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# THE MOUNT McKINLEY REGION, ALASKA

BY

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## WITH DESCRIPTIONS OF THE IGNEOUS ROCKS AND OF THE BONNIFIELD AND KANTISHNA DISTRICTS

BY

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# CONTENTS.

# ILLUSTRATIONS.

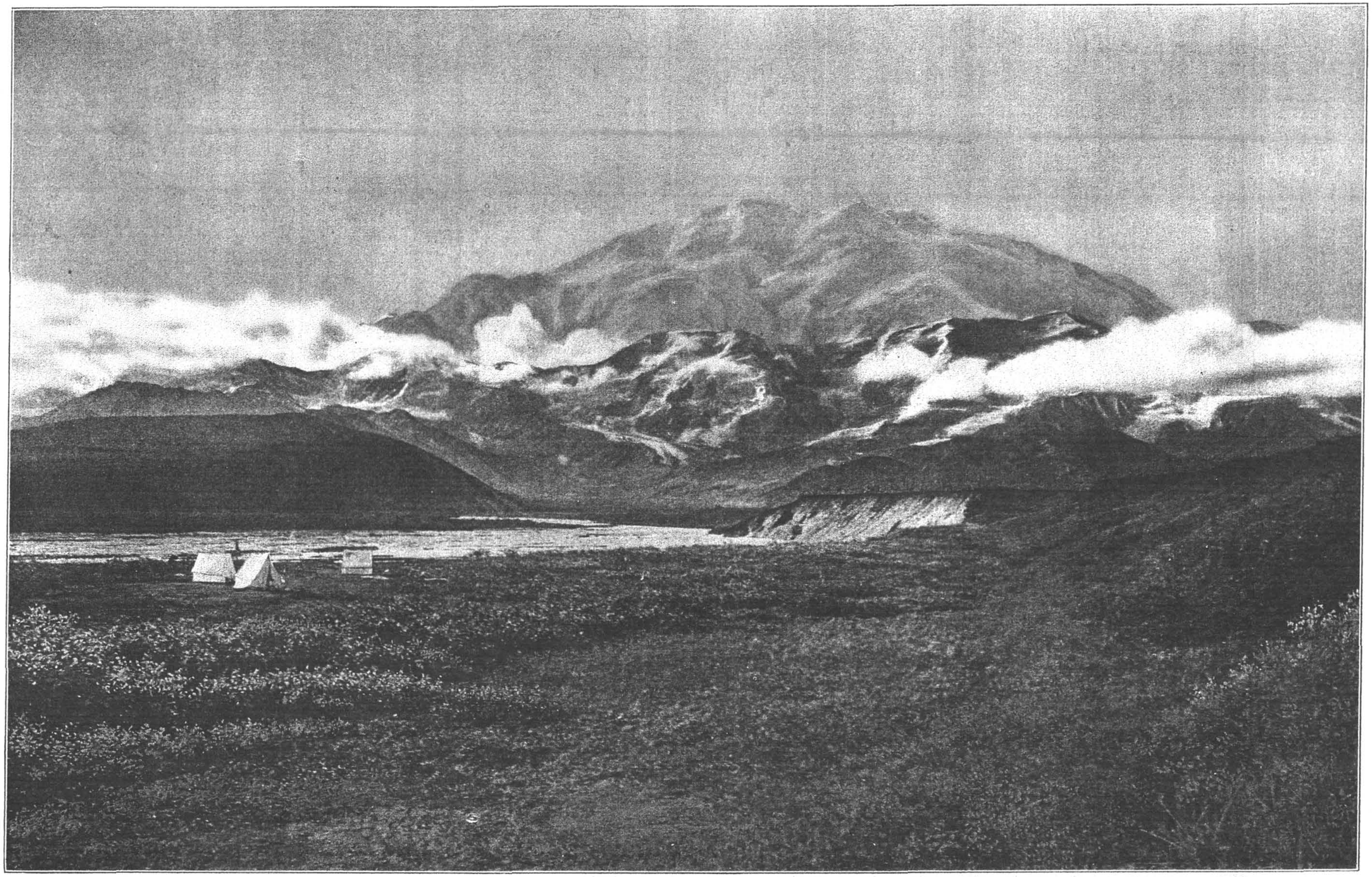
# PREFACE.

The original basis of this report was an exploratory journey made in 1902 from the Pacific seaboard through the Alaska Range along the northwest base of Mount McKinley to Tanana and Yukon rivers. During the long time in which the office work was in course of completion the conditions in the province here called the Mount McKinley region changed greatly. Much of the province that in 1902 had hardly been visited by white men has now been traversed by the indefatigable prospector and investigated and mapped by the Geological Survey.

Important industrial advances have been made in this region since 1902. The valuable Matanuska coal field has been prospected and surveyed, half a dozen gold-placer districts have been discovered and developed, and a score of settlements, large and small, have sprung up. Trails have been built, river steamboat service has been established, and a railway planned to traverse the province has been partly constructed. Both the mountaineer and the big-game hunter have been attracted to this field, some homesteads have been taken up, and the region now (1909) produces more than half of the annual gold output of Alaska.

It is therefore evident that a report which recorded only the results of the exploration of 1902 would not meet the present demands, and for this reason the original plan has been changed. Instead of presenting only an account of the geology and resources along the route of travel, the report has been made to cover the entire province.

The purpose of this volume is to furnish the prospector with a concise summary of the present knowledge of the mineral wealth of the region and to give the geologist an epitome of the stratigraphy, structure, and geologic history. As the Mount McKinley province is one of the best game fields in Alaska, the interests of the hunter are more fully considered than is usual in a publication of this character. In view of the fact that the region contains a large amount of arable land, some of which will undoubtedly be taken up by the homesteader, the available information in regard to climate, vegetation, agricultural lands, and means of communication is also summarized.



MOUNT McKINLEY FROM THE NORTHWEST.

Camp of August 4. See page 19.

# THE MOUNT McKINLEY REGION, ALASKA.

By Alfred H. Brooks.

## INTRODUCTION.

When in 1898 the Geological Survey began its task of exploring, surveying, and studying the mineral resources of Alaska, the first work was of necessity merely exploratory, for until the larger features of drainage and relief had been outlined it was impossible to plan areal topographic and geologic surveys. The demand of the prospector was for maps and information to guide him in hazardous journeys. The first two seasons were therefore devoted largely to exploration, but in 1900, though much of the Territory was still almost unknown, the rapid development of mining interests required that most of the money available be applied to areal surveys of regions having special economic promise.

Since that time there have been but few opportunities for important exploration. Nevertheless, during the five field seasons from 1898 to 1902 much of Alaska was covered by a network of reconnaissance surveys outlining the larger physiographic features—a skeleton to be gradually filled in by areal mapping. Of the country as yet unexplored, there was one region which held great interest for the geographer and geologist.

The great crescentic sweep of Alaska's southern coast line is broken at its most northerly point by Cook Inlet, an embayment which penetrates the mainland for nearly 200 miles. The drainage basin tributary to this embayment is cut off from the Yukon and Kuskokwim waters on the north and west by a chain of rugged mountains called the Alaska Range. At the heart of this chain stands Mount McKinley, the highest peak of North America, and its sister peak, Mount Foraker. Previous to 1902 this region constituted a great block of unknown territory. The country to the east, west, and south of it had already been explored, but as it gave no indication of placer gold, its isolation, far from the coast on the one hand and from navigable waters of the Yukon on the other, deferred its exploration.

Plans for the survey of the Mount McKinley region had been considered as early as 1899, but it was then deemed impracticable to complete the reconnaissance within the limits of a single field season, and the funds available were not sufficient to pay for a whole year's work. Gradually, however, experience taught means and methods of exploration which made it possible to cover larger areas. Moreover, with the substitution of pack horses for canoes cross-country journeys became feasible.

At last, in 1902, the plans took definite shape. The task of carrying them out fell to the writer. The following extract from his field orders indicates the scope of the project:

* * * You are hereby assigned to take charge of a party which is to make a geologic and topographic reconnaissance on the western side of the Alaska Range. The proposed route of survey is to extend from Tyonek, Cook Inlet, through the Skwentna Pass, and then along the foothills of the western slope of the Alaska Range to the Cantwell[1] River. From the Cantwell River it will extend by such routes as seem feasible to the Tanana. After reaching the Tanana you will choose such route to the Yukon as time and circumstances will permit. Should your party meet with any accident or delays, it is possible that you may have to abandon your outfit either on Kuskokwim or Tanana waters and proceed to the mouths of these rivers by boat or raft. In case you reach the Tanana in sufficient time it will be advisable to cross it and extend the work to Circle City, on the Yukon, making investigations of the Chena River gold fields. It will be the purpose of your expedition to obtain all possible information regarding the geography, topography, geology, and mineral resources along the route of travel.

[1] Now called the Nenana.

D. L. Reaburn, topographer, was detailed to accompany the expedition, and L. M. Prindle was engaged to cooperate in geologic investigations. To these, his colleagues in the scientific work, the writer feels under the deepest personal obligations, for the success of the expedition is due in large measure to their untiring fidelity to its best interests. The other members of the party were Odell Reaburn, recorder; Fred Printz and W. W. Von Canon, packers; and George Revine, cook. All four of these men were faithful to their tasks, ever ready to further the plans by any means in their power.

During the winter following the season of field work Messrs. Reaburn and Prindle revised their notes and practically completed their share of this report, but the writer's administrative duties have allowed only occasional opportunity for research or writing. Moreover, since its inception this report has been further interrupted by work incident to seven more field seasons in Alaska.

The more important results of the investigation have, however, been made public through various channels. The coal of Nenana River has been described[1] and something has been said as to the probable occurrence of placer gold in the Mount McKinley region.[2] A brief narrative of the expedition was inserted in the annual report of the Geological Survey,[3] together with a summary of the geology and geography of the district. A more popular account of the incidents of the journey has also been published.[4] The purely scientific results, with Mr. Reaburn's map, have been used by the writer in a recently published summary of the geography and geology of Alaska.[5] Thus, in spite of the delay in publishing this detailed account, the cause of exploration has not suffered through the suppression of any essential facts.

## OUTLINE OF FIELD PLANS.

It was proposed to make a way from the west shore of Cook Inlet to the Alaska Range and find a pass through those mountains, or traverse them by one of the gaps already known, then to proceed northeast along the western base of the mountains, mapping as much of their geology and topography as circumstances would permit, until Nenana River or one of its tributaries was reached, and then to turn northward to the Tanana. After crossing this river the most expedient course to the Yukon was to be chosen. Incidentally, it was hoped that the route thus outlined would touch the base of Mount McKinley, but no attempt to ascend the mountain was contemplated. The party was to consist of seven men, with the horses necessary to transport supplies. Three and a half months was allotted for the project should the season permit.

It was possible to map out the journey in some detail because, unexplored though this district was, adjacent surveys had given hints of its character and larger topographic features. As the event proved, the plans were entirely feasible and were executed without serious obstacle.

## EQUIPMENT.

The following notes on outfitting may be considered an epitome of all experience acquired during Alaskan surveys. They are published here in the belief that they may be of use for the guidance of others.

As the contemplated journey was longer than any similar one yet made in Alaska with pack horses, the question of equipment was of great moment. On one hand the party must be supplied for every emergency; on the other its mobility must not be impaired by excess of baggage. Fortunately the accumulated experience of some twenty expeditions sent to Alaska by the Geological Survey made it possible to determine the essentials to a nicety. The most important step was the selection of horses, for on their endurance would rest, in large measure, the success

[1] Collier, A. J., The coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, pp. 44-46.
[2] Brooks, A. H., Bull. U. S. Geol. Survey No. 225, 1904, p. 48.
[3] Walcott, C. D., Twenty-fourth Ann. Rept. U. S. Geol. Survey, 1903, pp. 94-102.
[4] Brooks, A. H., An exploration to Mount McKinley, America's highest mountain: Jour. Geography, vol. 2, 1903, pp. 441-469 (map). Reprinted in Smithsonian Rept., 1903, pp. 407-425. See also Brooks, A. H., The Alaskan Range, a new field for the mountaineer: Bull. Am. Geog. Soc., vol. 37, 1905, pp. 468-479 (map).
[5] Prof. Paper U. S. Geol. Survey No. 45, 1906.

of the expedition. Fortunately Messrs. Reaburn and Printz, to whom this duty was assigned, were expert in such matters. With a view to procuring hardy range stock accustomed to seek their own feed, it was decided to purchase the horses in eastern Washington.

As the writer was detained in the city of Washington, the task of outfitting fell almost entirely to Mr. Reaburn. In pursuance of his instructions he proceeded to North Yakima, Wash., about the middle of April, and there, with the aid of Mr. Printz, carefully selected some twenty horses. The preference was given to short, heavily built animals weighing from 800 to 1,200 pounds. Experience proved that the buckskins, bays, and sorrels had more endurance than the black or, especially, the white animals. The white horses suffered most from mosquitoes and were the first to give out.

As all the horses were to be used for packing supplies, eighteen were provided with sawbuck pack saddles equipped with strong breeching and breast straps. The question as to the desirability of aparejos was decided in the negative. Although the aparejo undoubtedly protects the horse's back better than the sawbuck, yet its great weight and the fact that it necessitates the chopping of a wider trail are serious disadvantages in swampy country. It also requires more attention from the packer than the sawbuck. Besides the eighteen sawbucks, one combination and one riding saddle were carried. These proved very useful when the horses developed sore backs, because an interchange of saddles shifted the pressure. Each animal was provided with a good halter, a heavy double blanket, sweat pads, two alforjas, a 10-ounce pack cover, and a cinch rope. As far as possible bags were used for packing the provisions, but three horses carried light wooden boxes as side packs, with heavy pads underneath to protect their sides. As a partial protection against insects, each animal was provided with a light duck blanket with two surcingles which, though they lasted but a few weeks, proved of great service during the month of June, when horseflies were plentiful. The horse equipment also included a shoeing outfit, two extra shoes for each horse, zinc ointment, extra leather straps, sole leather, rivets, etc. Subsequent experience showed that it would have been well to carry condition powders, as well as iodoform and hydrogen superoxide to treat sores and cuts.

After completing these purchases at North Yakima, Reaburn went to Seattle to procure provisions and the outfit. Much time and thought had been given to the ration list. On such an expedition food is a vital consideration. If the allowance is insufficient, the journey has to be curtailed or the risk of starvation incurred. On the other hand, too great a quantity hampers transportation and causes the expedition to fail. Variety is also imperative, for, although the simplest diet of flour, bacon, and beans may not prove harmful on a short journey, it has been found that such monotony of food can not be long continued without affecting the health. Alaskan exploration, under the best conditions, is a severe strain on the endurance of the average man, and variety of food tends to strengthen his powers of resistance. The ration chosen, as shown below, though providing ample quantity and considerable variety, did not exceed 3¼ pounds per man per day. Practically nothing but dried foods was taken. The staples—flour, bacon, beans, sugar, rice, and evaporated fruits and vegetables—were supplemented by farinaceous foods, cheese, desiccated eggs, and condensed soups, together with tea, coffee, chocolate, condensed cream, and a small quantity of delicacies. Though the region to be visited was believed to abound in game, this was not taken into consideration. Aside from the fact that it is never safe to rely on game, a party which has a definite journey to make within a limited time can not afford to stop for hunting.

*Ration per man per day.*

| | Pound. | | Pound. |
|---|---|---|---|
| Flour | 1.00 | Sugar | 0.35 |
| Bacon and pork | .75 | Coffee | .07 |
| Butter | .14 | Tea | .03 |
| Oatmeal | .18 | Salt | .08 |
| Rice | .10 | Miscellaneous | .12 |
| Beans | .17 | | |
| Dried fruit | .25 | | 3.24 |

By leaving out most of the dried fruit and some of the miscellaneous supplies and substituting tea for coffee at the ratio of two to five this ration can be reduced to 3 pounds or less. When means of transportation are limited to the most primitive form of back packing, bacon or pork can be substituted for butter and flour, or rice for oatmeal, in which case the ration need not exceed 2.9 pounds.

The relative proportions of the different articles in the preceding table have been carefully estimated on data furnished by the Alaskan parties of the Survey and compared with information gleaned elsewhere.[1] It is not possible, however, unless the daily ration is actually weighed, to insure that the provisions will come out even. For example, if much game is procured, the consumption of salt and bacon for cooking may result in a deficiency in those articles.

The complete list of provisions is as follows:

Wheat flour.
Graham flour.
Rolled oats.
Corn meal.
Macaroni.
Germea.
Rice.
Hard-tack.
Cheese.
Condensed milk.
Bacon.
Salt pork.
Ham.
Dried beef.
Butter and lard.
Evaporated eggs.
Beans, navy and bayo.
Sugar.
Chocolate.
Cocoa.
Canned jelly.
Tea.
Coffee.
Evaporated peaches.
Evaporated pears.
Evaporated apricots.
Evaporated nectarines.
Evaporated plums.
Evaporated currants.
Seeded raisins.
Pea-meal condensed soup (Erbsenwurst).
Bean condensed soup.
Potato condensed soup.
Corn condensed soup.
Tomato condensed soup.
Evaporated potatoes.
Evaporated onions.
Evaporated soup vegetables.
Evaporated Brussels sprouts.
Baking powder.
Yeast cakes.
Soda.
Salt.
Pepper.
Mustard.
Nutmeg.
Ginger.
Cinnamon.
Curry powder.
Vinegar.
Lime juice.
Pickles.
Matches.
Soap.
Candles.

The evaporated eggs, commercially known as crystallized eggs, have high nutritive value, but have usually proved unpalatable unless cooked with something else. The so-called Erbsenwurst, or pea-meal soup, is a combination of pea meal and beef extract, partly cooked and easy to prepare. In the experience of the writer it is the most valuable of the concentrated foods. With these foods can be grouped hard-tack, chocolate, smoked beef, and cheese, all of which are invaluable in forced marches when no cooking can be done. The large quantity of dried fruit taken was probably a sufficient safeguard against scurvy, but as an additional precaution lime juice put up in small capsules was freely used. These are also good for improving the taste of swamp water.

Most of the provisions were packed in paraffin bags holding 50 pounds each, placed inside of heavy canvas bags and tied up in such a way that no water could enter if the pack should be submerged. The wisdom of this precaution was proved many times. During the three and one-half months of the journey, though it happened over and over again that horses rolled into the water, only once was anything ruined, and the only loss of provisions was about 10 pounds of corn meal which became wet and moldy. Many an expedition has run short of food because the supplies were insufficiently protected against moisture.

[1] Snow, C. H., The equipment of camps and expeditions: Trans. Am. Inst. Min. Eng., vol. 29, 1899, pp. 157-186.

In each detail of the equipment it was advisable to obtain the utmost degree of lightness commensurate with durability. The cooking utensils were chiefly of tin and iron, which, though much heavier than aluminum, were found to wear longer. They were of such shapes that they could be packed compactly and were stored in two of the wooden side hampers. In view of the fact that much of the journey would be above timber line, where only small willow could be procured for fuel, a small sheet-iron stove was carried. This proved very serviceable, though it made an awkward pack on a horse. Especial care was taken to keep the matches in waterproof boxes and to distribute them in several packs.

The party was provided with three wall tents, 7 by 7 feet, made of cotton drilling and weighing but 10 pounds each. They were mosquito proof, the floor being sewed to the walls and the entrance arranged to close with a draw string. Ample ventilation was insured by large openings covered with double thicknesses of bobbinet. Besides the sleeping tents, there was one 8 by 10 foot cooking tent, also of cotton drilling, which demonstrated its utility toward the end of the season, when the stormy weather began.

Each man was provided with a sleeping bag weighing about 12 pounds, composed of two woolen bags and one duck cover. Personal equipment was cut down as far as possible, but each man carried at least one extra pair of stout walking shoes. Experience on previous expeditions had taught the writer that good footgear is the first requisite to rapid progress where men must move on foot. It was found that a rather light-weight 10-inch walking shoe is preferable to the high boot. The shoe-repairing outfit, including extra hobnails or screws, leather, wax, thread, and grease, was a very important part of the equipment. Each man was also provided with a bobbinet headdress to protect him from mosquitoes, and gauntlet gloves. For outer clothing duck or khaki is preferable, but underwear should be entirely of wool.

The weapons of the party were two .30–30 carbines and one .22 caliber rifle. For the carbines 250 rounds of ammunition was provided; for the rifle about 500 rounds. The small rifle, devoted to killing ptarmigan and grouse, was almost as effective as a shotgun in supplying the camp larder, and both the rifle and the ammunition were much lighter.

The heaviest and most awkward pack for the horses was a folding canoe and oars. This was considered essential because nothing was known of the character of the rivers to be encountered. As a matter of fact, it was never used. On the coastal side of the divide a large boat which had been brought from Tyonek was used, and at the Tanana the party was fortunate in finding a fairly good rowboat belonging to natives. At the latter point the folding boat was abandoned, and thereafter the rivers were crossed by the aid of hastily constructed rafts.

On a previous expedition the writer found that a practical boat could be made by stretching a large piece of waterproof canvas over a framework of dried spruce poles fastened together by crosspieces inserted in auger holes. The canvas alone does not weigh over 25 pounds; with the framework the total weight is 50 or 60 pounds.

There was an ample supply of axes, for these are liable to be broken or lost. Several of 3½-pound weight were carried, and three light hand axes. In the opinion of the writer the machete used in tropical countries would have been found useful in cutting trails through the dense growths of alder and willow which were frequently encountered. The rest of the tool equipment was very simple—a combination tool, a hatchet, some copper wire, a 1½-inch auger for constructing rafts, files, a whetstone for sharpening axes, a rivet set and punch, some sailmaker's needles, a sailmaker's palm, and a small saw.

The instruments for topographic work included an 18 by 24 inch plane table, a tripod fitted with Johnson movement, a telescopic alidade with micrometer attachment, a Saegmueller theodolite with 4-inch vertical and horizontal circles reading to 30 seconds, with two verniers to each circle, a stenometer, together with barometers and thermometers, including a maximum and minimum thermometer. Each geologist was provided with a Brunton pocket theodolite, an aneroid barometer, a hammer, a Zeiss field glass, and a compact 4 by 5 film camera with aluminum tripod. The films were packed separately in tin tubes made waterproof by the use of insulated tap. In addition, notebooks, drawing paper, and other stationery were carried, together with a small, carefully selected medical outfit, including bandages, etc.

The 105 days' provisions aggregated about 2,300 pounds; the rest of the outfit between 600 and 700 pounds. The total was a little less than 3,000 pounds, the pack thus averaging about 150 pounds to each horse. This would not have overloaded the horses had the trail been good; but, as it happened, the early part of the trip lay through swampy country, and it was fortunate that nearly one-third of the load could be sent by boat for the first 100 miles.

## NARRATIVE OF EXPEDITION.

The entire party of seven men, with twenty horses, assembled in Seattle on May 13, 1902, and two days later embarked on the steamer *Santa Ana* for Cook Inlet. After a coasting journey of nearly 2,000 miles, the vessel steamed up Cook Inlet on May 27, and the same night, with the aid of a lighter, the party was safely landed at Tyonek, on the west shore.[1] Here several days were spent in repacking provisions and outfit, breaking the horses, and attempting to gather information from Indians, prospectors, and traders. In this last particular no great degree of success was attained, for many of the people of the coast know little of the inland region beyond the first 20 miles. Although the Indians and traders agreed that with good luck we might be able to get through the range with our outfit, no one believed it possible that we could extend our work to the Tanana, much less to the Yukon. It was the general expectation that the party would return to Cook Inlet in the fall. This might have discouraged us had we not known that few of the longer explorations of the Geological Survey in Alaska had been regarded as practicable by traders who were most familiar with the localities. Alaska natives, as a rule, know only their own hunting grounds, and as they have no experience with pack horses, their opinion as to choice of routes is of no great value.

After weighing all the evidence and making a few preliminary reconnoitering trips, we chose a route which would cross Beluga River near its mouth and Skwentna River near the lower canyon. George Eberhardt and Joe Anderson, of Tyonek, were engaged to take a boat-load of supplies up the Susitna and its west fork, the Skwentna, to meet us at the point of crossing. The object of this was both to lighten the burden of the horses while they were traversing the flat, swampy coastal belt and to provide a means of crossing several of the large and turbulent rivers of the coastal slope. For their efficient performance of this task Eberhardt and Anderson deserve the highest praise.

Our fears that we might be delayed by a scarcity of forage for the horses proved groundless, for the snow was gone and the grass well advanced by June 1. On the 2d, all preparations being completed, we were able to get under way. About 1,000 pounds of the equipment was sent in the boat. The remainder, together with 200 pounds of grain for the stock, was distributed among the twenty horses.

The route lay along the western shore of Cook Inlet, over a gravel beach at the foot of a series of gravel bluffs which rise 50 to 100 feet above the water (Pl. IV, *B*, p. 44). This strip, limited by the inlet on one side and by the precipitous escarpment on the other, gave excellent opportunity to break in the pack horses, many of which were inclined to be fractious after their long confinement in the vessel. The second day found the party approaching the broad mud flats formed by the delta of Beluga River. To avoid this swamp it became necessary to climb to the level of the first terrace and chop a trail through the dense growth of spruce and birch. We reached the Beluga on June 4 and crossed on the following day with the aid of the boat brought by Eberhardt and Anderson. At flood tide, when the current slackened, the horses swam over without difficulty.

It now occurred to us that a comprehensive view of the country ahead could be obtained by climbing Mount Susitna. Leaving Mr. Prindle to study the local geology and the two packers to chop a trail inland, the rest of us made our way by boat to Alexander, a small native settlement at the head of the Susitna Delta. From this point we followed an Indian

[1] Landings are now made at Beluga, about 15 miles above Tyonek.

trail, winding in and out among swamps and lakes, through spruce forests, and across several streams on old beaver dams, to Mount Susitna, a granitic boss about 4,000 feet high lying 10 miles west of the river. The sides of the mountain rise gently to a height of 1,000 feet and then steepen gradually, so that the final stretch of the ascent must be made over a talus slope of maximum gradient. Heavy timber—birch, cottonwood, and spruce measuring up to 2 feet in diameter—extended to about 1,000 feet, and then gave place to dense growths of alder and willow, with scattered white birch. Beyond 1,500 feet the willow and alder were succeeded, except in the ravines, by grassy slopes, and the great abundance of fine red-top grass was very striking. Near the summit the remnants of the previous winter's snow contrasted strongly with the wild flowers and other vegetation.

