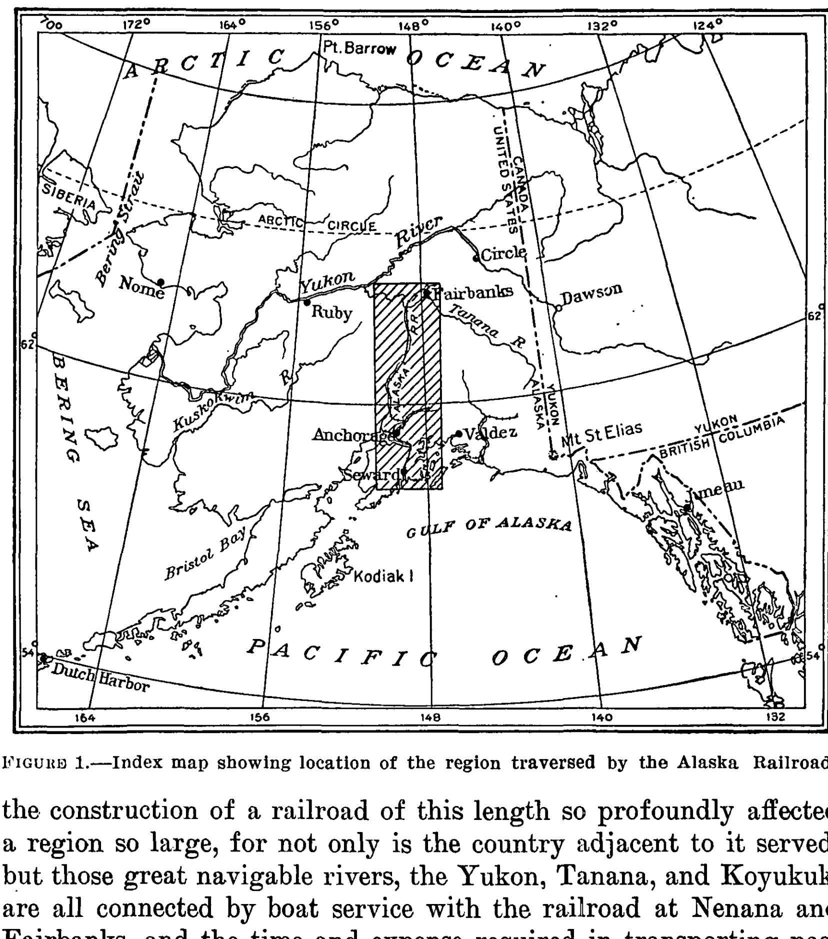


Figure 1.—Index map showing location of the region traversed by the Alaska Railroad.

the construction of a railroad of this length so profoundly affected a region so large, for not only is the country adjacent to it served, but those great navigable rivers, the Yukon, Tanana, and Koyukuk, are all connected by boat service with the railroad at Nenana and Fairbanks, and the time and expense required in transporting passengers and freight to the basins of these streams have been greatly decreased. Perhaps the advantages of direct rail connection with the coast will be appreciated by none so much as by the pioneers of the Yukon basin, who, in spite of the handicaps of slow river transportation in summer and almost complete isolation in the winter, have endeavored to develop the resources of the basin. A few years ago the Fairbanks mining man who had purchased supplies in Seattle during the winter or spring was unable to land them on his property much before the end of June, for it required three weeks or more to make the journey by way of Skagway and the upper Yukon, and that river is not navigable until it runs free from ice in the spring. Now it is possible to land a shipment at Fairbanks in half that time from Seattle at any season of the year. Not long ago the trip from Nenana to Seward by way of Broad Pass meant weeks of severe physical exertion over a trailless country by pack train in summer, or a hard, long trip by dog sled in winter. For weeks in the spring during the " break up " and in the fall during the " freeze up " the trails are practically impassable to all travel. Now the journey can be made in a few hours in comfort. Before the railroad was completed the miner in interior Alaska who in the spring or summer suddenly found that he needed machinery which could be obtained only by sending to Seattle had often to resign himself to the fact that he could not supply his needs in time to take advantage of the short summer season that year. Now only two or three weeks may be necessary before his order is delivered to him. The effects of the stimulus of better transportation are already evident. Ore shipments from the Yukon basin, even from points so far east as the Canadian side of the international boundary, are being diverted to the new railroad. Passenger travel that formerly followed either the upper or lower Yukon on the trip between Seattle and interior points now goes by way of the lower Tanana River and the railroad. By the broadening of markets farming and stock raising have been encouraged. Many mines that were once unprofitable can now be operated at a profit, and prospects that were worthless owing to the lack of transportation may now become paying mines.

The population now served by the railroad is no index of the number of people this region may some time support, for the railroad has been in operation too short a time to do more than start the intensive development of the country. No one questions that central Alaska will ultimately expand its mining industry, for it contains much placer ground, too lean to yield the rich, quick profits demanded in the days of bonanza mining, that will be exploited by the low-cost quantity methods of the dredge, the steam scraper, and the hydraulic nozzle. In the past lode mining in this region has been largely confined to localities that lay near routes of water transportation. The cost of transporting heavy machinery and supplies in a roadless country was too great to be borne by small lodes of medium grade. Now rail transportation will make it possible to place mining and milling machinery on lodes that have heretofore not warranted such an expenditure. The agricultural population of this region, however, may sometime outstrip in numbers that employed in mining. Mineral resources, even in a country rich in its mineral deposits, are exhaustible, whereas farm lands may produce indefinitely. It so happens that the Alaska Railroad touches the two districts in Alaska that are farthest advanced in their agricultural development—the Knik Arm-Matanuska district and the Fairbanks district. In each of these districts it has been conclusively demonstrated, by farming for several successive years, that properly selected crops can be matured, that stock can be raised, and that a livelihood can be gained by tilling the soil.

The 1920 census report shows that in 1919 crops from 4,473 acres, valued at $393,902, were harvested in Alaska. In 1921 some 3,500 bushels of spring wheat, of good milling quality, was harvested in the Fairbanks district and about 1,000 bushels in the Matanuska district. It is estimated that the Tanana Valley contains 640,000 acres of land available for agriculture, and that in the Cook Inlet-Susitna region 1,296,000 acres is suitable for farming without costly drainage. It is therefore obvious that only a very small fraction of the agricultural land in this region has been taken up, and that farming will increase as rapidly as the Alaska market for farm products develops. To be sure, the market for the crops raised in these districts has been mainly limited to such adjacent regions as were readily accessible. The railroad has now widened these markets, but the main outlet for Alaska farm products, except livestock, is likely to continue to be found in Alaska consuming centers. Stock raising in Alaska is believed by many to offer great possibilities for profit. Domesticated reindeer have for many years been successfully raised and furnish both food and clothing to their owners. Some reindeer meat has been shipped to the United States, and it is likely that a large market for this meat may be developed. There are now said to be more than 200,000 domesticated reindeer in Alaska, and those qualified to judge estimate that the Territory has sufficient pasturage to support many millions of these animals. A very large area of land in the vicinity of Broad Pass, tributary to the Alaska Railroad, has already been shown to be adapted to reindeer raising. Experiments have been made to determine whether or not the raising of cattle, sheep, and hogs can be carried on successfully in Alaska, for there are large areas in this region over which wild grass grows luxuriantly. There is no question that the native grasses will furnish excellent grazing during the summer, but the Alaskan summer is short, and the winter season, during which the animals would have to be fed, is long. It is likely that in time, by breeding hardy types of animals and by the use of ensilage made from wild grass, that cattle, hogs, and sheep can be raised successfully in favorable places in the Territory.

The mining industry within the region tributary to the Alaska Railroad is certain to expand under the present improved conditions of operation and marketing. In fact, the operation of the coal mines of the Matanuska Valley and of the smaller mines along the railroad route was impossible until rail transportation was available, for the railroad furnishes the only means of moving the coal to market and at present is itself the principal consumer of the coal produced. It is expected that eventually the Matanuska mines will supply coal for coaling stations on the Pacific, to serve vessels in the trans-Pacific and coastwise trade, and thus support a greatly increased mining population.

It is not yet possible to predict accurately which metal-mining regions will be the first to respond in a large way to the stimulus of railroad transportation, but many districts have already been greatly helped, and the beneficial effect will be cumulative. The Willow Creek gold lode district has always profited by its accessibility to water transportation during the summer but now has the added advantage of year-round transportation by rail. The Yentna district, always hampered by high freight costs and by a bad summer trail, can now be reached at any time over a road from the railroad at Talkeetna. The Iron Creek prospects, in the Talkeetna basin, heretofore too remote for development at a reasonable cost, can now be made accessible by a road, some 40 miles in length, from Talkeetna. Similarly, the lode district of the West Fork of Chulitna River, the Valdez Creek gold placer district, and the placer and lode mines of the Nenana basin and the Kantishna district are all greatly helped by the completion of the railroad, but they will receive the fullest possible benefit only when wagon roads connecting the mineral deposits with the railroad are completed. The Fairbanks district is already enjoying the advantages of frequent and easy contact with the coast and lower freight charges, and to a lesser degree these advantages extend to all the central Alaska mining districts that are connected with the railroad through the Yukon and its navigable tributaries. The Tolovana gold placer district is now indirectly connected with the railroad by wagon road and boat service, and the Hot Springs district, which contains gold placers and promising tin deposits, will profit by its steamboat connection with the railroad. As a whole, the area served directly and indirectly by the new railroad is rich in mineral wealth. Under the primitive transportation facilities of the past this area has produced minerals worth

$160,000,000. In 1922 the country immediately tributary to the railroad produced gold, silver, and coal worth $2,034,210 and in addition a small amount of lead, copper, and tin, and if the larger area indirectly benefited by the railroad is included, the production of minerals in 1922 was worth over $3,000,000.

Gold mining has been carried on in Kenai Peninsula for many years. In 1922 the output was about $40,000.

The Willow Creek lode district, north of the head of Knik Arm, has produced over $2,000,000 worth of gold in the last decade and in 1922 yielded $239,500 in gold and silver. The Matanuska coal field, served directly by a branch line of the railroad, yields a high-grade coal for railroad and industrial uses. The Yentna placer district, now connected with the railroad by wagon road from Talkeetna, produced gold worth $223,000 in 1922. There are many promising undeveloped copper and gold lodes in the Talkeetna Mountains and the Alaska Range south of Broad Pass, and gold placer gravels have long been mined in the Valdez Creek district.

The railroad crosses the Nenana lignite field, whose reserves are estimated at over 9,000,000,000 tons. Already coal from this field has reduced the cost of mining in adjacent districts. The Kantishna district, 60 miles west of the railroad, has valuable placer-gold deposits, as well as promising gold, silver, and lead lodes.

The Fairbanks district, at the inland terminus of the railroad, has since its discovery produced $73,686,976 worth of minerals, mostly in placer gold but including lode gold, antimony, tungsten, silver, and lead. Its gold output in 1922 was valued at $693,000.

In 1922 the Tolovana district produced minerals worth $222,000, and the Hot Springs district $55,000, mainly placer gold.

The completion of the railroad will greatly benefit both Alaska and the general public by making the Mount McKinley National Park accessible to travelers. This great park, established in 1917 and enlarged in 1922, now includes an area of over 2,600 square miles, comprising that portion of the Alaska Range that culminates in Mount McKinley, 20,300 feet above sea level, the loftiest peak on the continent. Flanking Mount McKinley to the south and east are great numbers of unnamed and unexplored snow-capped peaks, drained by a multitude of glaciers. The crest of the range is approachable from the north through many delightful valleys, the natural range of thousands of bighorn sheep and caribou, numerous bear and moose, and a great variety of fur-bearing animals. This park affords the visitor a remarkable opportunity to study a section of our fast disappearing wilderness, here fortunately preserved before the approach of civilization had brought about the destruction of its wild life. The east edge of this park lies close to the railroad in Nenana Valley, and the construction of a single road already projected from the railroad to the Kantishna mining district will make easily accessible 100 miles of a magnificent mountain range, a score or more of sheltered valleys, numberless unconquered peaks and glaciers to call the mountaineer, and a familiar contact with many of our noblest big-game animals. As a permanent asset to the Territory of Alaska and to the Nation, this park is likely to exceed in value even the richest of the mining districts, for all mines will sooner or later be exhausted, but the usefulness and value of such national recreation grounds will increase indefinitely throughout the years.

Although the railroad has already greatly improved transportation throughout a great area in central Alaska, its benefits to the Territory and its opportunities for usefulness are still limited by the difficulties of travel to the railroad from the many outlying mining and agricultural districts. As constructed, the railroad traverses a wilderness that was almost entirely devoid of trails and roads. Until roads are built from the mines and farms to the railroad the products of these districts can not move freely, and the railroad can not fully meet the needs for which it was designed. A vigorous program of road construction has been started by the Alaska Road Commission, the Bureau of Public Roads, and the Territorial Road Commission, and although much still remains to be done, many roads are already completed or well advanced.

In past years the casual tourist to Alaska has been limited to travel by the few routes over which he could procure regular transportation, and these routes were largely water routes. From Seattle regular steamship schedules were maintained along the coast by way of the "inside passage" to Skagway and thence westward to Prince William Sound and Cook Inlet ports. From Cordova the Copper River & Northwestern Railway runs inland 196 miles to the Kennecott mines, and from that railroad at Chitina a road, over which an automobile stage was operated in summer and a horse-drawn stage in winter, extended to Fairbanks. From Skagway the White Pass & Yukon Railroad crosses the mountains to the headwaters of Yukon River, and on that river and its larger tributaries there was regular steamboat service during the ice-free season. Summer service was also maintained by steamship from Seattle to Nome. The regular steamship routes were supplemented by smaller boat lines at various places. It will thus be seen that the only regular main lines of transportation in Alaska were confined to boat service on the coast and on the larger navigable rivers, except for the Copper River & Northwestern Railway, and the stage road between Chitina and Fairbanks. During the winter steamship sailings to Bering

Sea and upper Cook Inlet ports and all boat service on the rivers are suspended on account of ice.

The opening of the Alaska Railroad has now made possible an easy summer tourist trip that includes a great variety of scenery and a large area of country, a trip that could formerly have been made only at a much larger expenditure of time, money, and effort. The traveler can now leave Seattle or Vancouver on a comfortable ocean steamer and journey northwestward along the "inside passage" past Vancouver Island and through the picturesque and rugged Alexander Archipelago to Skagway, the ocean terminus of the White Pass & Yukon Railroad. A daylight trip of 112 miles across the coastal mountain range will bring him to the town of White Horse, Yukon Territory, at the head of river navigation in the Yukon basin. There river steamboats begin the long downstream journey through Lake Lebarge and Lewes River to the Yukon, past the mouth of the turbid, glacier-fed White River to Dawson, at the mouth of Klondike River. Continuing downstream he stops at the old settlements of Fortymile, Eagle, and Circle and crosses the Arctic Circle at Fort Yukon, at the great northern bend of the Yukon. From Fort Yukon the river flows in many branching channels through the Yukon Flats to the site of old Fort Hamlin, whence, once more confined to a single deep gorge bordered by high rock bluffs, it follows its devious course to the town of Tanana, at the mouth of Tanana River. At this point the route leaves the Yukon and ascends its largest tributary, the Tanana, to Fairbanks, the center of the great Fairbanks gold-mining district and the largest town of interior Alaska.

All the journey just outlined has been possible for the last 25 years, but to complete the trip from Fairbanks back to Seattle has heretofore required either a slow upstream return journey by the same route; a continuation of the down-Yukon trip through monotonous lowlands to the river mouth and St. Michael, thence to Nome, and by ocean steamer to Seattle; or a stage journey by automobile or horse-drawn sled to Chitina, on the Copper River & Northwestern Railroad, and thence by rail to Cordova and ocean steamer to Seattle. Now the traveler can take the train on the Alaska Railroad at Nenana or Fairbanks and travel southward, stopping off if he desires at the Mount McKinley National Park, cross the Alaska Range through Broad Pass, and follow down Chulitna and Susitna valleys, with the Talkeetna Mountains on the left and the great sweep of the Alaska Range on the right, dominated by Mount McKinley, America's loftiest mountain. The traveler then goes around the head of Knik Arm through the agricultural lands of lower Matanuska Valley and thence southwestward to Anchorage, on Pacific waters, a summer port on the long Cook Inlet embayment. At Anchorage alternate routes are available to Seward, either by continuing the railroad journey through the Chugach Mountains, skirting Turnagain Arm and going through the Kenai Mountains and past great valley glaciers to Seward, or by taking an ocean steamship down Cook Inlet and around the shores of Kenai Peninsula. From Seward coastwise vessels call at Prince William Sound ports, skirt the base of Mounts St. Elias and Fairweather, with their great piedmont glaciers, and enter the inside passage through Icy Straits, to return by the route already outlined past Juneau, Wrangell, and Ketchikan.

The trip here suggested, comprising a great loop, has the advantage of giving the traveler in a single journey at least a glimpse of the many varied types of country, climate, and vegetation to be found in Alaska. He leaves the heavily timbered islands of the coastal region, with its temperate and somewhat rainy climate, to cross the rugged snow-capped coastal mountains and enter the dry sunny valleys of the interior. The Alaska Range offers splendid glaciated mountains teeming with wild life; the Susitna basin reveals wide timbered lowlands with lofty bordering ranges; and the coastal mountains with their intricate fiords, tidal glaciers, and towering snow peaks present the forbidding barrier along the ocean front that has so long helped to establish the common misconception that Alaska is entirely a forbidden land of mountains, ice, and snow.

GEOGRAPHY.

In the journey from Seward, at the coastal terminus of the Alaska Railroad, to Fairbanks, the inland terminus, the traveler passes through parts of at least six distinct geographic and geologic provinces and near the edge of a seventh. These provinces differ from one another in the essential features of surface form, climate, soil, and vegetation, as well as in geology and mineral resources. As each of these features has a direct bearing upon the proper utilization of any area, and as the combination of them in each particular district will determine the kind and intensity of its future development, it seems proper to describe these provinces separately.

CHUGACH AND KENAI MOUNTAINS.

For the last 18 miles of the voyage from Seattle to Seward the steamship travels northward up the narrow embayment of Resurrection Bay, a glacial fiord that heads well back in the rugged Kenai Mountains. These mountains, together with their northward and eastward extension, the Chugach Mountains, and the St. Elias Range, still farther east, form the great coastal barrier that gives Alaska so forbidding an aspect as viewed from the Gulf of Alaska. These coastal ranges are characterized by high, rugged peaks and extensive snow fields and glaciers, and on Prince William Sound and southeastern Kenai Peninsula by an extremely irregular and intricate shore line indented by deep and narrow glacial fiords. Some of the largest North American ice fields, Malaspina and Bering glaciers, the St. Elias ice cap, and the great ice cap southwest of Seward, lie in this belt, and at many places great ice lobes push down to tidewater and discharge bergs into the sea. The steamship voyage along the rim of the Gulf of Alaska in clear weather gives a panorama of magnificent subarctic mountains and glaciers that can scarcely be matched elsewhere.

The climate on the immediate border of the Gulf of Alaska is surprisingly mild, for it is tempered by the nearness of this area to the warm Pacific waters. At Cordova the winter temperature in many years does not fall to 0° F. At a short distance back from the coast and into the mountains, however, there is a great change in the climate, with much more severe winters. The coastal mountains in general have a heavy precipitation, and much of it falls as snow, which accounts for the much greater development of glaciers near the coast than in equally high mountains in the interior. From Resurrection Bay and the Alaska Railroad the great ice cap of Kenai Peninsula is indicated mainly by the glacial tongues that stretch down toward tidewater from it. In northern Kenai Peninsula, however, the railroad passes close to the foot of two fine valley ice lobes, Bartlett and Spencer glaciers, and within sight of Portage Glacier.

The name "Kenai Mountains" is used to designate the mountains on Kenai Peninsula, which is limited on the north by the constriction between Turnagain Arm and Portage Bay. The position of these bays, however, is due merely to the accidents of glacial erosion, the Chugach Mountains, to the north, and the Kenai Mountains being continuous with one another in both the character and the structure of their rocks. They are here included as belonging to a single geographic province.

On the journey inland from Seward the traveler goes northward some 50 miles through the Kenai Mountains to Turnagain Arm, encircles the head of that embayment, follows the abrupt and cliffed shore of the Chugach Mountains, and leaves the mountains to enter the second geographic province, the Cook Inlet-Susitna lowland.

COOK INLET-SUSITNA LOWLAND.

The Cook Inlet embayment, including Knik Arm, is an arm of the Pacific that extends 200 miles into the body of Alaska and with the lower portion of the Susitna basin constitutes a great structural depression bordered on all sides except the Pacific by high mountains. This depression, including the inlet itself and the bordering low-lying areas, is here termed the Cook Inlet-Susitna lowland. It forms a province distinct in topography, soil, vegetation, climate, geology, and possibilities of development from the surrounding mountainous areas and is one of the most promising areas in Alaska for agriculture and stock raising.

In contrast to the bordering mountains, which are composed of hard rocks, the underlying materials in this lowland are mainly unconsolidated or only loosely cemented (Pl. I), so that the land forms take on smoothed, rounded shapes generally free from sharp peaks and abrupt slopes. The late geologic history of the lowland is that of constructive rather than destructive agencies, for the low-land has received the land waste removed from the surrounding highlands by streams and glaciers. The bench lands and inter-stream areas are largely floored with unstratified glacial débris and with gravel left as outwash from the great glaciers that formerly filled this basin. Aggradation or filling is still actively in progress in upper Cook Inlet through the discharge into tidewater by Susitna, Matanuska, Knik, and many other rivers of large quantities of gravel, sand, and silt, supplied to these streams by the glaciers in which they head. In this way upper Cook Inlet is slowly being filled in, the deltas of the larger rivers are creeping seaward, and the lowland areas are being enlarged at the expense of the water areas. This slow shrinkage of the area of Cook Inlet is somewhat offset by the wave activity in cutting back the shore cliffs in places, but the result of wave cutting also is to fill in the low places of the basin, with a constant though slow reduction in the volume of salt water in the Cook Inlet embayment.

The traveler going through this lowland by train gets the impression of an alternation of tracts of rolling country of moderate altitude, timbered by medium-sized spruce and birch trees and crossed at intervals by stream valleys trenched 100 feet or so beneath the general level, with broad open marshy tracts studded with lakes or ponds, containing only scattered groves and clumps of trees, and with ill-defined and shallow stream valleys. Around Knik Arm and in Matanuska Valley the land that has been cleared and developed for farming is for the most part high and fairly level bench land having a rather shallow soil overlying glacial outwash gravel. This land was naturally well drained and was easily cleared and prepared for the plow. In many large tracts, however, especially in the lower Susitna Valley, extensive drainage projects will be necessary before the land can be cultivated.

In certain well-drained portions of the lowland, especially near its upper edges and on the lower slopes of the surrounding mountains, there is a remarkably luxuriant growth of native grasses, in thick stands that in places reach a height of 5 feet or more. This grass, under favorable weather conditions, can be cut and cured to hay of good quality and affords excellent forage for stock. Without doubt it will sometime be used for raising stock on an extensive scale.

Above the junction of Talkeetna and Chulitna rivers with the Susitna the Susitna lowland narrows, is broken by ridges of hills, and loses its basin-like aspect. The structural basin between the Talkeetna Mountains and their northward extension, on the east, and the Alaska Range, on the west, persists, however, to Broad Pass, though it can not there be properly termed a lowland.

TALKEETNA MOUNTAINS.

On the northward journey from Anchorage to Matanuska River the Chugach Mountains rise steeply on the right. At the town of Matanuska the main line turns westward, to skirt the west base of another range, the Talkeetna Mountains. The traveler can catch a glimpse eastward up Matanuska Valley, a prominent glaciated valley, without realizing that it marks the border line between two great mountain ranges, the Chugach on the south and the Talkeetna on the north. Indeed, if the question were to be decided upon surface forms alone, there seems to be less reason for separating the mountains on the two sides of this valley into separate ranges than for using Knik River valley or some other stream trough as a dividing line. A study of the geology, however, both as to the rocks themselves and as to their structure, shows that the Chugach Mountains and the Talkeetna Mountains are composed of very different materials, have had widely different histories, and have properly been given distinct names. The geology of the Talkeetna Mountains is described on pages 91–98, but it may be stated here that in the Chugach Mountains the rocks are dominantly of sedimentary origin and their general structure is parallel with the axis of the range, whereas in the Talkeetna Mountains the rocks are mainly igneous and have no pronounced structural trend. Erosion of these two classes of material has produced very different effects upon the topography, and the granitic rocks of the Talkeetna Mountains show an extremely rugged sky line, with sharp peaks and ragged, pinnacled ridges in the higher parts of the range.

Although glaciers exist in the headward portions of many valleys in the Talkeetna Mountains, this mountain mass lies behind the coastal barrier ranges and has a relatively light precipitation, so that its glaciers, as compared with the great ice fields of the coastal mountains, are small. The size of the present glaciers, however, is no measure of the effect that glacial erosion has exercised in sculpturing the mountains to their present form, for the existing glaciers are only the shrunken remnants of the enormously greater ice fields that occupied this part of Alaska in glacial time. Then the Talkeetna Mountains were so deeply buried in ice and snow that only the highest peaks and ridges projected above the glacier's surface. At that time the entire basin of Susitna River and also the Copper River basin, to the east, were filled with enormous glaciers that extended well down the Cook Inlet depression. The movement of these great glaciers was largely controlled by the preexisting land forms, the ice in general following the valleys of the preglacial streams, but the erosive effect of these ice masses, hundreds and even thousands of feet thick and shod with effective grinding tools in the form of fragments, blocks, and boulders of rock, was profound. The mountains now retain a conspicuous glaciated topography, characterized by wide, open U-shaped valleys with hanging tributaries, glacial cirques and lakes, and many other evidences of the agencies by which they were sculptured.

COPPER-SUSITNA BASIN.

East of the Talkeetna Mountains lies another great basin region, of a complex geologic and physiographic history, many details of which still remain to be worked out. This basin is mainly tributary to Copper River, but a considerable area of its northwest corner drains into the Susitna, and a small portion to Bering Sea by way of the headwaters of Nenana River. This is not the place for a general description of the Copper River basin as a whole, for most of it lies east of the region here under discussion, but a considerable area in its northwestern part, mainly in the Susitna drainage basin, lies within this region. The headward tributaries of the main Susitna River derive their waters from the east and northeast slopes of the Talkeetna Mountains, from a portion of the south slope of the Alaska Range, and from a number of isolated groups of hills and mountains that rise through a broad expanse of glacial and alluvial deposits. The basin areas between and around these higher land masses can not properly be called lowlands, for their altitude ranges from 2,500 to 4,000 feet above sea level, but they are surrounded by much higher mountains, relative to which they are low. Their surface is generally more or less rolling, covered with scattered spruce timber, and dotted with a myriad of small lakes. In most places the major steams have intrenched themselves into the unconsolidated basin deposits. Like the Cook Inlet-Susitna lowland, the Copper-Susitna basin is mainly floored with detritus brought down to it by the glaciers that once poured into it from the mountains on all sides and with gravel laid down by the torrential streams that drained from those glaciers. The details of the ancient drainage have not yet been worked out, but sufficient facts are at hand to suggest strongly that at some past time the upper Copper River basin, above Woods Canyon, drained to the sea by way of Susitna River, and the old course of the river valley may have been along the upper Nenana and Chulitna valleys. There is reason to believe that the present Susitna Valley for some distance above the mouth of Indian River is postglacial.

The relatively high altitude of this portion of the Copper-Susitna basin, with its shorter growing season and more frequent frosts, makes this area unpromising as farming land. It would, however, support many grazing animals in the summer season, and it is believed to have important possibilities as a range for reindeer.

ALASKA RANGE.

The Alaska Range comprises a great crescentic belt of rugged and glaciated mountains that sweep northward from the base of the Alaska Peninsula to Mount McKinley and extend thence eastward and southeastward, continued by the Nutzotin Mountains, to Canadian territory. As thus defined the range has a length of nearly 600 miles and an average width of 50 to 80 miles and so constitutes one of the great physiographic features of North America. It is visible on the west from the railroad throughout the Susitna and Chulitna valleys and is crossed by way of Nenana Valley between Broad Pass and Nenana. Of particular interest to the traveler is Mount McKinley, to be seen on clear days from favorable points in the Susitna and Tanana basins. This majestic snow-clad peak has an altitude of 20,300 feet, thus surpassing in height all other mountains on the continent. It forms the central object in the Mount McKinley National Park, which includes a great area of the finest scenery west of the railroad. In a general way the range forms the watershed between the southward-flowing Pacific Ocean tributaries and those that flow westward to Bering Sea, though some notable exceptions, including Nenana and Delta rivers, have headward tributaries that receive their waters from the south side of the mountains and cross the entire range through deeply cut valleys on their course to Tanana River.

On its north front the main Alaska Range is flanked by minor foothill ridges, separated from the main mountain mass by basin-like depressions. These foothill ridges lie parallel to the main range and were formed during the same general period of mountain building.

The higher parts of the Alaska Range, notably just south and east of Mount McKinley, are the gathering ground for some of the largest Alaska valley glaciers. At least five of these great ice tongues are from 30 to 50 miles long and from 2 to 4 miles wide, and there are innumerable smaller ones, for the most part unnamed and unexplored. The present surface forms on this range are due in large part to the erosive action of these valley glaciers and of their enormously greater ancestors.

TANANA LOWLAND.

North of the Alaska Range lies a broad structural lowland basin that is continuous from Bering Sea by way of the Kuskokwim Valley northeastward across an 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 the general level of the plain. It is floored by unconsolidated materials, prevailingly gravel, that have been supplied by the erosion of the Alaska Range. It is likely that beneath the gravel there are extensive Tertiary deposits, which may contain lignite. Only the larger streams maintain well-defined channels across the lowland, the smaller tributaries sinking into the gravel to emerge again as sluggish, meandering creeks that drain the flat basin. The lowland surface consists of open marshy areas and lakes interspersed with patches of spruce and larch timber and is difficult to cross in the summer. In the area here considered Tanana River hugs closely the northern border of the lowland, for the major northward-flowing streams are glacier-fed and carry large quantities of gravel and silt, with which they have graded up the lowland. The tributaries of Tanana River from the north, by contrast, have low gradients and carry little detritus and have thus been at a disadvantage as compared with the heavily loaded streams from the south. As a result, the valley axis of Tanana River has been shifted northward and now follows closely the sinuous line formed by the base of the bordering hills on that side.

YUKON-TANANA UPLAND.

The part of the Yukon-Tanana upland that lies within the area here considered consists of smoothed and rounded ridges having a northeasterly trend and rising from flat lowlands by which the separate ridges are partly or entirely surrounded. The lowland is that of 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 of 1,000 to 3,000 feet, although farther north certain peaks and domes project above the level of the upland surface to a height 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 metamorphosed and folded 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 part of the Yukon-Tanana upland considered in this paper. The topography of the upland north of Tanana River is therefore in sharp contrast to that of the entire region south of the Tanana lowland, for there extensive glaciers have been developed at successive intervals 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 trend of the prevailing rock structure. The surface is generally covered by a thick mantle of soil, humus, and rock-disintegration products, and outcrops of rock 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, especially in the lower courses of the streams.

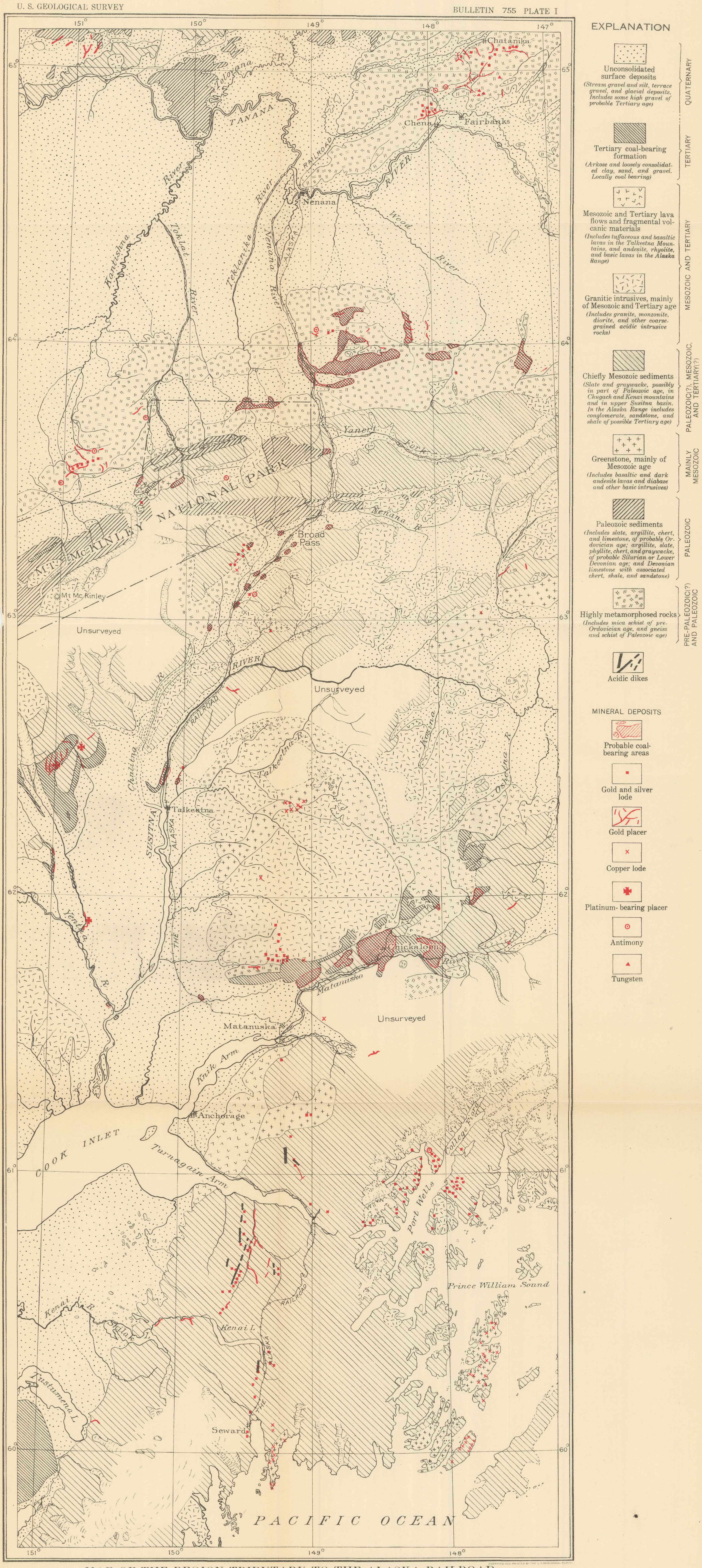
GEOLOGY.

GENERAL FEATURES.

The mapping of the geology of the region tributary to the Alaska Railroad has been a long and difficult task and is still incomplete. Since 1898, when the work was started, a large number of geologists have contributed their work season by season, until now only a relatively few small areas remain in which the major geologic units have not at least been outlined. Most of the work, however, has been of reconnaissance character, in which the geologists covered as large an area as possible in the short working season, and refinements of mapping still remain to be made in much of the area. It should be remembered by future geologists, who will be able to reach any part of this region within a few days from the railroad, that most of the results shown on Plate I were obtained at a time when there was not even regular steamship service to upper Cook Inlet, when the common means of inland travel were small boats propelled by hand on the rivers or pack horses in the upland areas, and when throughout a large part of this region there was not even a trail to follow. In the exploratory work of these geologists a large part of each man's energy was consumed in overcoming the mere physical difficulties of travel—chopping trail through the heavy brush, fording great rivers, or poling a boat upstream against the swift current. The person who realizes these facts will be less critical of the results here set forth than astonished that so much has been accomplished under conditions so difficult. In the present report the attempt is made to outline on the map (Pl. I) only a few of the great rock groups, in order to emphasize their relation to the mineral deposits of the region. The many geologic reports from which this paper is compiled have carried the subdivision of the rocks much further than is shown here. Anyone desiring more detailed information than is given here should apply to the Director of the United States Geological Survey for the latest report dealing with the district in which he is especially interested.

A study of the geologic map at once discloses the fact that most of this region is occupied by rocks of only moderate geologic age. The oldest rocks present are the mica schists that have generally been considered to be of early Paleozoic age, though it is not unlikely that they are pre-Cambrian. These rocks are present mainly on the north flank of the Alaska Range and in the vicinity of Fairbanks. Paleozoic rocks are rather scantily represented, for south of the Alaska Range only a few areas of undifferentiated metamorphic materials, probably of Paleozoic age, and some Devonian limestones are known. North of that range Paleozoic or older rocks are more abundant, occurring as extensive belts of mica schist, of less metamorphosed sediments, and of ancient lavas and associated sediments, all now greatly altered from their original state.

The prevailing rocks from Seward to Broad Pass are of Mesozoic age. They include great areas of slate, shale, and graywacke, some of which are of uncertain age, some fossiliferous sandstone and shale, a little limestone and quartzite, and large areas of basic lava and tuff. There are also great masses of granitic intrusive rocks that have penetrated the earlier Mesozoic materials as immense batholiths, such as that which forms most of the western Talkeetna Mountains, or as smaller scattered bodies. Tertiary rocks are also present in abundance and range in character from the hard, mountain-building conglomerate and shale of the Cantwell formation through basaltic lava and intrusive dikes and sills to the generally poorly consolidated sand, clay, and gravel of the coal-bearing beds. Widespread deposits of ancient gravel 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 glacial deposits. Stream, glacial, shore-line, and estuarine beds are being formed to-day at many places in the region.



MAP OF THE REGION TRIBUTARY TO THE ALASKA RAILROAD
SHOWING GEOLOGY AND MINERAL DEPOSITS

10 0 10 20 30 40 MILES

1924

This region is naturally subdivided into six geologic provinces, which differ in assemblage of rocks, in structure, and in geologic history. These provinces are the Chugach and Kenai mountains, the Talkeetna Mountains and their northward extension to Broad Pass, the Alaska Range, the Yukon-Tanana upland, and the two lowland areas, the Copper-Susitna basin and the Tanana lowland. The four mountain provinces will be described separately, in the order above named, as that is the order in which they will be seen in a trip over the railroad from Seward to Fairbanks. During the last great time division, the Quaternary, the mountain masses all stood at approximately their present positions and present altitude, and the geologic events that took place, including the shaping of the surface forms by erosion and deposition and the great invasions of glacial ice, affected all this region to a greater or less degree. The Quaternary geology of the whole region will therefore be discussed as a unit, and that discussion will include the two lowland provinces, whose deposits are largely of Quaternary age.

CHUGACH AND KENAI MOUNTAINS.

The Chugach-Kenai province includes the portion of the Chugach Mountains north and east of Turnagain Arm and Portage Bay that falls within this region and the structurally continuous Kenai Mountains of Kenai Peninsula and its bordering islands. This province is therefore bounded on the north and west by Matanuska River and the Cook Inlet-Susitna lowland and on the east and south by Prince William Sound and the Pacific Ocean. These mountains are structurally continuous with the great belt of coastal mountains of southern and southeastern Alaska, to the east, and with Afognak and Kodiak islands, to the southwest. This part of the great coastal mountain range lies at the elbow or hinge where the trend of the range changes from a northwesterly direction through southeastern Alaska to a southwesterly direction in Prince William Sound, Kenai Peninsula, and Kodiak Island.

METAMORPHIC AND IGNEOUS ROCKS.

The Chugach and Kenai mountains are composed primarily of sedimentary rocks that show a wide range of character and varying degrees of metamorphism. In the region between Matanuska and Knik rivers there are considerable areas underlain by metamorphic rocks that originally consisted of such acidic igneous materials as andesite and andesite porphyry and of basic rocks including peridotite, dunite, gabbro, pyroxenite, and various tuffs and agglomerates. Likewise there are materials in this area that represent the metamorphic equivalents of argillite, graywacke, and chert. This whole assemblage of materials has been severely altered by folding, faulting, and various metamorphic processes and has been cut by both basic and acidic dikes and sills.

The age of this group of metamorphic rocks is not known certainly, but they are older than the slate and graywacke that form most of this mountain range, which are believed to be Mesozoic. Nothing more can be said at present than that the metamorphic rocks just described are probably pre-Mesozoic and may even be pre-Paleozoic. They are here referred to as Paleozoic or older.

The main mass of the Chugach-Kenai mountains is composed predominantly of argillite, slate, and graywacke. The materials were deposited mainly as impure sand and mud; later they were cemented to shale and impure sandstone and then further altered during the folding of the mountains. They now appear commonly as hard shale, or argillite, and graywacke, or impure quartzite, although locally metamorphism has proceeded far enough to convert them to slate and schist. As a whole the rocks of this great mountain range, though composed dominantly of sedimentary beds, are almost entirely lacking in fossils by which the age of the beds could be accurately determined. The few fossils that have been found are either poorly preserved or are forms that are of doubtful value in correlation. In general, however, what evidence there is points to a Mesozoic age for much of the sedimentary rock of the Kenai and Chugach mountains. Possibly they contain considerable areas of Paleozoic rocks.

The lack of fossils, the succession of thick series of monotonously similar rocks, and the complex structure of these mountains together make the geology of this area so complicated that there still remains much to be learned about it. The series of argillite and graywacke must be many thousand feet in thickness, for it comprises the great bulk of a long range of mountains that is from 50 to 75 miles wide and has a vertical relief of more than 10,000 feet. In some sections the rocks seem to lie in rather simple folds. Elsewhere they are closely folded, crumpled, and contorted. The major structural features, however, are commonly parallel to the axis of the range.

In addition to the prevailing argillite and graywacke of the Chugach and Kenai mountains, conglomerate and limestone occur locally in minor amounts. Associated with these sedimentary materials there are in places large masses of greenstone and greenstone tuff that appear either interbedded with the sediments as flows or fragmental volcanic deposits, or cutting them as intrusive masses. The copper deposits of the region are generally associated with such greenstone bodies. Granitic rocks also intrude the sediments in many places, either as fairly large bodies or as dikes and sills. Both the greenstone intrusives and the granitic rocks are probably of Mesozoic age, though of course somewhat younger than the rocks they invade. The greenstone flows and tuffs are obviously of the same age as the sediments with which they are interbedded.

TERTIARY DEPOSITS.

In the Chugach and Kenai mountains Tertiary deposits are entirely lacking, but on their western flank Tertiary coal-bearing beds crop out in the Cook Inlet lowland, in the southwest corner of the area shown on the accompanying map (Pl. I). These Tertiary beds are similar to those occurring in the Susitna basin and are described more fully in that part of this report dealing with the Tertiary deposits of the Talkeetna Mountains. They consist of soft shale and sandstone with lignite beds. It is likely that this coal-bearing formation has a considerably wider areal distribution beneath the unconsolidated surface deposits than is shown on the geologic map.

UNCONSOLIDATED SURFACE DEPOSITS.

Within the mountainous areas of this province the unconsolidated surface deposits, of Pleistocene and Recent age, are of relatively small volume and small areal extent, being confined for the most part to the floors of the stream valleys. It is not possible to show most of these small areas on a map of the scale of Plate I. Bordering the mountains on the west, however, there is an extensive low-lying area, the Cook Inlet-Susitna lowland, in which the surface is almost entirely covered by a mantle of unconsolidated materials, including morainal deposits left by the last great glaciers during their retreat, of outwash gravel deposited by streams beyond the edges of these glaciers, and of the sand, gravel, and silt of river valleys, beaches, and tidal estuaries. These materials vary greatly in thickness but in general are thick enough to cover and conceal the underlying rocks. As all the agricultural lands of this region occur in areas that are floored with these materials, their economic importance is great.

TALKEETNA MOUNTAINS.

The Talkeetna Mountains proper include the rugged area that is bordered on the west and north by Susitna River, on the east by the Copper River basin, and on the south by the Matanuska Valley. For convenience in description they are also here made to include the northern extension of the area above defined, comprising a number of more or less isolated mountain ridges between upper Susitna and Chulitna rivers. These mountains lie north and east of the railroad all the way between Matanuska and Broad Pass, the railroad following the lowlands and valleys that flank the mountains on the west.

Geologically the Talkeetna Mountains are composed of a great variety of rocks of widely varying ages, but they differ from all other mountain ranges in this part of Alaska in the fact that they are composed mainly of igneous material (Pl. I).

PALEOZOIC OR OLDER ROCKS.

The oldest rock recognized in these mountains is a mica schist in the Willow Creek district, at the southwest corner of the mountain mass. This schist was probably once normal sedimentary rock, such as shale and sandstone, with which was associated some igneous material, but through a long history of successive periods of intense deformation it has been squeezed into contorted fissile rock and recrystallized until its original character is obscure. It has yielded some small gold placer deposits but otherwise is at present of no economic importance. Little is known of its age except that it is pre-Tertiary, but its highly metamorphic character and general appearance suggests its possible correlation with the early Paleozoic or older Birch Creek schist of the Tanana basin.

In the lower basin of Talkeetna River there are areas of fine-grained schist, slate, and other metamorphic rocks which have been little studied and the relations of which have not been determined. They are here tentatively classified as Paleozoic or older.

Within the great bend of upper Susitna River there is a complex assemblage of rocks including greenstone, schist, limestone, slate, quartzose rocks, and dioritic and diabasic intrusives. The age of this assemblage is not accurately known, but it has been tentatively assigned to the Paleozoic, with a suggestion that it is Carboniferous or older. So far as known these rocks have no economic importance.

MESOZOIC SEDIMENTS.

Mesozoic sediments and fragmental volcanic materials are widely distributed in the Talkeetna Mountains, especially along their south and southeast border in the headward basin of Talkeetna River and in their northward extension beyond Talkeetna River. They are especially well known in Matanuska Valley and vicinity, where they have been studied with some care and have yielded sufficient fossils to make their identification certain. As described by Martin and Katz[1] they include Lower Jurassic volcanic breccia, agglomerate,

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

and tuff that are extensively developed on the north side of Matanuska Valley and in the headward part of the Talkeetna River basin. These fragmental materials, with some interbedded lavas, are water-laid and well bedded and carry abundant marine fossils. In general they are of rather simple structure and have not been greatly deformed.

Lower Cretaceous rocks are known in this province at only a few localities, where relatively small areas of limestone occur. This limestone carries no fossils, but it lies unconformably upon Lower Jurassic volcanic rock and is provisionally correlated with the Lower Cretaceous. Sedimentary beds of Upper Cretaceous age cover a considerable area in the lower Matanuska Valley. They consist of shale and sandstone with a little conglomerate, have an aggregate thickness of at least 4,000 feet, and have been considerably faulted, folded, and deformed. The marine fossils found in these beds show clearly their Upper Cretaceous age.

On both sides of Susitna River, above its junction with Talkeetna and Chulitna rivers, and in many other areas in the northward extension of the Talkeetna Mountains there occurs an important group of sediments, mainly argillite and graywacke with minor amounts of limestone, that are almost devoid of fossils and that have on that account been difficult to correlate. Chapin[2] noted them on Tsisi Creek and suggested a correlation with the Upper Triassic rocks of the Valdez Creek district. Similar rocks occur east of Chulitna River, where they lie along the strike and seem to be a continuation of the slate and argillite of the Alaska Range, which have now been definitely shown to be, in part at least, of upper Mesozoic age.[3] From their lithology and structure these sediments are here mapped as of Mesozoic age.

MESOZOIC IGNEOUS ROCKS.

In the Mesozoic bedded rocks as described above has been included a series of volcanic breccia, agglomerate, and tuff, with some lava flows, all of which are of igneous origin, but having been laid down in sea water they are bedded and so may be described with the other sedimentary deposits. On the accompanying geologic map (Pl. I) the Mesozoic and Tertiary effusive and fragmental materials have for simplicity been grouped together and mapped with a single pattern. But far surpassing the sediments of the Talkeetna Mountains, both in area and in bulk, are the great masses of igneous rocks. These igneous materials fall into two classes—the acidic, coarsely

[2] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 27–28, 1912.