A rather toilsome climb brought us at last to our vantage point. Looking northward, whither our route lay, the eye swept the broad lowland of the lower Susitna, its dense forests of dark spruce diversified by the lighter greens of the open meadows, while here and there a gleam of reflected light marked the position of a lake or waterway. On the northeast the lowland stretched to the horizon, broken only by a few highland masses; on the northwest it culminated in the great Alaska Range. Above this snowy crest line rose the twin peaks Mount McKinley and Mount Foraker, asserting their stupendous height even at that distance, more than 110 miles. To the west the range dwindled into foothills 40 or 50 miles from the coast. We took cognizance of the many swamps and lakes with some premonition of the difficulties before us. Far to the northwest a break of considerable width in the Alaska Range appeared to mark the gap which was the immediate objective point of the expedition.

Mr. Reaburn made a latitude and azimuth and plane-table station on the summit, and was able to take the azimuth of Mount McKinley, almost due north, which helped to control in longitude much of the season's surveys, for the high peak was repeatedly sighted, almost throughout the summer.

Returning, we reached the base camp on Beluga River on June 7. The trail choppers had found the old Indian trail of which we had heard rumors at Tyonek, and thereby had been able to establish a route for 7 or 8 miles. On the 8th the reunited party resumed the march, dispatching Eberhardt and Anderson with the boat to a rendezvous on the Skwentna. The trail led northwestward over a gravel plateau which sloped up gently toward the mountains, interrupted here and there by knobs of granitic rocks (Pl. IV, *A*, p. 44). Many swamps retarded our progress and severely taxed the strength of the horses, but good grass was abundant. The many lakes and ponds were breeding grounds of waterfowl, and the camp larder was much improved by contributions of duck, geese, and sand-hill crane, as well as grouse. June 13 brought us to the foothills of the range, and for several days we made rapid progress over a country thickly covered with grass and studded with parklike groves of trees. In these highlands many large brown bear were seen. The Indian trail vanished above timber line, and on descending to the lowland of the Skwentna Valley we were compelled to do continuous chopping in order to penetrate the dense grove of alder, spruce, and birch.

On June 18 camp was made on Skwentna River, a western tributary of the Susitna. The original plan was to cross the river at this point and send down only a part of the pack train to meet the boat at the canyon, 20 miles below. But every effort to find a ford proved disastrous; the river, swollen to a rushing torrent by the melting snow in the hills, swept the horses off their feet and carried them and their riders downstream. Rather than risk the loss of equipment, if not of men and horses, the attempt was reluctantly abandoned, and the entire party set out down the river. On June 21, after three weary days of chopping trail through the dense thickets which clothe the river banks, we reached the lower canyon. Eberhardt and Anderson had arrived the day before. On the following day the horses were towed across the river behind the boat, one by one, but so swift was the current that even with four men at the oars a quarter of a mile or more was lost in gaining the opposite bank.

From the Skwentna the course lay in a northerly direction through a flat, heavily timbered region where almost continuous trail chopping was necessary. On the 28th we arrived at

Kichatna River, also belonging to the Susitna drainage, to find the men with the boat again awaiting us.

Nearly a third of the season and of the provisions had been consumed and less than a sixth of the distance had been covered. The swampy country had told disastrously on the strength of the horses, whose vitality was further drained by the clouds of horseflies and mosquitoes which harassed them day and night. Moreover, there had been an outbreak of distemper among them which threatened to become serious. The outlook was far from cheerful, for it hardly seemed possible that the survey could be carried to the Yukon, as planned, and it was uncertain in what straits the party might find itself when the cold weather in the fall should put an end to the use of horses. To provide for a probable retreat along the line of advance, a cache of a week's provisions was established at this point.

On June 30, when we started inland, Eberhardt and Anderson turned back with the boat. It was our last link with the world for nearly three months. Although we had remaining only 75 days' provisions, yet many of the horses had lost so much strength that the packs were too heavy for them and necessitated short marches. At first our course lay along the east bank of the Kichatna by the route that was followed in 1899 by Lieutenant Herron, of whose journey mention is made elsewhere. Herron's trail had in many places been destroyed by the undercutting of the river bank and had to be pieced out by chopping through the dense alder thickets. After three days, which netted only about 10 miles air line, we came to a bench bordering the east side of the valley, 50 feet above the river, which offered excellent traveling. An Indian trail was discovered leading through an open parklike stretch known as Nin Ridge. Everywhere appeared thick patches of red-top grass, the finest the writer has ever seen in Alaska. Much of it grew as high as 5 or 6 feet. The abundance of pasture and the disappearance of horseflies revived the energies of the horses somewhat, and for several days long marches were made.

After some 20 miles of this the bench merged into the river bottom and trail cutting again became necessary. Often the river flood plain was followed and the Kichatna was forded a number of times, not without serious danger, for it was here a turbulent glacial stream, full of large bowlders which offered but insecure footing. More than once men and horses were swept off their feet by the mad, rushing waters. At length we reached the headwaters of the river, and on July 12, in a dense fog, we crossed a pass, expecting to find the Kuskokwim waters beyond; but on the following day the stream that we were descending proved to be still on the coast side of the divide. Here the killing of a moose provided a welcome change of diet, and for two months thereafter we were almost always able to procure fresh meat. Before a route could be chosen from this point it was necessary to reconnoiter. Three men spent a day and the greater part of a night exploring in different directions, and at length found a pass which had long been used by the natives as a route between the Kuskokwim basin and the Cook Inlet region. Rainy Pass, as we called our new discovery, lies to the south of Simpson Pass, discovered by Herron. It has an altitude of about 2,950 feet and undoubtedly affords the best opportunity of piercing the southern part of the Alaska Range. This region appeared to abound in white Alaskan sheep.

On July 15 we crossed the pass, and two days later the party emerged from the mountains into the valley of the upper Kuskokwim (Pl. V, p. 46). This part of the Kuskokwim Valley had been surveyed in 1898 by Spurr, of whose exploration an account is given below.

Our route now followed the Kuskokwim for some 20 miles to the point where that river debouches on a broad lowland. Here, leaving on our left the route of Herron and Spurr, we branched off to the northeast along the northwestern margin of the range and again entered unexplored territory. It was not without misgivings that we took this second plunge into the unknown, for the time was more than half spent and we were still almost as far from Mount McKinley, our immediate objective point, as when we left salt water. Moreover, it was here in the Kuskokwim Valley that Herron's party had come to grief. Our fears, however, proved groundless, for subsequent events showed that the easier part of the journey was ahead of us.

From the main valley of the Kuskokwim for nearly 200 miles to the northeast the range falls off, in many places abruptly, to a gravel plateau (Pl. VI, *B*, p. 46). Along the inner margin of this plateau, keeping the snowy crest line of the range but a few miles to the right, we followed an almost air-line route N. 20° E. to the base of Mount McKinley, a hundred miles distant. Twice we had to cross spurs of foothills of considerable altitude which branched out from the main mountain mass, and here the horses had stiff climbing. But the smooth, moss-covered surface of the plateau, which was composed of glacial overwash material, afforded excellent footing for both man and beast. Our only serious interruptions were the glacial streams which emerged from the mountains, many of them with the volume of good-sized rivers, directly athwart our course. Fortunately, on each of them a ford was found, for the turbulent waters threatened a perilous passage to so frail a craft as our folding canoe. Some of the glaciers reached well out into the plateau region, and stemming the roaring torrent close to their moraine-covered fronts was exciting, if not always pleasant. In crossing every man was mounted on top of a pack. Occasionally a horse would roll over, but none was lost.

In spite of the rapid marches that were now made, most of the horses kept up well, for grass was plentiful. Unfortunately, two of them, which had never recovered from the physical strain of the first month, gave out and had to be shot.

Many of the camps were above the limits of spruce, but there was always sufficient willow for cooking purposes. In the foothills the white Alaska bighorn was abundant, the moss-covered plateau furnished plenty of caribou, and in the river bottoms an occasional glimpse of moose was obtained.

To the west the plateau sloped down to a broad wooded lowland of somber monotony, a gleam in the sunlight here and there marking a lake or a winding river course. Old Indian hunting camps were not infrequent, but there was no other evidence of the abode of man. Once, indeed, a smoke was sighted curling up from a forest miles away, and was marked with delight by eyes that had seen no human beings outside of the party for two months, and once the ax marks of a white man were seen.

Mount McKinley and Mount Foraker, which in clear weather had been visible for most of the time since we left the coast, loomed ever larger and more majestic as we approached (Pl. VI, *A*, p. 46). On August 4 camp was made only 14 miles in an air line from the summit of Mount McKinley (Pl. I, p. 11). Here a day's delay permitted the writer to climb a spur of the mountain to snow line and to obtain some clue to its geologic structure. But satisfaction at standing on its slopes, 9 miles from the summit, which had never before been approached by white man, could not but be tinged with regret that there was neither time nor means for reaching a higher altitude.

Beyond Mount McKinley the range swings somewhat to the northeast. The route, still following the base, swerved in the same direction. For the next 100 miles there was little change in the character of the topography, and we continued to make rapid progress. The streams which now crossed our path flowed northerly to the Tanana instead of westerly to the Kuskokwim.

On August 15 we made camp in the valley of the Nenana, which is tributary to the Tanana. Ascending this river to its main fork, we found a ford and made the last dangerous crossing of the season. It was not without relief that we saw the last horse and man safely landed on the left bank, for the turbulent waters reached well up to the horses' shoulders.

This had brought the party to the most northerly point of the Eldridge survey of 1898, to which further reference will be made. We now followed the left branch of the Nenana, called Yanert Fork, nearly to its glacial source (Pl. XII, *B*, p. 108), and then, crossing over, laid a northwesterly course into the Tanana Valley across the mountains which separate the two valleys. Our route through these mountains was one much used by natives, as indicated by their many camps.

August 24 was marked by an encounter with a white man and a band of Indians, the first human beings we had seen in nearly three months. They directed us to a trail long used by the Indians and recently improved by a party of white men with horses, who were reported to be making a survey for a railway. We followed this trail for 30 miles across the lowland of the Tanana. Broad meadows of magnificent grass alternated with belts of birch, cottonwood, and fine spruce, or with large marshes dotted with lakes. The timber was unusually large for the Yukon basin, trees 18 to 24 inches in diameter being not uncommon.

On the 29th we emerged from the forest on the south bank of the Tanana, at the small native settlement of Tortella[1] (Pl. VII, *A*, p. 48). To the natives the arrival of white men from the mountains seemed little short of miraculous, for all previous visitors had come by way of the river. Though these Indians ordinarily use only canoes, they happened to have one boat adapted to towing horses. After some bargaining this was hired and the crossing was made without serious delay.

On the 1st of September we made camp on the north bank of the Tanana, rejoicing in the knowledge that the most difficult as well as the most important part of the summer's work had been accomplished. Eighteen out of the original twenty horses had survived, but the three months of hard work had left many of them in poor condition. Moreover, the grass, though abundant, had been nipped by early frosts and appeared no longer to furnish sufficient nutriment.

There were two alternative routes for reaching the Yukon—one to continue northward and attempt to reach Circle, the other to take a northwesterly course to Rampart. As the season was well advanced and it was only a question of days when the horses would begin to give out, we decided to try for Rampart, that being some 50 miles nearer than Circle. The Indians gave no encouragement; rather, they declared that the swamps and thick timber made it quite out of the question to take horses through to the Yukon. They prophesied that the party would return to the Tanana by the time the snow came. So utterly foolish did the project seem to them that it was difficult to obtain any information in regard to routes.

With this not very cheering prospect we started northward on the 1st of September. The weight of the horses' packs had been reduced as far as possible by abandoning all except the most necessary part of the equipment. This, with the three weeks' provisions and the specimens which had accumulated during the summer, amounted to about 50 pounds to each horse.

For two days our route followed a series of low ridges, to the north of which stretched the broad lowland of Tolovana River. This lowland, by reason of its patches of thick timber, its swamps, its innumerable lakes, and its many sluggish streams and rivers, was regarded by the Indians as impassable for horses. After skirting its southern border for some 20 miles we turned to the northwest, directly across it. Though the distance to the highlands on the west was only about 30 miles, the difficulties of travel occupied the energies of the entire party for eight days, as much time had to be spent in building corduroy, bridging streams, and crossing rivers. Within six days five different bridges were constructed and six rivers were rafted.

On September 9 we left the low country behind, and thence to the Yukon our route lay through an upland region (Pl. VII, *B*, p. 48). Traveling here was comparatively easy, as there was little trail chopping to do. At this time the horses began to give out at an alarming rate. Though their loads were very light, yet the frost-bitten grass and the hard traveling through the swamps proved fatal to all except the strongest. During the rest of the journey shooting one or more horses was a daily incident. On the 14th we reached Little Minook Creek, and there found a trail which brought us to Rampart on the 15th. The next morning we boarded a river steamer bound for St. Michael. Thence the party returned to Seattle, arriving on September 30.

In 105 days the expedition had covered about 800 miles. During this time 94 camps had been made; between June 1 and September 15 the party had traveled every day except nine. Eleven out of the twenty horses reached Rampart.

[1] Now called Nenana.

## METHODS OF WORK.

Before describing the methods of work pursued by the different members of the party it may be well to outline the ordinary daily routine. All hands were usually called at 5, and while the packers were finding the horses the others took down the tents and packed up. The horses were saddled as soon as they arrived, and then breakfast was eaten. Between 6 and 6.30 began the packing of the horses, which occupied all except the cook from one to two hours. When the last horse was ready, usually before 8, the pack train started. The topographer, his assistant, and one of the geologists were separated from the party for the rest of the day, choosing such routes as their work demanded. The other geologist accompanied the pack train and usually made an excursion after camp was pitched in the afternoon. This routine was varied when thick timber or swamp required the entire force to cut trail or build corduroy. Under such conditions the topographic and geologic observations were mostly made after camp was pitched, which proved a severe strain on the observers. The pack train usually traveled six or seven hours and the technical members of the expedition worked from ten to fourteen hours daily.

Mr. Reaburn, elsewhere in this report (see pp. 32–39), gives a detailed account of the methods employed in the topographic surveys of the party. Here, therefore, it is sufficient to state that, thanks to his untiring activity, a survey was carried on throughout the journey from Cook Inlet to the Yukon. This was not the rough approximation so often used in exploratory work, but one based on trigonometric determination of positions and altitudes. It not only recorded a location of the route but also embraced a considerable area on both sides, aggregating in all about 6,000 square miles. To Mr. Reaburn[1] belongs the credit of having in the course of two successive seasons made instrumental surveys from the Pacific Ocean at Cook Inlet to the Arctic Ocean at Kotzebue Sound, covering a distance of about 2,000 miles.

The geographic results of the expedition are, first, the mapping of the western front of the Alaska Range and the headwaters of the Kuskokwim; second, the filling in of the gap between the four previous exploratory surveys (see pp. 27–29), so that they are now linked together and can be mutually adjusted. Furthermore, the region traversed between the Tanana and the Yukon, though frequently visited by white men, had not been mapped; hence this portion of the work is also a contribution to geographic knowledge. The same holds true of the first part of the route, between Cook Inlet and the Alaska Range.

The position of Mount McKinley was more accurately determined, as also its altitude, 20,300 feet. Mount Foraker, some 15 miles to the south of Mount McKinley, was also located, and its altitude of 17,000 feet determined. These observations were also made for a number of other peaks, varying from 8,000 to 11,000 feet. Although the actual surveys cover only 6,000 square miles, the information obtained and the correlations established between previous surveys throw additional light on the geography and topography of about 20,000 square miles.

The geologic work, though in many respects less satisfactory than the geographic, was also fruitful of results. The geologist obtained his field locations by foot traverses, laying courses by pocket compass and approximating distances by pacing. The traverses were platted directly in the notebook, with the aid of a celluloid protractor, on a scale of a mile to the inch, so that the observer at all times kept his location and gained at least an approximate idea of the relative position of the outcrops. On these sketch traverses contours were usually indicated, also notes on distribution of timber, as well as geologic observations. Verbal descriptions were added, and frequently sections were drawn to indicate the field interpretation of the facts. At night the record thus made was supplemented by fuller description. Specimens were of course taken wherever it was deemed advisable, considering the limited means of transportation. The collections of the summer aggregated about 600 specimens. The rapidity with which the field work had to be executed allowed little time for photographic work, nor were there transportation facilities for a large camera. Each geologist was provided with a 4 by 5 inch camera, which he constantly carried, and with these about 300 photographs were taken.

[1] Mr. Reaburn accompanied W. C. Mendenhall in a journey from Fort Yukon to Kotzebue Sound. See Prof. Paper, U. S. Geol. Survey No. 10, 1902.

These methods enabled the geologist to run from 12 to 15 miles of traverse in a day of ten or twelve hours, provided the country was open and the outcrops not too many or the structure too complex. The highest record attained during the season was 22 miles of traverse in a day of eighteen hours. This was in a region of considerable complexity and containing many outcrops. One great obstacle to effective field work was the impossibility of maintaining the same standard of observation and interpretation throughout the many hours of activity enforced by the rapid progress of the party each day. Toward the end the observer would become both physically and mentally weary and able to continue his observations and deductions only by the greatest effort of will power. Consequently there were many gaps in the record which could not be filled afterwards.

The party numbered so few men that one of the geologists could not be spared from the pack train while it was on the move, and his geologic observations had to be subordinated to this task. The other geologist and the topographer made such digressions as time would permit. On the north side of the range the average air-line distance between camps was 10 to 12 miles, so it was seldom possible to extend observations more than 4 or 5 miles from the route of travel. Even on these trips it happened several times that one of us missed camp and was forced to spend an uncomfortable night under a spruce tree, with a scanty supply of food. During the summer the writer's own traverses aggregated some 800 miles. The scope and character of the geologic results are discussed in another section of this report.

Mr. Prindle deserves special commendation for his activity in collecting plants throughout the summer and in keeping a daily weather record. (See pp. 199–201.) Only those who have participated in an exploration of this kind can appreciate what it means for any member of the party to voluntarily burden himself with additional duties. Each day is already full, and an extra line of work can be pursued only at the expense of sleep or rest. The specimens thus obtained by Mr. Prindle have been kindly determined by Mr. F. V. Coville, botanist, of the Department of Agriculture. (See pp. 208–211.)

## HISTORY OF PREVIOUS EXPLORATIONS.

No one can know how many generations of natives have wandered over this region, but it seems certain that the indigenous population was greater at the first coming of the white man than it is now. As the natives depended largely on the chase for subsistence, they must have frequented the slopes of the Alaska Range and the adjacent lowlands, for this is one of the best game regions in the Northwest. Much of the range formed an almost impassable barrier between the hunting ground of the Cook Inlet natives and that of the Kuskokwim Indians. It does not seem to have been named, for the Alaska Indian has no fixed geographic nomenclature for the larger geographic features. A river will have half a dozen names, depending on the direction from which it is approached. The cartographers who cover Alaskan maps with unpronounceable names, imagining that these are based on local usage, are often misled. Thus the Yukon Indians called White River the Yukokon, the Tanana natives called it the Nasina, the Kluane Indians called it the Nazenka, and the coastal tribe of Chilkats had still another name for it. No one of these can be said to have precedence over any other.

The immense height of Mount McKinley must have impressed the Indian. It was used as a landmark in his journeys. With its twin peak, Mount Foraker, it is interwoven in the folklore of the tribes living within sight of the two giant mountains. The tribes on the east side of the range, who seldom, if ever, approached it, termed it Traleyka, probably signifying big mountain. Those on the northwest side, who hunted the caribou up to the very base of the mountain, called it Tennally.

Bering, the first white man to approach this region, on his ill-fated voyage of 1741,[1] probably sighted the mainland or some of the islands near the mouth of Cook Inlet, but this was on his return voyage to Siberia, when the expedition had already become demoralized, and no attempt at exploration or survey was made. The first definite account of the shore

[1] Steller, G. W., Reise von Kamtschatka nach Amerika mit dem Commandeur-Capitän Bering, St. Petersburg, 1793.

line was obtained by Capt. James Cook, sent out by George III to seek a northwest passage from the Pacific side of the American continent. His orders bade him explore the coast to the sixty-fifth parallel if not impeded by ice. His charts and journal bear testimony to the thoroughness with which he executed his mission. Cook first sighted the American coast near the present southern boundary of Oregon in March, 1778. Standing northward, he located various points on the mainland and islands, entered Prince William Sound May 12, and discovered the inlet which bears his name on May 20.[1] He sailed up the inlet, which he believed to be the mouth of a great river, cautiously sounding and charting as he went, and on June 1 dropped anchor off Point Possession, at the southern entrance to Turnagain Arm. Here he again mistook a tidal embayment for a river, and, calling it Turnagain River in reference to his frustrated hope of finding a passage to the northeast, he turned back to seek for another break in the coast line. Cook's chart of the inlet is remarkably accurate, considering that he spent only a week in surveying it. He evidently failed to find the mouth of the Susitna; nor does he mention the Alaska Range. The towering peaks of this chain are plainly visible from tidewater, and would not have escaped note in Cook's very circumstantial journal had not the view to the west and northwest been interrupted by cloudy weather.

Sailing southwestward, Cook soon encountered evidence that the Russian trader to whose enterprise the Czar was to owe his American possessions had preceded him. After the survivors of Bering's expedition had returned to Siberia, in 1742, with the report of a promising field for the fur trade, the Siberian fur traders were not slow to investigate. Following the Aleutian chain of islands eastward, they had extended their trading expeditions, often better termed marauding expeditions, to the mainland and as far as Kodiak Island by 1762, though they had not yet made a permanent settlement on the American coast.[2]

But this freebooting fur trade of individuals was short-lived. A royal ukase granted the monopoly to one company. In 1783 this corporation established a permanent post at Three Saints Bay, on the south end of Kodiak, and from this vantage point exploited the trade of the neighboring regions.

When Dixon and Portlock,[3] two of Cook's officers, returned to Cook Inlet, in 1786, in command of two trading vessels, they found the Russian traders already established on the east shore. Though these two men were sent to the Pacific on a purely commercial enterprise, yet, true to their training under the great navigator, they did considerable exploratory work. They added something to the geographic knowledge of this part of Alaska, but like Cook they failed to obtain sight of the great snow-covered range which lies to the northwest of the inlet.

It fell to another of Cook's officers, George Vancouver, to complete the survey of the shore line of the inlet in 1794. Since Cook's time a Spanish officer, Fidalgo, had entered the embayment, and many Russians had visited its shores in quest of sea otter, but none of these appear to have done any charting. Vancouver[4] sailed to the head of the inlet and with painstaking accuracy delineated the shore line of Turnagain Arm, thus first proving that it was not the mouth of a great river. While surveying Knik Arm, a small embayment at the upper end of Cook Inlet, Vancouver appears to have caught a glimpse of the great Alaska Range to the northwest, for in describing the topography of the arm he says:[5]

> The shores we had passed were compact; two or three small streams of fresh water flowed into the branch between low, steep banks, above these the surface was nearly flat and formed a sort of plain, on which there was no snow and but very few trees. This plain stretched to the foot of a connected body of mountains, which, excepting between the west and northwest, were not very remote; and even in that quarter the country might be considered moderately elevated, bounded by distant stupendous mountains covered with snow and apparently detached from each other; though possibly they might be connected by land of insufficient height to intercept our horizon. [May, 1794.]

This seems to be the earliest of the few references to the Alaska Range found in literature. Even Vancouver failed to mention specifically the two high peaks which tower above the range,

1 Cook, James, A voyage to the Pacific Ocean, 2d ed., vol. 2, London, 1785, pp. 386–402.
2 Coxe, William, Account of the Russian discoveries between Asia and America, 3d ed., London, 1787.
3 Dixon, George, and Portlock, Nathaniel, A voyage round the world, but more particularly to the northwest coast of America, London, 1789.
4 Vancouver, George, Vancouver's voyage, vol. 5, London, 1798, pp. 147–275.
5 Vancouver, George, Voyages of discovery, vol. 5, London, 1801, pp. 210–211.

though the description "distant stupendous mountains covered with snow and apparently detached from each other" undoubtedly refers to Mount McKinley and Mount Foraker.

Though the Russians soon established themselves in this region, they apparently had no interest in extending the surveys of the English navigators. Mate Izmailov is said to have described the southwest side of Kachemak Bay in 1789,[1] but his report must have been lost. In 1834 Mates Dinglestadt and Chernov, employees of the fur company, examined a part of the west coast of Kenai Peninsula. Among the expeditions made during this period of which knowledge has come down to us, probably the most interesting was the ascent of Susitna River by Mate Malakoff[2] in 1834. But if he gave any report of the high range which his eyes must have swept many times while he was dragging his clumsy boat up the river, it was not considered important enough to be embodied in Tebenkoff's Atlas of Russian America, published in 1852.

Malakoff's journey was made in the interest of the fur trade, but some years later Doroshin visited this region on a totally different mission—the search for mineral wealth. He spent the greater part of two years, 1848–1850, looking for gold in the alluvium of Kenai Peninsula, and it is rumored that he also visited the Susitna basin, but this appears to be without foundation, for he makes no mention of it in his report or letters.

While investigation of the seaboard thus continued Russian traders were pushing their operations along Kuskokwim River; and though these did not actually extend into the region now under consideration, they added to the general knowledge of the province. Space will not permit mention of the individual expeditions which traversed the lower Kuskokwim basin during the Russian occupation of Alaska, but it is noteworthy that they began in 1830 and continued until the transfer in 1867. During this period a trading post was maintained at the Redoubt Kolmakof, about 400 miles from the sea. The lower Kuskokwim became fairly well known to the Russians, but of its headwaters they had only reports brought by the natives.