[3] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

granular granitic rocks, all of which were intruded and cooled at considerable depths below the surface, to be later exposed by erosion, and the basic rocks, commonly termed greenstones, which were mainly poured out upon the surface as lava flows. Of these two groups the granitic rocks greatly preponderate in this province. The main mass of the Talkeetna Mountains, outlined by Chickaloon, Matanuska, Susitna, and Talkeetna rivers, consists primarily of a single great batholith of diorite, and throughout the northern extension of the mountains there are many smaller intrusive masses of the same type, satellites of the central mass.

The age of these granitic rocks is difficult to determine, and it is entirely possible that intrusions of similar materials have taken place at different times. It has been definitely established that the main Talkeetna diorite intrusion took place in mid-Mesozoic time, probably early in the Middle Jurassic. Some evidence is at hand to indicate that some of the outlying granitic masses are of Tertiary age, but in the lack of conclusive proof on this point and for the sake of simplifying the geologic map (Pl. I) all the granitic rocks are here mapped with a single pattern and indicated as mainly of Mesozoic age. The granitic rocks of this province are important because in some places, the most conspicuous of which is the Willow Creek district, they contain valuable gold-bearing quartz lodes, and elsewhere they show some copper mineralization.

In addition to the Mesozoic granitic rocks, there are considerable areas of basic igneous materials that are cut by the granitic intrusives and are therefore older. Those in the western Talkeetna Mountains have been described [4] as being characteristically andesite greenstone flows with amygdules of epidote, though some coarse-grained intrusive phases are present. Farther northeast, in the region of the great bend of Susitna River, Chapin [5] observed similar basalt and andesite, with associated tuff and breccia, that he tentatively assigned to the Triassic. It is likely that these rocks are of the same age as the similar materials in the western Talkeetna Mountains. Their chief economic importance lies in the fact that in places, notably on Iron Creek, they contain copper minerals in encouraging amounts.

TERTIARY SEDIMENTS.

Sedimentary rocks of Tertiary age are present in the Talkeetna Mountain province in only small tracts (Pl. I), but their economic importance is out of all proportion to their area, for they contain the coal of the Matanuska and Susitna basins. The actual distribu-

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

[5] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 26–27, 1918.

tion of these beds is no doubt much greater than the map indicates, for there is reason to believe that they have a considerable extent beneath the unconsolidated Quaternary deposits of the Susitna basin. Unlike the Mesozoic beds of this province, the Tertiary deposits are not marine but are believed to have been laid down in valleys or estuaries. They commonly contain the remains of land plants, but no marine shells.

The basal Tertiary beds in this province are composed mainly of arkose, with some conglomerate, shale, and sandstone, derived by weathering and erosion from the granitic mass of the Talkeetna Mountains. In Matanuska Valley these beds lap up against and overlie the edges of the granitic rocks and may even have extended over large areas from which they have now been removed by erosion. The lower Tertiary beds are folded and faulted and are intruded by igneous dikes and sills, especially in Matanuska and Little Susitna valleys, where they are best exposed. This group of beds lies beneath the coal-bearing portion of the Tertiary. The coal-bearing Tertiary beds of the Talkeetna region have been most carefully studied in Matanuska Valley, where coal mining has been carried on for a number of years. There the coal-bearing group of beds has been called the Chickaloon formation by Martin and Katz,[6] who describe it as consisting of a monotonous succession of shale and sandstone, in which gray to drab, rather soft and poorly bedded shale predominates. The sandstone is yellowish, rather soft, and for the most part feldspathic. The formation appears to be at least 2,000 feet thick and contains numerous coal beds. The beds have been generally tilted and locally folded. Faults are common, and the formation is cut by many dikes and sills, some of considerable size. The fossil plants it contains show that this formation is certainly Tertiary and probably Eocene. The coal resources are discussed in another place in this report.

At many other places around the western margin of the Talkeetna Mountains, in Susitna and Chulitna valleys, there are small exposures of Tertiary rocks, many of which contain lignite beds. These exposures usually occur in stream bluffs where the surficial deposits of later materials have been cut through, and they indicate a much wider distribution of coal-bearing beds than is shown on the map (Pl. I). The coal is without exception lignite, of poorer grade than the best Matanuska coals but comparable with the coal from the Nenana field. It has no value for export, as it is too poor in quality for bunker fuel and deteriorates on handling and exposure, but it has found some local use and will prove useful as a local fuel supply.

[6] 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.

These scattered Tertiary beds have yielded no fossils, and their exact age is not known. It is possible, however, that the coal-bearing strata may ultimately be correlated with the Chickaloon formation.

Included in the areas mapped as Tertiary (Pl. I) there are certain large areas of massive conglomerate in the headwaters of Billy Creek and Oshetna and Nelchina rivers, which are doubtless Tertiary but whose exact age is not known. The Tertiary as mapped likewise includes the heavy Eska conglomerate of Matanuska Valley, which lies upon the Chickaloon formation and is overlain by Tertiary lava and tuff and therefore belongs within the Tertiary somewhere above the Chickaloon formation.

TERTIARY IGNEOUS ROCKS.

In the Talkeetna Mountain region igneous activity took place at intervals throughout Tertiary time. The igneous rocks range in kind from intrusive to extrusive and fragmental volcanic materials of basic and acidic character, and in age from the earliest Tertiary here represented to the latest. For the sake of simplicity the Mesozoic and Tertiary lavas and fragmental volcanic materials are here shown on the geologic map (Pl. I) as a single pattern.

The earliest Tertiary volcanic rocks that have been recognized in this region comprise certain basaltic lava flows that are interbedded with the basal Tertiary arkose in the Willow Creek district and therefore are probably of Eocene age. In the central Talkeetna Mountains, extending from Castle Mountain northwestward into upper Talkeetna Valley, there are extensive basaltic lava flows with intercalated pyroclastic rocks that cap the higher mountains of the region and are believed to be younger than the Eska conglomerate and may be as young as Miocene. Certainly these younger lava beds are much less deformed than the early Tertiary sediments. The Tertiary intrusive rocks of the Talkeetna province include a large number of irregular-shaped dikes and sills in the Matanuska Valley that are too small to be shown on Plate I. They are believed to be of late Tertiary age. In the northern extension of these mountains north of Susitna River there are considerable areas of intrusive rocks, including granite, quartz, monzonite, and granite porphyry, that are thought to be of Tertiary age. On the geologic map these rocks are grouped with the Mesozoic intrusives.

UNCONSOLIDATED SURFACE DEPOSITS.

In the Talkeetna Mountain province unconsolidated surface deposits in areas of noteworthy size are confined to the Susitna lowland, to the intermountain areas along the westward margin of the Copper-Susitna basin, and to narrow strips along the valleys of the larger streams. On a map of the scale of Plate I only the larger areas can be shown. These deposits overlie unconformably all the older rock formations and in general are present only as a surface mantle of no very great thickness, though thick enough to conceal the underlying harder rocks. In the central part of the Susitna basin they may in places reach a thickness of a few hundred feet, and in the Copper-Susitna basin Quaternary materials are present in large volume, being exposed along the main stream valleys in bluffs several hundred feet high. The oldest of the unconsolidated Quaternary materials are of glacial origin—either directly, having been deposited as moraines by the great glaciers that then overrode this region, or indirectly, having been deposited as silt, sand, and gravel by glacier-fed streams flowing from the ice fields into the bordering lowlands. Materials laid down in this way form the bulk of the Quaternary deposits. After the recession of the last great glaciers the streams began once more the task of establishing courses with adjusted gradients over the surface bared by the receding ice. In places they cut sharp canyons through the valley filling, or even into hard rock. Elsewhere temporary lakes were formed, to be later filled. The mountain streams, many of which still head in active glaciers, supplied large volumes of rock débris which was carried into the lowlands and spread out as great gravel plains.

Erosion and deposition are still very active in this province, and the adjustment of the streams to their loads and gradients is still far from complete. Broad gravel and sand plains with spreading, branching stream channels alternate with narrow, steep-walled gorges, falls, and rapids. Great quantities of material are yearly carried to the sea to increase the area of the Susitna delta and fill up the Cook Inlet embayment.

The lowland areas that are floored with Quaternary unconsolidated materials constitute the land upon which the future of agriculture in Alaska depends. The Cook Inlet-Susitna lowland has great areas that without doubt will some day support a large farming population. Already a considerable number of homesteads have been taken up in Matanuska Valley and around Knik Arm, and these pioneers have shown that a living can be won from the soil. The lowland surrounding Cook Inlet and in the lower Susitna Valley is one of the most promising areas in Alaska for agriculture, and its development, now barely begun, will be greatly stimulated by the advantages of rail and water transportation.

The lowlands on the western margin of the Copper-Susitna basin, though probably possessing fertile soils, are much less favorable for farming, for their altitude, about 3,000 feet above sea level, gives a much shorter growing season. Frosts may occur there during almost any month. They have large possibilities, however, as grazing lands.

ALASKA RANGE.

The portion of the Alaska Range here considered lies at the elbow or hinge where the trend of the mountains changes from a west-northwesterly direction east of Broad Pass to a southwesterly direction west of Susitna and Chulitna valleys. This range, which was elevated to about its present height in late Tertiary time, represents an ancient line of weakness in the rocks and has been the site of folding, close deformation, and mountain building repeatedly during the geologic history of the continent. The present range, which is conspicuous as one of the great physiographic features of North America and contains our highest mountain, is relatively young but is already in process of being torn down and leveled off by rivers and glaciers. The weakness of the rocks, however, will persist, and as in the past the range may be rebuilt again and again.

PALEOZOIC AND OLDER ROCKS.

Undifferentiated metamorphic rocks.—The recurrence of mountain-building processes in this range is shown by the varying degrees of alteration and deformation in the rocks that compose it, the oldest showing evidence of greatest and most numerous periods of stress and the youngest much less metamorphism and compression. The most ancient rocks in the range consist of mica schist, now closely folded, contorted, and recrystallized to such a degree that the character of the sedimentary beds from which it originated can scarcely be recognized.

These rocks, called the Birch Creek schist, form an important element of the northern flank of the mountains. They contain no fossils, any organic remains which they may once have carried having long ago been destroyed. Their age is not accurately known, but they are very ancient, probably pre-Cambrian. Similar rocks occur in the Willow Creek district of the Talkeetna Mountains, already described, and are widespread in the Yukon-Tanana upland, north of Tanana River. Their economic importance arises from the fact that in many places they contain gold-bearing quartz veins, and by the erosion of these veins and the concentration of the contained gold in the stream placers many rich deposits have been formed, including the highly productive placers of the Fairbanks district.

North of the belt of Birch Creek schist and forming the northern range of foothills of the Alaska Range is a parallel belt of undifferentiated metamorphic rocks that were originally mainly of igneous origin but contain also considerable sedimentary material. These rocks have been grouped as an undifferentiated complex of metamorphic materials and called the Totatlanika schist.[7] One characteristic phase is an augen gneiss, with quartz and feldspar crystals in a groundmass of fine-grained quartz and mica. With it are associated sericite schist and materials of sedimentary origin, including black slate, carbonaceous slate schist, limestone, and quartz conglomerate, so closely infolded and involved with the quartz-feldspar schist that they have not been differentiated. The age of this series of schist and gneiss is not accurately known, but its sedimentary phases have been correlated with the Tonzona rocks, tentatively considered as of Devonian or Silurian age. On the accompanying geologic map (Pl. I) the Birch Creek schist and the Totatlanika schist have been grouped together, as falling within the category of undifferentiated metamorphic rocks of Paleozoic age or older. The Totatlanika schist contains a few mineralized veins, some of which carry gold in encouraging amounts, associated with arsenopyrite, bismuth minerals, stibnite, and chalcopyrite. These veins in general are associated with the carbonaceous slate schist, are near small acidic intrusive bodies, and are related to faulting.[8]

Undifferentiated Paleozoic sediments.—In the part of the Alaska Range that lies west of the railroad, in the Broad Pass region, there are considerable areas of sedimentary rocks which are pretty definitely known to be Paleozoic but whose age has not yet been accurately determined. Thus, on the north flank of the main range and between Sanctuary and Nenana rivers there is a considerable area in which the prevailing rocks are black shale and slate that have been completely folded, faulted, and contorted, although less severely altered than most of the beds of the Tatina and Tonzona groups, described below. These beds underlie the Cantwell formation unconformably, and conceivably they may be Mesozoic, but their general character and relations point somewhat more strongly to a Paleozoic age, and they are here grouped with the Paleozoic sediments.

On the west side of Chulitna Valley, between Ohio Creek and Bull River, there is a belt of metamorphic rocks, mainly greenstone tuff and agglomerate but with associated chert and slate, that form the surface upon which the Triassic materials were unconformably laid down. Their age is not known except that they are pre-Triassic, and in the lack of more definite information they are here classed with the undifferentiated Paleozoic sediments.

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

[8] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 351–362, 1918.

Paleozoic sediments.—Within the portion of the Alaska Range here under discussion there are various areas of sedimentary rocks, all more or less metamorphosed, which have been determined with some degree of certainty to be of Paleozoic age. One such area, composed of beds of the Tatina group,[9] is a prominent element in the north flank of the Alaska Range west and north of Mount McKinley and is continued eastward as a narrow strip in the headwaters of Kantishna River. The Tatina group includes a thick series of limestone, black slate and argillite, chert, shale, and sandstone, all intensely folded, crumpled, and deformed. In this area these rocks have yielded no fossils, but they unconformably overlie the much older Birch Creek schist and are succeeded by the much younger Cantwell formation. Brooks has traced these rocks continuously southwestward beyond the area here considered into the upper Kuskokwim basin, where he found Ordovician fossils in the base of this group. The lower part of the group is therefore definitely of Ordovician age, but the unfossiliferous upper part may be as young as the Silurian.

A short distance north of the Tatina rocks, in the upper basin of Kantishna and Sanctuary rivers, is a narrow belt of sediments, lying parallel to the axis of the range, that consists of black argillite, slate, and phyllite, with some schist, graywacke, and chert, all much folded, faulted, and crumpled. These rocks, which have been called the Tonzona group, are to be distinguished from the Tatina rocks principally by the absence of limestone, although they are themselves more or less calcareous and are in places cut by multitudes of small calcite and quartz veinlets. They are considered by Brooks [10] to be of Silurian or Lower Devonian age. These Tonzona sediments are believed to be the equivalent of the sedimentary basal phase of the Totatlanika schist, already described with the undifferentiated Paleozoic rocks. In the Bonnifield region the Totatlanika schist, as described by Capps,[11] includes metamorphic rocks of both sedimentary and igneous origin, and the sedimentary phase is believed to correspond to the Tonzona beds as studied by Brooks farther west, where the igneous material was less abundant.

At the junction of Nenana and Cantwell rivers the railroad route crosses a belt of sediments, including massive limestone, black slate, graywacke, and chert, and some associated diorite intrusives. These rocks occupy the highest part of the range between the heads of Toklat and Cantwell rivers and are continued eastward into the

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

[10] Idem, p. 76.

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

upper Nenana basin by smaller, isolated masses. The most conspicuous member of this group is a massive white limestone, locally crystalline. All the sediments have been more or less metamorphosed, particularly in the vicinity of the diorite. The limestone itself has in several places yielded fossils of Middle Devonian age. The associated sediments have yielded no fossils, and all that can be said concerning any particular bed in this group is that it lies below or above the limestone and is therefore older or younger than the limestone. It seems safe to say, however, that most of these rocks are of Devonian age.

MESOZOIC AND EARLY TERTIARY (?) SEDIMENTS.

In that part of the Alaska Range here considered sedimentary rocks of Mesozoic or early Tertiary age constitute the largest single element, at least in point of area (Pl. I). These sediments may be divided into two major subdivisions—one of marine origin consisting primarily of shale, slate, and graywacke, with some limestone, and ranging in age from Triassic to Cretaceous, and the other a continental deposit, composed dominantly of conglomerate, sandstone, and shale, of late Mesozoic or earliest Tertiary age. The marine shale, slate, and graywacke are largely confined to the Susitna slope of the range.

Triassic rocks have been identified at two distinct localities in this province—one near Butte Creek,[12] in the Valdez Creek district, where the rocks consist prevailingly of dark-blue and black slate with interstratified beds of arkose and graywacke, and the other on the West Fork of Chulitna River,[13] where they include a series of limestone, tuff, and shale, with associated lava flows, in which are found mineralized areas containing copper and gold bearing lodes. These beds lie unconformably upon a group of tuffs and metamorphic sediments, supposedly of Paleozoic age, and represent the oldest known Mesozoic rocks of this region. In the valley of West Fork of Chulitna River there is a thick series of black argillite and slate, together with some graywacke and fine conglomerate, that extends across the strike for a distance of more than 7 miles, with prevailing steep dips to northwest. These beds seem to lie stratigraphically above the Triassic rocks and certainly are beneath the Cantwell formation, described below. They are therefore probably of Mesozoic age and may belong to either the Jurassic or the Cretaceous, or in part to each. This conclusion is confirmed by the strike of the beds, which would

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

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

carry their extension southwest to the Yentna district, where Mertie[14] has found fossils, determined as probably of Upper Cretaceous age, in a similar series of slate and graywacke. It is thus pretty definitely proved that the great sedimentary series that forms the southeast flank of the Alaska Range in the Susitna and Chulitna basins is mainly of Mesozoic age.

The second great subdivision of this Mesozoic-Tertiary belt, the continental phase, embodies the Cantwell formation, a thick series of conglomerate, sandstone, and shale that forms a major element in the range from Muldrow Glacier eastward to and beyond the east margin of the region here under consideration. These rocks are hard and resistant to weathering, form rugged mountains, and with the brightly colored lavas and intrusive rocks with which they are associated yield the striking scenery to be found in the upper Toklat basin. In general they are much less metamorphosed than any of the older formations, though locally they have been intensely crumpled and broken and even reduced to stretched conglomerate and schist. East of Nenana River the Cantwell beds have been extensively intruded by granitic rocks.

The age of the Cantwell formation is still open to discussion, for although fossil leaves, said to be of Eocene age, have been collected from it in several places, there seem to be certain conflicts between the evidence furnished by the fossil plants and that supplied by stratigraphy. There is no disagreement among the geologists who have studied this problem in regard to the conclusion that the Cantwell formation is younger than the Mesozoic shale, slate, and graywacke that are so abundant on the southeast slope of the range. Furthermore, the Cantwell beds appear much older, when judged on the basis of induration and metamorphism, than the next younger deposits, the Tertiary coal-bearing beds, and probably lie unconformably beneath them. Yet these loosely consolidated and only moderately deformed coal-bearing beds closely resemble and are generally correlated with the coal-bearing beds of the Matanuska field, which are assigned to the Eocene epoch—the same age assignment that has been made for the Cantwell. It is therefore suggested that if the coal formation in the Nenana basin is basal Eocene, then the Cantwell must be as old as Upper Cretaceous. If the Cantwell is Eocene, then the near-by coal formation must be later Tertiary than the Eocene. For the purposes of the present description the Mesozoic formations and the Cantwell formation have been mapped with a single pattern on the accompanying geologic map (Pl. I).

[14] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

TERTIARY COAL-BEARING FORMATION.

The Tertiary coal-bearing formation, though present in the Alaska Range only as small, irregular patches which even in the aggregate have no great area, is economically of great importance, for in most of the areas shown on Plate I it contains workable beds of lignite that together form a fuel reserve probably running into the billions of tons. From the character and habit of these beds they occur generally in the lowlands, where vegetation and younger stream and glacial deposits commonly mask the underlying rocks, and the outcrops are commonly found only in recent stream cuts of small area. The actual extent of the deposits is therefore considerably greater than is shown on the accompanying geologic map, where the formation appears only as small scattered dots and patches, except in the Nenana coal field, where the coal-bearing formation occupies a larger surface area.

The Tertiary coal-bearing formation consists mainly of unconsolidated or little consolidated clay, sand, and fine gravel, usually of rather light color, and at nearly every place where it is well exposed it shows the presence of lignitic coal. One unusually complete section measured on Healy Creek [15] shows 23 distinct coal beds ranging from 1 to 40 feet in thickness, with an aggregate thickness of lignite of over 230 feet. Other sections on Healy and Hoseanna creeks show from 10 to 15 lignite beds aggregating 60 to 130 feet in thickness. The lignite is of good grade, being similar in quality to that mined on lower Cook Inlet. It is now sometimes classified as subbituminous. It is known to occur at intervals from the head of Moose Creek, in the Kantishna district, eastward to and beyond the region here treated. The most completely exposed sections of this formation occur in the Nenana coal field, near the railroad, and this field contains so much easily accessible coal that it is unlikely that the smaller outlying areas will be exploited for a long time to come, except for local use.

The coal-bearing beds of the Alaska Range are certainly of Tertiary age, but they have not yet been finally assigned to any particular part of the Tertiary. Their only fossils are plant remains, which though abundant are usually not well preserved and occur in incoherent sediments too weak to stand collecting and shipment. Those that have been examined indicate a lower Eocene age. To the geologist familiar with the coal-bearing formation of Cook Inlet and the Susitna basin, the resemblance of the beds in the Nenana field to those there is so striking that he has little hesitation in correlating the two formations. The coal formation of the

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[15] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, fig. 3, 1912.

Susitna basin has yielded fossils that have been definitely identified as Eocene. Yet in the Alaska Range the Cantwell formation, which to judge by its lithology and degree of deformation is much older than the coal-bearing rocks, is also classified as Eocene, on the basis of its fossil plants. Therefore, if the age of the Cantwell formation is accepted as Eocene, it is necessary to conclude that the coal formation of the Nenana field is younger than Eocene and therefore younger than the coal formation of the Susitna basin and not to be correlated with it. Further facts will be necessary before this problem can be finally solved.

UNCONSOLIDATED SURFACE DEPOSITS.

The Alaska Range is largely bordered by areas of unconsolidated surface deposits. On the north the broad Tanana lowland, floored with alluvial deposits of gravel, sand, and silt, stretches northward to Tanana River, and on the south and east are other great basin areas in which glacial and stream deposits form a mantle over the underlying rocks. Within the range itself, too, there are large areas, including the valley floors of the larger rivers and the basins between the foothills and the main range, in which loose materials, mainly gravel, are present in considerable amount. On the accompanying geologic map (Pl. I) only the larger of such areas could be shown.

The unconsolidated surface deposits, as that phrase is here used, include materials of great range in age, as well as in character and mode of origin. The oldest beds included in this group are those of the Nenana gravel,[16] which occurs over an extensive area on the north flank of the Alaska Range and is well exposed along the line of the railroad between Healy and Moose creeks, where it may be seen in the high bluffs on the east side of Nenana River, with the coal-bearing formation in places showing beneath it. This gravel consists of fine to coarse unconsolidated stream deposits, rather poorly stratified, that were laid down as a great outwash apron along the north front of the range after the first great Tertiary mountain uplift. The deposits are deeply oxidized, in places show considerable folding, faulting, and tilting, and have been deeply eroded by many of the northward-flowing streams that cross them. On the mountain just north of the mouth of Hoseanna Creek gravel of this formation is to be found at an altitude of nearly 3,000 feet above the adjacent valley of Nenana River. Gold King Creek, farther east, has cut a wide valley 1800 feet deep into the gravel without exposing its base. On lower Healy Creek 1,760 feet of gravel is exposed, and the top of the formation is lacking.

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

The variations in the structural relations of the Nenana gravel from place to place indicate that the conditions of its deposition and later history were not everywhere the same. Thus in the Nenana coal field Martin found that the Nenana gravel is generally unconformable upon the coal-bearing Tertiary beds. In other parts of the region there is no recognizable unconformity between the two. The presence of an unconformity at the base of the gravel in some places shows positively that at those places the coal-bearing beds were somewhat uplifted and warped and then eroded before the overlying gravel was laid down. For the north flank of the Alaska Range as a whole, however, it may be said that the Nenana gravel has been uplifted, folded, tilted, and faulted to about the same degree as the underlying coal-bearing Tertiary beds, and most of the mountain-building movements that affected the coal-bearing formation affected the gravel also. This justifies the statement that if the main uplift of the Alaska Range took place before Quaternary time, then the Nenana gravel is Tertiary. On the other hand, the Nenana gravel carries on its surface, in places, great boulders and blocks that show striae and are apparently of glacial origin, and glaciated pebbles have been found that may have come from the gravel itself. If the Nenana gravel contains glacial pebbles, that indicates its Quaternary age. These apparently contradictory facts may be due to a different conception by various observers as to what deposits should be included in the Nenana formation.

Within the Alaska Range itself glaciation in Quaternary time was widespread, and the former more extensive glaciers left in many places moraines or till deposits. South of the range the glaciers reached tremendous size, entirely filled the intermountain areas, and sent tongues down Susitna and Copper rivers to the sea. Over that entire area glacial deposits form a large part of the unconsolidated surface materials. On the north flank of the Alaska Range, by contrast, the glaciers during Quaternary time were almost entirely confined to the mountains or at most protruded only short distances down the larger stream valleys into the bordering lowland. As a consequence, glacial deposits are much less abundant on the north slope of the range than on its south slope, and those on the north are to be found mainly in the larger stream valleys. In the higher mountains each valley head still contains a glacier, and ice streams of notable size radiate from the lofty group of peaks around Mount McKinley and from the high ridges near Cathedral Mountain, Mount Hess, and Mount Hayes. Each of the glaciers is engaged in gnawing its bed into the heart of the mountains, and the rock débris is deposited as moraines or delivered to the torrential streams to be laid down in the lowlands as fluviatile gravel. The deposition of glacial fluviatile gravel, though still actively in process, is now taking place on a much smaller scale than during the time of great ice expansion. The Tanana lowland north of the range is floored with a great sheet of these materials, and the aggradation of this lowland with stream-brought débris of glacial origin is still going on, though at a slower rate than in the past.

Stream gravel is present also along valleys that no longer contain glaciers and in places that have never been glaciated. In such places the valley deposits have not even a remote glacial orgin, but generally in this region the stream deposits are of complex derivation, part being the outwash from glaciers and part the result of normal stream erosion and deposition.

IGNEOUS ROCKS.

Igneous rocks occur in all the formations of the Alaska Range from the ancient Birch Creek schist to the Tertiary coal-bearing rocks. They include old Paleozoic and possibly pre-Paleozoic intrusives and flows that have been altered along with the sediments, to form the mica schist and gneiss; Mesozoic granite, intrusive and extrusive greenstone, and greenstone tuff; and late Mesozoic or early Tertiary rhyolite, andesite, and diabase, along with dikes and sills of the same age. Nevertheless, in spite of the many periods of igneous activity which this region has experienced and the great variety in the character of the igneous material, the portion of the Alaska Range shown on Plate I is composed mainly of sedimentary rocks, and the areas of igneous rocks it includes are of relatively small extent.

YUKON-TANANA UPLAND.

The northern edge of the region here described lies on the south margin of the Yukon-Tanana upland, a broad province roughly bounded by Yukon and Tanana rivers and the Alaska-Canada boundary. This upland consists of flat or slightly rounded, even-topped ridges reaching altitudes of 2,000 to 3,000 feet above sea level, separated by comparatively narrow, closely spaced valleys. This province has had a very different geologic history from the mountainous provinces farther south. The mountains owe their present altitude to the deformation of the rocks, which have been compressed into great folds, to be later carved by the agencies of erosion, as in the Chugach, Kenai, and Alaska ranges, or to the injection beneath the surface of great masses of igneous rock, with accompanying folding and faulting around the margins of the intrusion, as in the Talkeetna Mountains. The present relief of the Yukon-Tanana upland is to be explained in a different way. In the geologic past that region has been closely folded at successive periods, but apparently most of the folding ceased sometime in the Tertiary period and was followed by a long interval of time during which the agencies of erosion were active on this land mass, reducing it to a region of low relief. Later this area was uplifted bodily, without general folding, and the present surface forms are the result of stream erosion upon this uplifted land mass, the smooth ridge tops representing portions of the old land surface.

PALEOZOIC OR OLDER METAMORPHIC ROCKS.

The oldest rocks in the Yukon-Tanana upland and those of widest surface distribution belong to the assemblage known as the Birch Creek schist.[17] It includes quartzite schist alternating with quartz-mica schist; feldspathic, carbonaceous, and amphibole schists; and some crystalline limestone. These rocks are mainly of sedimentary origin and are similar in every way to the Birch Creek schist as described in the section on the geology of the Alaska Range. The structure of this formation is very complex, including close overturned folds and intricate crumpling, but the general strike is northeast. These schists are believed to be of pre-Ordovician age and may be in part as old as pre-Cambrian. Their areal distribution is shown on the accompanying geologic map (Pl. I). As will be shown later, their chief economic importance arises from the fact that they contain gold-quartz, antimony, and tungsten lodes, and from these erosion has produced rich gold placer deposits.

PALEOZOIC SEDIMENTS.

Within the region here considered the only rocks besides the Birch Creek schist that occupy large areas in the Yukon-Tanana upland are the beds of the Tonzona group, which have been described by Prindle[18] as comprising a series of red, green, and black argillite, conglomerate, and sandstone, with some chert and limestone. These rocks are all considerably metamorphosed and have yielded no fossils in the type areas, and their exact age is not known. They are believed to lie unconformably upon the older formations and are tentatively assigned to the Devonian. They are in many places cut by numerous veins and stringers of quartz, some of which are known to contain gold, and the erosion of these mineralized veins and the concentration of their heavy metallic content in the stream beds has led to the formation of valuable gold deposits in the Hot Springs district.

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[17] Prindle, L. M., The Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 35–36, 1913.

[18] Idem, pp. 44–45.

MESOZOIC AND TERTIARY SEDIMENTS.

Sedimentary rocks of Mesozoic and Tertiary age have been recognized at many places in the Yukon-Tanana region, but in that part of the region here described they are generally lacking.[18a]

IGNEOUS ROCKS.

Although the older schists of this region are mainly of sedimentary origin, they contain also some igneous materials that have been metamorphosed along with the inclosing sediments and like them have been reduced to schist. In addition to these altered igneous materials there are in the Yukon-Tanana upland many scattered areas of granitic intrusive rocks, some of which fall within the region shown on Plate I but most of which are too small to be shown on a map of this scale. For the most part these intrusions consist of granite, monzonite, or diorite, related coarse-grained rocks that were injected into the overlying rocks and cooled at depth. These intrusive rocks are thought to be mainly of late Mesozoic age. Elsewhere such intrusive masses are believed to have caused the mineralization of the surrounding country, for gold-bearing quartz veins are present near the margins of many such masses. The quartz veins in this region may be genetically related to the granite intrusives.

UNCONSOLIDATED SURFACE DEPOSITS.

The part of the Yukon-Tanana upland shown on the accompanying map (Pl. I) borders the north edge of the Tanana lowland, which is a region heavily mantled by unconsolidated surface deposits, including stream gravel, silt, and muck.[19] Glacial materials are lacking in this area, for the northward-flowing ice tongues of the Alaska Range never reach so far, and the Yukon-Tanana upland supported glaciers at only a few places. A fuller account of Quaternary events in the region north of Tanana River is given in the following pages.

PLEISTOCENE AND RECENT GEOLOGY.

In the discussions of the geology of the several mountain provinces of this region some description has been given of the unconsolidated deposits in each of them. By early Quaternary time the great mountain-building movements in this part of Alaska had been largely completed, and the greater topographic features, including the Chu-

[18a] In the extreme northwestern part of the region there are some rather large areas of highly folded argillite, slate, and quartzite that are now considered Lower Cretaceous, although they were considered Paleozoic when this report was written. This information came to hand too late to be incorporated in the accompanying geologic map.

[19] "Muck" is a miner's term for the prevailing thick layer of peaty and organic material that commonly overlies the gravel in the deep placer mines.

gach-Kenai Mountains, the Talkeetna Mountains, the Alaska Range, and the Yukon-Tanana upland, had been elevated to approximately their present altitudes and were surrounded, as now, by great lowland basins. These land areas at that time must have had a very different appearance from that we now see, however, for the agencies of erosion then active in sculpturing the land forms were those of a temperate climate, and glaciers, if present at all, existed only in the valley heads of the highest mountains and had as yet produced no effect upon the country as a whole. The Yukon-Tanana upland is an exception to the above general statement, for in early Quaternary time its appearance may have been much as it is now, except that the deep valley filling now present in so many stream basins did not then exist, and the relief was greater by an amount equal to the depth of that fill. Then, as now, the streams throughout this region had their sources in the mountains, flowed by steep gradients to the lowlands, and there gathered into great rivers that followed Tanana and Susitna valleys to the sea. The details of the drainage lines may have been very different, in large and small features, from those of the streams as shown on our present maps. The upper basin of Copper River probably discharged its waters into what is now the upper Susitna or Chulitna valley. Tanana River, instead of joining the Yukon, probably flowed southwestward into the upper Kuskokwim. Cook Inlet may have reached northward a much shorter distance than at present, and the south and east coast of Kenai Peninsula and the shores of Prince William Sound were much more regular and were lacking in the deep fiords and numerous islands by which they are now characterized. But the general position of the mountain ranges and their relations to one another and to the lowlands were in the main like those of to-day.

GLACIAL EPOCH.

GROWTH OF GLACIERS.

The glacial epoch, occupying that portion of geologic time known as the Pleistocene, was brought about by a change of climate that probably involved both a decrease in the mean annual temperature of the region and an increase in precipitation. The snow line in the mountains crept down to lower and lower altitudes, such glaciers as already existed in the high mountains became larger, and other valley heads that had earlier been free from glaciers now received a filling of ice and snow that grew in size and thickness from year to year. Like most other events in earth history this change must have been gradual, comparatively warm years alternating with more frequent and increasingly cold years. Perhaps had there been people living in the region at the time, the change during any one man's life-time 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 trunk 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 their basins brim full. This process continued until a very large part of the region here considered was buried hundreds and even thousands of feet deep beneath a great mass of slowly moving ice. The direction of the ice movement 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 a 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 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 lowlands. This was especially true of the glaciers on the Pacific slope, for on that slope the precipitation was heaviest and the growth of the glaciers was therefore most rapid. The Copper-Susitna basin, completely surrounded by the lofty ridges of the Chugach and Alaska ranges and the Talkeetna and Wrangell mountains, was inundated by ice from a multitude of vigorous tributary glaciers until it was filled to overflowing. This great Copper River glacier found many outlets through which to discharge its ice and its waters. A part of its drainage escaped southward through the narrow gorge of Copper River at Woods Canyon, a gorge which is of glacial and postglacial origin and which has been the outlet for the drainage of this great basin only since glacial time. Some of the ice and water of this glacier escaped northeastward into upper Nabesna Valley and northward through Suslota, Mentasta, and Delta passes to the Tanana, but a larger part of the ice probably moved westward into the Susitna basin by way of Matanuska Valley and across the lowland to the present valley of upper Susitna River. The Copper River glacier thus formed a continuous ice field with that in the Susitna basin.

The Susitna-Cook Inlet depression was likewise filled with ice at the time of the maximum glaciation. The much larger ancestors of the present glaciers of the Alaska Range poured down their mighty ice streams to coalesce in the lowland with one another, with the over-flow ice from the Copper River glacier, and with the glaciers reaching down from the Talkeetna, Chugach, and Kenai mountains. The Susitna glacier filled its basin with ice to a great depth, overflowed northward across the range through Nenana Valley, and pushed southward well down the present Cook Inlet embayment. At their greatest the glaciers south of the Alaska Range were so large and thick that only the highest ridges of the great mountain masses projected above the surface of the ice. In the valleys of Chulitna and Susitna rivers the main ice lobe at one time stood to depths of 3,000 and 4,000 feet, with steeply sloping tributaries pouring down to it from all sides.

On the northern, 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, chief of which was the lesser precipitation. The asymmetric position of the axis of the range, which is much closer to the north flank of the mountains than to the south flank, also played a part, as it gave the northward-flowing glaciers a much smaller collecting ground. At any rate, the glaciers from the Alaska Range tributary to Tanana Valley, though reaching far beyond their present limits, at their maximum succeeded in pushing northward but a short distance beyond the mountain front and out into the lowland. So far as is now known, none of these ice streams stretched northward as far as the present course of Tanana River, and they failed to spread laterally in the lowland sufficiently to coalesce with one another.

The Yukon-Tanana upland, being a region of only moderate relief and of small precipitation, was at no time in the Pleistocene epoch extensively invaded by glacial ice. On a few of the highest peaks and domes small valley glaciers formed, but these never reached any great size.

In a few places in Alaska evidence has been found of at least two ice advances, one much older than the last. We know that elsewhere on the American continent there were several successive ice advances, separated by periods of deglaciation, and probably the same thing is true of Alaska also, but the available evidence on this point is meager, the last glaciers having to a great extent overridden the deposits of their predecessors and destroyed or confused the evidence. Along the course of the railroad in the Nenana Valley, however, the deposits of two distinct periods of glaciation can be seen. The terminus of the ice during its last pronounced advance lay in the vicinity of the junction of Healey and Dry creeks with Nenana River, and a terminal moraine may be seen on the west side of the river north of Dry Creek. Farther north, near the point where the railroad emerges from the foothills onto the lowland, there are near the railroad track a number of large granite boulders that

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were brought from the mountains by an older and more extensive glacier. The northern limit reached by that glacier is not known, but it possibly extended some distance out upon the lowland.

EFFECT OF GLACIATION ON LAND FORMS.

The glaciers of this region have had profound effects on the shape of the land forms as we now see them, effects which in the highlands resulted mainly from the sculpturing by the vigorous, rock-studded ice streams of the sides and beds of their confining valleys, while in the lowlands and near their termini the glaciers modified the surface by depositing the great quantities of detritus torn from the headward portions of their beds. In all the higher mountains, where the glaciers had steep gradients and relatively rapid motion, the valleys are now broadly U-shaped in cross section, have wide floors with steeply rising walls, and are straight or bend only in broad, sweeping curves. They thus differ strikingly from normal stream-eroded valleys, which are V-shaped in cross section and follow a sinuous course between the spurs that descend to the valleys from both sides. Glacial valleys are also characterized by amphitheater-like heads, with steep surrounding cliffs, by hanging tributary valleys, by lakes, and by many other features that show plainly the powerful erosion to which a glacier subjects its bed.

In the lowlands the visible results of the former occupancy by glacial ice are of a different character. There the glaciers, having descended to altitudes at which the mean temperature was no longer low enough to favor the accumulation of ice, were gradually wasted by melting and so dropped their loads of débris picked up farther toward their heads. The débris was deposited as terminal moraine, of hummocky, irregular surface, or as ground moraine beneath the ice, or was fed to the torrential streams that flowed from the melting ice and deposited farther downstream as outwash materials. On the accompanying map the lowland areas are shown as occupied by unconsolidated surface deposits, and these deposits are, in large part at least, composed of materials that directly or indirectly are of glacial origin. In many places these unconsolidated deposits are very thick over large areas. The stream bluffs of Copper River, near Copper Center, and of many of its tributaries show glacial till, sand, silt, and gravel to a depth of more than 500 feet without revealing the underlying bedrock, and it is safe to say that throughout that basin, an area of some 3,000 square miles, the materials of glacial origin average over 100 feet in thickness. The northwest border of this extensive basin deposit lies in the east-central portion of the area here under discussion, and the glacial materials so thoroughly conceal the topography of the underlying bedrock that it is still impossible to say just what course the preglacial drainage from the Copper River basin followed to join the Susitna, but doubtless that course is buried somewhere in the upper Susitna basin.

The size, shape, and depth of upper Cook Inlet and the surface forms throughout the Cook Inlet-Susitna lowland have been greatly modified by the deposition of débris from the glaciers. The discharge of glacial sand, gravel, and silt was doubtless much more active during the periods of great ice expansion than it is now, and glacial till and outwash materials were deposited in great quantity throughout this lowland, as may be seen from the wide distribution of such deposits, as shown on the accompanying map (Pl. I). These deposits have not generally been so deeply dissected by streams as those in the Copper River basin, and their thickness can only be inferred, but on the east shore of Cook Inlet, from Anchor Point to Point Possession, there are almost continuous bluffs, from 100 to 400 feet high, that show unconsolidated surface materials without generally revealing the underlying Tertiary rocks.

To-day, during a period of ice recession, the deposition of glacial outwash is still actively in progress at the mouths of Matanuska, Knik, and Susitna rivers and many other smaller streams. Their deltas are encroaching on the shallow waters of Cook Inlet, and great volumes of silt, carried back and forth by the tides, are being built up as extensive low-tide mud flats and shoals.

The Tanana lowland was never extensively invaded by glacial ice, but its surface has been greatly modified by glacial outwash brought down from the Alaska Range by the many glacial streams. By no means all the unconsolidated sand, gravel, and silt of that lowland, however, can be ascribed to glacial erosion and extraglacial deposition, for the filling of the lowland with detritus from the mountains began in preglacial time, perhaps about the middle of the Tertiary period, when the elevation of the Alaska Range first began. Since then deposition in the lowland has been continuous, though with greatly varying rapidity. No doubt the removal of material from the mountains and its transportation northward to the lowland by glaciers and the torrential glacial streams were tremendously stimulated at times of widespread glaciation, and some measure of that quickening may be gained by observing the heavy load of detritus now carried by the streams that head in the greatly shrunken glaciers that remain to-day.

Since mid-Tertiary time the Tanana lowland has been filled up to a depth of many hundred feet with unconsolidated deposits of gravel, sand, and silt, mainly derived from the Alaska Range. This filling has not only altered the whole appearance of the Tanana lowland but has had a far-reaching economic effect upon the gold placer deposits of the Fairbanks district. The Fairbanks gold placers, as well as those of the Tolovana district, are unusual in that in the headward, steep portions of the streams the gravel is shallow and the streams flow near the bedrock floors of their valleys, whereas in their lower courses the bedrock floor is deeply buried by gravel and muck, and the streams flow over a valley filling whose thickness reaches 100, 200, or even 300 feet. The cause for this deep burial of the bedrock floor and consequently of the placer gold, which usually occurs in gravel near the bedrock, is probably complex and may involve many factors, including warping, but certainly one cause that may be competent to explain most of the present conditions is the gradual deep filling of the Tanana lowland by débris from the range to the south. The building of alluvial fans northward into the Tanana lowland by such glacial streams as Kantishna, Nenana, Wood, Little Delta, and Delta rivers has crowded Tanana River northward out of the valley axis, so that it now flows in a sinuous course that follows closely the foot of the rock hills that border the basin on the north. The small, sluggish tributaries of the Tanana from the north, carrying little débris, were unable to throw out comparable fans, and as the valley filling from the south progressed their gradients were decreased, their lower courses became marshy, and vegetation accumulated to form the muck now generally present.

There is evidence in the Fairbanks district that in time past the valley filling was considerably deeper than it is now, but there still remains a filling in the lower valleys of Chatanika River and other tributaries of the Tolovana that is at least 200 to 300 feet thick, and this probably represents the minimum measure for the average thickness of unconsolidated materials in the Tanana lowland. At the valley axis these deposits may be very much thicker.

POSTGLACIAL EROSION.

Since the retreat of the last great glaciers aggradation has continued in many parts of the lowlands, but in the higher mountains glaciers and streams have continued to erode their beds and to modify the surface uncovered by the retreating ice sheets. In places in the lowlands, too, the streams have deeply intrenched themselves in the glacial deposits. Where changes of drainage or of gradient were brought about by the glaciers, the streams have cut in some places and filled in others, in their attempt to reestablish normal stream gradients in their valleys. The shore lines of Cook Inlet have been modified by wave action, and the normal agencies of stream and subaerial erosion have taken up the eternal task of reducing the land masses and filling the depressions.

MINERAL RESOURCES.

The mineral resources of the region to be served by the Alaska Railroad comprise a great variety of metallic and nonmetallic minerals. Some of these have been actively exploited for many years. Others have awaited the lower cost of development and operation that will prevail, now that the railroad is completed. A brief statement of the value of minerals produced from this region up to the end of 1922 is given on pages 76–77. Here, as in most other frontier countries, the earliest prospectors searched for the precious metals, especially for placer gold, for placer gold mining can be done 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 they recovered a few ounces of gold. Since the early nineties, however, there has been continuous prospecting, and a number of gold placer camps have been established.

The next stage to follow the search for and exploitation of the gold-bearing stream gravels is the attempt to find the bedrock source of the gold from which the placers have been derived, and there are now a number of districts in this region in which gold quartz mining is carried on. The Willow Creek district has already produced over $2,000,000 worth of lode gold, the Fairbanks district over $1,337,000, and there are promising though as yet little developed gold lodes in Kenai Peninsula, in the Knik-Turnagain Arm district, and in the Yentna, Talkeetna, West Fork of Chulitna, Kantishna, and Bonnifield districts. Like gold placer mining, gold lode mining can be carried on in rather inaccessible regions, for although the cost of transporting such supplies as powder, steel, and machinery to the mine is often very high, the metal recovered, if the ore is free milling, can be taken out without great difficulty. Lode deposits of gold ore in which the gold is not free milling and can not be recovered by amalgamation, and of such other metals as silver and copper, which commonly occur as sulphide ores, can generally not be profitably exploited without fairly good transportation facilities, for not only must all supplies and machinery be brought to the ore deposit, but the heavy ore or concentrates produced must be transported to smelters to be reduced. Many low-grade gold placers also, which require for their working heavy hydraulic equipment, steam-scraper plants, or dredges, are dependent on reasonable transportation costs before they can be developed at a profit. It is obvious that to be mined profitably a mineral deposit must contain sufficient valuable minerals to pay not only the cost of mining and reducing the ore and of getting the product to the market but a profit to the miner as well. The value of an ore deposit thus depends to a large degree upon its location in respect to routes of transportation, as well as upon its metal content, and an inaccessible ore deposit that would have great value if cheap transportation to it were available may be worthless. The completion of the Government railroad from Seward to Fairbanks has greatly improved the transportation to a large number of mines and prospects in this region and should make profitable the exploitation of many mines whose development could heretofore not be undertaken. One of the most valuable mineral resources of this region is coal. High-grade bituminous coal is found in Matanuska Valley, and lignite of very fair grade occurs in a great number of localities on Cook Inlet, in Susitna and Chulitna valleys, in the Nenana coal field, and at many places along the north flank of the Alaska Range. All these coal deposits are potentially valuable, but except for supplying small local markets their present value depends upon good transportation more than upon any other single factor. The present development of the coal fields is considered elsewhere in this report.

GEOLOGIC RELATIONS OF MINERAL DEPOSITS.

An important service that the geologist can render to the mining industry is in recognizing and pointing out the relations of the several rock formations to the ore deposits, in determining which rocks are likely to contain valuable minerals and which hold out little promise to the prospector, and in mapping the areal distribution of the different rock formations so that the prospector can choose as the field for his search those areas that are most likely to yield him the reward he seeks. A large part of the region here considered has been mapped geologically (Pl. I) in at least a reconnaissance way, so that the main facts concerning the distribution of the rocks are known. It is therefore pertinent to summarize at this place the salient points in regard to the distribution of the ore deposits and the association of the different kinds of valuable mineral deposits with certain types of rocks. This summary will be given in the general geographic order of the deposits along the railroad from Seward northward into interior Alaska.

CHUGACH-KENAI REGION.[20]

The central and northern portions of Kenai Peninsula are composed mainly of a great series of Paleozoic and Mesozoic rocks, chiefly shale, slate, argillite, and graywacke, with very minor

[20] For a full discussion of the mineral deposits of Kenai Peninsula, see Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, 1915.

amounts of granitic material and of greenstone. In that region there are a great number of placer mines and prospects; many gold lode prospects, a few of which have been mined; and a large number of copper prospects and one copper mine that has long been one of the large copper producers of the territory. Placer mines contain gold that has been concentrated in the stream beds from some bedrock source, and after the metal particles have been delivered to the stream the relation of the gold to the underlying bedrock at the point where it comes to rest is purely accidental. If the miner can find the veins from which the gold comes, however, and can learn the relation of the veins to their country rock, he is aided in the search both for other similar veins and for the stream placers derived from them.

GOLD LODES.