As to other geographic features, the Russians appear to have known the general course of the Susitna, and on some of their longer trading voyages up the Yukon they had reached the mouth of the Tanana, which drains the northern part of the field.

Of the existence of high mountains between the Kuskokwim and Susitna basins they were doubtless aware, for Grewingk, who summarized the geography of Alaska in 1852, indicates on his map the axis of such a range, to which he gave the name Tchigmit Mountains.[3] But there are few references to them in Russian literature, and not one has yet been found which refers directly to the high mountain whose snowy summit is visible from tidewater on Cook Inlet. That this mountain was known to the Russians, however, is evidenced by their name for it—"Bulshaia Gora," meaning big mountain. Who it is that first noted this culminating peak of the continent will probably never be known. Possibly it was Doroshin, the Russian mining engineer, who named it while seeking gold on Kenai Peninsula. In any event it is certain that up to the close of the Russian occupation of Alaska there was practically no attempt, except that of Malakoff, to explore the region in its vicinity.

The exploration carried on by Kennicott, Dall, and others in choosing a telegraph route did not reach this part of Alaska. Dall,[4] however, made mention of the high mountain chain and was the first to give it the name Alaska Range.

The Russian maps of this region published in 1860 and later correctly delineate the general course of Susitna and Matanuska rivers. It seems probable, therefore, that some of the Russian traders visited the Matanuska, which was readily accessible from ports on Knik Arm. As to the source of their knowledge of the Susitna less is known. There is no evidence that any Russian visited the Susitna except Malakoff, whose journey in 1834 has already been men-

[1] Tebenkoff, Michael, Hydrographic atlas and observations, St. Petersburg, 1848–1852, p. 17.

[2] A brief reference to Malakoff's journey is contained in "Hydrographic notes to the northwest shores of America, the Aleutian Islands, and some other places of the north Pacific Ocean," by Captain of first rank Tebenkoff, St. Petersburg, 1852.

[3] Grewingk, C., Beiträge zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nordwest Küste Amerikas, St. Petersburg, 1850.

[4] Dall, W. H., Proc. Boston Soc. Nat. Hist., November 4, 1868, vol. 12, p. 144. Dall believed these mountains to be a northwestern extension of the Rockies, a theory which later exploration has proved erroneous.

tioned. It does not seem likely that Malakoff visited the head of the river, for his journey is said to have been made in summer by boat, and the Susitna above the mouth of Indian River is unnavigable. Nevertheless the general course of the Susitna appears to have been known to the Russians, either through exploration or through the reports of natives. It appears quite probable, therefore, that some explorations were made of the upper Susitna of which no record is preserved. They could have been accomplished by winter journeys up the Matanuska and across the divide into the Susitna basin.

With the transfer of Alaska to the United States, in 1867, interior exploration received no impetus. The American fur trader succeeded the Russian, with an almost equal indifference to anything but his vocation. So matters stood until the advent of the restless prospector; and it is to him, and almost to him alone, that we owe our extension of geographic knowledge. Not until he at his own risk and cost discovered gold did the Government take any systematic steps toward scientific investigation of this northern realm.

About 1872 a small band of prospectors, including Jack McQuesten, A. Mayo, and Arthur Harper, reached the Yukon by the old Hudson Bay Company route from the Mackenzie to the Porcupine. Most of these men were old Cassiar placer miners who had come to the north in quest of gold. For a number of years, however, they supported themselves by fur trading, and some became agents of the powerful commercial company, successor to the Russian fur company. They sought every opportunity to increase their knowledge of this new field, and on their own initiative undertook many daring expeditions.

In the fall of 1878 Harper and Mayo ascended the Tanana a distance estimated at 250 to 300 miles, which would bring them to the present town of Fairbanks. This was the first exploration of the Tanana by white men.[1] They reported the finding of alluvial gold in the bars of the river and also that there was a high snow-covered mountain plainly visible to the south; this, of course, was Mount McKinley.

In the succeeding decade parts of the Tanana Valley were probably traversed by prospectors, but there are no records of these journeys. It is known that about 1880 a trading post was established on the Tanana 20 miles above its mouth. This the first white settlement in the Tanana Valley was abandoned when the wife of the trader, a man named Bean, was murdered by the Indians.[2]

In 1889 an Alaska pioneer, Frank Densmore, with several others, crossed by one of the portages from the lower Tanana to the Kuskokwim.[3] About the same time another prospector, Al. King, made the same trip. Densmore must have had a glorious view of Mount McKinley. Apparently it was his description of it which led the Yukon pioneers to name it Densmore's Mountain, and as such it was known on the Yukon long before anyone realized its altitude.

While these pioneers were exploring the Yukon basin the Cook Inlet region remained as little known as during the Russian régime. An American company had succeeded to the interests of the Russian corporation along the coast, but its agents were content to keep near tidewater, and it was many years before the federal authorities became interested in the interior. A few prospectors searched the coastal region for gold, and the coal seams at Kachemak Bay were spasmodically developed. Petrof's exhaustive compilation (1880) of all existing information about Alaska contains only the following reference to this region:[4]

> What the country north of Cook's Inlet is like no civilized man can tell, as in all the years of occupation of the coast by the Caucasian race it has remained a sealed book. The Indians tell us that the rivers lead into lakes and that the lakes are connected by rivers with other lakes again, until finally the waters flow into the basins of the Tennanah

[1] E. W. Nelson, of the Biological Survey, who was at that time stationed in Alaska, under date of April 13, 1909, makes the following reference to the Harper and Mayo trip in a personal letter:

"I find by my Alaska notebooks that Harper and Mayo made their first boat trip up the Tanana River (to an estimated distance of from 250 to 300 miles) the fall of 1878. At this time they found good prospects of gold on the river bars and expected to return for further work. They reported having seen a great ice mountain off to the south which was plainly visible from the Tanana. I received a letter during the winter following this trip in which the ice mountain was mentioned, and the following spring both men described it to me as one of the remarkable things they had seen on this trip. They also showed me a small bottle of black sand and gold dust as the result of prospecting on the bars of the upper Tanana."

[2] Schwatka, Frederick, Report of a military reconnaissance in Alaska, made in 1883, Washington, 1885, p. 96.

[3] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 96.

[4] Petrof, Ivan. Alaska; its population, industries, and resources: Tenth Census, 1880, vol. 8, 1884, p. 86.

and the Yukon; but conflicting with this intermingling of the waters are stories of mountains of immense altitude visible for hundreds of miles. The natives living north of this terra incognita give, however a similar description, which may be accepted until reliable explorers are enabled to penetrate this region.

When, ten years later, a second census of Alaska was taken, the region north of Cook Inlet could still be described only as follows:[1]

Of the nature of the country intervening between the Kinik and Sushitna rivers, as well as of the headwaters of these two large streams, very little is known beyond a rather vague description given by natives and a brief account obtained from prospectors who attempted to follow up the Sushitna to its head. These men, after equipping themselves for a year's sojourn in the wilderness, returned in three weeks completely discouraged, and, when asked what the country was like, replied that "it might contain the most beautiful scenery in the world or the richest mines, but that clouds of mosquitoes obscured their vision and occupied their attention to the exclusion of everything else." It is safe to assume that this region presents the features common to all central Alaska—swampy plateaus, tundra, and numerous lakes, with belts of timber along the river courses—but as to the topographical and geological features, or the height of the divide between the Kuskokwim and Cook Inlet drainage systems, we have not yet emerged from the field of conjecture.

A new era in Alaskan exploration was inaugurated by Schwatka's reconnaissance of the Yukon;[2] for, though the journey had been made by many others before him, his dramatic narrative gave the touch which awakened public interest. The first result was the dispatching of Lieut. (now Maj.) W. R. Abercrombie to explore the Copper River valley, in 1884.[3] Little was gained, for Abercrombie penetrated only to the rapids which now bear his name and appears to have made no surveys.

The following year the War Department began one of the most important explorations ever undertaken in Alaska. Lieut. (now Maj.) Henry T. Allen[4] led an expedition through the Copper River basin, across the mountains, and down the Tanana to the Yukon; and not content with this, he also explored the lower Koyukuk for some 300 miles. Thus he traversed the northern part of the field here under discussion and was the first to map Tanana River. In his rather circumstantial narrative Allen mentions the high range of mountains which lay to the south of the Tanana, but does not specially remark on the altitude of any individual peak. He observes:[5] "South of the Tanana River and north of the Kuskokwim is an extension of the Alaska Range containing some peaks several thousand feet higher than exist where we crossed the range." And again:[6] "The range south of the middle part of the Tanana contains some very high snow-clad peaks." In 1890 E. H. Wells, of the Frank Leslie expedition, continued Allen's exploration in the Tanana basin.[7] Wells was the first white man to cross from Fortymile to the Tanana.

The discovery of placer gold in the Yukon basin effected great changes. After 1880 prospectors began to flock into this interior region, and, through the store of information gathered by the earlier pioneers, became acquainted with the Alaska Range and the high mountain discovered by Densmore. Stories of its great height were told in many an isolated post and around many a lonely camp fire, but these did not reach the outer world in sufficiently definite form to be noted by cartographers.

On Cook Inlet, too, the finding of gold in 1894 wrought rapid transformation. The trader who was content to remain at his post and have the natives bring their furs for barter was succeeded by the restless prospector, who, following the traditions of his class, made his way inland in quest of new fields. Some pushed up the Susitna and must have obtained first-hand knowledge of the Alaska Range and its two towering peaks, but most of them cared only for gold and were little interested in extending or disseminating geographic knowledge.

One, however, W. A. Dickey, of a different type from the rest, recognized the surpassing height of the peak and its geographic import and gave it the name Mount McKinley. His

[1] Porter, Robert P., Report on population and resources of Alaska: Eleventh Census, 1890, Washington, 1893, pp. 70–71.

[2] Schwatka, Frederick, Lieut., A military reconnaissance in Alaska: Senate Ex. Doc. No. 2, 48th Cong., 2d sess., Washington, 1885.

[3] Abercrombie, W. R., Supplementary expedition into the Copper River valley: Compilation of narratives of explorations in Alaska, Washington, 1900, pp. 383–408.

[4] Allen, H. T., Report of an expedition to the Copper, Tanana and Koyukuk rivers, in the Territory of Alaska, Washington, 1887, 172 pp.

[5] Op. cit., p. 156.

[6] Op. cit., p. 69.

[7] Wells, E. H., Up and down the Yukon: Compilation of narratives of explorations in Alaska, Washington, 1900, p. 513.

exploration in 1896 was probably one of the first extensive journeys in this district since that of the Russian Malakoff in 1834. With three other men he ascended Susitna River to the trading station at the head of the delta; then constructed boats of whipsawed lumber and continued his journey up the main Susitna to the mouth of Indian Creek. From this place he explored a part of the upper canyon of the Susitna and also made a journey westward to the Chulitna, reaching the foot of the glacier which discharges into this river and has its source on the slopes of Mount McKinley. It was after this journey that he published his description of the mountain, in which he named it and stated its altitude as over 20,000 feet.[1] He told the writer that he had no instruments, but made his estimate, which has proved to be remarkably accurate, with careful consideration of the atmospheric conditions, as well as of the probable distance to the base of the peak. In 1897 he made a second trip into this region, with one companion, and extended his previous explorations. He was the first to call attention to the great lowland drained by Tokichitna River and to the low divide which separates it from the Kuskokwim drainage, later explored by Spurr, Herron, and the writer.

There were probably many prospectors who visited parts of the Mount McKinley region about this time and before accurate surveys were made, but these have left no record of their journeys. For example, in 1895 Harry Hicks, with one companion, prospected along the length of the Matanuska Valley. The knowledge Hicks gained of this region was of great service to Glenn and Mendenhall, for he accompanied them in their journey of 1898 (p. 28). A year or two before Hicks made his first trip in this region a prospector named King built a cabin at the mouth of the tributary to the Matanuska which now bears his name. In the summer of 1897 W. G. Jack made an extensive journey in the upper Susitna basin. The following year he served as guide to the Eldridge party.

The world at large paid little heed to Dickey's high peak, for his report was classed as only another of the wild tales which emanated from Alaska; but another discovery about the same time—the Klondike gold—was destined to alter the status of Alaska in the public mind. Then, at last, the Government began to realize its long neglect of this vast possession. Money was appropriated for its development, and among other agents the United States Geological Survey was enabled to begin the series of explorations and surveys which have extended to some of the remotest parts of the Territory.

Of the six parties which were sent to Alaska in 1898, four traversed the province here under discussion. It fell to one of these, led by George H. Eldridge and Robert Muldrow, to make the first determination of the height and position of Mount McKinley.[2] These men, with five camp hands, made their way up the Susitna, dragging their loaded canoes against the swift current, as Malakoff had done half a century before. The topographer, Muldrow, carried a survey and by a rough triangulation verified Dickey's remarkably accurate estimate of the height of Mount McKinley. (See above.) It was only after the publication of the results of this survey that Dickey received any adequate recognition from the public for his important contribution to geographic knowledge.

It was the purpose of the Eldridge party to cross from the Susitna to the Tanana waters, and so reach the Yukon. They very naturally followed the main branch of the Susitna, but by this route the head of canoe navigation is reached at the mouth of Indian Creek, which, as the event proved, is 100 miles from a tributary of the Tanana. Had the west fork of the Chulitna been chosen, a portage of not more than 10 miles between the two basins would have been found. Nevertheless the party pushed on and after a week's journey found themselves on Nenana River, almost without food and 100 miles from their base of supplies. There was no choice but to turn back, and they reached the cache in a half-starved condition. The season was then too far advanced to choose a new route, so they returned to Cook Inlet.

J. E. Spurr[3] and W. S. Post, also of the Geological Survey, in the same year ascended the Skwentna, a western fork of the Susitna which heads in the Alaska Range. This, too, was a

[1] New York Sun, January 24, 1897.

[2] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 1-29.

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

difficult task. Their canoes were repeatedly overturned in the mad, rushing waters, and when they finally reached a pass their provisions were low. They resolved to push on, however, and, portaging two of their canoes and what was left of their provisions, they reached the Kuskokwim waters. Here they launched their frail crafts and boldly followed the course of the unknown river. Once, where the stream plunged through a rocky canyon, a hidden bowlder upset a canoe, and its occupants were rescued with difficulty. Finally they reached a point where the river is joined by another of equal size flowing from the southwest slope of Mount McKinley, and its course turns to the southwest toward Bering Sea. Their scanty provisions were made to hold out until they reached Bethel mission, near the mouth of the river. This the first party to cross the Alaska Range determined the general features of the geography and geology of the province.

While these expeditions were exploring the Alaska Range, Mendenhall [1] was studying the geology and geography of an adjacent region to the east. In 1898 the War Department had dispatched Capt. (now Lieut. Col.) F. W. Glenn to Cook Inlet to explore a route to the interior. Mendenhall, who was detailed from the Geological Survey as geologist to this party, found himself forced by stress of circumstances not only to make the geologic investigations, but also to act as topographer. Before starting with the main expedition he first crossed from Prince William Sound to Turnagain Arm by way of the Portage Glacier, and later Kenai Peninsula from Resurrection Bay to Turnagain Arm. He then accompanied the party in a journey by pack train from Knik Arm northward through the Alaska Range, along Delta River, to the Tanana. They returned to the coast by practically the same route. Mendenhall made not only a reconnaissance of the geology along the route but also a topographic sketch map based on a traverse plane-table survey. In addition to the main work of the expedition, Lieut. (now Capt.) J. C. Castner [2] explored Volkmar River, while at the same time Lieut. (now Capt.) H. G. Learnard [3] and Sergt. William Yanert made some minor explorations in the Susitna basin.

By these three expeditions three sides of the area here under discussion were roughly outlined. A fourth led by W. J. Peters, to which the writer was attached as geologist, traversed Tanana River on the north.[4] The Peters party reach the Yukon basin by the then much-traveled route to the Klondike, ascended the White with canoes, portaged to Tanana waters, and followed the Tanana to its junction with the Yukon. The snowy peaks of the Alaska Range were visible for some time, and the altitude and position of some of the nearer ones were determined. Mount McKinley, though 150 miles distant, was sighted. Tanana River was surveyed and some idea was gained of the geology of the region.

These surveys of 1898 had circumscribed an area of about 50,000 square miles which was still unexplored. Within it lay Mount McKinley, the highest peak on the continent, as the general public, hitherto skeptical as to its reported altitude, was beginning to realize. A demand for information now arose; but the Geological Survey was busy in other parts of Alaska, and the execution of the next exploration fell to the Army.

On June 1, 1899, a party of six white men and two natives, with fifteen horses, commanded by Lieut. (now Capt.) Joseph S. Herron,[5] was landed on the north bank of the Kichatna, a northern tributary of the Yentna, from a steamer which had been brought to Cook Inlet for the use of the expedition. From this point, relying on Spurr's map [6] and the experience of the Indians for general guidance, Herron made his way up the Kichatna and crossed the range by a gap which he called Simpson's Pass. All went well so far, but in crossing the range he passed beyond the hunting grounds of his two native guides. Terrified at the thought of penetrating an unknown country, the two valiant warriors stole away one night, but Herron

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

[2] Castner, J. C., A story of hardship and suffering in Alaska: Compilation of narratives of explorations in Alaska, Washington, 1900, pp. 686–709.

[3] Learnard, H. G., A trip from Portage Bay to Turnagain Arm and up the Sushitna: Idem, pp. 648–679.

[4] Brooks, A. H., A reconnaissance in the Tanana and White river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 425–494.

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

[6] Spurr's route lay to the southwest and parallel to Herron's.

determined to continue his march in the hope of finding other natives. Reaching the Kuskokwim, previously mapped by Spurr, he continued downstream to its junction with the north fork. Here, to reach his objective point, the mouth of the Tanana, he turned northward and soon became lost in the great timbered lowland of the upper Kuskokwim. By September 8 early frost had killed the grass and travel by pack train seemed impracticable. Abandoning his horses and a good part of his supplies, Herron built a raft and started downstream with the purpose of finding natives. But the attempt ended in failure; his rafts were wrecked and he started back on foot. After traveling for some ten days the party was overtaken by a native who had found one of Herron's caches and had been trailing the white men, and who guided them to Telida, a native settlement on Tatlathna River, a tributary of the East Fork of the Kuskokwim. Here they remained until the arrival of snow brought easier traveling, when they were guided by the natives to Fort Gibbon, at the mouth of the Tanana, which they reached on December 11.

This journey, planned as a summer's trip, had lasted more than five months. The results of the exploration were the discovery of a new pass through the Alaska Range and a sketch map of an unknown region lying between the areas covered by Spurr's exploration of the Kuskokwim and Allen's of the Tanana.

While Herron was exploring west of the Alaska Range some minor explorations were being carried on east of the mountains by other detachments of Major Glenn's command.[1] Sergt. William Yanert continued his reconnaissance surveys in the Susitna basin. Yanert's record in Alaska showed him to be a man of determination and resources. Traveling alone or with only one or two men and without means of transportation except that of back packing, he not only performed some remarkable journeys, but made surveys which have been proved remarkably accurate. George Van Schoonhoven, also of Glenn's command, in 1899 led a well-equipped party with pack train up the Susitna and across the divide to Nenana River, but the results of this expedition appear to have been meager.

Herron, though he had carried on no exact instrumental surveys, had reduced the size of the unknown area; but it was still left for someone to survey the range and to set foot on the slope of Mount McKinley. Three years elapsed before this could be undertaken. Meanwhile prospectors had traversed much of the Susitna basin and a small steamer is said to have been taken up the Kuskokwim to its main forks. During the winter of 1901–2 a man named Dalzell reached Cook Inlet with a party of natives from the winter camp of this steamer, probably having crossed the range by Rainy Pass.

In the summer of 1902 was undertaken the journey on which this report is based and of which a narrative has been presented. The fact that the members of our party were the first to set foot on the slopes of the highest mountain on the continent was widely circulated by the daily press, and for the time being caused popular interest in the results of the expedition out of proportion to their importance. Among mountaineers an intense curiosity sprang up in regard to this new field of operations, and to satisfy the demand for information an article[2] was published outlining briefly what appeared to be the most feasible routes to the base of the mountain. With this article appeared the first approximately correct map of the Alaska Range, and it has been used to illustrate several subsequent papers.

The first man to attempt the ascent of Mount McKinley was James Wickersham, then judge of the district of Alaska, now Delegate to Congress from the Territory. He had already mountaineered on Mount Rainier. Moreover, his several years of judicial duties in Alaska, involving many long journeys, both winter and summer, had equipped him with a fund of experience for overcoming the physical obstacles of this undertaking. Judge Wickersham has unfortunately published no complete itinerary, but the following account is derived from a manuscript report which he kindly loaned the writer.

After holding court at Fairbanks, in the then newly discovered placer district, on May 16, 1903, Wickersham proceeded by steamer with four men and two mules to the head of naviga-

[1] Compilation of narratives of explorations in Alaska, Washington, 1900, pp. 736–737.

[2] Brooks, A. H., and Reaburn, D. L., Plans for climbing Mount McKinley: Nat. Geog. Mag., vol. 14, 1903, pp. 30–35.

tion on the Kantishna, a southerly tributary of the Tanana. From this point the journey was conducted partly in poling boats, partly overland. On June 14 the party camped at the débris-covered front of the glacier which drains the northern slope of Mount McKinley, and which they called the Hannah Glacier.[1] A week was spent in attempting the ascent of the mountain, but facilities and provisions were inadequate and the party was forced to turn back after reaching an altitude estimated at 10,000 feet. The return to the Tanana was made in part overland, in part by raft, and was attended by considerable hardship, as the provisions ran out and subsistence was dependent on game. Wickersham's topographic notes on the region traversed contain many important corrections to existing maps.

About the time that Wickersham left the mountain to return to his judicial duties at Fairbanks the second party to essay the summit landed at Tyonek. It appears that the credit for the organization of this expedition belongs entirely to its leader, Dr. Frederick A. Cook, then already well known as an Arctic and Antarctic explorer.[2] The route of approach to the mountain and the method of travel accorded with the plans proposed by Mr. Reaburn and the writer,[3] except in the one important particular of starting a month later, which foredoomed the attempt to failure.

Cook took fourteen horses to carry the provisions for his party of five men. He had the advantage of the experience of Robert Dunn, who had previously made some difficult journeys in the far northwest, and also of Fred Printz, who, as chief packer of our party the year before, had become thoroughly familiar with the route and was able to guide the party along the trail previously established. The journey to the base of the mountain occupied them forty-nine days in spite of the facts that they had a trail to follow, a guide familiar with the region, and a good topographic map. Our party the year before made the same distance in sixty-two days, though we were forced to cut over 40 miles of trail and explore a new route while keeping up instrumental surveys. The slow progress of the Cook party is no reflection on its members; the start was made so late that the morasses had thawed out and were well-nigh impassable for horses.

Two attempts were made to climb the mountain—one from the headwaters of Tatlathna River and a second apparently along the glacier traversed by Wickersham a few weeks before. On the second trail, at an altitude determined by aneroid barometer as about 11,000 feet, the party was confronted by an insurmountable wall of granite and was forced to turn back.

As it was too late in the season to look for another approach to the summit and the return to the coast was unavoidable, a route was chosen which added materially to geographic knowledge. After following the Geological Survey trail along the base of the mountains for some 25 miles to Muldrow Glacier, the party chose a northeasterly and easterly course which brought them directly into the heart of the Alaska Range. Here began the actual exploratory work. After crossing several divides between northward-flowing streams the party traversed the main watershed by an ice-covered pass and reached an unknown river. The valley was a veritable canyon, impassable for horses, so the animals were abandoned and the journey continued on a raft. The swift current soon carried them out of the mountains, when they discovered that they were on a westerly tributary of the Chulitna. The downstream journey to Cook Inlet was accomplished within a few days and without incident. Though Cook was unsuccessful in his main purpose, the fact that he traversed about 100 miles of unexplored territory amply justified the expedition because of its important contribution to geographic knowledge.

The discovery of the rich placers of the Fairbanks district in 1901–1903 attracted a large population to the lower Tanana Valley. Among the many prospectors there were some who made their way southward, and as early as 1903 the discovery of auriferous deposits was reported from what was called the Mount McKinley district, embracing a region lying within 30 to 50 miles northwest of the mountain. Mr. Prindle gives an account of these finds else-

[1] Our party had named this glacier the Peters Glacier.

[2] Cook, F. A., America's unconquered mountain: Harper's Monthly Mag., January, 1904, pp. 228-239, February, 1904, pp. 335-344; Round Mount McKinley: Bull. Am. Geog. Soc., vol. 36, 1904, pp. 321-327; To the top of the continent, New York, 1908. Dunn, Robert, The shameless diary of an explorer, New York, 1907.

[3] Plans for climbing Mount McKinley: Nat. Geog. Mag., vol. 14, 1903, pp. 30-35.

where in this volume (pp. 169–180). In the succeeding three years several bands of prospectors journeyed southward from this new camp, traversing the region explored by our party.

A similar activity took place south of the range, and gold was found in the Yentna basin in 1904. Meanwhile the engineers of the Alaska Central Railway Company carried surveys from Knik Arm to Fairbanks by way of Chulitna, Susitna, and Nenana rivers.

Doctor Cook, nothing daunted by the hard experiences of his first attempt, again essayed the ascent of Mount McKinley in 1906. His party, including among others, Prof. Herschel Parker, Belmore Brown, R. W. Porter, topographer, and Fred Printz, the veteran packer of the two previous expeditions, landed at Tyonek late in May and made its way up the Susitna. Part of the journey was made overland with pack train, part by water with a motor launch. The party spent most of the summer south of Mount McKinley in exploring the region tributary to the Susitna. They tried without success to cross the range at the head of the Yentna. The attempt to reach the summit from the south was equally futile, but the journey added much to geographic knowledge of the region. Of special value is the topographic map made by Porter (see pp. 39–42), a reproduction of which accompanies this volume (Pl. XV, in pocket).

In August the expedition reassembled at Tyonek and split up into several parties, Professor Parker returning to Seattle. The subsequent explorations made by Doctor Cook are described in the following summary by Professor Parker:[1]

> After the writer left the expedition Doctor Cook modified somewhat the plans for further exploration. Only two members of the party were sent into the Kichatna region, two more going to the mouth of the Matanuska River, while Doctor Cook and two companions returned with the launch by way of the Chulitna River to a point near the previous camp at the foot of the glacier, from which the reconnoitering trips were made, the purpose being the exploration of the glaciers to the southeast of Mount McKinley as a possible route to the top for an expedition the following year.
>
> By chance, however, the party happened to come upon a glacier that sweeps the upper eastern slope of Mount McKinley and offered an excellent highway to the mountain. In three days after leaving the boat this glacier was explored and the party came upon the northeastern edge. Here the position was so favorable that Doctor Cook decided to push on notwithstanding the lateness of the season. On the fourth day after leaving the launch the top of the ridge was gained and the party were confronted by a granite cliff which rose some 4,000 feet into the air on top of the ridge, which was about 12,000 feet high. Continuing on with one companion, Edward Barrill, a way was found around the cliff by cutting steps in cornices of ice, and a climb of 2,000 feet made the fifth day. On both the sixth and seventh days a gain of 2,000 feet was made and a point attained very near the summit. Starting early on the morning of the eighth day, a dash was made for the top. Two peaks were encountered and the southwestern chosen. At 10 o'clock on the morning of September 16 the top was reached, but only the briefest stay could be made. In four days the mountain was descended and the homeward journey commenced.

It is unfortunate that the above can not be considered a final statement of Doctor Cook's journey. Soon after his return from the Arctic regions in 1909 charges began to appear in the press that he had not reached the summit of the mountain. These finally took definite form when his companion, Edward Barrill, made an affidavit to the effect that the party had not been nearer than 9 miles to the summit of the mountain. Other members of his party also expressed doubt about the achievement. Though Cook strenuously asserted his claims through the daily press, yet he withheld any proofs of his achievements except the narrative[2] and accompanying photographs which had appeared in book form. The whole matter was finally subjected to a close scrutiny by a committee of the Explorers' Club of New York. This committee, which included some eminent scientists, reported that it had not been able to find any proof that Cook reached the summit. Though Cook had been invited to appear before the committee and submit his proofs, such as original observations, notebooks, and photographs, he did not avail himself of the opportunity.

According to dispatches from Fairbanks, four Alaska prospectors reached the summit of Mount McKinley in the spring of 1910.[3] The party was under the leadership of Thomas Lloyd and included William Taylor, Pete Anderson, and Charles McGonnagell.

In the summer of 1910 two more expeditions were organized to climb Mount McKinley. One of these was under the leadership of Herschel Parker and Belmore Brown, both members

[1] Parker, Herschel, The exploration of Mount McKinley: Review of Reviews, November, 1906, p. 58.
[2] Cook, F. A., To the top of the continent, New York, 1908.
[3] Thompson, W. E., First account of the conquering of Mount McKinley: New York Times, June 5, 1910.

of the second Cook party. The other was organized by C. E. Rust, of Portland, Oreg. Both planned to approach the mountain from the Susitna side. At this writing newspapers report that neither party reached the summit and that the information obtained seems further to discredit Cook.

In 1906 members of the Geological Survey were again at work both east and north of the Alaska Range. T. G. Gerdine and Adolph Knopf surveyed parts of the Matanuska basin and R. H. Sargent and Sidney Paige extended the work northward into the Talkeetna basin.[1] Mr. Prindle (see pp. 169–180) with a small party again visited the Nenana River basin and explored both east and west of the route of 1902. Explorations were again extended in the same general field by the Geological Survey in 1909, when D. C. Witherspoon and George C. Martin made a reconnaissance survey of the Iliamna and Clark lakes region.[2]

In 1907–8 Charles Sheldon spent about a year in the upper Kantishna basin and adjacent regions. His purpose was the study and collection of animals. Mr. Sheldon has not yet published any of the results of his investigations, but he has kindly placed his topographic data at the disposal of the writer, and these have been embodied in the map forming Plate III (in pocket).

In 1910 G. C. Martin, assisted by F. J. Katz and Theodore Chapin, undertook a detailed geologic survey of the southwestern part of the Matanuska coal field, an area of which a detailed topographic map had been prepared by R. H. Sargent in 1909. The results of these geologic studies will only be available after the completion of the office work, but as the writer spent some two weeks with Mr. Martin in this field he has been enabled to embody some of the general conclusions in this report.

## TOPOGRAPHIC SURVEY.

By D. L. Reaburn.

### INTRODUCTION.

The topographic work of the expedition was done by the plane-table method, with a Johnson tripod, an 18 by 24 inch plane-table board, and a telescopic alidade with micrometer attachment, on a field scale of 1:180,000 and with a contour interval of 200 feet. The area covered ranges in width from 10 to 40 miles. The positions and elevations of a number of prominent mountain peaks were determined by intersections from plane-table stations. A continuous system of vertical angles was started from sea level and carried through. The elevations were computed in the field and the topographic features were sketched in contours.

The vertical-angle observations on Mount McKinley and Mount Foraker yielded the results given below.

*Height of Mount McKinley above mean sea level.*

| | Feet. |
|---|---|
| As determined from a station at a distance of— | |
| 113 miles | 20,492 |
| 95 miles | 20,135 |
| 41 miles | 20,077 |
| 28 miles | 19,918 |
| Mean of above figures | 20,155 |
| As determined by Robert Muldrow, topographer, United States Geological Survey, in 1898 | 20,464 |
| Mean of last two determinations | 20,309 |
| Adopted elevation (compare p. 33) | 20,300 |

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1910, 71 pp.

[2] Martin, G. C., and Katz, F. J., Outline of the geology and mineral resources of the Iliamna and Clark lakes region: Bull. U. S. Geol. Survey No. 442, 1910, pp. 179–200.

*Height of Mount Foraker above mean sea level.*

| As determined from a station at a distance of— | Feet. |
|---|---|
| 107 miles | 17,147 |
| 85 miles | 17,115 |
| 47 miles | 16,900 |
| 38 miles | 17,197 |
| 16 miles | 17,125 |
| 14 miles | 17,137 |
| 20 miles | 17,029 |
| 20 miles | 16,980 |
| Mean of above figures | 17,079 |
| Adopted elevation | 17,100 |

The magnetic declination was determined at seventeen azimuth stations as shown in the following table:

*Magnetic declination at different camps.*

| Date of camp. | Latitude. | | Longitude. | | Declination (east). | |
|---|---|---|---|---|---|---|
| | ° | ′ | ° | ′ | ° | ′ |
| May 29 | 61 | 03 | 151 | 10 | 27 | 00 |
| May 16 | 61 | 45 | 151 | 40 | 28 | 00 |
| May 28 | 62 | 06 | 151 | 31 | 28 | 30 |
| July 6 | 62 | 14 | 152 | 25 | 27 | 15 |
| July 13 | 62 | 10 | 152 | 51 | 27 | 15 |
| July 16 | 62 | 17 | 153 | 15 | 26 | 40 |
| July 19 | 62 | 25½ | 153 | 26 | 26 | 45 |
| July 24 | 62 | 39½ | 152 | 47½ | 27 | 20 |
| July 29 | 62 | 53 | 152 | 16 | 27 | 30 |
| August 1 | 63 | 06 | 151 | 39 | 28 | 10 |
| August 4 | 63 | 15 | 151 | 12 | 28 | 30 |
| August 7 | 63 | 28 | 150 | 33 | 28 | 45 |
| August 14 | 63 | 42 | 149 | 23 | 29 | 35 |
| August 15 | 63 | 43 | 149 | 04 | 29 | 50 |
| August 26 | 64 | 10 | 149 | 01 | 30 | 10 |
| August 29 | 64 | 34½ | 149 | 05 | 30 | 45 |
| September 6 | 65 | 05 | 148 | 54 | 30 | 50 |

Since these results were obtained the Coast and Geodetic Survey has determined the position and altitude of Mount McKinley by triangulation from Cook Inlet. The report by William Bowie, chief of the computing division, is as follows:[1]

I have the honor to report that the computation and adjustment of the horizontal and vertical angles to determine the geographic position and elevation of Mount McKinley, Alaska, have been completed. The resulting position for that mountain, on the Valdez datum, is north latitude 63° 03′ 56.83″, west longitude 151° 00′ 41.31″.

The Valdez datum is based upon the value of the longitude at the astronomical station in the town of Valdez and the mean of the latitudes observed at three astronomical stations in Prince William Sound, Alaska, and is the datum upon which are based the Coast charts between Cape St. Elias and the Alaskan Peninsula.

The resulting elevation of Mount McKinley above mean sea level is 20,300 feet.

The above position was obtained from the adjustment of horizontal directions observed from four stations of the Cook Inlet triangulation, three of which were occupied in 1909, while one was occupied the previous year. All of the observations were made by the party under Assistant H. W. Rhodes, commanding the United States Coast and Geodetic Survey steamer *McArthur*. The angle subtended at Mount McKinley was 15° 08′ and the correction to any one direction, as given by the adjustment, was not greater than 11″. It is seen from this that the geographic position is well determined. The nearest point from which the mountain was observed was 204 kilometers (127 miles), while the farthest point from which it was observed was 302 kilometers (188 miles).

Having found the distance from certain stations to the mountain, its elevation was determined from vertical angles taken at Race Point and Little, two of the stations from which horizontal directions were observed. The two values of the elevation of Mount McKinley obtained from them are 6,179.7 meters and 6,194.3 meters. The weighted mean of these two elevations is 6,187.5 meters, or 20,300 feet. This value is identical with the mean value previously adopted by the United States Geological Survey, which has superseded the value 20,464 feet given in the "Dictionary of altitudes" published by that bureau in 1906.

The coefficient of refraction which was deduced from the observations made in 1894 to determine the elevation of Mount St. Elias was used in determining the elevation of Mount McKinley. Its value is 0.083. It was believed to be nearer the truth than the coefficient which was determined from the reciprocal observation made in Cook Inlet in 1909, because those observations were made almost entirely over water, while the lines of the two mountains (Mount St. Elias and Mount McKinley) were, for the most part, over land and ice.

It is believed that the value (20,300 feet) for the elevation of Mount McKinley is correct within 150 feet.

[1] Determination of height and geographic position of Mount McKinley: Bull. Am. Geog. Soc., vol. 42, No. 4, 1910, pp. 260-261.

The topographic reconnaissance map which accompanies this volume (Pl. III, in pocket) is based largely on the work of the United States Geological Survey. The route from Tyonek through Rainy Pass and the western and northern fronts of the Alaska Range were surveyed by the writer in 1902. In 1898 (see pp. 27–28) Robert Muldrow and W. S. Post, of the Geological Survey, traversed Susitna, Yentna, and Kuskokwim rivers, and their results were included on the first edition of this map, published in 1906.[1] A route survey was also carried by the writer from Nenana River to Rampart in 1902, but since that time D. C. Witherspoon and R. B. Oliver have completed the areal mapping of this region, and their results are embodied in the present (second) edition of this map (Pl. III). This later edition also includes the results of the reconnaissance surveys of T. G. Gerdine and R. H. Sargent (see p. 32) in the Matanuska and Talkeetna basins, as well as of the surveys of the region lying between Mount McKinley and Yentna River made by Russell W. Porter, of the Cook party, in 1906. (See pp. 39–42.)

## TOPOGRAPHIC CONTROL.

### CHARACTER OF WORK.

The latitude and longitude of Tyonek as given on the best available maps were verified by observations and accepted as the starting point for the season's work.

Owing to unfavorable conditions at Tyonek, no attempt was made to develop plane-table triangulation from a measured base, and the work was controlled by latitude and azimuth observations and the measurement of distances by the micrometer method. These latitude observations were made with a Saegmueller theodolite designed especially for exploratory work, with 4-inch vertical and horizontal circles reading to 30 seconds, supplied with two verniers to each circle and reading glasses with pointers. The control in latitude consisted of seventeen observations, of which ten were on the sun and seven on Polaris.

The solar observations for latitude consisted of twelve pointings, six direct and six reversed, of the altitude when near the meridian; and the stellar observations of six pointings, three direct and three reversed, of the altitude of Polaris at any hour angle.

The primary control in longitude consisted of five azimuth lines between points whose latitudes were determined. These lines were as follows: Tyonek to Mount Susitna, 30 miles; Mount Susitna to Mount McKinley, 113 miles; Mount McKinley to Toklat Butte, 66 miles (by occupying a point between them); Minook Summit to Toklat Butte, 100 miles. From Minook Summit the azimuth of a point 44 miles nearly due north was observed, and the resulting longitude agreed within 0.4 mile of the determination made in 1901 on the survey from Fort Yukon to Kotzebue Sound.

Twenty-eight observations for azimuth were made, of which twenty-four were on the sun and four on Polaris. The solar observations consisted of six measures, three direct and three reversed, of the horizontal angle between the sun and azimuth mark, and also of the altitude. The stellar observations consisted of two measures of the horizontal angle between the azimuth mark and Polaris at any hour angle, one with telescope direct and one with telescope reversed.

Examples of the various records and computations follow:

### EXAMPLE OF LATITUDE FROM CIRCUM-MERIDIAN ALTITUDES.

The formula used in the reduction of these observations is $\phi = 90° + \delta - A$, in which the following notation is employed:

$\phi$=latitude.

$\delta$=declination.

$A = a + x$, the meridian altitude.

$a$=observed altitude corrected for parallax, refraction, semidiameter, and instrumental errors

$x$=CK, the reduction to the meridian altitude.

$K = \frac{2 \sin^2 \frac{1}{2}t}{\sin 1''}$ which is taken directly from the tables, with the argument $t$, the small hour angle.

$C = \cos \phi' \cos \delta \sec a$.

$\phi'$ is an approximate value of the latitude $\phi$, which may be conveniently calculated by substituting the largest value of the observed altitude for A in the formula.

[1] Prof. Paper U. S. Geol. Survey No. 45, 1906, Pl. XI.

*Record and computations at Tyonek, Alaska, May 28, 1902.*

[Longitude, 151° 10′. Watch 4m 07s fast on local mean time. Instrument, 4-inch theodolite. Observer, D. L. R.]

**Telescope direct.**

| Watch time. | Meridian distance ($t$). | K | $x$=CK. | Vertical circle. Vernier A. | Vernier B. | Mean. | Reduced readings. |
|---|---|---|---|---|---|---|---|
| 11h 56m 19s | 04m 48s | 45″ | 32″ | 50° 38′ 30″ | 50° 38′ 00″ | 50° 38′ 15″ | 50° 38′ 47″ |
| 11 56 50 | 04 17 | 36 | 25 | 50 38 45 | 50 38 15 | 50 38 30 | 50 38 55 |
| 11 57 47 | 03 20 | 22 | 16 | 50 39 00 | 50 38 45 | 50 38 52 | 50 39 08 |
| **Telescope reversed.** | | | | | | | |
| 11 59 12 | 01 55 | 07 | 05 | 50 39 30 | 50 38 30 | 50 39 00 | 50 39 05 |
| 11 59 56 | 01 11 | 03 | 02 | 50 39 30 | 50 39 00 | 50 39 15 | 50 39 17 |
| 12 00 44 | 00 23 | 00 | 00 | 50 39 00 | 50 38 30 | 50 38 45 | 50 38 45 |
| **Telescope direct.** | | | | | | | |
| 12 01 49 | 00 42 | 01 | 01 | 50 39 30 | 50 38 30 | 50 39 00 | 50 39 01 |
| 12 02 26 | 01 19 | 03 | 02 | 50 39 00 | 50 38 30 | 50 38 45 | 50 38 47 |
| 12 03 01 | 01 54 | 07 | 05 | 50 39 00 | 50 38 30 | 50 38 45 | 50 38 50 |
| **Telescope reversed.** | | | | | | | |
| 12 04 07 | 03 00 | 18 | 13 | 50 39 15 | 50 39 15 | 50 39 15 | 50 39 28 |
| 12 05 00 | 03 53 | 30 | 21 | 50 39 00 | 50 39 00 | 50 39 00 | 50 39 21 |
| 12 05 55 | 04 48 | 45 | 32 | 50 38 45 | 50 38 30 | 50 38 37 | 50 39 09 |

Computation of approximate latitude:

| | | | |
|---|---|---|---|
| Highest altitude | 50° | 39′ | 15″ |
| Sun's semidiameter and refraction | | 16 | 30 |
| Altitude | 50 | 22 | 45 |
| Declination | 21 | 25 | 16 |
| Approximate latitude | 61 | 02 | 31 |

Computation of C:

| | |
|---|---|
| Log. cos. lat. 61° 03′ | 9. 6849 |
| Log. cos. dec. 21 25 | 9. 9689 |
| Log. sec. alt. 50 23 | 0. 1954 |
| Log. C=0.706 | 9. 8492 |

| | | | |
|---|---|---|---|
| Apparent noon | 24h | 00m | 00s |
| Equation of time | | −03 | 00 |
| Local mean time of culmination | 23 | 57 | 00 |
| Watch correction reversed | | +4 | 07 |
| Watch time of culmination | 0 | 01 | 07 |

| | | | |
|---|---|---|---|
| Mean of reduced readings | 50° | 39′ | 03″ |
| Parallax | | | + 6 |
| Refraction | | | −48 |
| Sun's semidiameter | | −15 | 48 |
| Sun's meridian altitude | 50 | 22 | 33 |
| Sun's declination | +21 | 25 | 16 |
| Latitude | 61 | 02 | 43 |

| | | | |
|---|---|---|---|
| Declination at Greenwich apparent noon | 21° | 21′ | 10. 7″ |
| Hourly change +24″. 3 | | | |
| Multiply by 10. 1 | | | |
| | | +04 | 05. 4 |
| Declination at time of observation | +21 | 25 | 16. 1 |

In the above computation the correction to the mean refraction, depending on the readings of the thermometer and barometer, was disregarded.

## EXAMPLE OF LATITUDE FROM ALTITUDE OF POLARIS.

The formula used in reducing these observations is $\phi = A - p \cos t + \frac{1}{2} p^2 \sin 1'' \sin^2 t \tan A$, in which the following notation is employed:

A=corrected altitude.
$\phi$=latitude.
$p$=polar distance expressed in seconds of arc.
$t$=hour angle.
$\delta$=declination of Polaris.

*Record and computation at camp of September 6, 1902.*

[Longitude, $9^h\ 56^m$. Watch $3^m\ 17^s$ slow on local mean time. Instrument, 4-inch theodolite. Observer, D. L. R.]

| Watch time. | Vernier A. | Vernier B. | Mean. |
|---|---|---|---|
| Direct: | | | |
| $6^h\ 48^m\ 30^s$ | 64° 35′ 30″ | 64° 35′ 00″ | 64° 35′ 15″ |
| 6 49 37 | 64 35 45 | 64 35 15 | 64 35 30 |
| 6 51 00 | 64 36 00 | 64 35 30 | 64 35 45 |
| Reversed: | | | |
| $6^h\ 52^m\ 24^s$ | 64 37 30 | 64 37 00 | 64 37 15 |
| 6 54 31 | 64 38 15 | 64 37 30 | 64 37 52 |
| 6 56 29 | 64 39 00 | 64 38 00 | 64 38 30 |

| | |
|---|---|
| Mean | $6^h\ 52^m\ 05^s$ |
| Watch correction | + 3 17 |
| Local mean time of observation | 6 55 22 |
| Reduction to sidereal interval | + 1 08 |
| Sidereal interval since noon | 6 56 30 |
| Greenwich sidereal time of mean noon | 10 58 34 |
| Reduction to local time of mean noon | + 1 38 |
| Local sidereal time of observation | 17 56 42 |
| Right ascension of Polaris | 25 24 55 |
| Hour angle $t$ | 7 28 13 |
| Mean observed altitude | 64° 36′ 41″ |
| Refraction | −27 |
| A | 64 36 14 |

| | |
|---|---|
| Declination of Polaris | 88° 47′ 06″ |
| $p=90°-\delta$ | 1 12 54 =4, 374″ |
| Log. $\delta$ 4,374″ | 3. 64088 |
| Log. cos $t$ $7^h\ 28^m\ 13^s$ | 9. 57459 |
| Log. 1,642″=−27′ 22″ | 3. 21547 |
| Log. $\frac{1}{2}$ | 9. 69897 |
| Log. $p^2$ | 7. 28176 |
| Log. sin 1″ | 4. 68557 |
| Log. $\sin^2 t$ | 9. 93400 |
| Log. tan A | . 32353 |
| Log. 84″=1′ 24″ | 1. 92383 |
| A | 64° 36′ 14″ |
| −second term | +27 22 |
| +third term | + 1 24 |
| $\phi$ | 65 05 00 |

EXAMPLE OF AZIMUTH AND TIME FROM THE ALTITUDE OF THE SUN.

To compute azimuth and time from these observations the following formulæ are used:

$$\tan^2 \tfrac{1}{2} A=\frac{\sin (S-\phi) \sin (S-h)}{\cos S \cos (S-p)}$$

$$\tan^2 \tfrac{1}{2} t=\frac{\cos S \sin (S-h)}{\sin (S-\phi) \cos (S-p)}$$

in which—

A=azimuth reckoned from the north either way.
$\phi$=latitude.
$h$=true altitude of center.
$p$=polar distance.
$S=\frac{1}{2}(\phi+h+p)$.
$t$=hour angle.

*Record and computation near camp of August 27, 1902.*

[Latitude, 64° 10′; longitude, 149° 00′. Time, $9^h\ 56^m$. Instrument, 4-inch theodolite. Observer, D. L. R.]

| | Vertical circle. | | | Horizontal circle. | | |
|---|---|---|---|---|---|---|
| | Vernier A. | Vernier B. | Mean. | Sun. | Mark. | Watch time. |
| Direct | 22° 00′ 00″ | 21° 57′ 30″ | 21° 58′ 45″ | 292° 02′ | [a] 70° 35′ | $7^h\ 55^m\ 44^s$ |
| | 22 07 30 | 22 05 30 | 22 06 30 | 292 22 | Mag. N. | 7 57 04 |
| | 22 12 30 | 22 10 30 | 22 11 30 | 292 34 | 209° 13′ | 7 57 54 |
| Reversed | 21 50 00 | 21 49 30 | 21 49 45 | 292 55 | ........ | 7 59 19 |
| | 21 55 30 | 21 55 00 | 21 55 15 | 293 08 | ........ | 8 00 14 |
| | 21 59 30 | 21 59 30 | 21 59 30 | 293 18 | 70 33 | 8 01 00 |
| Mean | ........ | ........ | 22 00 13 | 292 43 | 70 33 | 7 58 33 |

[a] The azimuth mark is Mount McKinley, 97 miles distant.

| | | | |
|---|---|---|---|
| Mean observed altitude | 22° | 00′ | 13″ |
| Refraction | | −2 | 23 |
| $h$ | | 21 | 57.8 |
| $\phi$ | | 64 | 10.0 |
| $p$ | | 79 | 46.4 |
| 2 S | | 165 | 54.2 |
| S | | 82 | 57.1 |
| S−$h$ | | 60 | 59.3 |
| S−$\phi$ | | 18 | 47.1 |
| S−$p$ | | 3 | 10.7 |
| Check | | 165 | 54.2 |
| Log. sec S | 0.91113 | | |
| Log. sin S−$h$ | 9.94177 | | |
| Log. sin S−$\phi$ | 9.50788 | | |
| Log. sec S−$p$ | .00067 | | |
| Log. tan² | .36145 | | |
| Log. tan | .18072 | | |
| ½ A | 56° | 35′ | 30″ |
| Azimuth from north (A) | 113 | 11 | |
| Azimuth from south | 293 | 11 | |
| a | 137 | 51 | |
| Azimuth of mark | 71 | 02 | |
| b | 138 | 39 | |
| Magnetic north | 209 | 41 | |
| Magnetic declination (east) | 29 | 41 | |

| | | | |
|---|---|---|---|
| Greenwich date, August 27, 5.9 hr. | | | |
| Hourly change | | | −52″.4 |
| Declination at Greenwich noon | 10° | 18′ | 48″ |
| | | −5 | 09 |
| Declination at time of observation | 10 | 13 | 39 |
| Polar distance | 79 | 46 | 21 |
| Mean angle to azimuth mark | | 70° | 34′ |
| Mean angle to sun | | 292 | 43 |
| a (angle between mark and mean position of sun) | | 137 | 51 |
| Angle of magnetic north | | 209 | 13 |
| Mean angle to azimuth mark | | 70 | 34 |
| b (angle between magnetic north and mark) | | 138 | 39 |
| Log. cos S | | | 9.08887 |
| Log. sin S−$h$ | | | 9.94177 |
| Log. cosec S−$\phi$ | | | 9.49212 |
| Log. sec S−$p$ | | | .00067 |
| Log. tan² | | | 9.52343 |
| Log. tan | | | 9.76171 |
| ½ $t$ | 2ʰ | 00ᵐ | 04ˢ |
| $t$ | 4 | 00 | 08 |
| Apparent time | 7 | 59 | 52 |
| Equation of time | | +1 | 34 |
| Local mean time | 8 | 01 | 26 |
| Watch time | 7 | 58 | 33 |
| Watch correction | | +2 | 53 |

## MICROMETER MEASUREMENTS.

### CHARACTER OF WORK.

The determination of distances by the micrometer consists of the measurement of the angle subtended by two signals erected at the ends of a short measured base.

These base signals, which consisted of rock cairns, blazed trees, blazed poles with cross arms, etc., were erected at prominent plane-table stations along the route of survey. They were made as nearly as possible at right angles to the route of travel and their approximate azimuths were taken with a small prismatic compass.

The lengths of the bases ranged from 10 to 600 feet, in conformity with the local conditions and the greatest probable distance from which they were to be observed.

The function of the micrometer is the measurement of the angle at the instrument between the lines of sight to both ends of the base. This angle is measured by the movement of a hair that is attached to a sliding plate moved by means of a screw, the head of which, beneath the micrometer box, is a wheel about three-fourths of an inch in diameter and having its circumference divided into 100 spaces. By a series of tests upon measured bases at known distances the angle subtending the movement of the hair by revolving the micrometer head one space can be computed.