The gold lodes of the Chugach-Kenai region, as shown on Plate I, may be divided according to their distribution into two main groups—one having a north-south linear arrangement and extending from Resurrection Bay to Turnagain Arm, and the other group being massed around the shores of Port Wells. Throughout both of these groups there is a striking similarity in the geologic relations of the ore deposits, for the gold occurs in veins that cut the slate and graywacke in districts where these sediments have been intruded by granitic or siliceous materials. A few exceptional veins occur in bodies of granite.

In northern Kenai Peninsula there is a series of siliceous dikes that strike in a northerly direction, and the gold lodes bear a striking relation to these dikes. The veins ordinarily consist of a quartz gangue containing, in addition to native gold, the sulphides arsenopyrite, galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, and more rarely molybdenite. In places the ore is very rich and yields fine specimens, but even in the better veins the gold content is irregularly distributed, few mines have been profitably operated, and the total yield from all the gold lodes of the region together has so far not been large.

GOLD PLACERS.

The gold placers of the Kenai Peninsula-Turnagain Arm region are the result of the erosion and concentration by the streams of gold from the lodes, and the ultimate origin of the gold of both lodes and placers is therefore the same. The occurrence of placer gold, however, depends on physiographic processes, the most important of which are long-continued erosion and the concentration by some stream of the gold particles contained in the rock débris into a single restricted channel. In this region normal stream erosion was for a long time interrupted by the invasion of glacial ice. Probably much richer and more extensive placer deposits existed here in preglacial time, but they were in large part removed and scattered by the glaciers. It is only in especially favored localities that workable placers now exist, either in places that escaped glacial scour or in places where postglacial concentration of gold from the lodes or of scattered gold in glacial deposits has been especially rapid. It is only by close and intelligent prospecting that such localities are likely to be discovered.

The mining of gold placer gravel on Kenai Peninsula has been confined largely to the valleys of the streams draining to Turnagain Arm, though a little mining and prospecting has been done in the basin of Kenai River. Gold is widely distributed and has been found in terrace gravel, glacial deposits, and the present stream gravel. The earliest producing streams of the region were Resurrection Creek, which through much of its length flows through a deep, canyon-like channel,[21] and Palmer Creek, a tributary from the east. Sixmile Creek and its tributaries Canyon Creek and East Fork have also produced considerable gold, and a large hydraulic plant is at present in operation on lower Canyon Creek.

On the north side of Turnagain Arm, in the basin of Crow Creek, a tributary of Glacier Creek, placer mining has long been conducted. On lower Crow Creek an ancient channel containing placer gold has been found deeply buried beneath glacial moraines and gravels. On upper Crow Creek paying placers have been found in a gravel-filled basin lying behind a glacial moraine of coarse boulders and till.

The placer mines of Kenai Peninsula and the Turnagain Arm district have been worked more or less vigorously since about 1894, reached their highest yield between 1897 and 1899 with an annual production of $150,000 to $175,000, and then declined rapidly to less than $40,000 in 1912, since when the annual output has ranged from $20,000 to $40,000. In 1922 about a dozen gold placer mines were operated, with an estimated production of $40,000.

COPPER LODES.

In the Chugach-Kenai region there are only two important areas in which copper lodes occur, one just east of Resurrection Bay and the other farther east, on the islands of Prince William Sound and centering at Latouche. An examination of the accompanying geologic map (Pl. I) at once draws attention to the fact that in both of these areas the copper lodes are associated with bodies of green-

[21] Moffit, F. H., and Stone, R. W., Mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 279, pp. 33–48, 1907.

stone, which occur either as intrusive masses or as lava flows. This association of copper deposits with basic igneous rocks interbedded with or cutting sediments is general throughout Alaska. The lodes that lie just east of Resurrection Bay are as yet only prospects, and no systematic mining has been done on them, but the copper-bearing sulphides, mainly chalcopyrite, occur in shear zones in the slate and graywacke and in the greenstone.

The largest and best-equipped copper mine in the Alaska maritime provinces is the property of the Kennecott Copper Corporation, generally known as the Beatson Bonanza mine, on Latouche Island. The extensive ore deposit at this mine, as well as many other copper lode prospects on Latouche and Knights islands, is in the slate and graywacke in a district where these sediments are cut by and interbedded with greenstones. These deposits are described by Johnson [22] as occurring in brecciated or sheared zones in both the sedimentary rocks and in the greenstone of these islands. The ore bodies are primary deposits, the sulphides impregnating or replacing the sediments and greenstone and filling small fractures and openings in the material of the shear zones. The ores are chiefly sulphides in a gangue consisting principally of crushed and altered country rock. The commercially important copper-bearing mineral is chalcopyrite, and it is associated with chalmersite, native gold, silver, pyrrhotite, pyrite, sphalerite, and galena, with locally some arsenopyrite and nickeliferrous pyrrhotite, in a gangue containing quartz, feldspar (?), chlorite, ankerite, calcite, and epidote. The only large producing mine in this group, that of the Kennecott Copper Corporation, has been actively exploited for years and has produced a large amount of copper.

Considerable development work has been done on a number of other properties, and it is likely that some of them will become mines.

TALKEETNA MOUNTAINS.

As has already been shown, the outstanding feature of the geology of the Talkeetna Mountain region is a group of large and small granitic intrusive masses and smaller amounts of basic intrusives and flows with associated fragmental volcanic materials, the igneous materials intruding or overlying sediments that range in age from early Paleozoic or older to Tertiary. Plates I and II show the salient facts about the areal geology of the western Talkeetna Mountains and the location of the mines and prospects. Metal mining in this region has been limited to gold placer mining at a number of localities and to the exploitation of the gold lodes of the Willow

[22] Johnson, B. L., Geology and ore deposits of Latouche and Knight islands and vicinity, Prince William Sound, Alaska: U. S. Geol. Survey Bull. — (in preparation).

Creek district. There are, however, many other districts in which are found lode prospects, including lodes carrying gold, copper, and antimony, that may be developed into producing mines. In addition to the Willow Creek gold lode district, the principal areas that have promising ore deposits are the Iron Creek district, with its numerous copper prospects, and the Nelchina gold placer district. The high-grade coals of Matanuska Valley and the lignite deposits of Susitna and Chulitna valleys are described in another section of this report.

GOLD LODES.

Willow Creek district.—The gold lodes of the Willow Creek district constitute by far the most important developed metal resources in the Talkeetna region. From 1908 to 1922 these lodes yielded over $2,194,000 worth of gold and silver, and the output in 1922 was worth $239,500. These lodes consist of quartz veins which cut quartz diorite.[23] The diorite is generally massive, coarse grained, and little altered but in places is somewhat schistose. Most of the veins strike in a general north-south direction, and they dip westward at an average angle of 39°. The veins are in sharp, clean fissures in quartz diorite. They probably represent fillings of early joint planes and are now paralleled and intersected by other sets of joints that have no vein filling. Ore has been deposited in some of the veins at repeated intervals, as is witnessed by the banding of the ore. Some movement has taken place since the ore was deposited, resulting in shearing, faulting, and the formation of gouge along many of the veins.

The gold is present in the veins largely as native gold, and much of it is recoverable directly by amalgamation. The tailings carry some gold entangled in the pyrite, which is generally treated by cyanidation. Associated with the gold in the veins are the metallic minerals pyrite, arsenopyrite, stibnite, chalcopyrite, bornite, chalcocite, galena, malachite, limonite, and cinnabar. Except for the limonite and malachite, which are plainly secondary after pyrite and chalcopyrite, and the cinnabar, which was introduced after the gold mineralization, the assemblage of minerals listed is characteristic of gold-bearing veins of deep-seated origin, deposited by aqueous solutions. The district lies in an area of severe Quaternary glaciation, and the oxidized zone is very shallow. Most of the ore mined is primary ore. The accompanying sketch map (Pl. III) shows the distribution of both gold lode and gold placer mines and prospects in the Willow Creek district. The above description of the character of the veins probably applies also to a number of veins farther

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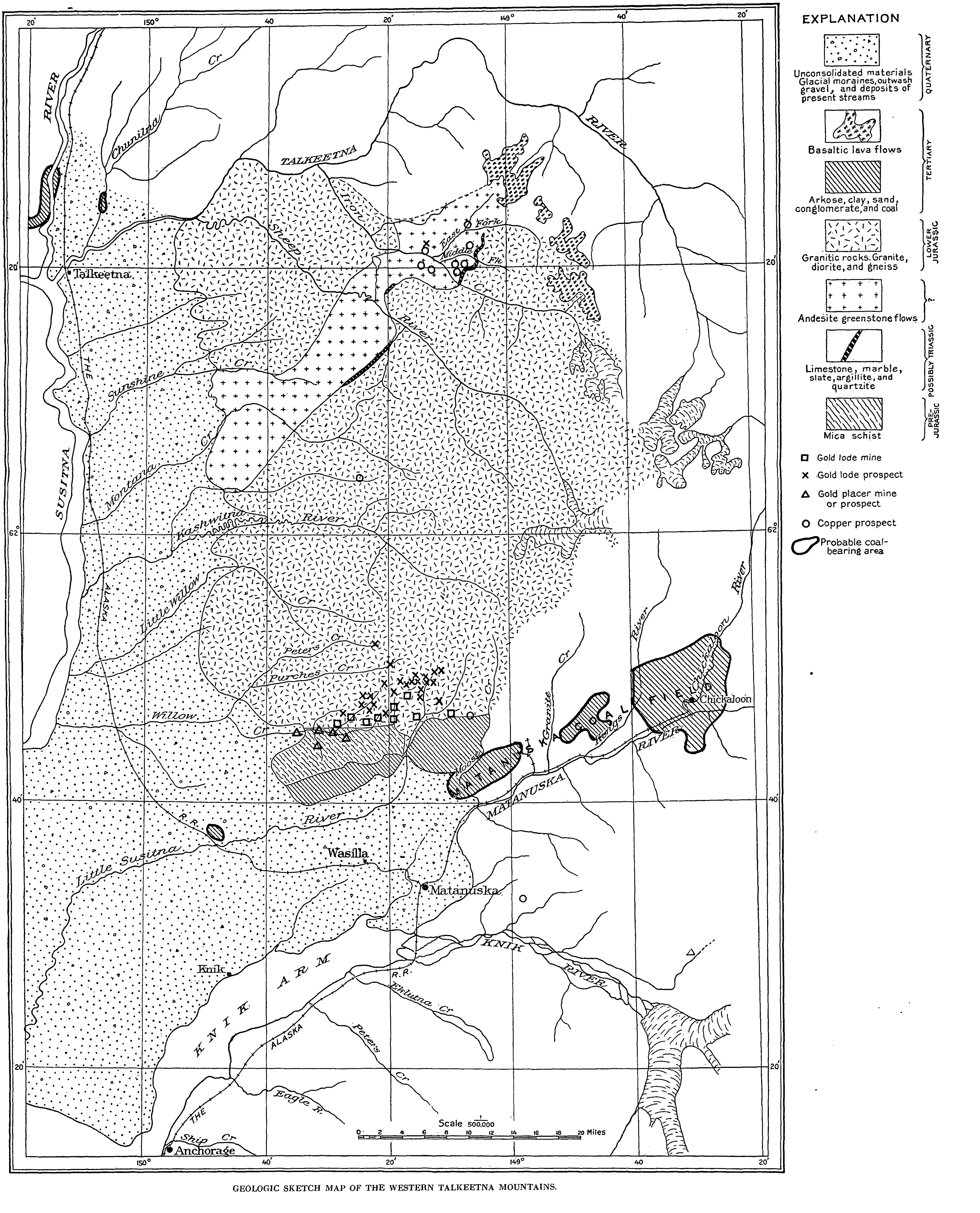
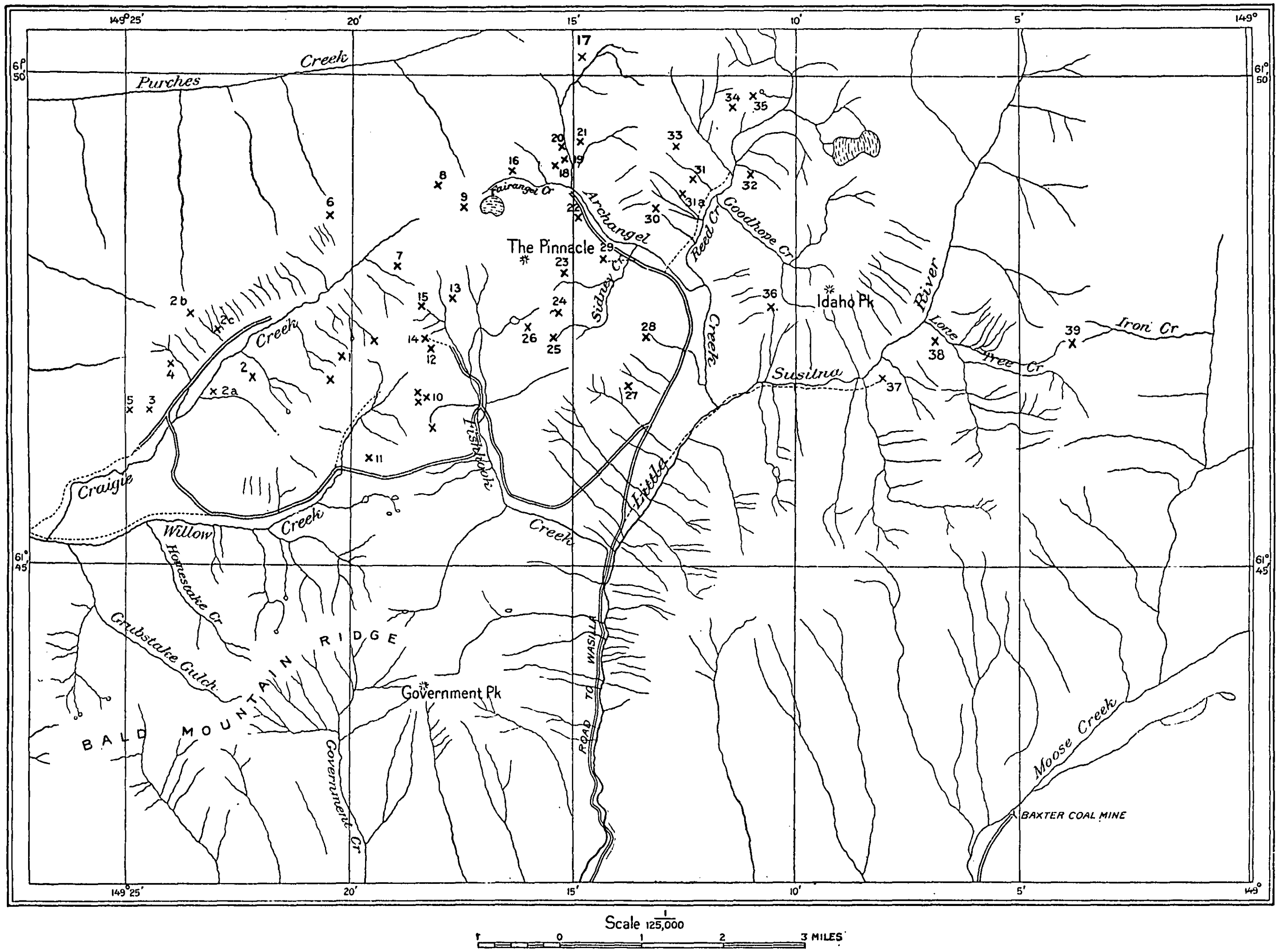
[23] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 55–60, 1915.



GEOLOGIC SKETCH MAP OF THE WESTERN TALKEETNA MOUNTAINS.



SKETCH MAP OF WILLOW CREEK DISTRICT, SHOWING LOCATION OF LODE MINES AND PROSPECTS.

1. Gold Bullion mine.
2. Golden Light prospect.
2a. Rainbow prospect.
2b. Golden Top prospect.
2c. Comeback prospect.
3. War Baby mine.
4. Panhandle prospect.
5. Lucky Shot mine.
6. Gold King prospect.
7. Newman & Miller prospect.
8. Dixie prospect.
9. Little Willie prospect.
10. Brooklyn-Willow Creek Gold Mining Co.
11. Mammoth prospect.
12. Alaska Free Gold mine.
13. Gold Cord mine.
14. Independence Gold Mines Co.
15. Kelly-Willow Creek Mining Co.
16. Consolidated Mining Co.
17. Anchorage Gold Mines Co.
18. Rutland prospect.
19. Fern & Goodell prospect.
20. Giant Gold Mining Co.
21. Little Gem Gold Mining Co.
22. Webfoot prospect.
23. Mohawk prospect.
24. Keystone prospect.
25. Smith-Sargent prospect.
26. Rae-Wallace mine.
27. Shough prospect.
28. Mabel mine.
29. Arch prospect.
30. Opal prospect.
31. Idamar prospect.
31a. Home Builder prospect.
32. Mary Ann prospect.
33. Snow King prospect.
34. Willow Creek Development Co.
35. ——— prospect (idle).
36. Le Roi Mines Co.
37. Gold Mint mine.
38. Maverick prospect.
39. Moose Creek copper claims.

north, in the Peters and Purches creek basins, that have not been studied.

Iron Creek district.—A lode in the Iron Creek district that is valuable chiefly for its gold content occurs under the same conditions as the copper lodes in that vicinity. It carries copper also and is described below. The Iron Creek district lies some 40 miles by trail west of the railroad at Talkeetna, in the basin of Iron Creek (Pl. II). Stated in simplest terms, the rocks of this district include a sedimentary series of limestone, marble, slate, argillite, and quartzite, cut and overlain by basic dikes and flows, and both sediments and basic rocks extensively intruded and surrounded by great masses of granitic rock. Some basaltic lava flows are also present.

COPPER LODES.

The following description of the lodes of the Iron Creek district is based on an examination made in 1917.[24] As no geologist of the Geological Survey has visited the district since that time, and as the edition of the report on it is exhausted, the lodes are here described in greater detail than would be given if the literature on them were more voluminous or more easily accessible. The position of the lodes and the general distribution of rock formations of the district are shown on Plate II.

The principal valuable minerals of the lodes are copper and gold. Most of the ore bodies are due to the replacement, along zones of faulting and shearing, of andesite greenstone, but one or two, also in andesite greenstone, have some of the aspects of contact-metamorphic deposits, though they lie some distance from the contact of diorite that intrudes the greenstone. So far as is known the content of the ores in free gold is not sufficient to justify milling them on the ground. The base character of the ore will necessitate smelting for the recovery of the copper and gold. Hence cheap transportation to a smelter is essential before these lodes can be developed.

Copper Queen group.—The Copper Queen group includes two claims that lie on the north side of Iron Creek, 2 miles below the mouth of East Fork. Developments at the time of visit had been confined to stripping the vegetation from the ore body and the excavation of a shallow open cut. The country rock is an andesite greenstone with amygdules of greenish-yellow epidote. The ore body, which lies along a sheared and crushed zone that strikes N. 10° E. and stands nearly vertical, has been formed by the replacement of the sheared andesite, which is heavily mineralized throughout a width of 21 feet across the strike, though there are many large

[24] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 187–207, 1919.

lenticular horses of nearly barren country rock. Pyrite, arsenopyrite, and chalcopyrite are the common metallic minerals and occur as nearly pure masses of one or the other of these sulphides or intimately intergrown with one another. Some quartz is present in the ore as gangue but is not abundant. Scattered specks and blotches of sulphides occur both in the horses within the ore body and in the wall rock for some distance back from the zone of shearing. This lode is unusual in this district in that assays of ore from it are said to show a high gold content, so that its value for gold probably exceeds its value for copper.

Copper King group.—The Copper King group comprises six claims that lie on the south valley wall of Iron Creek opposite the mouth of East Fork. The principal workings are at an altitude of about 3,300 feet, 1,500 feet above the valley bottom, and consist of a number of trenches and open cuts excavated to demonstrate the presence of a long, continuous ore body. They show that the andesite greenstone country rock is cut by a shear zone that strikes northeast and dips about 60° E., in which the sheared material has been replaced in part by metallic minerals and some quartz. The shear zone ranges in width from 6 to 20 feet, and the degree of replacement of the sheared andesite greenstone differs greatly from place to place. The best showing of ore was in a large open cut that had been excavated down to undisturbed bedrock. In this cut, through a width of 9 feet across the strike of the shear zone, abundant chalcopyrite and specular hematite with some pyrite and a little quartz were exposed. The ore is banded parallel to the direction of the shear zone and consists of alternating bands of nearly pure chalcopyrite, specular hematite intergrown with quartz, and pyrite. The individual bands are more or less discontinuous, and the characteristic mineral of one band may be present in small amounts in the other bands. Another cut near by shows several feet of nearly pure hematite with only small amounts of other sulphides. Locally some quartz is present in the shear zone in small distinct veins. The ore from this group of claims is said to carry only small amounts of gold and silver.

Copper Wonder group.—The Copper Wonder group comprises seven claims that lie on the south slope of Iron Creek valley south of the mouth of Middle Fork. These claims were first staked in June, 1917, and the only development work done by August of that year was the excavation of three open cuts in the bluffs of Alder Gulch, at an elevation of about 2,500 feet. These cuts show a zone of strong shearing in andesite greenstone country rock, but the ground has been much disturbed, and in the shallow excavation the strike and dip of the shear zone could not be definitely determined. In the larger open cut the andesite greenstone is seen to be much altered along the shear zone, in which there is a heavy deposit of specular hematite, together with some pyrite and bunches of chalcopyrite as large as a man's fist. A little quartz was also noted as a gangue mineral. The hematite has a thickness of 2 to 3 feet through an exposed vertical distance of 20 feet, and there is considerable copper carbonate stain in the altered shear-zone material. Scattered specks of sulphides were seen in the andesite country rock outside of the shear zone.

Phoenix group.—The Phoenix group includes three claims on Hyphen Gulch, a small tributary of Iron Creek from the northeast, a little more than a mile above the mouth of Middle Fork. The only locality at which any noteworthy excavation had been made was at an altitude of 3,600 feet, where an open cut showed a small shear zone, 2 to 3 inches wide, in andesite greenstone. This shear zone, or line of faulting, strikes S. 30° W. and dips 65° NW. It contains gouge and decomposed materials, with a little quartz and some copper carbonate stains. The andesite greenstone wall rock is, however, much stained with copper carbonate and has locally been partly replaced by chalcopyrite, bornite, specular hematite, and quartz. The bornite is closely associated with chalcopyrite and is apparently a surface occurrence only, for a shallow excavation made at the best showing of bornite showed little bornite at a depth of a few feet below the surface but an increasing abundance of chalcopyrite. A number of narrow veins of nearly pure hematite with small quantities of associated sulphides have been found on this property.

Blue Lode group.—The Blue Lode group of five claims lies on the south side of the valley of Middle Fork of Iron Creek, about 2½ miles above the mouth of that stream and 1 mile northeast of the Phoenix group. The principal excavation is at an altitude of 4,200 feet, where a large open cut has been made along a fault or shear zone about 2 feet wide that strikes N. 16° E. and dips 80° W. This zone is filled with gouge, fine crushed and decomposed material, and some quartz that contains chalcopyrite. The wall rock of this shear zone is andesite greenstone, which has locally been replaced by specks and bunches of bornite and chalcopyrite. An andesite greenstone cliff above the excavation shows abundant stains of azurite and malachite. Broken surfaces of the surface wall rock show bornite and chalcopyrite intimately intermingled, but a few feet below the surface the bornite becomes relatively scarce and chalcopyrite predominates, suggesting that the bornite occupies only a shallow zone of enrichment and that at greater depth the chalcopyrite will prove to be the prevailing sulphide. Another open cut farther down the mountain shows chalcopyrite but no bornite. This property was staked only a few weeks before it was visited, and too little development work had been done to determine either the size of the ore body or its character at depth.

Eastview group.—The Eastview group of two claims lies in the basin of Middle Fork of Iron Creek half a mile southeast of the Blue Lode group and about the same distance northeast of the Phoenix, at an altitude of 4,500 feet. The country rock is andesite greenstone, and the workings include three open cuts, from which have been taken large lumps of banded quartz, hematite, and chalcopyrite. In these lumps of ore chalcopyrite is locally abundant, but as none of the cuts had been carried down to undisturbed bedrock at the time of the writer's visit, no ore in place was seen, and nothing is definitely known about the size or position of the ore body.