The micrometer observations consisted of one to ten measurements of the angle. The precision to be attained in the measurement of the angle is defined by the scale of the map and the relation of the size of the angle to the distance to be determined. On a scale of 1:180,000 the smallest distance that can be plotted on the plane-table sheet is about one-fiftieth of a mile, and, as the resulting error in the determined distance is proportional to the error in the measurement of the angle, we have $\frac{A}{50\,D}$ (in which A = angle in seconds and D = distance in miles) as the allowable error in the measurement of the angle.

For example, a base of 256 feet at right angles to the line of sight and at a distance of 10 miles subtends an angle of about 16′ 40″, or 1,000″, and a precision of $\frac{A}{50\ D}=\frac{1{,}000''}{500}=2''$ in the measurement of the angle will be required to determine the distance within the limits of plotting.

Under favorable conditions a single measurement should determine the angle within 5″. The base should be of sufficient length to insure a good determination of the distance by a single measurement of the angle.

The advantages of the micrometer method of measuring distances as compared with the stadia method are that the angle, being a horizontal one, is not affected by differential refraction, no rodman is required, longer distances can be measured, and by means of the method of repetitions a closer determination is possible.

The formula used for the reduction of micrometer readings was $H=\frac{bC\ \sin a \cos V}{R}$, in which—

R=difference of readings of micrometer.
H=horizontal distance in miles.
*b*=length of base in feet.
*a*=angle between line of sight and the base.
*d*=value of one division of micrometer.
C=micrometer constant.
V=vertical angle.

EXAMPLE OF DETERMINATION OF VALUE OF ONE DIVISION OF MICROMETER.

*Readings of micrometer at Tyonek, Alaska, May 29, 1902.*

[Instrument, Fauth micrometer alidade. Observer, D. L. R.]

| Right target. | Left target. | R. | Right target. | Left target. | R. |
|---|---|---|---|---|---|
| 550. 0 | 88. 0 | 462. 0 | 540. 0 | 78. 3 | 461. 7 |
| 540. 5 | 76. 5 | 464. 0 | 540. 4 | 77. 6 | 462. 8 |
| 537. 5 | 75. 0 | 462. 5 | 540. 0 | 78. 5 | 461. 5 |
| 521. 0 | 58. 0 | 463. 0 | 554. 0 | 92. 0 | 462. 0 |
| 520. 5 | 58. 5 | 462. 0 | 554. 0 | 91. 5 | 462. 5 |
| 521. 0 | 58. 0 | 463. 0 | 553. 3 | 91. 3 | 462. 0 |
| 538. 5 | 76. 0 | 462. 5 | 524. 0 | 64. 0 | 460. 0 |
| 538. 5 | 76. 5 | 462. 0 | 525. 0 | 64. 0 | 461. 0 |
| 536. 0 | 74. 0 | 462. 0 | 526. 0 | 65. 0 | 461. 0 |
| 536. 0 | 74. 0 | 462. 0 | 527. 0 | 65. 0 | 462. 0 |
| Mean of 10 readings | | 462. 5 | Mean of 10 readings | | 461. 65<br>462. 5 |
| | | | Mean of 20 readings | | 462. 075 |

The readings were taken on two targets at right angles to the line of sight, 21.25 feet apart and at a distance of 2,859.5 feet from the instrument, all measures being nearly in the same horizontal plane. The value of *d* in seconds of arc is given by the formula $d=\frac{b}{H\ R \sin 1''}$, in which—

*d*=value in seconds of arc of one space of the micrometer wheel.
H=distance from instrument to base.
*b*=length of base.

Computation of *d*:

*b*=21.25 feet, log ........ 1. 32736
H=2,859.5 feet, colog ........ 6. 54371
R=462.075 colog ........ 7. 33529
sin 1″, colog ........ 5. 31443

log. *d*=0. 52079

*d*=3″.317.

The value of C is given by the formula $C=\frac{1}{5{,}280d \sin 1''}$, in which—

C=constant or ratio to be found for each instrument.
$d$=value in seconds of arc of one space on micrometer wheel.

Computation of micrometer constant C:

| | |
|---|---|
| 5,280, colog | 6. 27737 |
| $d$=3.317, colog | 9. 47921 |
| sin 1″, colog | 5. 31443 |
| | log. C=1. 07101 |

C=11.777.

### EXAMPLE OF DETERMINATION OF DISTANCE BY THE MICROMETER ALIDADE.

*Record and computation near mouth of Nenana River, Alaska, August 30, 1902.*

[Instrument, Fauth micrometer alidade. Observer, D. L. R.]

| Readings. | | | Computation. |
|---|---|---|---|
| Right signal. | Left signal. | R. | |
| 311. 0 | 79. 2 | 231. 8 | |
| 311. 0 | 79. 2 | 231. 8 | |
| 311. 0 | 81. 0 | 230. 0 | $b$=573.8 feet, log. 2. 75876 |
| 310. 8 | 80. 6 | 230. 2 | $a$=82°, log. sin 9. 99575 |
| 310. 5 | 80. 0 | 230. 5 | Constant, log. of C 1. 07101 |
| 310. 2 | 80. 0 | 230. 2 | R=231.01, colog 7. 63637 |
| 311. 2 | 80. 0 | 231. 2 | |
| 310. 5 | 80. 0 | 230. 5 | log. H=1. 46189 |
| 311. 2 | 79. 4 | 231. 8 | H=28.97 miles. |
| 311. 3 | 79. 2 | 232. 1 | |
| Mean of 10 readings | | 231. 01 | |

The vertical angle V in the foregoing example was too small to be considered. The angle $a$ was determined by taking the difference of the magnetic azimuth of the base and the line of sight.

## SURVEYS BY COOK PARTY IN 1906.

By Russell W. Porter.

The Cook party arrived at Tyonek May 29 and started up Susitna River the next day in the power launch *Bolshoy*. The Yentna was ascended in three days to a point 20 miles above the Kichatna, where a base camp was established. While awaiting the arrival of the pack animals, which came overland, a reconnoitering party ascended the west fork of the Yentna to ascertain if a pass existed through the range in this locality. A way through appeared feasible, and after returning to the base camp, on the arrival of the pack train the entire party proceeded up the west fork to the backbone of the range. Here the headwaters were found to run into box canyons impassable to pack horses; as there was no practicable route around them or along the mountain slopes, the party returned to the base camp.

This journey consumed the month of June. On July 3 the party traversed the Yentna River bottom to the east fork, crossed over Kliskon Mountain (3,800 feet), and descended to Sunflower, a mining camp of tents on Sunflower Creek, tributary to Lake Creek. (See Pl. XV, in pocket.) The route now lay along the southeastern base of the Alaska Range, first over flat, partly wooded country, at an elevation of 1,500 feet, to Kariltna Creek, thence up Dutch Creek to a pass (3,100 feet), and down Bear Creek to the Tokichitna (500 feet). Here, some 3 miles up the left margin of the Tokichitna Glacier, another base camp was established and reconnoitering parties were sent out on exploration work. The writer, crossing the glacier, followed a ridge lying between it and another glacier immediately east of it, to the base of Mount McKinley.

On July 25 Dr. Cook detached the writer on topographic work, with one man (a packer), a horse, and outfit, and instructed him to rendezvous at Susitna station in the latter part of September. The main party then returned to tidewater over the back trail.

The desirability of continuing the survey eastward along the range was considered, but on taking into account the somewhat fragmentary condition of the traverse already accomplished the writer decided to go back westward along the base of the range, expanding the work both northward into the mountains and southward to the lowlands of the Susitna River valley. This program was carried out. In general the plane-table sheets resulting from the work cover the area along the southeast side of the Alaska Range, 30 miles wide and 80 miles long, with a horizontal and vertical control carried from tidewater.

While mapping the neighborhood of Cache and Peters creeks (tributaries of the Kariltna) the party found about 50 miners working placer claims on these creeks and their feeders. Gold was discovered in this locality the year before.

The source of Lake Creek is a lake 8 miles long and 1 to 2 miles wide lying entirely in the mountains. A raft was built, on which the head of the creek was reached, and the range was then penetrated to a point 15 miles from Mount Russell. Large areas around Mounts Dall, Russell, Foraker, and McKinley were not mapped on the plane-table sheets, for lack of time and facilities for their survey.

The Yentna (east fork) was reached the middle of September, a raft was built, and the horses were shot. Dropping downstream, the party ascended Mount Yenlo on a perfectly clear day—a rarity. Out of one hundred and ten days it rained fifty, and during the latter part of August it poured incessantly for two weeks in the region of the lake. The writer joined Dr. Cook at Susitna station September 23, and Tyonek was reached two days later.

The route of the survey covered 500 miles—275 by water and 225 by land. The results are embodied in the accompanying map (Pl. XV, in pocket).

The topographic field sheets were made on a planetable 18 inches square, with box compass attached at one side. The planetable was set up on the theodolite tripod. The alidade had open sights only. The scale used was 1:190,080, or 3 miles to the inch. The position and heights of some 300 points were obtained and the topography sketched in, no attempt being made to work out the actual contours while in the field. Fifty-six planetable stations were occupied. Vertical angles were taken with a small altazimuth instrument designed by C. L. Berger & Sons for the Ziegler polar expeditions. Both vertical and horizontal circles are 4 inches in diameter, carry double verniers, magnifying glasses, and pointers, and give a least count of single minutes of arc. Half and quarter minutes can be estimated. The needle is carried in a tube fastened to and under the telescope. In a few places where the theodolite could not be transported vertical angles to points at short distances were measured with an Abney level.

The height of Mount McKinley as measured from five different stations is as follows:

*Height of Mount McKinley above sea level.*

| | Feet. |
|---|---|
| From station 1, 61 miles distant | 20,380 |
| From station 16, 53 miles distant | 20,376 |
| From station 31, 32 miles distant | 20,164 |
| From station 38, 45 miles distant | 20,362 |
| From station 52, 70 miles distant | 20,270 |
| Mean (compare pp. 32–33) | 20,310 |

Below is given the magnetic declination at several azimuth stations:

*Magnetic declination at azimuth stations.*

| Date. | Time. | Station. | Latitude. | Longitude. | Declination (E.). |
|---|---|---|---|---|---|
| | h. m. | | ° ′ | ° ′ | ° ′ |
| June 2 | 0 27 | Alexander | 61 25.0 | 150 40.8 | 26 30 |
| June 3 | 20 41 | 55 | 61 30.5 | 150 33.7 | 25 54 |
| June 8 | 22 43 | 1 | 62 17.6 | 151 59.6 | 26 11 |
| July 17 | 7 2 | 20 | 62 38.8 | 150 49.0 | 27 52 |

Base lines were measured at six different places, most of them on river bars, with a steel tape, measurements being taken both ways. The theodolite was then set up at the ends of the base line and the distance and direction of several points were determined by triangulation. These computations were made in the field and the points were platted on the plane-table sheets. Where a tape-measured base was impracticable, the arc was measured at the theodolite between two signals a known distance apart by taking the mean of ten repetitions and computing the base from this arc and the distance between the signals.

Control in latitude consisted of eighteen observations—thirteen circum-meridian altitudes on the sun and stars and five on Polaris at any hour angle. Each solar observation (when weather permitted) consisted of twelve pointings on opposite limbs—six direct and six reversed. An example of the latitude determinations is given below.

The formula used in the reduction of these observations is $\phi = 90° + \delta - A$, in which the following notation is employed:

$\phi$=latitude.
$\delta$=declination.
$A = a + x$, the meridian altitude.
$a$=observed altitude corrected for parallax, refraction, semidiameter, and instrumental errors.
$x$=CK, the reduction to the meridian altitude.
$K = \frac{2 \sin^2 \frac{1}{2}t}{\sin 1''}$, which is taken directly from the tables, with the argument $t$, the small hour angle.
$C = \cos \phi' \cos \delta \sec. a$.
$\phi'$ is an approximate value of the latitude $\phi$, which may be conveniently calculated by substituting the largest value of the observed altitude for A in the formula.

*Example of latitude determination from circum-meridian altitudes on the sun.*

[Station, No. 1. Date, June 9 0, 1906. Instrument, C. L. Berger & Sons theodolite. Vertical circle reading from the vertical axis. Observer. R. W. Porter. Chronometer, watch No. 15. Temperature, 67° F. Barometer, 29.78.]

| Sun's limb. | Record. | | | Computation. | | | | |
|---|---|---|---|---|---|---|---|---|
| | Chronometer time. | Vertical circle. A. | Vertical circle. B. | Mean zenith distance. | Hour angle (t). | K. | x=CK | Zenith distance to sun's center. |
| | h m s | ° ′ | ′ | ° ′ | m s | | ′ | ° ′ |
| Dir. L. | 9 56 45 | 39 43.0 | 44.0 | 39 43.0 | 15 9 | 450 | 5.1 | 39 22.0 |
| Rev. U. | 59 15 | 320 49.4 | 50.8 | 9.9 | 12 39 | 314 | 3.5 | .3 |
| Rev. U. | 10 3 45 | 51.5 | 52.7 | 7.9 | 8 9 | 130 | 1.5 | .3 |
| Rev. U. | 5 30 | 52.0 | 53.2 | 7.4 | 6 24 | 80 | .9 | .4 |
| Dir. L. | 7 30 | 39 38.2 | 39.0 | 38.6 | 4 24 | 38 | .4 | .3 |
| Dir. L. | 8 30 | 38.2 | 39.0 | 38.6 | 3 24 | 23 | .2 | .5 |
| Dir. L. | 9 25 | 37.8 | 38.8 | 38.3 | 2 29 | 12 | .1 | .3 |
| Dir. L. | 10 15 | 37.7 | 38.8 | 38.2 | 1 39 | 5 | ....... | .3 |
| Dir. L. | 11 40 | 37.7 | 38.9 | 38.3 | 14 | ....... | ....... | .4 |
| Rev. U. | 13 15 | 320 52.8 | 54.0 | 6.6 | 1 21 | 4 | ....... | .5 |
| Rev. U. | 14 35 | 52.5 | 53.6 | 7.0 | 2 41 | 14 | .1 | .8 |
| Rev. U. | 15 38 | 52.5 | 53.7 | 6.9 | 3 44 | 27 | .3 | .5 |

| | | | | |
|---|---|---|---|---|
| Zenith distance | 39° | 22′ | cosec. | 0.1977 |
| Declination | 22 | 55 | cos. | 9.9643 |
| Latitude | 62 | 17 | cos. | 9.6675 |
| C | | 0.675 | log. | 9.8295 |

| | h | m | s |
|---|---|---|---|
| Chronometer correction on local mean time reversed | 10 | 12 | 56 |
| Equation of time | | −1 | 6 |
| Chronometer time of apparent noon | 10 | 11 | 50 |

Greenwich date, June $9^d\ 10^h\ 1^m\ 50^s$.

| | ° | ′ |
|---|---|---|
| Mean | 39 | 22.4 |
| Refraction and parallax | | +0.6 |
| Zenith distance | 39 | 23.0 |
| Declination | 22 | 55.1 |
| Latitude | 62 | 18.1 |

The primary control consisted of a system of azimuth lines between points fixed in latitude, running from Tyonek to Mount Susitna, Mount Susitna to Mount Yenlo, and Mount Yenlo to several points in the range.

Twenty-three azimuth and time observations were made. Each consisted of six pointings—three direct and three reversed—on the limbs of the sun in opposite quadrants of the reticule, both circles being read.

The height of Mount Susitna was determined by triangulation from two base lines at Alexander and Susitna station and vertical angles taken to this point from several stations in the range. The elevation of the forks of Susitna and Chulitna rivers, as determined by the Alaskan Central Railway, was also tied to.

Time was kept by three Waltham chronometer watches, rated by solar observations at intervals of about a week throughout the season. They were compared daily. Watch No. 4 was put out of service June 25 and No. 14 on August 24, both from being submerged in water. No. 15, used for recording, was set to approximate Greenwich mean time and ran continuously. The errors of this watch (No. 15) on local and Greenwich mean time and its daily rate for the season were as follows:

*Rates and errors of watch No. 15.*

[Assumed longitude of Tyonek, 151° 10′ west.]

| Station. | Local astronomic date. | | Error on local mean time. | Error on Greenwich mean time. | Interval (days). | Daily rate. |
|---|---|---|---|---|---|---|
| 0 | May | 29.2 | −10h 8m 45s | −0h 4m 5s | | |
| 55 | June | 3.8 | 10 6 59 | 5 6 | 5.6 | −10s.9 |
| 1 | June | 8.7 | 10 12 56 | 5 36 | 4.9 | 6.1 |
| 1 | June | 16.8 | 10 13 49 | 6 29 | 8.1 | 6.5 |
| 14 | June | 27.3 | 10 15 4 | 5 49 | 10.5 | 3.8 |
| 15 | June | 28.8 | 10 15 32 | 5 42 | | |
| 1 | July | 2.9 | 10 13 41 | 6 21 | 4.1 | −9.5 |
| 16 | July | 8.2 | 10 13 19 | 6 40 | 5.3 | 3.6 |
| 19 | July | 14.3 | 10 11 48 | 7 21 | 6.1 | 6.7 |
| 20 | July | 17.0 | 10 10 44 | 7 42 | 2.7 | 7.8 |
| 20 | July | 25.8 | 10 10 46 | 7 44 | 8.8 | .2 |
| 19 | Aug. | 1.2 | 10 12 57 | 8 30 | 6.4 | 7.2 |
| 38 | Aug. | 17.2 | 10 15 58 | 10 48 | 15.7 | 9.4 |
| 40 | Aug. | 23.8 | 10 17 38 | 11 48 | 6.6 | 9.1 |
| 40 | Aug. | 30.9 | 10 18 23 | 12 33 | 7.1 | 6.4 |
| 40[a] | Sept. | 6.9 | 10 16 52 | 11 2 | 7.0 | +12.7 |
| 48 | Sept. | 7.2 | 10 17 4 | 11 19 | | |
| 51 | Sept. | 14.2 | 10 15 56 | 10 56 | 7.0 | 3.3 |
| 52 | Sept. | 15.2 | 10 15 46 | 10 49 | | |
| 56 | Sept. | 24.2 | 10 14 14 | 9 47 | 9 | 6.9 |
| 0 | Sept. | 27.2 | 10 14 15 | 9 45 | 3 | .7 |

[a] Dropped watch movement.

## GEOGRAPHY.

### GENERAL FEATURES.

The Pacific margin of the North American continent is marked by a broad mountainous belt which extends northwestward from Mexico through the United States and Canada into Alaska as far as the one hundred and fiftieth meridian, where, paralleling the coast line, it makes an abrupt bend to the southwest and continues toward Asia in the highlands of the Alaska Peninsula and the Aleutian Islands. The western part of this cordillera, embracing many distinct ranges, together with transverse lines of considerable height and some areas of lesser relief, but in general forming a rugged mountainous belt 50 to 200 miles in width, has been called the Pacific mountain system.[1] In Alaska this system is bounded on the inland side by the central plateau region, which may be broadly correlated with the plateau or great basin region of western Canada and the United States.

[1] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 27-36.

The Pacific mountain system at the international boundary includes the great mass of snow-clad peaks and connecting ridges, about 80 miles in width and from 8,000 to over 19,000 feet in altitude, to which the name St. Elias Range has been given. To the northwest this highland mass widens and is divided by the Copper River and upper Tanana drainage systems into two divergent mountain ranges. (See Pl. II.) The Nutzotin Mountains, 5,000 to 8,000 feet high, form the northern fork of the system and connect the St. Elias Mountains with the Alaska Range, 8,000 to 20,000 feet in height. These ranges encircle the northern and western margins of the Copper and Susitna basins. The southern fork of the St. Elias system, extending westward, is formed by the Chugach Mountains, 6,000 to 8,000 feet high, and their extension, the Kenai Mountains, 5,000 to 6,000 feet high, and these ranges together constitute the rugged coastal barrier stretching from St. Elias to Cook Inlet.

Two rugged mountain masses lie within the reentrant formed by the two forks of the St. Elias Range. One, on the east—a group of irregularly distributed snow-covered volcanic peaks 8,000 to 16,000 feet in altitude, called the Wrangell Mountains—is between Chitina River on the south and Copper River on the north. The other range, on the west, called the Talkeetna Mountains (see Pl. II), is a roughly circular area of high relief, 5,000 to 8,600 feet in height, lying in the region tributary to Cook Inlet.

The axes of all these ranges have the northwesterly trend characteristic of the Pacific mountain system of Canada and the United States about as far west as the one hundredth and forty-eighth meridian, then bend sharply to the southwest to meet the northeasterly extension of the Asiatic continent. In other words, these axes are in general parallel to the Pacific shore line, forming a crescentic curve around the Gulf of Alaska. As shown on pages 52–53 and 111, this great bend is the resultant of the control of the relief by the bed-rock structure.

The drainage of the ranges above described is carried for the most part southward to the Pacific Ocean. Among the larger rivers are the Copper, flowing directly into the Pacific, and the Susitna and Matanuska, tributary to Cook Inlet. A broad, flat, silt-covered area standing about 3,000 feet above sea level, called the Copper River plateau, lies between the westerly tributaries of the Copper and the headwaters of the Matanuska and Susitna.

The northerly slopes of the Pacific ranges descend in most places abruptly to a gravel-floored plateau which, stretching around their margins, slopes gradually to the valley of the Kuskokwim on the west and to that of the Tanana on the north (Pl. VI, *B*, p. 46). Both these rivers meander through broad lowlands which, in turn, are delimited on the north and west by an abrupt rise of land marking the southerly boundary of an upland. This upland, best known north of the Tanana Valley, is characterized by level, flat-topped interstream areas 2,000 to 3,000 feet in altitude, and forms a part of the central plateau region.

The Mount McKinley region lies, for the most part, in the Pacific mountain system, but also stretches northward into the central plateau region. It is roughly bounded by meridians 148° and 154° west and parallels 61° and 65° 20′ north and has an area of about 40,000 square miles. This report, however, deals more specially with the Alaska Range proper, and the detailed discussion will be confined largely to the region, embracing about 10,000 square miles, lying between the Susitna basin on the south and the Kuskokwim and Tanana basins on the west and north.

## TOPOGRAPHIC PROVINCES.

As just stated, the Mount McKinley region falls within two of the larger physiographic provinces of Alaska, but when the features of the relief are analyzed in detail seven topographic subdivisions can be recognized. These are, named from south to north, (1) the Cook Inlet littoral, (2) the Susitna lowland, (3) the Alaska Range, (4) the piedmont plateau, (5) the Kuskokwim lowland, (6) the Tanana lowland, and (7) the Yukon-Tanana upland. (See Pl. II.)

### COOK INLET LITTORAL.

Cook Inlet is a deep reentrant of the southern coast of Alaska which is separated from the Pacific Ocean by Kenai Peninsula. It occupies a broad, fairly symmetrical depression lying between the Kenai Mountains on the east and the Alaska Range and the north end of the

Aleutian Range on the west. Heavy gravel sheets bury the bases of these ranges and form broad terraces whose surfaces slope gently toward the inlet, terminating at the shore line in steep escarpments (Pl. IV, *B*). These gravel-formed plateaus have been deeply trenched by streams tributary to Cook Inlet, whose sources lie in the high ranges on either side.

On the south the Kenai Mountains terminate in steep, rocky slopes, and one of these forms the bold headland called Cape Elizabeth, which marks the east side of the entrance to Cook Inlet. Sixty miles of water separate this point from Cape Douglas, of lesser relief but also a rocky headland, forming the west side of the entrance.

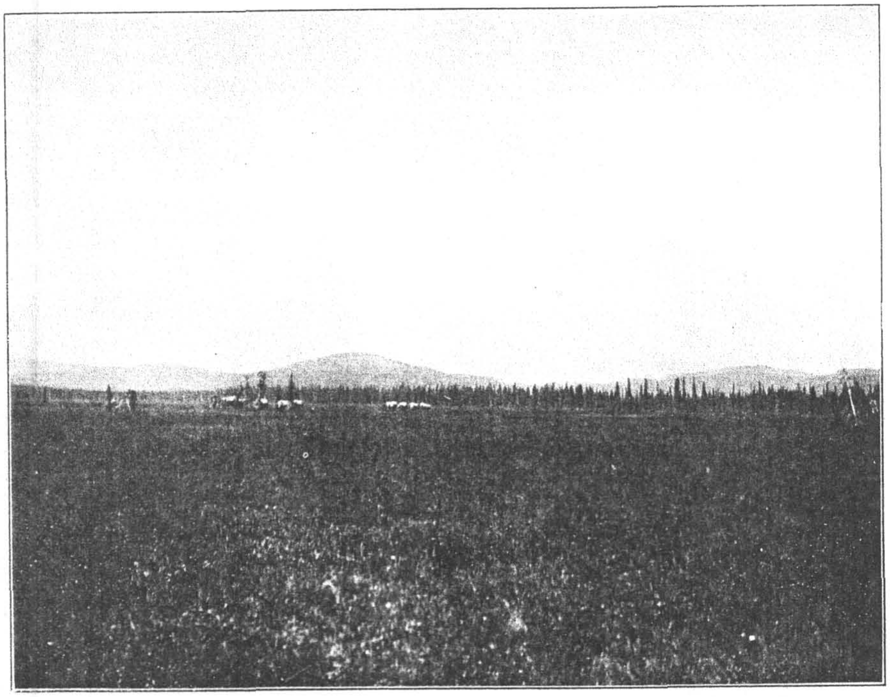
Along the lower reaches of the inlet rocky, precipitous, and irregular slopes rise directly from tidewater. In this part of the inlet lies the little rocky islet Augustine, with its beautifully symmetrical volcano. North of Kachemak Bay, an easterly indentation of the inlet, the irregularities of shore line give way to an almost unbroken steep rock escarpment which rises from a narrow, shelving beach. At an altitude of about 400 feet above tidewater the hard rock is mantled by the gravel which forms the terraces mentioned above. This rock escarpment decreases in altitude to the north until, at the settlement of Kenai, the base of the gravels is practically at sea level. The same topographic types persist along the western shore of the inlet. South of Snug Harbor the shore line is irregular, with rocky headlands; to the north there are long, smooth stretches of sandy beaches, mostly less than 100 yards in width and terminating in steep-walled gravel bluffs. Here and there are low, sandy reefs just out from the main shore line, with which they are connected by crescentic stretches of sandy beach. The shore line is of this type and the inlet is shallow for 150 miles to the northeast. Beyond, the inlet makes a right-angled bend to the east, and a long reentrant, called Turnagain Arm, penetrates the Kenai Mountains. This embayment has a steep, rocky shore and deep water, with high tides, treacherous currents, and violent storms, all of which form a serious menace to navigation. The head of Turnagain Arm is connected with Portage Bay of Prince William Sound by an ice-filled pass, long used by the natives as a winter route of travel.

### SUSITNA LOWLAND.

The Cook Inlet trough is continued northward by broad alluvial-floored valleys, which form the lower reaches of Susitna River and some of its tributaries. These valleys are here referred to collectively as the Susitna lowland. On the east the lowland is bounded by the Chugach and Talkeetna mountains and on the west by the Alaska Range. Both these barriers are deeply trenched by rivers tributary to the Susitna or flowing directly into Cook Inlet.

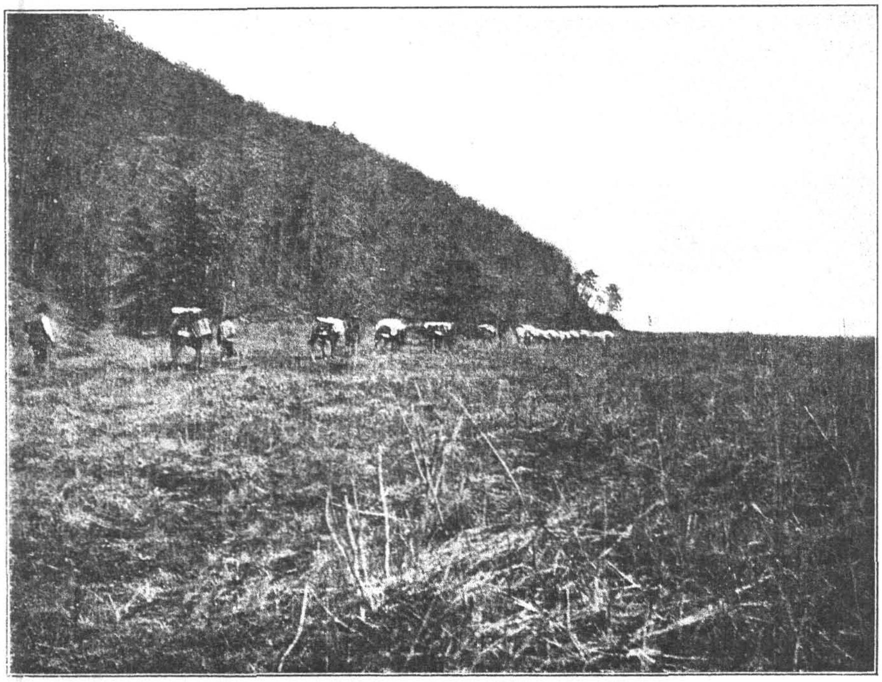
Susitna River occupies a roughly axial position in this trough. Its broad delta, a silted-up part of Cook Inlet, is still rapidly encroaching on the embayment and marks the south end of a lowland that sweeps around Knik Arm eastward into the Matanuska Valley and northward to the Chulitna and extends to the west and northwest, where it includes the lower courses of several of the tributaries of the Susitna. This lowland is timbered and dotted with innumerable lakes. Its boundaries along the highland rim are marked by a series of gravel terraces which rise en échelon to the gentle hillslopes above. Above the mouth of the Chulitna the Susitna Valley is more constricted but still has a gravel floor, and it maintains this character as far as the mouth of Portage Creek, where the river emerges from a rock-bound canyon.

Matanuska River flows through a broad depression which marks the boundary between the Chugach Mountains on the south and the Talkeetna Mountains on the north. The lower 20 miles of its valley is a part of the Susitna lowland; above the rim it has incised a steep-walled gorge in an older valley floor now in part preserved as a rock bench. Talkeetna River and other smaller streams, all tributary to the Susitna from the east, rise in the Talkeetna Mountains and flow first through broad valleys, then in steep-walled, glacier-scoured canyons, until they emerge on the Susitna lowland. The sources of the Matanuska and Susitna lie in the Copper River plateau east of the mountains. The westerly tributaries of the Susitna, including the Yentna, the Tokichitna, the Chulitna, and many smaller streams, have a ramifying drainage system, much of which reaches far back into the Alaska Range. Their sources are for the most part



*A.* TIMBERED FLAT AND MEADOWS NORTHWEST OF COOK INLET.

Near camp of June 2. See page 17.



*B.* SEAWARD-FACING ESCARPMENT OF GRAVEL TERRACE ON WEST SIDE OF COOK INLET.

Near camp of June 2. See page 44.

glacial, and within the high range they flow in steep-walled valleys which open out as they approach the Susitna, their flood plains finally merging with that of the main stream.

Gravel terraces flank nearly all the valleys of the drainage courses of this province and become of increasing prominence toward the mouths of the streams. Their lower parts are, as a rule, deeply incised in gravel sheets which mantle the foothills of both the ranges bounding the lowland.

### ALASKA RANGE.

The Alaska Range[1] is a rugged mountain mass which sweeps as a great crescent around the Susitna and Copper basins, constituting for the most part the watershed between the Pacific Ocean and Bering Sea. Trending northeastward from the unexplored region near Lake Clark, the range continues to bend to the east as far as Delta River, where the axis of the mountains takes a southeasterly direction and is continued in the so-called Nutzotin Mountains[2] as far as White River. The axis of this range, which has a parabolic form, is between 500 and 600 miles in length, and the range is from 50 to 80 miles wide. In the southern part of the range the peaks range from 5,000 to 8,000 feet in altitude. When traced northward and eastward, the crest line is found to maintain an altitude of 7,000 to 10,000 feet to the vicinity of Mentasta Pass, beyond which it is continued by the Nutzotin Mountains at a lower altitude. Its longitudinal extent, breadth, and mass make the Alaska Range one of the most prominent mountain chains of the continent. It is both higher and broader than the Sierra Nevada and of greater relief and extent than the Alps of Europe.

The region lying between Cook Inlet and Lake Clark, about 80 miles wide, has been little explored, but is known to be of high relief. In this belt is the north end of the Aleutian Range, represented by Redoubt Volcano, and also the south end of the Alaska Range. Osgood[3] reports that the mountains at the head of Lake Clark are from 4,000 to 6,000 feet high[4] and include a number of small glaciers drained by streams tributary to the lake. This comparatively unexplored region stretches northward for a hundred miles, draining in part to the Skwentna, in part to the Kuskokwim, and in part to Lake Clark. It probably includes a number of high ridges trending north and south, separated by rather broad valleys and with peaks 8,000 to 9,000 feet high. From Cook Inlet the eastern face of these mountains can be seen as a rather abrupt scarp which rises to a summit level covered with snow and is broken by a number of glaciers discharging into streams flowing into the inlet. Mount Spurr,[5] 10,500 feet high, is the most prominent peak in this mountain mass.

In the headwater region of the Yentna there is a break in the range, and several gaps from 2,900 to 3,000 feet high afford easy routes of travel between Cook Inlet and the Kuskokwim. Spurr, the first to explore this region, in 1898 discovered a broad gap about 3,000 feet high at the head of Pleasant River. Captain Herron in the following year discovered and named Simpson Pass (Pl. XI, *A*, p. 88), about 3,000 feet above sea level, at the head of the Kichatna and north of the pass traversed by Spurr. The writer found a third gap between these two, which has been called Rainy Pass (Pl. V, *B*) and stands about 2,950 feet above sea level. In the vicinity of these passes the mountains rise to 7,000 and 9,000 feet, with sharp crest lines and steep slopes. The watershed here lies well toward the inland front of the range.

The Tordrillo Mountains, so named by Spurr, lie west of the south fork of Kuskokwim River and form a subordinate unit of the main range. They are probably 5,000 to 6,000 feet high and trend about north and south. To the south the mountains appear to increase in altitude, as they are snow-capped and give rise to a number of glaciers which discharge into the Kuskokwim.

The Alaska Range maintains the same general character for a distance of 100 miles northeastward from the Skwentna basin. Here the inland slope rises abruptly from the gravel-floored

[1] This name was first applied by W. H. Dall to that part of the range which lies between the Susitna and Kuskokwim basins.

[2] Brooks, A. H., Reconnaissance from Pyramid Harbor to Eagle City: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 346.

[3] Osgood, W. H., A biological reconnaissance of the base of the Alaska Peninsula: North Am. Fauna No. 24, Biol. Survey, U. S. Dept. Agr., 1904.

[4] This is confirmed by the recent surveys by Witherspoon and Martin.

[5] Named by the writer after J. E. Spurr, who explored the Skwentna and Kuskokwim valleys in 1898.

plateau to the crest of the range, not more than 5 to 10 miles distant from the mountain front (Pl. VI, *B*). The crest line, a high, serrated ridge 7,000 to 10,000 feet high, joins a series of dominating peaks, including Mount Dall[1] (9,000 feet), Mount Russell[2] (11,350 feet), and the two giant peaks Mount Foraker (17,000 feet) and Mount McKinley (20,300 feet). (See Pls. I, p. 11, and VI, *A*.) East of the crest line are other high peaks, unmapped and almost unknown, which probably attain altitudes of 10,000 to 15,000 feet. In this part of the range valleys of the southeastward-flowing streams reach far back into the mountains and are, as a rule, filled with glacial ice well out toward the Susitna lowland. These glaciers form the most extensive ice sheets of inland Alaska. The valleys of the westward-flowing streams are short and are only in part filled with glacial ice. Some of the largest glaciers, like those finding sources on Mount McKinley and Mount Foraker, extend to the inland front of the range. (See Pl. III, in pocket.)

From the Muldrow Glacier, near the one hundred and fifty-first meridian, the range trends northeastward to Nenana River, and this part has been but little explored. Apparently the peaks rise to altitudes of not over 8,000 or 9,000 feet, and the crest line lies well back in the heart of the mountains. In this region a subordinate range is set off from the main mountain mass to the south by a series of broad depressions. This series of depressions is extended east of the Nenana by the valley of Yanert Fork.

That part of the range which lies between the head of the Chulitna and the Tanana Valley includes a mountainous area in which at least three subordinate ranges can be recognized, with an aggregate width of nearly 100 miles. The broad valley of the Nenana, traversing two of these ranges, is connected by a broad, low gap called Broad Pass (2,400 feet) with the valley of the Chulitna, a stream that flows south.

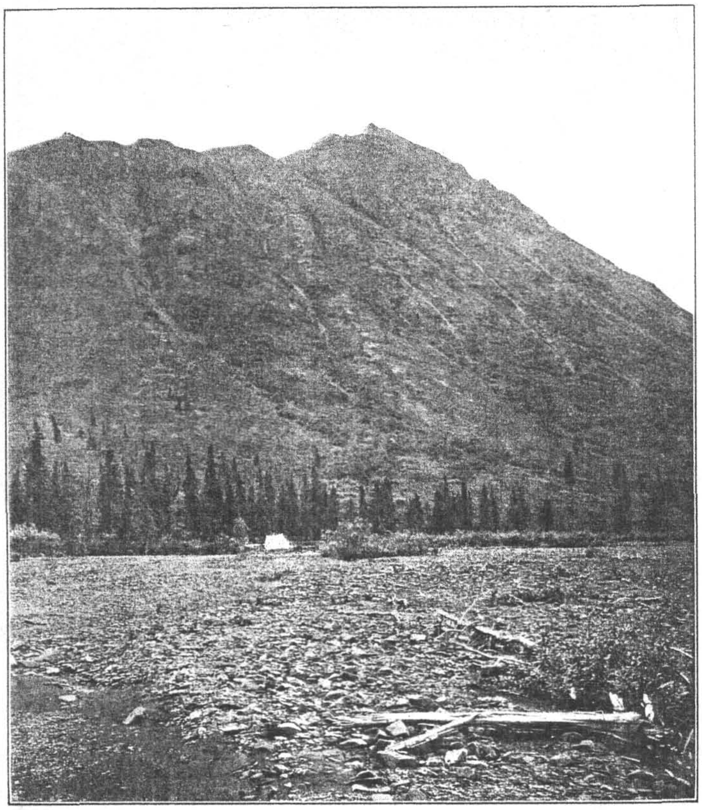
The range is continued in a southeasterly direction by a broad mountain mass which is unexplored[3] except along the valley of Delta River. This stream, rising in the Copper River plateau south of the range, traverses the entire mountain mass through a steep-walled trench about 40 miles long. The adjacent peaks are from 8,000 to 10,000 feet high, but a few miles to the west is Mount Hayes, whose snow-capped summit stands about 13,800 feet above sea level. This part of the range contains many small glaciers, some of which discharge north and some south of the watershed.

From Delta River to Mentasta Pass the range is unbroken, and its snow-covered crest line averages probably 7,000 to 9,000 feet in altitude. Here too it gives rise to glaciers, which are drained by Copper River or Tanana River (Pl. XII, *B*, p. 108). The elevation of Mount Kimball, the highest peak, is probably about 10,000 feet. Mentasta Pass is a broad, flat depression 3,000 feet high. From Mentasta Pass the range finds its continuation to the southeast as far as White River in the Nutzotin Mountains, which embrace a rugged area 100 miles in length and 40 miles in width. These mountains are bounded on the north by the alluvial flats of the Tanana and of White River and its tributaries and on the south in part by the Copper River valley, in part by a series of depressions separated by high passes which connect the tributaries of the Tanana and the White. The large valleys—those of Nabesna and Chusana rivers, which unite to form the Tanana—break the continuity of the range. The mountains have remarkably even crest lines which stand at elevations between 7,000 and 8,000 feet, but above this level rise several peaks that are 9,000 to 10,000 feet high. Besides the larger transverse rivers mentioned above, many smaller watercourses sharply dissect the range. The southeastern termination of the Nutzotin Mountains is usually placed at the White River valley, but the same axis of uplift is continued to the southeast by lower mountains which skirt the southern border of Lake Kluane.

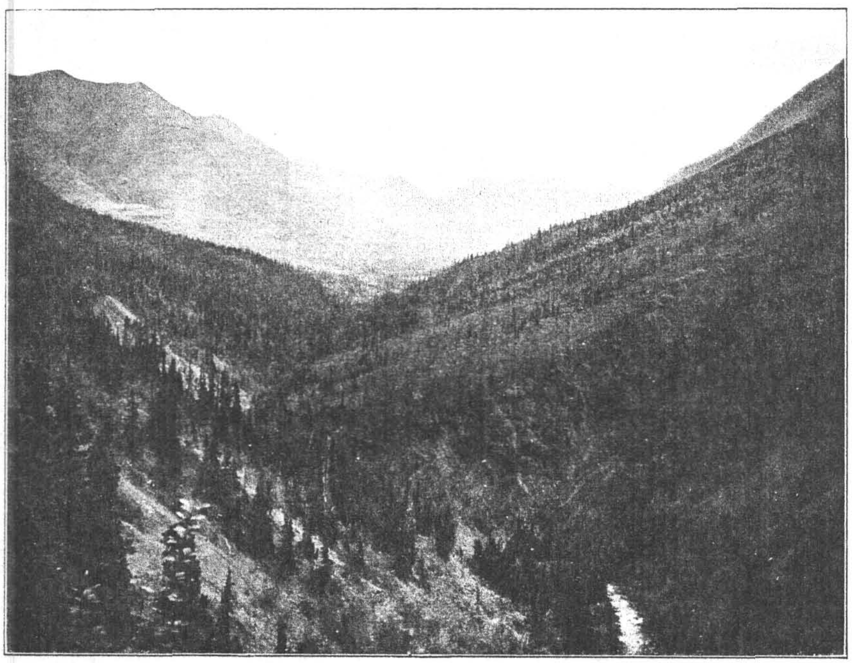
### PIEDMONT PLATEAU.

The north and west fronts of the Alaska Range slope down abruptly to a plateau which stands at 2,500 to 3,000 feet above sea level (Pl. VI, *B*). This topographic feature is well marked along the west front of the range, where it faces the Kuskokwim basin. Here the

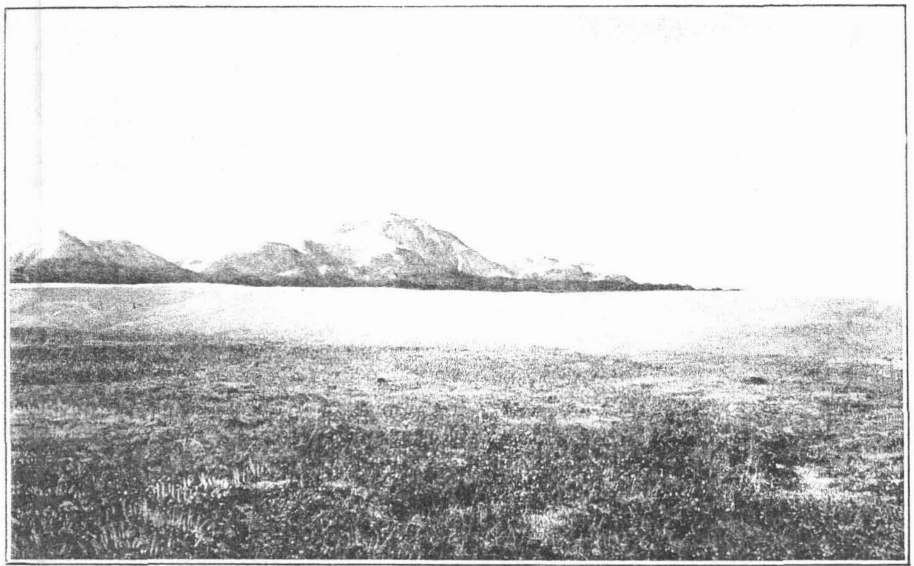
[1] Named by the writer after W. H. Dall.
[2] Named by the writer after I. C. Russell.
[3] This region was surveyed in 1910 by J. W. Bagley, D. C. Witherspoon, and E. C. Giffen, of the U. S. Geological Survey.



*A.* TATINA RIVER VALLEY, KUSKOKWIM BASIN.
Camp of July 17. See page 18.

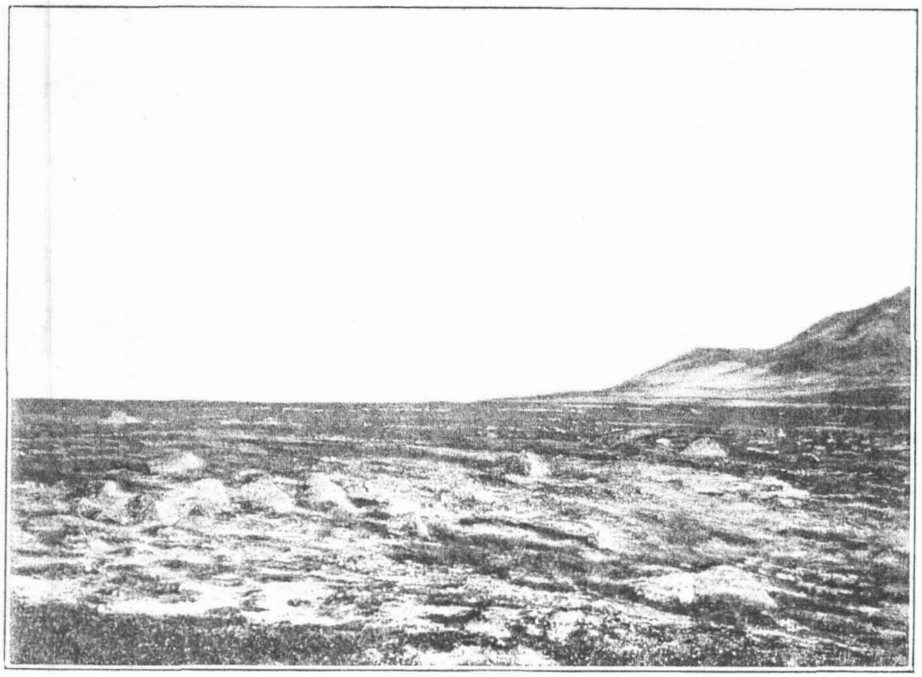


*B.* VALLEY OF DALZELL CREEK, LOOKING SOUTHEAST.
Near camp of July 15. Rainy Pass in the distance. See page 46.



A. MOUNT McKINLEY (IN THE CENTER) FROM THE NORTH.

Mount Foraker to the right, in the distance; Piedmont gravel-floored plateau in the foreground. Near camp of August 8. See page 46.



B. PIEDMONT GRAVEL PLATEAU AT NORTHWEST BASE OF ALASKA RANGE.

Showing glacial erratic bowlders. Near camp of July 29. See page 46.

surface of the plateau, which slopes gently away from the mountains, is remarkably even, being broken only by the valleys of the streams which have dissected it and by outliers of the highlands which rise here and there island-like above it. The surface of the plateau is for the most part above timber line and is covered with moss, affording excellent pasturage for the herds of caribou that wander across it.

The plateau is underlain by gravels and sands which have been deeply dissected by the streams. In these materials the larger watercourses have cut broad trenches; in some places the underlying bed rock is exposed. Some of the larger valleys are half a mile wide, and all have steep slopes. The waterways have in general parallel northerly courses across the plateau, modified in places by the obstructions caused by the outliers of the mountains.

The general slope appears to be unbroken to the timbered lowland of the upper Kuskokwim basin, a distance of 20 to 30 miles. This part of the area was not visited by the writer, and it is possible that the plateau here ends in an inland-facing escarpment, as it does on the Tanana.

East of the Toklat basin the route of travel lay within the mountains, and no opportunity was afforded of studying the piedmont plateau, but on emerging from the mountains east of Nenana River the party observed similar features. Here the plateau is represented by the remnants of a great gravel terrace which mantles the mountains along the southern border of the Tanana Valley (Pls. XII, *A*, p. 108; XIII, *A*, p. 120). The surface slopes gently toward the axis of the valley, ending about 10 miles from the mountain front in a steep escarpment, hence the scattered terrace remnants. The investigations of Mr. Prindle and the reports of prospectors indicate that similar heavy gravels extend eastward to the Delta Valley.[1]

### KUSKOKWIM LOWLAND.

The drainage of the inland front of the Alaska Range is carried to Kuskokwim River by many tributaries, some of which reach well back into the mountains. Most of these streams are tributary to the East Fork of the Kuskokwim, which in turn joins the main Kuskokwim about 30 miles from the mountains. The main stream rises in the unexplored region north of Lake Clark; the East Fork in a flat which has been termed the Kuskokwim lowland. This lowland embraces a broad, level-floored basin bounded on the east by the piedmont plateau and on the west by an unexplored highland area in which lies the Yukon-Kuskokwim divide. On the south the lowland gradually narrows down until it merges into a well-defined valley about 30 miles below the junction of the East Fork and the main Kuskokwim. On the north the lowland is probably separated by only very low divides from the waters flowing into the Tanana.

This lowland is known to the writer only through observations made from the inland front of the Alaska Range, where it was seen sweeping toward some distant hills as a great forested flat, dotted here and there by lakes and open marshes. Across its surface meander many sluggish streams with numerous oxbow bends.

### TANANA LOWLAND.

That part of Tanana River below the mouth of the Delta traverses the northern portion of the Mount McKinley region, flowing westward. At Delta River the Tanana emerges from a rather narrow valley to a broad flat, here called the Tanana lowland, which widens toward the Yukon. This lowland is extended in the highlands north of the Tanana by many reentrants which mark the valley mouths of the larger tributaries of the river. On the south it is bounded by gravel terraces which are remnants of the plateau already described (Pl. VI, *B*), and near the mouth of the Tanana by an unexplored highland area. The largest of the northern reentrants is that of the Tolovana Valley, where there is a lowland 25 miles wide that stretches northward for 30 miles. Each of these tributary lowlands merges toward the north with the valleys of the confluent streams.

The highland rim north of the Tanana lowland in general rises steeply from the plain, which the river in most places hugs closely. This alluvium-floored lowland is locally heavily timbered

[1] This is verified by the observations made in this area in 1910 by S. R. Capps, of the U. S. Geological Survey.

and is dotted with numerous lakes and swamps, the relics of former watercourses. Some low hills that lie out in the flat are probably remnants of a gravel sheet which once filled much of its upper part.

From Delta River to the Yukon the lowland measures about 150 miles in an air line and its width varies from 10 to 30 miles. It stands 300 to 600 feet above sea level.

#### YUKON-TANANA UPLAND.

The region lying between the Tanana and the Yukon is characterized by broad, flat interstream areas 1,200 to 3,000 feet high, with scattered domes whose rounded summits stand between 4,000 and 5,000 feet above the sea. This region, the Yukon-Tanana upland, is a part of what has been called the Yukon plateau of Alaska, and lies in the central plateau region.[1] In this region the bed rock is characteristically buried by a deep mantle of residual soil, and outcrops only on the crest lines and in the smaller stream valleys. The large watercourses occupy broad valleys with gentle slopes, whose rock floors are mantled by a deep cover of alluvium. Some of the smaller streams have incised this mantle and flow in rock-bound canyons.

The part of this upland embraced in the Mount McKinley region includes an irregular area bounded by Tanana and Yukon rivers. Its ridges have a general uniform northeasterly trend, with valleys of two types—those parallel to the ridges, which are broad, with gentle slopes, and those transverse to the ridges, which are narrow and steep-walled. Near the Yukon there are modifications of the general topography, because here an older valley system has been deeply buried in silt deposits. The ridges are remarkably flat-topped, generally rising from about 1,000 feet in the lower part of the Tanana Valley to about 3,000 feet near Delta River.

Domes and rugged peaks rise above the general level of the ridges. The most conspicuous of these are Wolverine Mountain (Pl. VII, *B*) and some adjacent peaks south of Rampart, which are sharp and rugged and attain altitudes of 4,000 to 5,000 feet.