Talkeetna group.—The Talkeetna group of nine claims lies in the valley of Prospect Creek, about 2 miles above the mouth of that stream. The claims were staked in the spring of 1916, and their exploration and development had been limited to strippings and open cuts made in the endeavor to show the character of the ore in place. At the time of the writer's visit eight men were employed on this property. The main ore body is on the claim known as Talkeetna No. 2, where an extensive gossan on the steep mountain slope, at an altitude of 4,200 feet, renders the ore deposit conspicuous from a distance. A number of trenches and open cuts have been excavated through this gossan, but these were made for the purpose of ascertaining the character of the unoxidized ore body, and no consistent effort had been made to outline the area of mineralization or to determine its structure and relations. The country rock is an amygdaloidal andesite greenstone, and the amygdules consist of epidote. This greenstone is cut by a shear zone that strikes approximately east and dips 75° N. The shear zone has acted as a channel for the circulation of mineralizing solutions, and the sheared material, as well as the massive wall rock, has been in part replaced by specular hematite, chalcopyrite, pyrite, and quartz. The area of intense mineralization, so far as could be determined from the workings, is several hundred feet long and is locally at least 30 feet thick. Its long dimension is parallel to the strike of the shear zone, which itself lies almost parallel to the steep mountain face, so that the ore is exposed on the surface through a vertical distance of at least 50 feet. The gossan is only a few feet thick and is abundantly stained with copper carbonate.

Specular hematite is by far the most abundant metallic mineral and occurs in massive aggregates many feet thick, in which the only other conspicuous mineral is granular quartz that is intimately intergrown with the hematite. Another abundant type of ore consists of an intergrown aggregate of hematite, chalcopyrite, and quartz that forms the matrix of a breccia and surrounds angular fragments of andesite greenstone, themselves partly replaced by iron and copper minerals. Elsewhere the ore consists of sheared and schistose andesite greenstone largely replaced by metallic minerals and banded with small quartz veinlets that include the same minerals—pyrite, chalcopyrite, and hematite. Veinlets of ore shoot off from the main ore body into the country rock, and sulphides and hematite are widely disseminated in the country rock for some distance on both sides of the shear zone. These claims are being prospected as a source of copper, and a large amount of work must be done before a proper estimate can be made of the amount of copper ore of any particular grade that is available. The principal copper mineral, chalcopyrite, differs greatly in abundance from place to place within the ore body. Locally hematite is present to the almost complete exclusion of the sulphides. Elsewhere chalcopyrite forms the bulk of the ore. In some places the chalcopyrite crystals are surrounded by a thin zone of hematite, and that by quartz. It is reported that assays show from less than 1 per cent to 8 per cent of copper and small amounts of gold and silver. Underground exploration alone can determine the character and metallic content of this ore body at depth, but the great size of the deposit may make possible the development of a mine, even if the ore is of comparatively low grade.

Shallow excavations have been made on croppings of metallic minerals on claims No. 3 and No. 7 of this same group, on the north side of Prospect Creek, where a number of open cuts, for the most part shallow and in disturbed ground, show similar ores, which have the same association of pyrite, hematite, and chalcopyrite.

OTHER PROSPECTS.

A number of claims or groups of claims, in addition to those described above, have been staked in the basin of Iron Creek, but on most of them little work had been done, and the restrictions of time imposed upon the writer made it possible to visit only those properties that had been best developed. The location of some of these groups is shown on the accompanying map (Pl. II). Vigorous prospecting in this district has been carried on only since the spring of 1916, and many of the claims were staked in 1917, so that the amount of work that has been done on any property is not necessarily an index of the value of the ore deposit, and some of the properties not visited and not described specifically may be of greater merit than some of those that are more fully described here. The possibilities for the discovery of still other ore deposits in this area have by no means been exhausted, and it is likely that other ore bodies more valuable than any yet discovered may be found. A large area in the basins of Sheep River, Montana Creek, and Kashwitna River has received scant attention. Hand specimens of rich copper and gold ores have been brought out from this area by prospectors, but the localities from which they came could not be learned, and the deposits were not visited by the writer. Later in the summer of 1917 reports were circulated of the discovery on a northward-flowing tributary of Talkeetna River, opposite the upper basin of Iron Creek, of a large dike whose surface croppings yielded gold upon panning and which was said to show an encouraging gold content upon assay.

NELCHINA DISTRICT.

The Nelchina district lies at the eastern border of the region here considered, on the eastern flank of the Talkeetna Mountains, in the basin of Nelchina River, whose waters reach Copper River by way of Tazlina Lake and Tazlina River. The portion of the accompanying sketch map (Pl. I) showing the general geology and the location of the gold placer prospects in this district is taken from the first published description of this region by Chapin,[25] and the description here given is abstracted from that and a later more complete report by the same author.[26] The geologic formations in the neighborhood of the gold-bearing gravels include Jurassic and Cretaceous conglomerate, limestone, sandstone, and shale, associated with Jurassic andesitic greenstone and various Tertiary lavas. Extensive Quaternary deposits of glacial and fluviatile origin pave the valley floors and the entire Copper River basin, to the east.

The only known mineral resources of this district are the deposits of auriferous gravel that have received considerable attention in the last eight or nine years. Gold has been found in encouraging amount only in a small area, confined to the tributaries of Little Nelchina River, Tyone Creek, and Oshetna River. (See Pl. I.) So far little gold has been recovered in this district.

The bedrock source of the placer gold is obscure, but it is believed that most of the gold has been brought to the neighborhood where it is now found by glaciers, and that the placers have been formed by the postglacial concentration by streams of the gold scattered through the glacial deposits.

Crooked Creek, a tributary of Little Nelchina River, has yielded little gold but has locally been vigorously prospected. On one claim a shaft was sunk to a depth of 180 feet, in 1914, without reaching bedrock.

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[25] Chapin, Theodore, Auriferous gravels of the Nelchina-Susitna region: U. S. Geol. Survey Bull. 622, pl. 6, 1915.

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

On Albert Creek some mining was done in poorly stratified gravel that overlies a bedrock of tuffaceous sandstone and shale, associated with volcanic rocks. The gold was found to be scattered through the gravel, with little or no concentration on bedrock. A few thousand dollars' worth of gold is said to have been taken from this stream valley.

Considerable prospecting has been done from time to time on Little Nelchina River, Poorman, Yacko, Fourth of July, and Daisy creeks and Oshetna River, without finding any large deposits of workable ground. A few prospectors retain their faith in this district, and some prospecting and mining is done there each year.

MATANUSKA COAL FIELD.

Within the lower basin of Matanuska Valley there is an extensive coal field that has been widely credited as constituting one of the country's greatest coal reserves on the Pacific coast. The existence of this coal field was largely responsible for the first attempt to build a railroad from Seward northward into interior Alaska and had a large influence in determining the route for the Alaska Railroad.

The coal-bearing beds in Matanuska Valley[27] all occur in the Chickaloon formation, a series of shale and sandstone of Tertiary, probably Eocene age, which is underlain by Tertiary arkose, shale, and conglomerate and overlain by later Tertiary conglomerate. The whole series is intruded by numerous bodies of igneous rocks that include andesite, gabbro, diabase, and diorite, in fairly large masses, and by many dikes and sills.

The coals of Matanuska Valley range in grade from low-grade bituminous to high-grade bituminous. The low-grade bituminous coals are found in the valleys of Young, Eska, and Moose creeks; the high-grade bituminous coals in the valleys of Chickaloon and Kings rivers and on the south side of Matanuska River in the vicinity of Coal Creek. All these coals are probably of about the same age, their difference in character being due to differences in the amount of metamorphism which the beds have undergone from place to place. The lowest-grade bituminous coals are least folded, faulted, and intruded, and their poorer quality is in a measure offset by the ease and cheapness with which they can be mined. The high-grade bituminous coals have been more severely folded, faulted, and intruded.

Prospecting on these coal beds was begun 20 years ago, and in the spring of 1913 a shipment of several hundred tons was mined

[27] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912. Chapin, Theodore, Mining delevopments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–168, 1920.

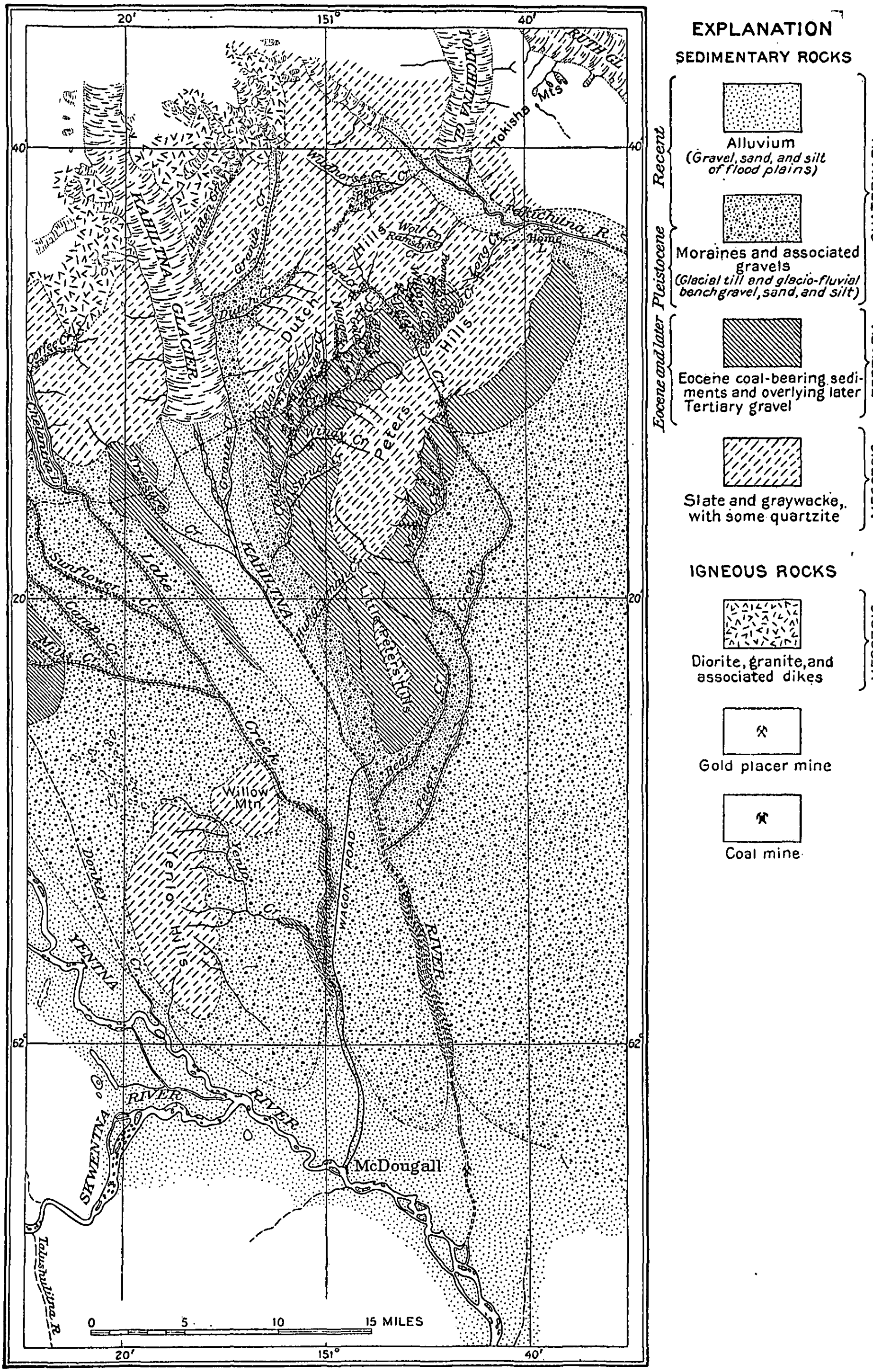
and tested by the U. S. Navy. With the commencement of construction on the Alaska Railroad, in 1915, prospecting became more vigorous and mining was begun, with a view to supplying fuel for the railroad. Up to 1922 the Matanuska field has produced over 305,000 tons of coal, a considerable part of it from mines operated by the Government. A large amount of prospecting has also been done. Although high-grade bituminous coals exist at many places in the valley, the beds so far exploited are so much faulted and broken that the cost of mining has remained high. Prospecting for more favorable beds, where mining can be done more cheaply, will continue. In the meantime the lower grade but more easily mined coals will continue to supply the needs of the railroad and other local demands.

Large areas in the Matanuska coal field are still insufficiently prospected to justify a statement as to the area of coal there that is minable under present conditions. Certainly there is a large tonnage of coal available. Whether or not any particular area there can be mined will depend on the relation between the cost of mining, and the cost of competing fuels. With abundant cheap fuel oil on the Pacific coast, and plentiful, more cheaply mined coals of lower grade available along the Alaska Railroad, the higher grade but more difficultly mined coals of the Matanuska Valley may be unmarketable. Yet, if a sufficient demand for high-grade coal arises, these coals may be mined to supply needs that can not be met by the cheaper fuels.

Exposures of lignitic coal are known to occur at intervals around the entire margin of the Cook Inlet-Susitna basin, from lower Cook Inlet to Broad Pass, and the number of localities at which this coal has been found is steadily increasing. The distribution of these coal localities and the attitude of the beds there indicate that coal-bearing Tertiary beds are of widespread distribution in this basin, and that they contain an enormous tonnage of lignite. At present this fuel has little value for other than local uses, but the time may come when it can be mined and sold at a profit.

YENTNA DISTRICT.

The Yentna district is on the southeast flank of the Alaska Range, 40 miles west of the town of Talkeetna, from which it can be reached by a wagon road and trail. This district has yielded a steady and increasing production of placer gold since its discovery, in 1905, and the successful operation of a dredge there in recent years gives encouragement for the belief that it will long continue to be a productive mining camp. The following brief notes are abstracted



GEOLOGIC SKETCH MAP OF THE YENTNA DISTRICT.

from reports on this district by Capps [28] and by Mertie,[29] who visited the district in 1911 and 1917, respectively. For a more complete description of the mining operations the reader is referred to the original reports. In 1922 the Yentna district produced $222,000 worth of placer gold.

The geology of this district is fairly simple, the prevailing rock formations being a series of slate and graywacke, with some quartzite, of Mesozoic age, cut by large masses and dikes of Mesozoic granitic rocks and in part overlain by Eocene coal-bearing beds and later Tertiary gravel. There are also extensive deposits of Quaternary materials, including glacial and glaciofluviatile deposits and the alluvium of the present streams. The major features of rock distribution and the position of the gold placer mines and of one coal mine are given on Plate IV.[30]

The only important placer-mining operations in this district are on Cache and Peters creeks and their headward tributaries. Only mining for placer gold has so far been done, though a small amount of placer platinum has also been recovered, and the presence of cassiterite (tin oxide) and scheelite (calcium tungstate) indicates that there may be workable lodes of tin and tungsten ore in the district. The original source of the gold is believed to be in quartz veins that cut the Mesozoic slate and graywacke. This gold was concentrated, before the earliest Tertiary beds of this district were laid down, into residual placer deposits, which were later partly reworked and contributed gold to the lowest Tertiary beds. Later on the region was glaciated, and the glaciers removed and incorporated into their own débris some of the gold-bearing gravel from the Tertiary beds and from stream placers. The present stream-placer deposits are believed to have been derived largely through the reconcentration, in the beds of the present streams, of the gold from the lower Tertiary beds and from the glacial deposits. In places also the earliest Tertiary beds and the overlying glacial till are mined for placer gold.

The largest single mining operation in the district is that carried on by the Cache Creek Dredging Co., which built a dredge in the valley of Cache Creek at the mouth of Windy Creek in 1917. Since that time the dredge has proceeded up Cache Creek, working gravel that ranges from 3 to 7 feet in thickness and overlies the fairly soft Eocene sand, gravel, and clay. The pay streak is from 150 to 300 feet wide and is believed to extend upstream for several miles. The dredge is of the flume type, with buckets of $7\frac{1}{2}$ cubic

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

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

[30] Mertie, J. B., jr., op. cit., pl. 6.

feet and a daily capacity of 2,000 cubic yards. It is operated by hydroelectric power.

A number of hydraulic mining plants have been operated each year on Cache Creek and its principal tributaries, Nugget, Thunder, Falls, Short, and Dollar creeks. Thunder Creek has usually supported two or three mining plants, and about that number of operations have been conducted each year on the other tributaries named. The magnitude and number of these operations are limited by the amount of water available for the hydraulic nozzles.

For a number of years the principal mining on Thunder Creek has been done by a large hydraulic plant, which has been engaged in sluicing the stream and bench gravels of that stream. The bench gravel mined at places reaches a thickness of 80 feet. The bedrock in places consists of the coal-bearing Eocene formation, though elsewhere a much weathered phase of the underlying slate and graywacke projects through the coal-bearing beds.

A very interesting condition is displayed by the placer excavations on this creek. Associated with the coal-bearing formation are two well-defined beds of quartzose material, each averaging about 12 feet in thickness, consisting of angular or only partly rounded fragments of quartz in a matrix of white clayey material that proves to be a siliceous clay. In this material there are also fragments of coal. The quartzose seams carry considerable gold and have been mined for their gold content. They are evidently of Tertiary age and present the unusual condition of a placer-gold concentration in an early Tertiary sedimentary series that is sufficiently rich to justify mining by hydraulic methods. Two mines are reported to have been operated on Thunder Creek in 1921.

Placer mining has been done on Falls Creek for many years, with varying degrees of activity. In 1917 two plants, employing five men altogether, were operated, one on a bench about 35 feet above the creek and the other on the creek gravel at the mouth of the canyon. In 1921 two mines were in operation in this valley.

Mining operations on Dollar Creek have been carried on for many years, mainly by a single mining company. Most of the work has been done on claim No. 1 above Discovery, where on the east side of the creek there is a high bench in which the conditions somewhat resemble those on Thunder Creek, above described. A hard bedrock composed of slate and graywacke is overlain by a gold-bearing stratum of Tertiary quartzose material, which in turn is overlain by a body of gravel and glacial clay. The quartzose stratum is about 60 feet thick in the middle of the cut and contains about equal amounts of imperfectly rounded to angular fragments of quartz and graywacke. At one place a bed of lignite was seen lying upon this deposit, thus indicating its Tertiary age. The gravel above the quartzose stratum contains considerable gold, and the glacial clay a little, but most of the gold here recovered comes from the quartzose deposit. Mining is done by hydraulic means, with water under a head of 200 feet. Two properties are said to have been operated on Dollar Creek in 1921.

Some hydraulic mining is done on Windy Creek, a westward-flowing tributary of Cache Creek, on a bench deposit that consists of 40 to 60 feet of gravel overlain by 100 feet of glacial clay. The gold occurs mainly in the lower portion of the gravel, and its concentration therefore preceded the last glacial ice advance. The gravel overlies the coal-bearing formation. In this gravel some pyrite, arsenopyrite, and magnetite and a little cassiterite, native copper, and scheelite are found.

Placer mining by pick and shovel methods was done in 1921 on Short and Gold creeks, both tributaries of Cache Creek from the west. In the Peters Creek basin placer mining has been carried on for many years more or less continuously. Gravel has been worked above, in, and below the canyon through the Peters Hills. The largest operations have been on the stream gravel and benches near the mouth of the canyon. In 1921 two hydraulic mines, employing 12 men, were operated on Peters Creek and made a considerable production of gold. No details are at hand regarding the exact localities of these workings.

On Poorman Creek, a tributary of Cottonwood Creek in the headward basin of Peters Creek, one small placer mine was operated by pick and shovel methods in 1921. The placer gravel of this stream contains appreciable amounts of platinum. In the same year one mine was worked on Willow Creek, also a tributary of Cottonwood Creek, by the use of water under pressure. The Willow Creek placers yield considerable cassiterite, though not in commercial quantities. Bird Creek, a tributary of Peters Creek from the west, has been mined more or less regularly for many years, but the individual operations have been small. Placer mining has been carried on from time to time at many other places in the Yentna district. The bars of Lake Creek and Kichatna River have yielded considerable placer gold, and Mills and Twin creeks, tributaries of Labor Creek, still contain a good deal of unworked placer ground, but mining there is difficult on account of the meager supply of water. There is much ground on Kahiltna River, near the mouth of Cache Creek, and on Peters Creek below the canyon that contains placer gold and may sometime prove to be rich enough for dredge mining.

As has been stated, the Eocene coal-bearing formation is widely distributed in the Yentna district and at a few places is known to contain lignite beds of workable thickness. On Cache Creek near the mouth of Short Creek a coal bed has been worked to supply fuel for a gold dredge and for other local uses. The coal is of about the same quality as that found generally throughout the Susitna and Chulitna valleys and in the Nenana coal field. Coal from the Yentna district will probably never find any but a local market.

UPPER CHULITNA REGION.

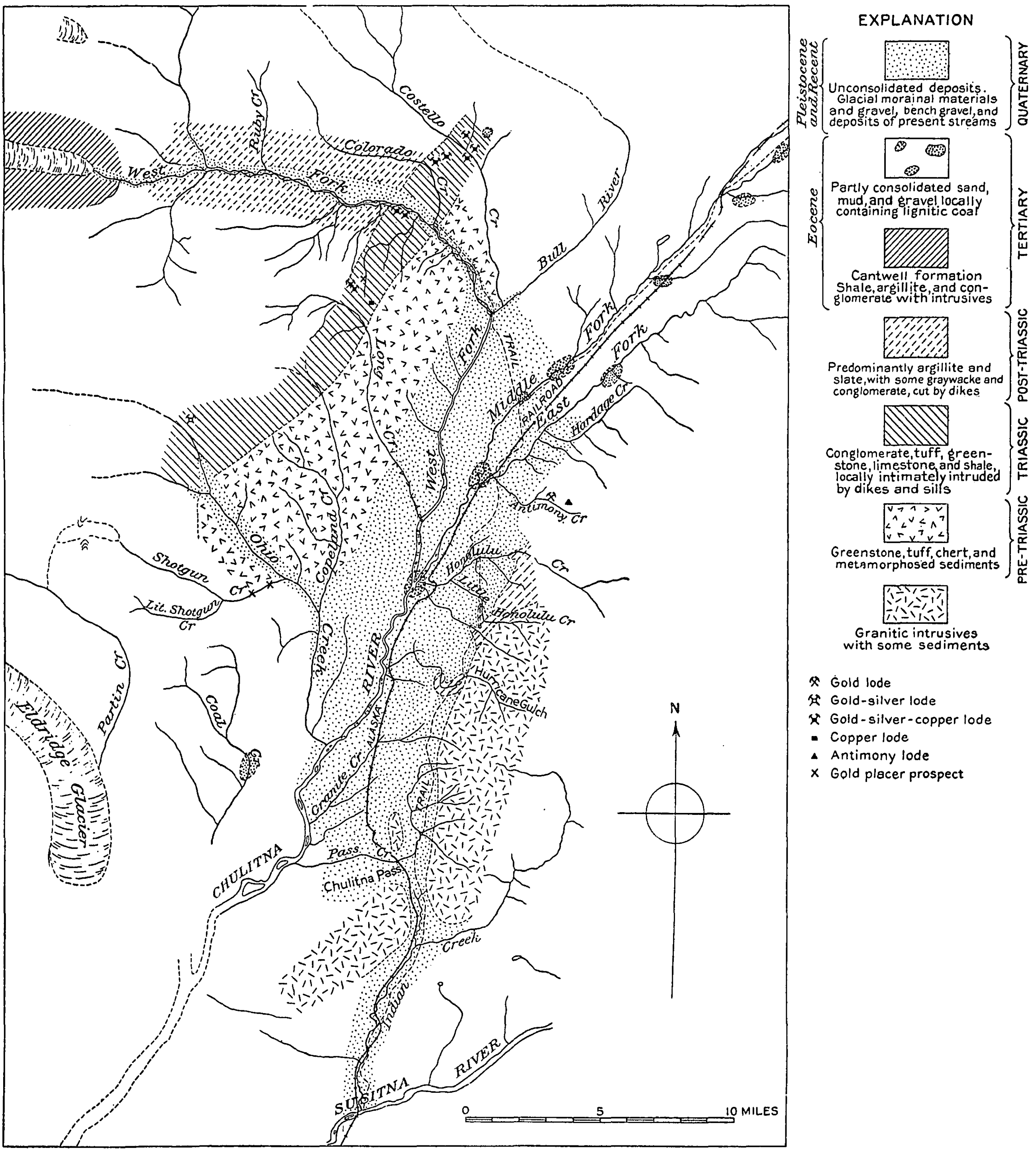
The headwater region of Chulitna River, often referred to as the Broad Pass mining district, contains copper and gold bearing lodes on which prospecting has been done for many years. Most of these lodes lie in the basin of West Fork of Chulitna River, only 6 or 8 miles west of the railroad. The original prospecting in this country was done under great difficulty, for before the railroad was built the region was remote and difficult of access, and prospecting, especially the driving of rock tunnels and shafts on lode deposits, was expensive. Now that railroad transportation is brought close to these prospects they are sure to be scrutinized closely, and producing mines will be developed if the lodes are sufficiently rich to justify mining.