The Yukon has trenched this upland to a depth of 1,200 to 1,800 feet and its valley has a width of half a mile to 2 miles. The steep valley walls, broken here and there by terraces, have led to the designation "The Ramparts" for that part of the Yukon Valley lying between the flats and the mouth of the Tanana.

## GEOLOGY.

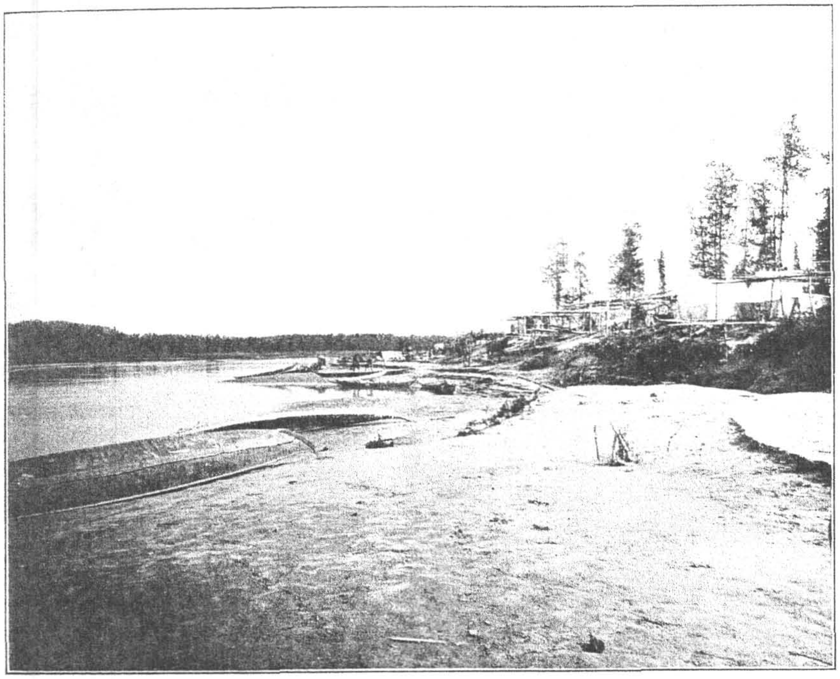
### INTRODUCTION.

Reference has been made in the foregoing narrative to the difficulties encountered during the journey, and these of necessity caused many interruptions to the scientific investigations. An exploration seldom affords favorable conditions for geologic research, and in a region like this, of stratigraphic and structural complexity, the data collected in a rapid journey are far from adequate for a satisfactory analysis of the many problems encountered. The absence of detailed studies was, however, in part compensated by the opportunity afforded for obtaining a comprehensive view of a large province. The geologic investigations whose results are here presented covered an area of nearly 10,000 square miles, stretching from the Pacific Ocean to the Yukon. This fact may justify certain correlations which would not be made if only a small part of the field had been under investigation by a single observer. The delay in the preparation of this report has had the advantage of making available the results of geologic studies that have been carried on in adjacent fields since the exploration was completed. This makes it possible to present a discussion of the salient features of the geology of an area of about 30,000 square miles, or three times as large as that actually investigated by the writer.

### OUTLINE OF GEOLOGIC INVESTIGATIONS.

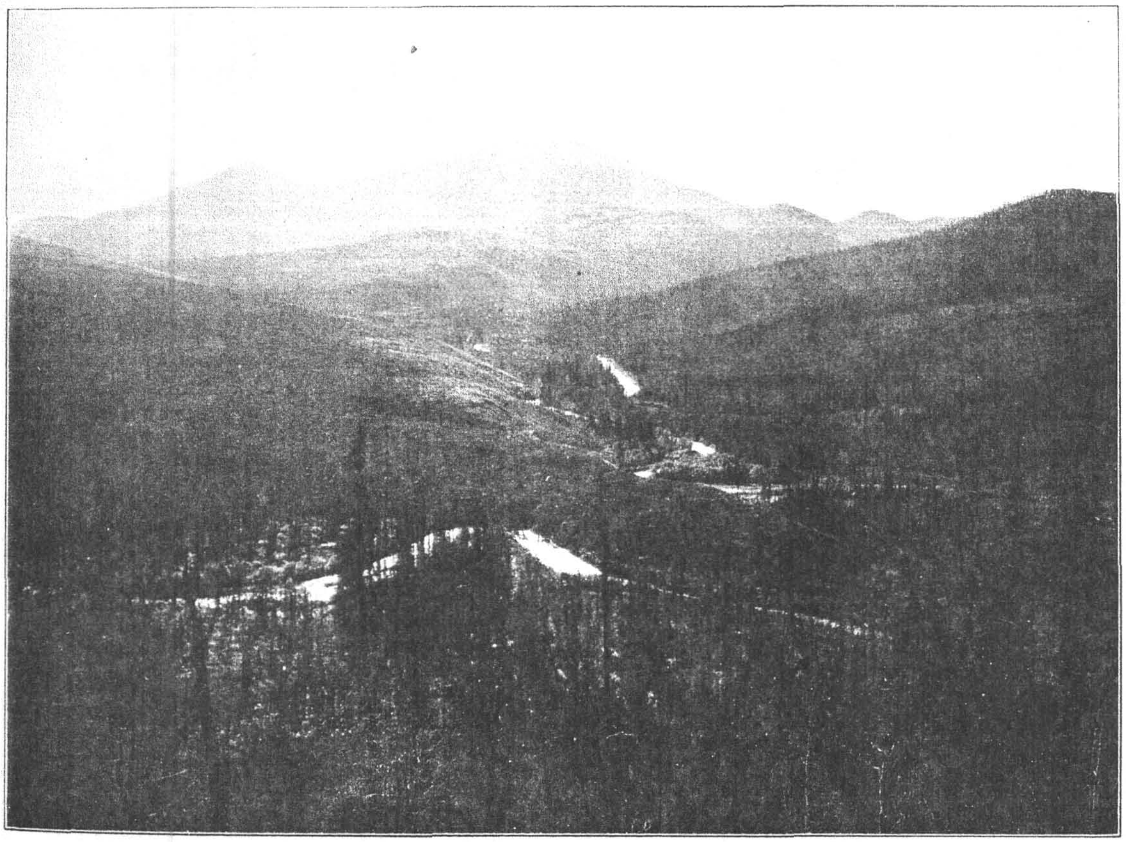
A number of the earlier explorers of Cook Inlet made desultory observations on the topography and geology which are chiefly of historical interest, but a noteworthy section of the Kenai sediments on the east side of the inlet was made by Von Wrangell and published by

[1] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 36–41.



A. TANANA RIVER AT TORTELLA.

Camp of August 29. See page 20.



B. WOLVERINE MOUNTAIN FROM THE EAST, LOOKING UP QUAIL CREEK VALLEY, YUKON-TANANA UPLAND.

Near camp of September 10. See page 48.

Grewingk.[1] The first systematic geologic studies in this field were those made by Dall[2] during his coastal explorations from 1879 to 1886. In 1895 Dall, in company with G. F. Becker, extended his observations in this region. The most important results of this investigation, so far as Cook Inlet is concerned, bore on the stratigraphy of the Tertiary coal-bearing sediments[3] and the distribution of placer gold.[4]

In an expedition already referred to, Mendenhall[5] in 1898 traversed Kenai Peninsula from Resurrection Bay and from Portage Bay to Cook Inlet, and then carried a reconnaissance up Matanuska River and down Delta River to the Tanana. Besides working out the general physiographic history of the region, he proved the extensive development of metamorphic sedimentary rocks in Kenai Peninsula and the Alaska Range and also the presence of Mesozoic strata in the Matanuska Valley. In the same year Spurr[6] explored the Skwentna basin and a part of the upper Kuskokwim. His most important results, so far as they bore on the area here considered, were the division of the component strata of the Alaska Range into different formations, the determination of the synclinal character of the folding, and the proof that intrusive rocks form an important element of these mountains.

At the same time Eldridge[7] carried an exploration up the Susitna and into the Tanana basin. He determined the presence of and described the Cantwell conglomerate (here termed the Cantwell formation and provisionally assigned to the Carboniferous) and found extensive areas of slates in the Susitna basin.

The work of 1902 included not only the studies set forth in this paper but also an important investigation by Mendenhall[8] in the Copper River basin to the east. The results of Mendenhall's work showed that the metamorphic schists previously discovered by him along Delta River extend eastward, forming the backbone of the Alaska Range, and are separated from a belt of Paleozoic rocks on the south by a profound fault. One of the most important facts brought out by this investigation was the presence in this region of some 7,000 feet of "Permian" strata, later proved to be of Pennsylvanian ("Upper Carboniferous") age.

Robert Dunn, who accompanied the first Cook expedition (1903), made geologic observations along his route of travel from the Muldrow Glacier on the north side of the range to the Chulitna on the south. His notes, which he kindly placed at the disposal of the writer, recorded a belt of conglomerates and volcanic rocks succeeded on the south by a zone of quartzites and limestones and these separated from the Chulitna Valley by an extensive area of slates with some intrusive rocks.

Martin[9] in 1903 and in cooperation with Stanton[10] in 1904 determined the Mesozoic sequence in the region southwest of the Mount McKinley area. In 1904 Moffit and Stone[11] obtained much additional information on the geology of Kenai Peninsula. The general distribution of the Tertiary and Mesozoic rocks in the Matanuska Valley was determined by Martin[12] in 1905 during the course of a rapid reconnaissance, in which he obtained also a more thorough knowledge of the coal beds. Paige and Knopf[13] completed the reconnaissance mapping in this field and carried it into the Talkeetna basin. Their investigations determined the stratigraphic sequence from the metamorphic slates to the recent deposits, two divisions of the

[1] Grewingk, C., Beiträge zur Kenntniss der orographischen und geognostischen Beschaffenheit des Nordwest Küste Amerikas mit den anliegenden Inseln [with geologic and other maps], St. Petersburg, 1850, p. 39.

[2] Dall, W. H., Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 232-268.

[3] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 763-908.

[4] Becker, G. F., Reconnaissance of the gold fields of southern Alaska, with some notes on general geology: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 81-82.

[5] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 265-340.

[6] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Idem, pp. 31-264.

[7] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska: Idem, pp. 1-30.

[8] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906.

[9] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: Bull. U. S. Geol. Survey No. 250, 1905.

[10] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, pp. 391-410.

[11] Moffit, F. H., and Stone, R. W., Mineral resources of Kenai Peninsula, Alaska: Bull. U. S. Geol. Survey No. 277, 1906.

[12] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906.

[13] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907.

Jurassic, one of the Cretaceous, and one of the Tertiary being recognized. They also showed that the Talkeetna Mountains consist for the most part of a huge granite batholith.

Geologic investigation in the northern part of the Mount McKinley region was begun by Spurr,[1] who in 1896 made a reconnaissance down the Yukon and into adjacent areas. He visited the Rampart district and made some important contributions to the knowledge of the geology of the entire province. Many of the stratigraphic subdivisions which he proposed are still in use. The writer[2] in 1898, while exploring Tanana River, determined the presence of extensive areas of schists on the lower Tanana, together with a younger unconformable sedimentary series.

From 1903 to 1909 Prindle[3] was engaged in mapping the general geology of the region lying between Yukon and Tanana rivers, and in 1906 he extended his work south of the Tanana to the base of the Alaska Range. In association with E. M. Kindle, the writer[4] in 1906 studied the geology of the upper Yukon and an area between Circle and Fairbanks and Fairbanks and Rampart.

As this volume goes to press a few changes and corrections have been made based on the surveys of 1910, the detailed results of which are not yet available. In 1910 G. C. Martin, assisted by F. J. Katz and Theodore Chapin, made a detailed geologic survey of a part of the Matanuska coal field. F. H. Moffit, assisted by B. L. Johnson, carried a geologic reconnaissance survey along the southern base of the Alaska Range, between the Fairbanks trail and Valdez Creek, and S. R. Capps did similar work north of the mountains, between Nenana and Delta rivers.

As a result of all these investigations the general stratigraphic succession in this part of the Yukon basin, beginning with an older metamorphic series called the Birch Creek schist and extending through the Carboniferous, has been fairly well established. This is especially true of the Carboniferous strata. The Devonian beds are less well known, and Ordovician and Silurian fossils have been found in only a few localities. Considerable light has also been thrown on the distribution of some Jurassic-Cretaceous slates and on the problems connected with the Tertiary sediments and with the recent geologic history of the province.

As has been stated and as is indicated by the geologic map (Pl. IX, in pocket), the investigations of the field under consideration form a connecting link between the studies carried on by one group of men in the Cook Inlet region and those by another group in the Yukon-Tanana region. It is one purpose of this paper to discuss the broader correlations between these fields. This discussion will be the first attempt to present a systematic account of the geology of the region between the Pacific and the Yukon, and as much of the field is unknown or at best but imperfectly known, it is obvious that only tentative conclusions can be reached.

## OUTLINE OF GEOLOGY OF CENTRAL ALASKA.

The term central Alaska can be conveniently used to designate the region lying between the Pacific and the Yukon and bounded on the east by the international boundary and on the west by the one hundred and fifty-fourth meridian. The Mount McKinley province as here defined forms the western part of the central Alaskan region. With the purpose of presenting the broader relations of the problems here to be discussed, the geology of central Alaska will first be considered. The sketch map (Pl. VIII) graphically summarizes the salient geologic features of this field.

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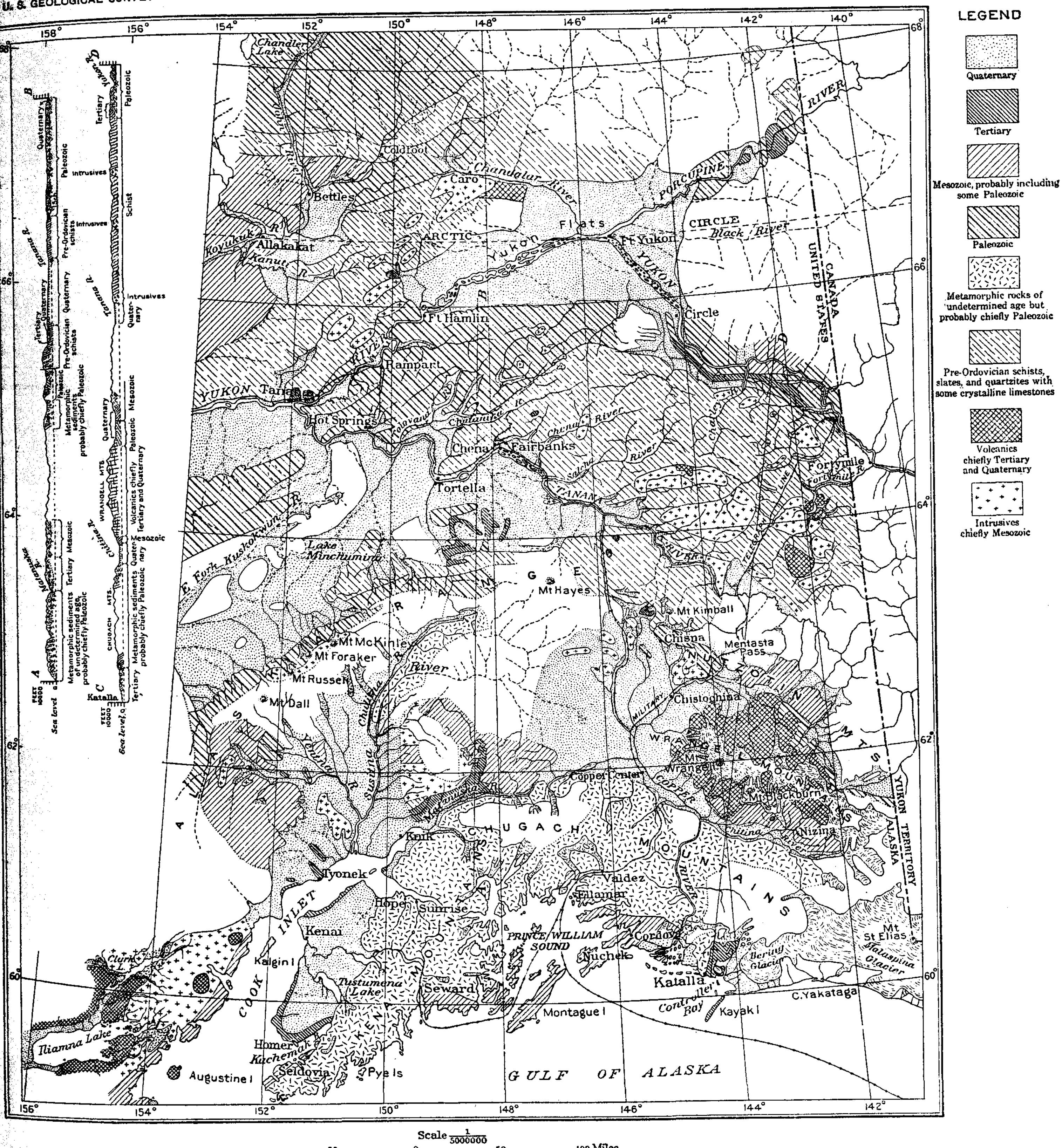
[1] Spurr, J. E., Geology of Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 87–392.

[2] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 425–494.

[3] Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 251, 1905. Prindle, L. M., and Hess, F. L., The Rampart gold-placer region, Alaska: Bull. U. S. Geol. Survey No. 280, 1906. Prindle, L. M., The Yukon-Tanana region, Alaska—Description of Circle quadrangle: Bull. U. S. Geol. Survey No. 295, 1906; The Bonnifield and Kantishna regions: Bull. U. S. Geol. Survey No. 314, 1907, pp. 205–226; The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908; Occurrence of gold in the Yukon-Tanana region: Bull. U. S. Geol. Survey No. 345, 1908, pp. 179–186; The Fortymile quadrangle, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 375, 1909. Prindle, L. M., and Katz, F. J., The Fairbanks gold-placer region: Bull. U. S. Geol. Survey No. 379, 1909, pp. 181–200.

[4] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 255–338.




GEOLOGIC SKETCH MAP OF CENTRAL ALASKA, WITH SECTIONS.

See page 50.

### METAMORPHIC ROCKS.

What are believed to be the oldest rocks in this region are a series of closely folded schists and quartzites, with subordinate crystalline limestone masses and considerable igneous material, which stretch as a broad zone westward from the international boundary nearly to the Yukon below the big bend. These are mantled by the younger Paleozoic rocks. Within these metamorphic schists occur many bodies of intrusive granites of at least two ages. The younger granites (to be discussed below) are shown on the map; the older, which are represented by gneisses and gneissoid granites, are not differentiated from the other metamorphic rocks.

These rocks extend to the southwest in a narrow zone which forms the east end of the Alaska Range and, continuing westward, are found in a foothill belt north of the mountains, finally passing underneath the Quaternary deposits of the Kuskokwim lowlands. A second area of metamorphic rocks, probably equivalent in age to those described above, lies north of the Yukon. Both are provisionally correlated with the pre-Ordovician quartzites and slates exposed along the Porcupine Valley near the international boundary.

Another broad belt of closely folded metamorphic sediments skirts the Pacific seaboard and forms the southern boundary of the region. These comprise slates, phyllites, quartzites, conglomerates, and graywackes, and are considerably less altered than the metamorphic rocks of the Yukon. This metamorphic belt as mapped on Plate VIII includes some Mesozoic rocks, but most of the series is known to be pre-Jurassic and is probably Paleozoic. Rocks of a similar character occur in the upper Susitna basin, where they probably occupy a considerable area.

### PALEOZOIC ROCKS.

The largest areas of Paleozoic rocks of the province occur in the Yukon basin, where Ordovician, Silurian, Devonian, and Carboniferous formations have been recognized. It should be noted, however, that the data regarding the stratigraphy of the rocks below the Middle Devonian are very fragmentary. These older formations are much altered and are more closely folded than the Middle Devonian or later Paleozoic rocks. The Paleozoic strata above described lie north of the metamorphic belt, and another area, probably made up of the same terranes, bounds the metamorphic rocks on the south.

The Paleozoic rocks exposed along the northwestern front of the Alaska Range are known to include Ordovician, Devonian, and probably some Silurian and Carboniferous strata, and are intensely folded and faulted. At the head of Copper River the Paleozoic is represented chiefly by Carboniferous rocks.

### MESOZOIC ROCKS.

The Mesozoic strata are extensively developed in central Alaska. On the upper Yukon occur slates and quartzites of Lower Cretaceous age,[1] and in the Rampart region are some small areas of Upper Cretaceous sandstones and shales. At the head of Copper River and in the adjacent areas Triassic and later Mesozoic rocks are extensively developed. These beds appear to form a broad belt caught up in the synclinorium which marks the structure of the Nutzotin Mountains. The same formations are exposed on the south side of the Wrangell Mountains, whose structure is probably synclinal. (See section *C–D*, Pl. VIII.) In the Matanuska basin and in the eastern part of the Susitna basin two Jurassic formations and one of Lower Cretaceous age have been found. Middle Jurassic beds also occur in the Alaska Range, where they occupy a broad synclinorium in the heart of the mountains. In the coastal region of Kenai Peninsula and Prince William Sound the Orca group, made up of slates and graywackes and provisionally referred to the Mesozoic, is extensively developed.

### TERTIARY DEPOSITS.

The Tertiary deposits of central Alaska probably belong chiefly to the Kenai formation (upper Eocene) and are fresh-water beds, in large part of fluviatile origin. A series of such deposits occurring along the Yukon and in the Cook Inlet region is believed to mark the

[1] The beds carrying *Aucella crassicolis* Keyserling which Stanton assigns to the Upper Jurassic or Lower Cretaceous will here for convenience be called Lower Cretaceous.

position of the Tertiary drainage. On Alaska Peninsula some marine Eocene beds have been found. Though most of these Eocene deposits are only slightly deformed, some are intensely folded and faulted. In addition to these fresh-water Eocene beds, a closely folded series of Tertiary deposits occurs east of the Copper and near the Pacific coast which carries a marine fauna provisionally assigned to the Miocene. Rocks of Miocene age have also been found on the Alaska Peninsula.

### QUATERNARY DEPOSITS.

Quaternary deposits occupy large areas in central Alaska, including preglacial, glacial, and postglacial material. The most extensive are the silts, sands, and gravels deposited during the retreat of the ice sheet, and these are probably of Pleistocene age. Since their deposition they have been deeply dissected. (See Pl. XIII, *A*, p. 120.) In the Yukon basin there are some high gravels which may be Pleistocene or older. The Recent deposits comprise chiefly those of the present watercourses.

### VOLCANIC ROCKS.

There are two important centers of volcanic acitvity in Alaska—one in the Wrangell Mountains and the other in the Aleutian Range. The ejecta of the former occupy an area of 5,000 or 6,000 square miles in the Copper River basin near the international boundary. These effusive rocks are in part Quaternary, in part Tertiary, and some may be as old as Mesozoic. There are several active volcanoes in the Wrangell Mountains.

The Aleutian Range includes a series of volcanoes, some still active, which stretches through the chain of islands of the same name and extends northeastward as far as Redoubt Volcano, on Cook Inlet. The northernmost end of this belt of volcanism is shown on the map (Pl. VIII). Like those of the Wrangell Mountains, the volcanic rocks of the Aleutian Range include both Tertiary and Quaternary lavas and possibly some of Mesozoic age. It is of interest to note that if the Wrangell and Aleutian volcanic rocks are connected by a line paralleling the major structures of the province it will pass through an area of Tertiary or recent lava flow (too small to show on the general map) which lies along the eastern margin of the Talkeetna Mountains. (See geologic map of Mount McKinley region, Pl. IX, in pocket.)

### INTRUSIVE ROCKS.

The intrusive rocks shown on the map are chiefly granites, granodiorites, and diorites. For convenience of description, they will be referred to here as granite. South of the Yukon basin they are distributed along two general axes. One of these passes through the central part of the Alaska Range and is continued southeastward by the granite stocks of the upper part of the Copper River basin. A further extension of this axis would carry it into the Coast Range intrusive belt of southeastern Alaska. A second axis is defined by the granites of the Iliamna Lake region, the Mount Susitna stock near the upper end of Cook Inlet, the batholith of the Talkeetna Mountains, and the stocks lying near the southern margin of the Copper River basin. A third axis may be defined by the granitic rocks which are intrusive in the metamorphic belt southeast of Fairbanks. The granites of the Alaska Range and the Talkeetna Mountains are in part Middle Jurassic, and it seems probable that the others represent about the same epoch of intrusion. It should be noted, however, that granites cut the Upper Cretaceous rocks of the Rampart region and that there is no proof that the granites of the upper Copper basin are later than upper Carboniferous. It is perhaps fair to assume that there was a general period of intrusion, beginning possibly in late Paleozoic time and in some parts of the province extending through to the Upper Cretaceous, but having its maximum development late in the Jurassic period. In the Yukon-Tanana region, as already stated, there are some gneissoid granites which belong to an older period of intrusion.

### STRUCTURE.

The trend of the bed rock in this region is parallel to the Pacific coast line and to the dominant mountain axes. In the western part of the province it is northeastward, then gradually bends to the east and finally to the southeast. In other words, the dominant strike lines mark a crescent opening toward the Pacific. (See Pl. VIII.) The metamorphic sediments of the Chugach and Kenai mountains are closely folded and east of Copper River are flanked on the seaward side by closely folded and intricately deformed Miocene beds. (See section, Pl. VIII.) The scant evidence indicates that the structure of the coastal system of mountains is of a general synclinal character. North of these are the Mesozoic beds, thrown into broad, open folds, broken in the Talkeetna Mountains by a huge granite batholith, and in the Wrangell Mountains covered in part by thousands of feet of Tertiary and recent volcanic rocks. The structure of the Alaska Range is synclinal, accompanied by profound faulting in the western limb. Mesozoic formations are involved in this folding and also some Tertiary beds.

A belt of metamorphic rocks lying south of and adjacent to the Tanana Valley probably marks another anticlinal axis. North of this valley lies the main zone of metamorphic rocks, which are closely folded but are believed to have the structure of an anticlinorium, and are bounded on the northwest by Paleozoic rocks. These Paleozoic strata are less intricately folded than the metamorphic rocks. They comprise at least two unconformable series, the lower of which is more intricately folded than the upper.