The geologic formations present in the region of the lodes include a group consisting of greenstone, tuff, chert, and metamorphic sediments of pre-Triassic age; Triassic conglomerate, tuff, greenstone, limestone, and shale, locally cut by dikes and sills; Mesozoic sediments of post-Triassic age, consisting predominantly of argillite and shale, with some graywacke and conglomerate, all cut by dikes; late Mesozoic or early Tertiary shale, argillite, and conglomerate, with some intrusives; partly consolidated sand, clay, gravel, and lignite beds, of Tertiary age; and widespread deposits of glacial moraine and outwash materials and stream gravel. The general distribution of the rock formations and the location of the mineral deposits are shown on Plate V, which with the following notes is taken from a publication[31] that describes in some detail the conditions in this district at the time of the writer's visit in 1917.

The first mining done in this district resulted in the recovery of a little placer gold in 1909. Since that time the interest of the prospectors has centered on the lodes, some of which contain gold, copper, and antimony in encouraging amounts. The ores are not free milling, however, and the prospective value of the lodes lies in their possibility of yielding a large tonnage of ore of moderate richness rather than small quantities of high-grade ore.

The ore bodies occur in that part of the group of Triassic tuffs and sediments in which calcareous rocks are present, either as lime-

[31] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 207–232, 1919.



GEOLOGIC SKETCH MAP OF THE UPPER CHULITNA REGION.

stone, marble, or limy shale. Furthermore, in the vicinity of the ore bodies there is an unusual amount of igneous material, injected as dikes into the tuff, limestone, and shale. The ore bodies themselves, as exposed in the scanty workings, are not sharply outlined and have not generally a definite veinlike character. They appear to be irregular masses showing in places heavily mineralized rock that fades out into less mineralized country rock in all directions. Scattered specks of sulphides can be found in these rocks over wide areas. The principal metallic minerals recognized include arsenopyrite, pyrite, sphalerite, chalcopyrite, pyrrhotite, stibnite, and galena, and assay returns show the presence of gold. Some small distinct veins cut the ore bodies, and these carry sulphides in a gangue of quartz or calcite, or both, but most of the ore seems to consist of sulphides that have replaced limy rocks, or else it occurs as disseminated sulphides in different types of material, including tuff, chert, limestone, and the dike rocks themselves. The information at hand therefore indicates that as the result of the intrusion of acidic dikes the intruded rocks suffered some contact metamorphism. Mineralized solutions from the igneous mass penetrated the neighboring rocks and replaced certain of the limy beds. The calcareous beds were not alone affected, however, for the sulphide-bearing solutions also penetrated certain tuff and chert beds and replaced parts of these beds with sulphides, but the larger ore bodies, as at present exposed, seem to represent the replacement of calcareous sediments by metallic sulphides. The following descriptions of the several groups of claims are abstracted from the report on this district already cited, written as a result of a visit in 1917. As that report is out of print, fuller descriptions are given here than for other districts concerning which detailed accounts in print are still available.

The Northern Light group of three claims lies on the northeast side of Costello Creek a short distance below the mouth of Camp Creek. The country rock comprises a confused assemblage of volcanic tuff, impure limestone, and shale, cut by dike rocks. The sediments and tuff and even the dike rocks are calcareous. The area of strongest mineralization, which is discolored to a rusty red on the outcrop, is irregular in outline and has a greatest width of about 30 feet. It strikes about N. 65° W. and dips 70° SE. It is apparently the result of the replacement of a limy bed by sulphides and contains veins and bunches of quartz. The ore is said to carry gold and silver in encouraging amounts. The minerals that have been recognized include arsenopyrite, pyrite, chalcopyrite, sphalerite, and a little stibnite.

The Lucrative group, consisting of five claims, lies on Costello Creek near the mouth of Camp Creek. The small amount of development work that had been done at the time of visit showed a rusty mineralized vertical stockwork in a mass of intrusive rock. The principal metallic minerals seen consisted of abundant arsenopyrite in bluish banded quartz, with some specks of chalcopyrite.

The Silver King group, consisting of two claims, lies on the northeast side of Colorado Creek about 1½ miles above its mouth. The development work in 1917 consisted solely of open cuts, which failed to penetrate to solid undisturbed rock, so that little could be seen of the relations of the ore deposit. The center of mineralization seemed to be a highly altered dike. The dike probably cuts calcareous sediments, for it contains calcite. There is apparently a large mass of material that contains abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, pyrrhotite, and stibnite, both as massive aggregates and finely disseminated through the country rock. The gold and silver content of this material was not ascertained.

The Riverside group comprises several claims that adjoin West Fork of Chulitna River on its southwest side about a mile above Bryn Mawr Creek. The development work in 1917 consisted of a number of large open cuts and some short tunnels and shafts, all at the base of a steep rock bluff at the edge of the gravel flat of West Fork of Chulitna River. The rocks exposed include steeply dipping green to red tuff, with which are associated pale-pink, green, and blue-gray cherts, locally banded; rusty-gray and white marble; and abundant dikes of medium-grained acidic intrusive rocks. The tuff is hard and dense and ranges in texture from fine grained to very coarse. The marble and chert are less abundant but are visible in several of the open cuts. Tuff, chert, and calcareous beds are all more or less altered by contact metamorphism, as a result of their intimate intrusion by dike rocks. Such data as could be obtained from the meager surface exposures and the workings indicate that here, as at other places in the district, the mineralization consists in the replacement of calcareous materials by quartz and metallic sulphides, introduced by mineralizing solutions that were related to the intruded dike rocks. The ore examined contained abundant sulphides, including arsenopyrite, pyrite, chalcopyrite, galena, and probably sphalerite, inclosed in a quartz gangue, and specks of these sulphides occur without quartz gangue in marble, tuff, and dike rocks. It is reported that average assays taken over a 12-foot zone in marble yielded encouraging amounts of gold and silver.

The Lindfors group includes three claims at the head of Bryn Mawr Creek. No development work had been done here in 1917 other than some open cuts and strippings. The country rock includes tuff, marble, and dike rocks in different stages of alteration, all containing some disseminated sulphides. It is evident that on these claims the mineralization consists in the replacement of calcareous sediments by quartz and sulphides and the impregnation of different types of country rock with sulphides introduced in connection with the intrusion of acidic dikes. No large body of minable ore had been developed on these claims at the time they were visited.

The Golden Zone group of three claims, at the head of Byrn Mawr Creek, is conspicuous on account of the rusty-red appearance of the hill on which the claims are situated. This hill is composed of a body of acidic rock that is intruded into an assemblage of material including tuff, marble, and shale. The intrusive mass is generally impregnated with scattered specks of sulphides, but locally the mineralization has been more intense and the rock is cut by small veinlets. These claims in 1917 were developed by many open cuts and 221 feet of underground workings. The metallic minerals that have been recognized on this property include arsenopyrite, pyrite, sphalerite, galena, malachite, and probably stibnite. It is reported that assays of the average material removed from the tunnel show several dollars to the ton in gold and silver, and some rather high assays were produced.

The Hector group includes two claims that lie on the Long Creek side of the divide between Long Creek and West Fork of Chulitna River, opposite the head of Bryn Mawr Creek. The development work that had been done in 1917, consisting entirely of shallow open cuts, revealed a country rock that included the metamorphic equivalents of siliceous shale, graywacke, and tuffs, intricately cut by dikes and sills of acidic intrusive rocks. Certain chert bands are highly siliceous, but all the other materials are limy. The ore body as exposed consisted of intimately mixed chalcopyrite and pyrrhotite disseminated through the coarser sediments and the dike rocks. The sulphides have replaced certain beds, but the chert is almost entirely free from mineralization. The suphides range in abundance from scattered specks of chalcopyrite and pyrrhotite to masses of sulphides in which little rock is visible. Assays of the best ore are said to yield 17 per cent of copper, but sufficient work had not been done to determine either the size of the ore body or the average copper content of the ore.

The Ready Cash group lies on the northeast side of Ohio Creek, about 3 miles above the mouth of Christy Creek. The country rock consists of interbedded argillite, graywacke, and greenstone tuffs, all more or less metamorphosed. On this property a large quartz vein 8 to 10 feet wide, showing some rusty coloration and stains of copper carbonate, cuts the sediments. No information was obtained concerning the assay value of the ore at this property.

The North Carolina group of claims lies in the upper basin of Antimony Creek, a small tributary of East Fork of Chulitna River that joins that stream from the east 1 mile above its mouth. The country rock consists of shale, impure limestone, and graywacke, cut by basic dikes. At one place an antimony lode has been found, consisting of stibnite in a quartz gangue. The only opening on the ore body was caved in at the time of visit, but the dump showed several tons of massive stibnite ore that included both finely granular stibnite and a mixture of granular stibnite with coarse acicular crystals of the same sulphide. Some specimens contain considerable quartz, but in others there was almost no gangue. The workings were insufficient to determine the size or position of the ore body.

Throughout this general region there are many other lode prospects that are not here described individually, either because too little development work had been done to demonstrate the position or relations of an ore body, or because they were not visited. They are of general interest, however, in showing that sulphide minerals are widely distributed in this district, and there is every prospect that producing mines will be opened on some of the lodes in this general vicinity.

As in so many places in the Susitna basin, there are many localities in the headwater region of Chulitna River in which early Tertiary beds containing lignitic coal have been found. Some of those localities are shown on the accompanying geologic map (Pl. I). Although the structure of the coal-bearing beds differs from place to place, the association of beds is everywhere similar, slightly consolidated clay, sand, and gravel being interbedded with lignite. The lignite is of about the same average quality as that mined in the Nenana field. At a number of localities small quantities of this coal have been mined for domestic fuel, and large quantities of it are available, but it is of too low grade for other than local use. The similarity in character, structure, and general appearance between the coal formation of the upper Chulitna basin and that of other parts of the Susitna basin and the Nenana coal field suggests strongly that all these deposits are of about the same age.

VALDEZ CREEK DISTRICT.

The Valdez Creek gold placer district lies at the east margin of the area here under discussion, in the upper reaches of Susitna River. Valdez Creek joins the Susitna from the east some 25 miles below the source of that stream in Susitna Glacier. Gold was first discovered in this district in 1903, and although the area of workable gold placer gravel is small, mining has been carried on vigorously until within the last few years. The conditions in this district in 1910 are described at length by Moffit, [32] and the following notes are abstracted from his report. Most of the placer gold produced has

[32] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, 1912.

been taken from a few claims at the west end of Valdez Creek, just above the place where the canyon opens out into the flats of Susitna River, and from Lucky Gulch. In the vicinity of the mines on Valdez Creek that stream has cut its canyon through the gravel into the slate beneath to a depth of 175 feet and in so doing has intersected an older gravel-filled canyon whose bottom is 60 feet higher than the present creek level. The largest deposits of gold placer gravel were found in that old gravel-filled canyon and in the present creek gravel below the old canyon, indicating that the present stream gravel derived its gold from the erosion of an older, buried placer deposit. The bedrock source of the gold is believed to be certain iron-stained siliceous veins containing pyrite, sphalerite, and galena, which cut Upper Triassic slate. These veins, though known to be gold bearing, have nowhere been found to be minable as gold lodes. The placer deposit in the old buried channel of Valdez Creek is of preglacial origin and is another indication that in the region south of the Alaska Range there were probably many rich placer deposits in preglacial time but that most of these deposits were destroyed by the advancing ice, and the gold was scattered. It is only in such exceptional places as the Valdez Creek district, where the older placer deposits were buried and preserved, or at a few other places where postglacial concentration of gold from glacial deposits or from the bedrock source has occurred, that placers are now found.

On Valdez Creek mining has been most profitable on four or five creek claims, on which the richest gravels have now been mined, and on the Tammany bench claim, which includes the old buried canyon. This old canyon was mined by a tunnel from Valdez Creek, which in 1910 was about 700 feet long. The pay streak is 100 feet or less in width. Most of the gold is found in the lower 5 feet of the gravel filling. A ditch 8,600 feet long was constructed to bring water to this claim for hydraulic mining, and some hydraulic mining has been done, but the remoteness of the district has made operations expensive, and mining has been interrupted from time to time. It is said that much rich ground still remains to be worked.

Aside from the claims on Valdez Creek, described above, the only other mining of consequence in this district has been on Lucky Gulch, about 6 miles east of the main camp on Valdez Creek. The bedrock is the Upper Triassic slate series. The gulch is narrow, and the stream deposits, consisting of angular fragments and slabs of slate, are in places as much as 25 feet thick. The gold in this gulch is exceptionally coarse, nuggets weighing 32 and 52 ounces having been found.

Prospects on White and Rusty creeks give some hope that these streams also contain workable gold placers.

BONNIFIELD REGION.

The Bonnifield region is generally understood as that part of the north slope of the Alaska Range and its outlying foothills that extends eastward from Nenana River to Delta River. Gold was first discovered in this region in 1903, and since that time placer mining has been carried on continuously, and the gold production, though never large, has been steady. Gold lode prospects have received some attention for more than 15 years, and within the last half dozen years a number of lodes containing gold, bismuth, and antimony have been staked and some development work has been done on them, but no actual mining has so far been done on metal-bearing lodes. The Bonnifield region was visited by Capps [33] in 1910.

In 1916 parts of the Nenana coal field were studied in detail by Martin,[34] the lode prospects of the region near the Nenana coal field by Overbeck,[35] and the gold placers of the same area by Maddren.[36] The following notes are abstracted from these reports, to which the reader is referred for fuller descriptions of the individual mines.

GOLD DEPOSITS.

The localities in which placer gold in paying quantities has been found in this region all lie in the foothill belt between the Tanana Flats and the high schist range to the south. The present streams derived the gold from a variety of sources, chief of which is a heavy deposit of ancient high gravel that is widely distributed in this region and is known to contain some gold at many places. At one or two places, however, the gold of the present streams seems to have come directly from a bedrock source in lodes that have been eroded by the streams in postglacial time. Almost all the gold placer deposits in the Bonnifield region are either in the valleys of relatively small streams that escaped invasion by glacial ice during the last great ice advance or in postglacial valleys cut into the Nenana gravel and bedrock since the glaciers retreated. Attempts have been made at many places to mine the Nenana gravel in a small way, and one large hydraulic plant was installed for this purpose on Gold King Creek, but none of these operations have been financially successful, for apparently the gold in the Nenana gravel is too widely distributed and insufficiently concentrated to justify mining unless it has been reconcentrated by the present streams.

According to present reports the most extensive mining operations in 1922 were on Moose Creek, a tributary of Nenana River, and on

[33] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912.

[34] Martin, G. C., The Nenana coal fields, Alaska: U. S. Geol. Survey Bull. 664, 1919.

[35] Overbeck, R. M., Lode deposits near the Nenana coal field: U. S. Geol. Survey Bull. 662, pp. 357–362, 1917.

[36] Maddren, A. G., Gold placers near the Nenana coal field: Idem, pp. 363–402.

Totatlanika River and its tributaries. The placer-gold output of the Bonnifield region in 1922 was about $10,000, and the total output from 1903 to 1922 has been about $285,000.

There has been no lode mining of metals in the Bonnifield region, but there are a number of lode prospects that offer some promise. These include the gold-arsenopyrite-bismuth lodes on Moose and Eva creeks and a few gold quartz lodes on McCuen Gulch and in the basin of Wood River. The country rock of the lode prospects on Moose and Eva creeks and in the Totatlanika basin is a dark carbonaceous phase of the Totatlanika schist which has been cut by igneous dikes. Too little work has yet been done to outline the ore bodies, or to determine whether any of them are likely to develop into mines.

NENANA COAL FIELD.

One of the most valuable mineral resources in the region tributary to the Alaska Railroad is the coal of the Nenana field, which includes the coal-bearing areas that lie in or near the basin of Nenana River. In that field occur the thickest sections of the coal-bearing series that have been examined and the largest amount of minable coal, but similar coal-bearing beds are known to occur at intervals along the entire northern flank of the Alaska Range, from Muldrow Glacier on the west to the international boundary on the east. Naturally the availability of transportation and the grade of the coal will determine the localities that will be first developed, and therefore the favorable location of the series of thick coal beds in the valleys of Healy and Hoseanna creeks, directly adjoining the new railroad, will hasten their devolopment, whereas many other coal beds situated at more remote points will long remain undeveloped or at best will be opened to supply only local needs.

As a detailed examination was made by Martin [37] of the surveyed coal lands just east of Nenana River, only a general statement concerning this field will be given here. The coal, which is a lignite of very fair grade, occurs in a series of Tertiary sediments consisting of slightly consolidated sand, clay, and gravel, which reaches a known thickness of 1,200 to 1,500 feet. The coal-bearing beds rest unconformably upon pre-Cambrian or Paleozoic schist and igneous rocks and are overlain unconformably by later Tertiary or Quaternary gravel, 1,500 or 2,000 feet thick. The structure of the coal beds is fairly simple. The individual coal areas consist of shallow and gently warped basins in which the beds are locally folded or faulted against the older rocks that separate the basins. The dips are in general not greater than 10° or 15°, though there are local

[37] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 1919.

zones in which the dip is steeper, as well as broad areas in which the rocks lie nearly flat. No intrusive rocks are known to cut the coal measures in the areas near Nenana River, though farther west, in the Kantishna region, similar coal-bearing beds contain abundant fragments of igneous material and are believed to be cut by dikes.

The coal of the Nenana field occurs in many beds of different thickness, the thickest measuring perhaps 30 to 45 feet, though locally some beds have been thickened by deformation to considerably more than that. The lignite beds are distributed rather uniformly through the coal measures, and there are at least twelve coal beds of workable thickness, and six or more measure over 20 feet. A single section measured on Healy Creek showed a total thickness of 230 feet of coal in 23 beds, of which seven beds contain 174 feet. Analyses show that the coal is a lignite of good grade, of about the same quality as that of Cook Inlet. It has been estimated that the Nenana coal field contains reserves of more than 9,000,000,000 tons.

Prospecting and mining of coal in the Nenana field has been greatly stimulated since railroad transportation has been available. Several coal beds along Nenana River and on Hoseanna and Healy creeks have been opened, and a considerable tonnage of coal has been mined for the railroad and for general use in Nenana and the Fairbanks district. Already the cost of fuel for domestic purposes, for power, and for steam raising in the Fairbanks placer mines, where it is necessary to thaw the frozen ground, has been reduced. This coal will continue to furnish a valuable and much needed fuel supply for a large area in interior Alaska, but its market is likely to continue to be limited to that area, as it is of too low grade and too fragile to stand shipment outside of Alaska in competition with higher-grade coals and oil.

In the spring of 1923 vigorous development was begun on a coal bed that crops out just west of the railroad, at mile 341, near Yanert station. The occurrence of coal at this locality is of especial interest, for the coal bed lies in the Cantwell formation, of early Tertiary age, and is the first workable coal bed that has been found in that formation. During the summer of 1923 mining developments demonstrated that the coal bed contains from 5 to 6 feet of workable coal lying interbedded with the steeply dipping shale, sandstone, and conglomerate of the Cantwell formation and closely paralleled on its hanging wall by a thick sill of intrusive rock. The coal is a bright, clean, noncoking bituminous coal and is apparently of higher quality than any of the other coals of the Nenana field. In appearance and in analysis it compares favorably with the better coal of the Matanuska Valley. The discovery of good bituminous coal in the Cantwell formation opens up interesting possibilities, for that formation is of widespread distribution in the Alaska Range, and it may contain workable coal beds elsewhere. Mining developments on coal in the Cantwell formation are, however, not yet far enough advanced to determine whether the quality of the coal has been affected favorably or unfavorably by the near-by intrusive sill.

KANTISHNA DISTRICT.

The Kantishna mining district is about 60 miles west of the railroad on the north side of the Alaska Range, about 30 miles north of Mount McKinley. Gold-placer mining has been conducted there continuously each summer since 1905, and for the last ten years or so lode mining and prospecting has attracted increasing attention. Although the yield of placer gold has never been large, it has been steady. The value of the gold produced in 1922 was about $32,000, and the total value of the placer output of this camp from 1903 to 1922 is $509,000.

The geology and the location of the mineral deposits of this district are shown on the accompanying map (Pl. VI). The bedrock in the vicinity of the placer mines is the Birch Creek schist, which is cut by some acidic intrusive bodies, and the placer gold is believed to have been derived by the erosion of gold-bearing quartz veins that cut the schist. Some of these veins also carry rich silver-bearing galena, and others have large deposits of stibnite. In 1921 the known mineralized area in the Kantishna district was extended southward nearly 20 miles by the discovery on Copper Mountain, just west of Muldrow Glacier, of sulphide veins that occur in quartzite, limestone, and slate cut by granodiorite. These veins carry gold, silver, and copper.

The geology and mineral resources of the Kantishna district were studied by Capps[38] in 1916, and the reader is referred to his report for the details of mining developments up to that time. There is given here only a brief summary of the mining activities in the district and of developments since 1916.

GOLD PLACERS.

For many years after the discovery of gold in the Kantishna district in 1915 the interest of miners and prospectors was confined to the gold placer gravels. Mining was done on many streams that head in the Kantishna Hills, but the chief activity has always centered on Moose Creek and its tributaries, Glen, Eureka, and Friday creeks, and on Glacier and Caribou creeks. On all these streams most of the gold produced has been obtained from the creek

[38] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 1919.

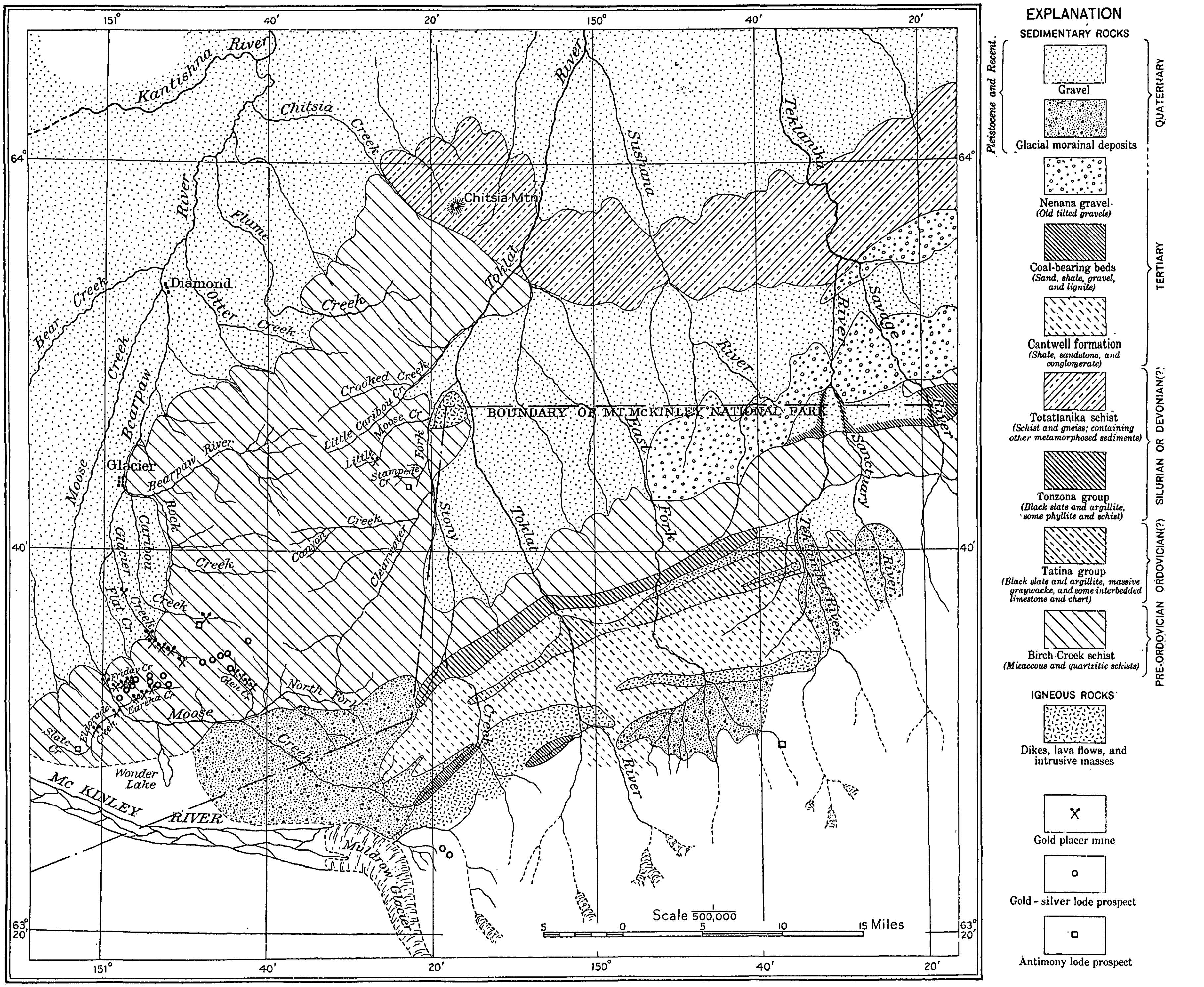
gravel, which is generally of moderate thickness and lies on a schist bedrock. The gold in this district is coarse, nuggets worth as much as $900 having been found. Eureka and Friday creeks in particular are noted for the rough, unworn character of their placer gold, which has evidently traveled only a short distance from its bedrock source. On the larger streams, notably Moose, Glacier, and Caribou creeks, there are extensive deposits of bench gravel that are known to carry gold in encouraging amounts and are susceptible of large-scale hydraulic mining. Moose Creek has also much ground that has been prospected for dredging. In 1922 two large hydraulic mines were opened in this district. One, the property of the Kantishna Hydraulic Mining Co., is on Moose Creek, the ground extending from a point near the mouth of Eureka Creek for about 3 miles downstream. Water is procured from Wonder Lake and is brought to the mine through a ditch and a steel pipe. The placer gravel is underlain by a false bedrock of sticky blue clay at a depth of 6 to 10 feet. The depth to true bedrock is not known. The richest ground is found near the false bedrock, although some gold is distributed throughout the gravel. Hydraulic giants with nozzles ranging from 3 to 4 inches in diameter are used. Seven men were employed in 1922, and a large amount of gravel was sluiced.

A hydraulic mine was opened in 1922 on ground said to include all the creek gravel along Caribou Creek for several miles and a large number of bench claims. Mining was done on the gravel of Caribou Creek about 2 miles below Last Chance, the water being taken from Caribou Creek by ditch and steel pipe. A large area of bedrock is said to have been uncovered.

The installation of large-scale hydraulic-mining operations in the Kantishna district will, if successful, greatly increase the placer output from this camp and encourage the thorough prospecting of other areas which are known to be gold bearing but in which the gold content of the gravel is too low to support mining on a small scale.

GOLD AND SILVER LODES.

For the last 10 years it has been known that this district contains quartz vein deposits that carry a promising content of gold and silver. Most of these lodes lie within a small area along the high ridge of the Kantishna Hills, between the big bend of Moose Creek and Spruce Peak, an area underlain by the Birch Creek schist, cut by a few granitic intrusive masses. The veins are fissure veins that cut across the foliation of the schist, are undeformed, and were therefore deposited after the last period of deformation that affected the schist. They are probably genetically related to the granitic intrusive rocks that cut the schists and that are abundant a few miles south of this



GEOLOGIC SKETCH MAP OF THE KANTISHNA DISTRICT.

area. Many of these veins have been prospected by open cuts, tunnels, and shafts, and the quartz has in places been shown to carry a high content of free gold and silver-bearing galena. No mining has been done on veins whose chief value is in gold, but in 1919 a silver-bearing galena deposit, lying between Eureka and Friday creeks, was opened up, and about 1,100 tons of hand-picked ore has been shipped. This ore yielded about 140 ounces of silver and $3.25 in gold to the ton, also some lead and copper. It is believed that some of the richer gold-silver quartz veins will be found rich enough to justify mining, as exceptionally high assays in gold and silver have been obtained from some of them.

In 1921 sulphide-bearing lodes carrying gold and silver were discovered on the south flank of the Alaska Range some 20 miles southeast of Eureka Creek, in what is called the Copper Mountain district.[39] This district lies just east of Muldrow Glacier. Granodiorite is the prevailing country rock and is found in large areas and as dikes that cut quartzite, limestone, and slate that are probably of Paleozoic age. The ore-bearing zone has been traced for about 2 miles and is characterized by abundant sulphide minerals concentrated into ore bodies. Some of these bodies have definite walls; in others the ore grades into the country rock. They occur chiefly in the quartzite, but some are in the granodiorite and others at the contact between the two. The ore consists chiefly of galena, chalcopyrite, zinc blende, pyrite, and bornite, with galena predominating. The gangue is quartz and country rock, chiefly quartzite. Grab samples have yielded as much as 270 ounces of silver and $8 in gold to the ton and from 1 to 8.8 per cent of copper. Up to July, 1922, little work had been done on these claims, and their value could not be predicted, but the surface exposure fully justified careful prospecting.

ANTIMONY LODES.

A number of lodes in the Kantishna district contain considerable deposits of stibnite, the antimony trisulphide, and mining or development work has been done on at least three lodes, with the purpose of shipping the ore for its antimony content. Genetically the antimony lodes are related to the gold-silver lodes already described, and the veins have the same association of minerals, but in the antimony lodes stibnite occurs in large masses containing only small amounts of gold and silver, whereas in the gold-silver lodes antimony, although occasionally recognized, is a minor constituent.

Although the presence of considerable masses of stibnite in veins in this district has been known since the first years of mining, it

[39] Brooks, A. H., The Alaskan mining industry in 1921: U. S. Geol. Survey Bull. 739, pp. 35–37, 1922.

was not until the demand for antimony during the World War raised the price of that metal to many times its pre-war value that any attempt was made to exploit these veins. In 1915 the Taylor mine, on Slate Creek, was opened, and by 1916 about 125 tons of hand-picked ore had been mined and preparations were made to ship the ore out by way of Kantishna River to the Tanana and thence to Seattle. Before the ore was shipped, however, the price of antimony declined so that this ore could not meet the high cost of transportation, and it was never marketed. In the Taylor mine the stibnite formed an ore body along a well-defined fissure in the Birch Creek schist. The ore body had a maximum width of 15 feet and constituted a reticulated stockwork of quartz and stibnite with irregular bunches and horses of decomposed clayey schist, all much broken and confused. The stibnite occurred in veinlets and veins of almost pure stibnite and in irregular lenses and bunches.

The only other antimony lode on which any mining has been attempted is on Stampede Creek, a tributary of Clearwater Fork of Toklat River from the southwest. There a large open cut, excavated in 1916, disclosed a large body of nearly pure stibnite, apparently at least 12 feet thick. About 40 or 50 tons of selected stibnite almost entirely free from gangue or impurities had been mined and stacked, but none of this was ever shipped. Too little work had been done at the time of examination to disclose the size or relations of this ore body.

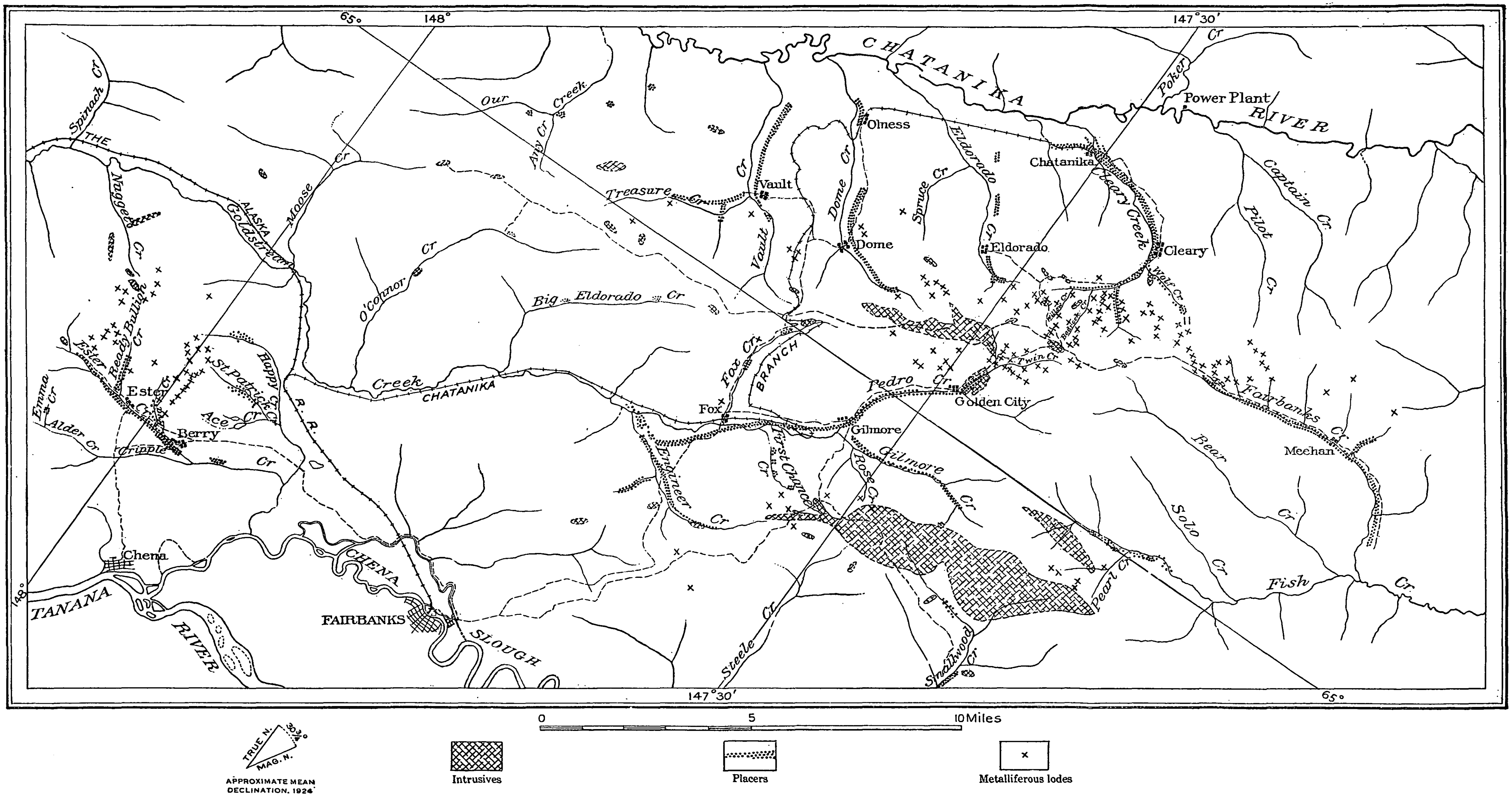
A third antimony lode, on upper Caribou Creek, was prospected in 1906 by two shafts 30 and 40 feet deep. These shafts showed a mixture of quartz and stibnite in a vein cutting hornblende schist. This ore body, as developed by the shafts, does not appear to be as large as either of the two lodes already described. Assays showed the ore from this place to carry from a fraction of an ounce to 4 ounces of silver to the ton. No attempt has been made to mine this lode.

FAIRBANKS DISTRICT.

GOLD PLACERS.

The Fairbanks mining district lies on the north side of Tanana River, in the extreme northwest corner of the area here considered. The town of Fairbanks is the inland terminus of the Alaska Railroad. From the beginning of placer mining in 1903 to 1922 this district has produced over $72,037,000 worth of gold—$71,973,000 in placer gold and $367,000 in lode gold—also nearly $377,000 worth of silver, all recovered as an alloy with the gold. No mining for silver as the chief metal produced has been done in this district.

The geology of the Fairbanks district is shown on the accompanying map (Pl. VII). This district has been visited by many geol-



MAP SHOWING POSITION OF LODE MINES AND PROSPECTS AND PLACER GRAVELS IN THE FAIRBANKS DISTRICT.

ogists of the Geological Survey, and descriptions of the mining developments year by year have been published in the annual reports on the mineral resources of Alaska. The most complete report on the geology and mineral resources of the Fairbanks district is that by Prindle, Katz, and Smith,[40] which describes in detail the mining developments that had taken place up to 1912. The reader is referred to that report for general information about the Fairbanks quadrangle. The present brief account is summarized from that report and from the various other Geological Survey publications.

The geology of the Fairbanks district may be stated in very simple terms. The prevailing bedrock is a schist of sedimentary origin known as the Birch Creek schist, cut by moderately large to small masses and dikes of granitic intrusive rock. Most of these intrusive masses are too small to be shown on the accompanying geologic map (Pl. I), but many are shown on Plate VII. There is believed to be a genetic relation between these acidic intrusive rocks and the gold-bearing quartz veins in the schist, the erosion of which has supplied the gold to the placer deposits. The erosional history of this district has been complex, a period of stream erosion in which deep broad valleys were cut into the schist and intrusive rocks having been followed in late geologic time by a period of more sluggish drainage, during which thick deposits of stream gravel, muck, and ice filled these valleys to a depth of several hundred feet. This filling was once much deeper than it is now, as shown by elevated terraces of silt and gravel, but in their lower courses all the major streams still flow on the surface of a deep valley filling, the bedrock lying as much as 100, 200, or even 300 feet below the present stream plain. A fuller explanation of the causes for this deep burial of the rock valley floors is given in another section of this report.

The main concentration of placer gold in the Fairbanks district took place before the old valleys were filled with their present great accumulations of material. This material is now generally frozen solid. To prospect and mine these old buried pay streaks, which usually are found on or near bedrock, it is necessary to sink shafts through the frozen valley filling, and if paying ground is found on bedrock, then the gold-bearing gravel must be thawed and brought to the surface, and the gold extracted by the ordinary methods of washing the gravel through sluice boxes. A large part of the gold recovered in this district has been mined in this way. In other places, however, principally near the heads of the streams, where the altitude of the bedrock floor is greater than the height to which the valleys have been filled, the bedrock approaches closer to the surface, the streams flow over a gravel filling of only moderate depth,

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

and open-cut methods of mining, by steam scraper, dredge, hydraulic, or pick and shovel, are employed. Large areas of gravel of moderate gold content remain to be worked by mechanical and to a lesser extent by hydraulic methods, but most of the rich, shallow gravel has long ago been worked out.

The list of producing creeks in this district changes from time to time, as some are mined out and others become productive through new discoveries. The largest producing streams to date are, in the order of their production, Cleary, Goldstream, Dome, Fairbanks, Ester, Vault, and Little Eldorado creeks.

The placer gravel in any stream basin consists of pebbles and boulders of the rocks that crop out in that basin. In this district it includes quartzite, schist, and igneous rocks. The richest gravel almost invariably occurs immediately above the bedrock, and the gravel having sufficient gold content to justify mining ranges in thickness from a few inches to about 10 feet and averages about 6 feet. The pay streak varies greatly in width but throughout the district has an average width of about 200 feet. The value per cubic yard of the ground mined has greatly decreased since the installation of dredges and hydraulic mines on a large scale, for these mines are able to handle profitably gravel of much lower grade than can be worked by underground mining. It is estimated that the average gold content of the ground mined in 1908 was $5.60 to the cubic yard. By 1922 the average value had fallen to $1.34 to the cubic yard. These figures indicate the trend of mining in the district, and it is to be expected that the future will see a still further decrease in the gold tenor of the ground mined, as the richer but smaller placer deposits are exhausted and large-scale mechanical operations are extended. The great bulk of the gold recovered is composed of flattish pieces a quarter of an inch in maximum diameter; of granular pieces, some of which are minute; and of considerable very fine gold. The proportion of nuggets is small; those worth a few dollars are common, and some ranging from $100 to $529 have been recovered. The gold ranges in value from about $16 to over $19 an ounce. In 1922 the producing creeks and their tributaries were, in the order of their production, Goldstream, Fairbanks, Dome, Little Eldorado, Cleary, Ester, and Vault.

GOLD LODES.

Prospecting in the endeavor to find the lodes from which the placer gold of the stream beds was derived has attracted the attention of many men since the early years of placer mining in the Fairbanks district. By 1910 many lodes had been located, and a few of them were opened and some mining was done that year. From

1912 to 1915 great activity was displayed in developing lode mines, and during those years the annual production from such mines ranged from over $200,000 to nearly $400,000 in gold and silver. By 1916,[41] however, the cost of supplies, power, and labor had so greatly increased that the production fell off sharply, and it remained below $50,000 each year until 1922, when $54,000 worth of lode gold was produced. This increase is probably attributable to the opening of railroad communication with the Nenana coal field. With the cheaper power that will be possible by using Nenana coal for raising steam, the output of the lode mines will doubtless continue to increase. In 1922 active mining was done on five properties, and prospecting and development work on a number of others.

The lodes, most of which are valuable chiefly for their content of free gold, are quartz veins in the schist, and the age of the mineralization is not well known. Some of the veins cut the schist; others lie parallel to it. There has been considerable local faulting, which in places makes it difficult to follow the ore bodies. Quartz is by far the most abundant vein mineral, but a little orthoclase and some sericite are found. The metallic minerals so far recognized in the veins include pyrite, limonite, stibnite, arsenopyrite, galena, bismuthinite, scheelite, sphalerite, and gold. Cassiterite, wolframite, and bismuth have been found in the stream gravel and must occur in the bedrock somewhere within the district. The gold-bearing veins are generally narrow, ranging from a few inches to 3 or 4 feet in width, and pinch and swell in thickness both horizontally and vertically. The gold is unequally distributed in the quartz, rich shoots of ore being succeeded by relatively lean ore. More than a dozen mines in the district have at one time or another been equipped with ore-crushing machinery, and others have sent ore to custom mills for reduction. The present outlook for lode mining indicates many small mines working relatively rich ore rather than large mines operating on ore of moderate to low grade. For a more detailed account of lode-mining developments in 1922 the reader is referred to a fuller account by Davis.[42]

ANTIMONY LODES.

As a result of the war demand for antimony in 1916 and the consequent high prices offered, several mines were operated in the Fairbanks district to produce antimony ore from stibnite-bearing veins, and about 4,000 tons of ore was shipped. Since 1916 none of these mines have been operated. The ore occurs in quartz veins in the

[41] Mertie, J. B., jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 403, 424, 1918.

[42] Davis, J. A., in Stewart, B. D., Annual report of the mine inspector to the Governor of Alaska, 1922, pp. 88–113, 1923.

Birch Creek schist, in genetic relation to granitic intrusive rocks. The metallic minerals in the antimony veins are the same as in the gold quartz veins, the principal difference being in the greater abundance of stibnite and the smaller gold content of the veins that have been mined for antimony. It is not likely that the antimony mines of this district will again be actively exploited unless there is some great increase in the price of antimony, and such an increase can not be foreseen.

TUNGSTEN LODES.

During the war years 1915 to 1917 tungsten, like antimony, was in great demand and commanded a high price. It had been known for many years that tungsten-bearing minerals occur in the Fairbanks district, and under the stimulus of high prices prospecting for tungsten lodes was vigorous, and in 1915 and 1916 workable lodes were discovered and mining begun. The principal mining was done on the divide at the head of Gilmore Creek, though promising prospects were also found on the divide between First Chance and Steele creeks. At the principal producing properties, the Tungsten and Scheelite claims, at the head of Gilmore Creek, the country rock consists largely of crystalline limestone that is extensively silicated at certain horizons; this silicated limestone contains mineralized zones or ore shoots that carry the tungsten mineral scheelite in amounts that constituted workable ore at the prices obtainable in 1915. The scheelite is disseminated through the country rock and also occurs in pegmatite. There are two bodies of porphyritic granite within two-thirds of a mile of the ore deposits, and the presence of tungsten-bearing pegmatite plainly indicates the genetic relation of the scheelite to the granitic intrusives.

On the Tanana group of claims, at the head of First Chance Creek, a number of scheelite-bearing lodes, in quartzite schist country rock, were prospected, and some mining was done. The ore occurs in mineralized zones 3 to 8 feet thick, lying parallel to the major structure of the schist or at its contact with granitic intrusive bodies. The scheelite is in part disseminated in the country rock, in part in gold and scheelite bearing quartz veins and veinlets and as scheelite-bearing pegmatite.

On the Black Joe and Mizpah claims, on Fairbanks Creek, scheelite occurs in a gold-bearing quartz vein in quartzite schist; the gold and the scheelite, however, are found in different parts of the vein.

On at least half a dozen other claims in the district scheelite lodes have been discovered with geologic relations similar to those in the lodes already described. Since 1917 all mining on tungsten lodes in the Fairbanks district has ceased, as the decreased price for the metal has made mining unprofitable.

HOT SPRINGS DISTRICT.

Gold placer mining began in the Hot Springs district in 1902 and has been continued each year since. The gold yield from this district has aggregated $6,268,000 up to 1922 and in seven separate years reached a value of $400,000 or more, but in 1921, as a result of the high cost of mining, the output fell to $35,000. In 1922 $55,000 worth of gold was produced, and a further increase in output is likely to follow the cheapening of mining operations that will be possible, now that railroad transportation from the coast to Tanana River is available.

The most complete report on the geology and mining of the Hot Springs district is that by Eakin.[43] The following notes are abstracted from that report and from various other later publications.

All the gold mined in this district has been taken from placer deposits. The bedrock source of the gold is believed to be in the slate, quartzite, and schist of the Tonzona group, probably of Silurian or Lower Devonian age. This series of altered sediments is cut by abundant quartz veins, and although none of these veins have yet proved rich enough to make lode mining profitable, many of them are known to contain gold. There is some evidence also that gold occurs locally in the slate and quartzite without quartz gangue and in hematite bodies near Hot Springs and on Roughtop Mountain. No doubt all these sources have contributed gold to form the placer deposits. The placer gravel of Sullivan Creek also carries considerable amounts of the tin oxide, cassiterite. The abundance of cassiterite in the gravel deposits varies with their richness in gold, the placers that contain the most gold also carrying the highest proportion of cassiterite. The district has produced several hundred tons of tin ore, although the tin saved has been a by-product of gold mining. In fact, many operators consider the tin to be a nuisance, its presence causing a greater increase in the cost of separating the gold than its market value. The source of the tin is not known, and no tin-bearing lodes have yet been found.

The principal mining activities of the Hot Springs district are centered around Tofty, on Sullivan Creek; on American Creek; and in the basin of Baker Creek, which lies just north of the area covered by Plate I and is therefore outside the field of this discussion.

The gold placers in the headward portion of the Patterson Creek basin and on American and Woodchopper creeks are of especial interest in that in many places they have no evident relation to the present streams. Much of the placer gravel mined occurs as benches

[43] Eakin, H. M., Reconnaissance of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, 1913.

on gently sloping hillsides, where the well-rounded gold-bearing gravel is overlain by silt or by black muck and silt. Much of the mining has been done by drifting, and the depth to the pay streak was in places as much as 70 feet.

Recent operations near Tofty include hydraulic mining after the ground had been thawed by the cold-water method, and this has decreased mining costs in an encouraging way. The lack of sufficient water for extensive mining is a serious handicap.

On American Creek mining has recently been done by means of a steam scraper in ground that averaged about 9 or 10 feet in depth to bedrock before the surface muck was removed by ground sluicing. Some drift mining is still carried on there.