## CORRELATIONS.

The accompanying provisional table of correlations is an attempt to epitomize the stratigraphy of central Alaska so far as the evidence at hand will permit. Thanks to the stratigraphic work of the geologists who have investigated this field, but more especially to the paleontologic studies made by Stanton, Kindle, Schuchert, Knowlton, and Girty, the data here set forth are presented with a far greater degree of confidence than could have been done had the report been prepared immediately after the close of the field work in 1902. Yet much remains to be done, and at present a large part of the data presented in the table can be considered little more than suggestive. Besides the usual difficulty of making correlation in the absence of detailed studies and extensive fossil collections, the paleontologist and stratigrapher are in this region confronted with an additional handicap in the fact that the faunas of some of the horizons, notably in the Silurian and Carboniferous, are foreign to those known to occur in other parts of the continent, their affinities being rather Asiatic and European than North American. This biologic phase of the problem lends a fascinating interest to the work but greatly increases the labor of the paleontologist who is specializing on North American stratigraphy. But few members of the Geological Survey have yet found the time to study exhaustively even the collections that have been made. Many of the assignments in this table to definite positions in the stratigraphic column must therefore be regarded as provisional, but with regard to correlation between different parts of the region there are a number of horizons, especially in the Mesozoic and upper Paleozoic, whose synchrony is well established.

In addition to the paleontologic and lithologic evidence on which the terranes are correlated, certain phases of the dynamic history have been of much aid in establishing the equivalency of some rock groups and formations. Thus the rocks earlier than Middle Devonian include only strata which have suffered more or less metamorphism. The lower Carboniferous formations were separated from later rocks by what is believed to have been a widespread interval of erosion. Lower Cretaceous time is marked off from later epochs by an extensive crustal disturbance.

In the later pages of this report the character of the evidence on which the more important correlations are based is considered in detail. The fossiliferous formations are indicated in the table, and where the fossils appear to have little stratigraphic value they are noted as incomplete or fragmentary.

The data presented have been compiled mainly from the reports or unpublished notes of others. The writer has not hesitated to put his own interpretation, where the facts seemed to warrant, on the published sections and statements, and thus attempt to bring them into harmony with the stratigraphy of adjacent areas.

## AREAL AND STRATIGRAPHIC GEOLOGY.

### INTRODUCTION.

In this section the formations indicated on the map (Pl. IX, in pocket) will be considered in their areal and stratigraphic relations. The matter to be presented will be chiefly descriptive, but the probable correlations with the rocks of other parts of central Alaska will be pointed out. For a discussion of the physical conditions existing during the various epochs, involving the more theoretical considerations, the reader is referred to the outline of geologic history (pp. 113–118). The lithology of the igneous and metamorphic rocks will receive only brief mention here, as it is treated in detail by Mr. Prindle on pages 136–154.

Before outlining the stratigraphy of central Alaska it should be noted that this region embraces three different geologic provinces, between which correlations of only part of the sequence of strata have been established.

In the southern portion of the region the Mesozoic rocks, from Middle Jurassic to Cretaceous, are well developed, and there are also an older metamorphic series and younger Tertiary beds, together with large areas of granitic rocks. In this area Paleozoic rocks have not been definitely recognized, though some sediments have been provisionally assigned to this era. The metamorphic rocks, which comprise sediments as well as igneous rocks, are probably early Paleozoic or pre-Paleozoic.

Along the inland front of the Alaska Range is a great belt of closely folded and profoundly faulted Paleozoic sediments. Paleontologic evidence shows that these rocks include Ordovician and Devonian formations, and it is believed that the Silurian and Carboniferous are also represented. On tracing the belt to the northeast the younger Paleozoic strata are found in unconformable relation with metamorphic sediments here assigned to the pre-Ordovician. No Mesozoic rocks have been found in this part of the region, but some younger beds, assigned to the Tertiary on the evidence of plant remains, occur infolded with the Paleozoic rocks. Extensive faulting characterizes the structure of this area, Devonian and what are probably Ordovician strata being thrust up over the Tertiary beds.

In the region lying north of the Tanana there is a series of highly altered and closely folded sediments, termed the Birch Creek schist, which are succeeded, probably unconformably, by a sequence of fragmental rocks, together with greenstones and limestones. The Birch Creek schist is provisionally assigned to the pre-Ordovician; the succeeding rocks with an almost equal degree of uncertainty to the Silurian or Devonian. Under the Devonian of this area are grouped a heavy blue limestone, locally fossiliferous, and slates. The relation of these beds to the Silurian rocks has not been determined. The Mesozoic is represented by small areas of slates and conglomerates of Upper Cretaceous age resting on a quartzite which may be Lower Cretaceous. Some friable conglomerates, sandstones, and shales, with lignitic coal beds, are referred to the Eocene on the evidence afforded by fossil plants. All these rocks except the Tertiary beds are closely folded. The deformation of the Birch Creek schist was far more intense than that of the later formations, the folds being for the most part overturned to the northwest.

In the following table an attempt is made to harmonize the rock sequence in the three areas above described, in order to furnish a summary of the stratigraphy for the purpose of elucidating the detailed descriptions.

*Stratigraphy of Mount McKinley region.*

| System. | Series. | Group or formation. | Description. | |
|---|---|---|---|---|
| Quaternary. | Recent. | | Silts, sands, and gravels. | Include some glacial deposits. |
| | Pleistocene. | | Terrace silts, sands, and gravels. 50–2,000± feet. | |
| Tertiary. | Post-Eocene. | | Basaltic lavas in Talkeetna region (1,000+ feet) and diabase dikes in Alaska Range. | |
| | Eocene. | Kenai formation. | Conglomerates, sandstones, and shales, with coal beds, widely distributed. Carbonaceous slates and sandstones in Alaska Range. 150–10,000+ feet. | |
| Cretaceous. | Upper Cretaceous. | | Black slates and conglomerates in Rampart region. 100–300+ feet. | |
| | Lower Cretaceous. | | Quartzites in Rampart region, age uncertain. Limestones in Matanuska basin. 300 feet. | |
| Jurassic. | Upper Jurassic. | | Granites, granodiorite, and diorites, widely distributed. | |
| | Upper and upper Middle Jurassic. | | Shales, sandstones, conglomerates, arkose, and tuffs in upper Matanuska basin. 2,000+ feet. | |
| | Middle Jurassic. | Tordrillo formation. | Conglomerates, grits, sandstones, slates, and shales, and shales with some tuffs, in Alaska Range and Matanuska basin. 2,000–3,000+ feet. | |
| | Lower Middle Jurassic. | Skwentna group. | Andesitic, basaltic, and other lavas and tuffs, with some sediments, in Alaska Range and Talkeetna region. 1,000–4,000+ feet. | |
| Carboniferous(?) | | Cantwell formation. | Heavy chert and quartz conglomerates, sandstones, and slates, with some volcanic rocks, in Alaska Range. Age uncertain. 2,000+ feet. | |
| Devonian. | Middle Devonian (?). | | Heavy fossiliferous limestone, with some argillites, in Alaska Range and Yukon-Tanana region. 200+ feet. | |
| Devonian or Silurian. | | Tonzona group. | Black, red, and green argillites and cherts, with some graywackes, along inland front of Alaska Range and in Yukon-Tanana region. Age uncertain. 4,000–5,000± feet. In upper Nenana basin some gneisses (altered rhyolites) are associated with these rocks. | |
| Ordovician. | | Tatina group. | Blue limestones interbedded with black carbonaceous argillites and thin-bedded siliceous limestones and calcareous slates, along north front of Alaska Range. Ordovician fossils found in argillites. 4,000–5,000+ feet. | |
| (?) | | | Along the south front of the Alaska Range there are large areas of undifferentiated sediments, probably chiefly Paleozoic. Slates, phyllites, and graywackes, with some volcanic and intrusive rocks, in Knik Arm region and Susitna basin. Probably Paleozoic. | |
| (?) | | Birch Creek schist. | Mica, graphitic, and quartz schists, and schistose quartzites, with some limestone and intrusive rocks, in Yukon-Tanana region and northeastern part of Alaska Range. Age uncertain; probably pre-Ordovician. | |

## GEOLOGIC RECONNAISSANCE MAP.

A graphic epitome of the areal geology and stratigraphy of the region, so far as known, is presented on the geologic reconnaissance map (Pl. IX, in pocket). It can not be too strongly emphasized that the mapping and implied correlations and age determinations have by no means the same value throughout the area here represented. The geologic mapping of the Matanuska and Talkeetna basins, being reduced from a map by Paige and Knopf,[1] the stratigraphy of which is based in a large measure on fossil evidence, is probably in general correct. The correlation of the metamorphic rocks of Turnagain and Knik arms with those of the upper Susitna basin, however, is only provisional. Eldridge's hasty exploration[2] and some fragmentary notes by Robert Dunn furnished the data for the geology of the upper Susitna basin,

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, Pl. II.

[2] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, map 3.

and this part of the map will probably be considerably changed when areal mapping is undertaken.

The geologic coloring and the implied correlation for the southwestern part of the region, including the basins of Yentna and upper Kuskokwim rivers, are based on work by Spurr[1] and the writer, and are far from being considered final, even to the scale of the map. The boundaries of the Jurassic rocks and their relations to the older rocks are fairly well established, but the structure and stratigraphy of the other formations are very imperfectly known. The same general criticism applies to the mapping along the inland front of the Alaska Range as far as Tanana River. The boundary between the two Paleozoic series and the pre-Ordovician sediments is probably approximately correct, as is the delineation of the Cantwell formation (Carboniferous?). The mapping of what are believed to be Tertiary beds infolded with the Paleozoic rocks is intended to be suggestive rather than to indicate the outline of occurrences actually traced. These Tertiary beds, chiefly slates with some sandstones, whose age determination rests on fragmentary plant remains, closely resemble some of the Paleozoic rocks. The margins of the intrusive stocks indicated on this part of the map have only in part been traced, and there are probably many others within the heart of the range.

The geology of the area lying north of the Tanana is based on the work of a number of investigators (see p. 50) during the last decade. In this region, with its deep residual soils mantled by vegetation and its broad alluvium-filled valleys, outcrops of bed rock are so scarce as to make the tracing of formation boundaries difficult or in places impossible, even when detailed surveys are made. The mapping of the rock formations in this region can therefore be regarded only as an approximation. The stratigraphic succession in this part of the field is by no means definitely established, though it is probable that Devonian and Silurian sediments and older schists are present.

Of the map as a whole it can be said that the distribution of the Mesozoic formations, of the intrusive rocks, and of most of the Tertiary beds is presented with considerable confidence as to its accuracy. Within the areas mapped as Paleozoic there may be included some younger or older rocks, but if such is the case they occur only in small bodies. The northern belt of metamorphic rocks, here called the Birch Creek schist, is fairly well known and is probably pre-Ordovician; those of the Susitna and Turnagain Arm region may in part or as a whole fall anywhere in the geologic column below the Jurassic, but are probably Paleozoic or older.

## METAMORPHIC ROCKS.

So far as known, the oldest rocks of the district are to be sought in the complex of metamorphic sediments and intrusive rocks called the Birch Creek schist. These include some gneisses formerly provisionally assigned to the Archean but now regarded as altered intrusive or extrusive rocks. The Birch Creek schist is probably pre-Ordovician, but no closer age assignment can now be made. In the southeastern part of the region there is another complex of sediments, including some intrusive and volcanic rocks, which are also much altered but not to so great an extent as the Birch Creek schist. These are known to be older than the Middle Jurassic and are provisionally referred to the Paleozoic. Similar groups of rocks occur along the upper Susitna, but less definite information is at hand concerning them.

There are, then, three areas of metamorphic sediments, one assigned to the pre-Ordovician and the other two doubtfully to the Paleozoic. The distribution and occurrence of these rocks are of economic interest, as they are locally known to be auriferous.

### BIRCH CREEK SCHIST.

#### CHARACTER AND DISTRIBUTION.

In the northern part of the region are several large areas of metamorphic rocks which are here grouped together under the name Birch Creek schist. The typical Birch Creek schist of the region is well developed in an area lying north of Fairbanks, where it is made up for the

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, maps 12 and 14.

most part of quartz and biotite schists that are closely folded and deformed. With these schists occur considerable masses of quartzite which grades into schistose quartzite and biotite schist. In a few localities lenses of crystalline limestone are included in the schists. Some greenstone masses, both massive and schistose, also occur in the schist area. In an eastern extension of this belt gneissoid granite is present in considerable areas surrounded by the schistose rocks. These granites, which were formerly supposed to be a portion of an older basal complex, are now regarded as infolded igneous rocks. So far as known, they do not occur in the Birch Creek schist within the area here described, but similar rocks are found in association with Paleozoic slates and cherts south of the Tanana. Stocks of massive granite are also present within the schist area.

The typical rocks of the Fairbanks area include mica schist, mica-quartz schist, schistose quartzite, and masses of micaceous quartzite, together with a small amount of highly crystalline limestone. (See Pl. XVII, p. 180.) Mica, including both biotite and sericite, forms the dominating mineral of the schist, which also contains considerable quartz and here and there some feldspar, together with some subordinate minerals which will not be considered here. The rock is finely foliated and as a rule highly contorted, and the unweathered specimen has a silvery-gray color. Considerable areas of this schist carry a large amount of carbonaceous matter, usually in the form of graphite. Though these rocks are typically schists, they grade into less altered phases which can be termed phyllites and in some cases slates. The weathered phases of the schist, which are the types most common in the region, are light gray to buff in color, locally stained red with iron. On decomposition they yield a micaceous yellow to reddish clay carrying considerable grit. Small quartz veins and stringers are present at most places in these schists, and some of them are iron stained, indicating the presence of pyrite.

The quartz schist is similar in every way to the mica schist except that it contains a very large percentage of quartz and is usually less sheared than the mica schist. The quartzite ranges from blue to gray in color and usually contains considerable mica and in places some feldspar. Greenstones, which are not very common in this part of the Yukon-Tanana region, appear to be largely altered diabasic or dioritic rocks and now occur for the most part as chloritic schist.

The Fairbanks area of schist is wedge shaped, opening out toward the east end of the region. It is bounded on the northwest by sediments here assigned to the Devonian or Silurian, which appear to rest on it unconformably. The southern boundary is formed by the alluvial flats of Tanana River. The schists of the Tanana area appear to be nonresistant to weathering and are characterized by a deep residual soil. The higher domes of this region (Pl. VII, *B*, p. 48) are for the most part granitic stocks, adjacent to which the schists are somewhat altered and more highly resistant to erosion.

The second belt of schist includes a narrow wedge-shaped area lying near the northwest corner of the region. It includes both schists and crystalline limestone.[1] The schist is made up of garnet, quartz, and mica; the limestone is highly crystalline and termed a marble. The eastern edge of this belt lies on the west wall of the valley of Big Minook Creek, and the belt appears to widen to the southwest, though it has been traced only a few miles. Similar rocks are exposed along the Yukon about 10 miles above the mouth of the Tanana, and these presumably represent a southwestern extension of the same belt.

Rocks believed to be of Silurian age bound the schist belt on both sides and probably rest unconformably on it. These rocks evidently differ from those of the Fairbanks area in having a very much larger amount of calcareous matter and in the entire absence of the quartzite phase. They resemble very much the metamorphic rocks of the east end of the Yukon-Tanana belt, to which reference is made below. Another belt of schist occurs along the Tanana below the mouth of Baker Creek. This is made up of phyllites, and it is not impossible that it may be of later age than the Birch Creek schist.

The foothills along the northern base of the Alaska Range, south of the Tanana Valley, are made up chiefly of a series of schistose metamorphic sediments, which are here provisionally

[1] Prindle, L. M., and Hess, F. L., The Rampart gold-placer region, Alaska: Bull. U. S. Geol. Survey No. 280, 1906, p. 18.

correlated with the Birch Creek schist and form the second extensive belt of these rocks within the Mount McKinley region. As in the Fairbanks area, the dominating types of rocks are sericite and quartz schists which are finely foliated and highly contorted. With these schists, however, also occur some fine-grained fragmental rocks, which differ from most of those found to the north in the fact that they have preserved in many places their planes of sedimentation and are therefore readily recognizable in the field as of clastic origin. These rocks are well exposed along a small creek which flows into Healy Creek, of the Nenana basin, about 2 miles from the main stream. Blue, red, green, and silvery curly phyllite and schist dominate in the rocks exposed in this section. The phyllite and schist are composed chiefly of mica and quartz and range from a finely foliated schistose rock to somewhat more massive quartzose phases. Interbedded with the schists are some gray and bluish metamorphic graywackes. In the hand specimens of these rocks can be seen small rounded grains of quartz and feldspar in a matrix of siliceous material, together with some muscovite. Although the genesis of these rocks is not without question, it seems most likely that they are altered sediments representing metamorphic phases of fine conglomerate or grit. Nothing resembling these rocks has been found north of the Tanana, and it is possible that they represent infolded members of the younger series. They resemble to a certain extent the graywackes of the Tonzona group (Silurian or Devonian). So far as observed, however, they appear to be an integral part of the schist and phyllite. Diabase and diorite dikes are of common occurrence, following for the most part the foliation planes of the schist.

This Tanana belt of Birch Creek schist has a width of about 10 miles along the Nenana, whence it stretches eastward into an unmapped region toward Delta River, probably widening, as will be shown below. It has also been traced to the southwest for about 20 miles and probably passes underneath the Quaternary deposits of the Kuskokwim Valley. It has been recognized by Prindle in the upper basin of the Kantishna region, where the rocks have about the same general character as those here described. In the Kantishna region Prindle[1] noted the presence of considerable crystalline limestone associated with these schists. So far as known, no limestones occur in the schists of the Nenana basin.

All the rocks above described are cut locally by quartz veins and stringers, but these are especially abundant in the more schistose phases. In exposures along the Tanana the writer has noted some calcite veins and quartz and calcite veins intergrown in the form of pegmatites, which cut the Birch Creek schist. This peculiar pegmatitic intergrowth of quartz and calcite has been seen only along the lower Tanana, but calcite veins are found here and there in other parts of the field. The quartz schists are in many places stained with iron, and some of them are known to carry gold and other metalliferous minerals. They are probably the source of the gold of the auriferous districts, for the Birch Creek schist forms the bed rock in the most important of the placer districts of the Yukon-Tanana region.

### STRUCTURE.

The general trend of the Birch Creek schist is northeastward, parallel to the dominant structure line of the northern part of the region. The dip of the foliation is usually to the southeast, though there are many local variations from this direction. All these rocks are closely folded and probably extensively faulted. Numerous minor faults have been observed, but in the absence of evidence of stratification or recognizable subdivisions of the series it is impossible to state of what magnitude the dislocations are. The deformation to which these rocks have been subjected has been intense. A single hand specimen may show an enormous number of crenulations. The lack of planes of stratification which characterizes most of the rocks of the period makes it impossible to work out any of the details of structure. It is probable, however, that they consist of innumerable closed folds overturned toward the northwest and much faulted.

[1] Prindle, L. M., The Bonnifield and Kantishna regions: Bull. U. S. Geol. Survey No. 314, 1907, p. 206.

#### AGE AND CORRELATION.

There is no direct evidence of the age of the Birch Creek schist. In the region lying north of the Tanana (within the area covered by the geologic map) the schists appear to be overlain unconformably by a group of sediments which are probably Silurian or Devonian. If the age determination of these sediments is correct, the Birch Creek rocks must be older than the Silurian. Their highly metamorphic condition suggests that they have been subjected to earth movements previous to the deposition of the younger strata.

In the section exposed along Porcupine River, north of the area considered here, Kindle has worked out the stratigraphic column of the Paleozoic with a fair degree of completeness. (See correlation table, p. 52.) The oldest fossiliferous formation along the Porcupine contains Ordovician fossils. Below this horizon Kindle found a series of black slate and quartzite which he regards as of pre-Ordovician age. They may be Cambrian or even pre-Paleozoic. The rocks along the Porcupine are entirely unaltered, but if they were metamorphosed they would resemble closely the Birch Creek schist, which is for that reason provisionally correlated with them. This evidence, so far as it goes, indicates that the Birch Creek schist is pre-Ordovician and may possibly be pre-Cambrian.

The recent studies of Keele [1] in the Mackenzie Mountains, between Yukon and Mackenzie rivers, have furnished some new evidence on the age of the metamorphic rocks of the Yukon basin. Keele [2] found Middle Cambrian fossils in some limestones which are associated with dolomites, purple and green argillites, and calcareous sandstones.[3] This group he considers younger than the more highly altered rocks of Pelly River, which are here correlated with the Birch Creek schist. If these interpretations of the stratigraphy and the correlations are correct, they would go to prove that the Birch Creek schist is older than the Middle Cambrian.

The Fairbanks area of Birch Creek schist represents the west end of the great belt of metamorphic rocks stretching westward from the international boundary and including most of the area lying between the Yukon on the north and the Tanana on the south. Spurr, who first described these rocks, gave the name Birch Creek "series" to a complex of quartzite, quartzite schist, and mica schist which is extensively developed in the Birch Creek placer district, northeast of the area here considered. These metamorphic rocks form a continuous belt from the Birch Creek region to the Tanana at Fairbanks, though at the southwest end of the belt they seem to be somewhat more schistose and to contain less of the arenaceous material. The identity, therefore, of this area of Birch Creek schist with those originally described by Spurr [4] can not be called in question. Prindle has also found by field observation that there is a continuous belt of metamorphic rocks extending from the Birch Creek region eastward to the international boundary. Near the boundary, however, the metamorphic rocks are more largely made up of marble and garnetiferous schists than they are farther west. Spurr, who recognized this fact, regarded these calcareous sediments as representing a higher formation than the Birch Creek schist, and termed them the Fortymile series.[5] A more detailed study of this area by Prindle has failed to prove definitely that the Fortymile "series" is distinct from the Birch Creek schist. The Fortymile may represent a higher member of the metamorphic series, or it may represent a more calcareous phase of the Birch Creek schist due to differences of physical conditions during deposition. In 1898 the writer [6] traversed the same belt of rocks east of the international boundary, along the valley of White River. Here the metamorphic sediments include mica-quartz schist, together with a broad belt of marble. The haste of the reconnaissance work in this field made it impossible to differentiate the marble and schist belt

[1] Keele, Joseph, A reconnaissance across the Mackenzie Mountains on the Pelly and Gravel rivers, Yukon and Northwest Territories: Pub. No. 1097, Geol. Survey Branch, Dept. of Mines, Canada, Ottawa, 1910.

[2] Op. cit., p. 36.

[3] The description suggests a lithologic resemblance between this series and one occurring on the Yukon near Circle which has been provisionally referred to the Devonian or the Silurian. Compare Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 278-280

[4] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 140.

[5] Op. cit., p. 145.

[6] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 460-470.

into separate formations. The whole group was therefore designated the Nasina "series" and provisionally correlated with the Birch Creek schist and Fortymile group, exact equivalency being left for future determination.

The detailed study of McConnell[1] in the Klondike gold field, lying about 60 miles east of the international boundary, shows that the same group of rocks occurs in this area and that they consist essentially of siliceous and argillaceous sediments altered into quartzite and quartz-mica schist and associated in places with bands of green chlorite and actinolite schist and crystalline limestone. This group of rocks was traced by McConnell into the Fortymile district and proved by him to be identical with the metamorphic rocks in that region previously described by Spurr. McConnell, however, like Prindle, failed to find definite evidences that there were two distinct groups, and hence was unable to use Spurr's nomenclature. Following the writer's usage, he termed these rocks the Nasina "series." It has already been noted that the small belt of metamorphic rocks lying in the western part of the region here discussed—that is, west of Minook Creek—resembles in its mineralogical composition the calcareous phases of this metamorphic group, or, in other words, the Fortymile "series," to use the term proposed by Spurr.

The westward extension of the belt of Birch Creek schist lying south of the Tanana is, as has been shown, probably mantled by the alluvial deposits of the upper Kuskokwim Valley. The eastern extension of this belt lies in an unexplored area between the Nenana and the Delta. Along the Delta River valley is exposed a similar series of rocks which has been described by Mendenhall.[2] These rocks include a series of highly contorted quartz-sericite schists with acidic and basic intrusive rocks as well as many quartz veins. Similar rocks have been noted by the writer[3] on the upper Tanana and termed by him the Tanana schist, and Mendenhall used the same stratigraphic term. The schists of the upper Tanana have been proved by Prindle's later work to belong to the same general complex as the Birch Creek schist, and hence the name "Tanana" schist can be abandoned.

The schists exposed along Delta River stretch eastward, forming the crest line of the Alaska Range between the Chistochina on the south and the Tanana on the north. These rocks appear to extend eastward as far as Mentasta Pass, beyond which they are buried under Paleozoic and Mesozoic sediments. The metamorphic rocks of this area (the headwater region of the Chistochina), as described by Mendenhall,[4] are made up of schistose graywacke, feldspathic schist, mica schist, green chloritic schist, and carbonaceous schist. These rocks of Delta River and the eastern part of the Alaska Range are undoubtedly to be correlated with the metamorphic schists occurring in the Nenana region already described, and it seems most likely that they can also be correlated with the Birch Creek schist north of the Tanana.

For the sake of clarifying the stratigraphic nomenclature of the metamorphic rocks of central Alaska, it should be stated, first, that the name Nasina "series," which preferably should be Nasina group, includes Spurr's Birch Creek and Fortymile "series." The term Birch Creek schist includes Spurr's Birch Creek and may also include the Fortymile "series." The term "Tanana schist" can be regarded as equivalent to Birch Creek schist and be abandoned. Schrader[5] found some metamorphic rocks northwest of the Yukon, in the Chandalar basin, which he divided into the "Rapids" schist and the "Lake quartzite schist," both nongeographic terms. These two formations can be provisionally correlated with the Birch Creek schist.

[1] McConnell, R. G., Report on the Klondike gold fields: Ann. Rept. Geol. Survey Canada for 1901, n. s., vol. 14, 1905, p. 12B.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 313-315.

[3] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 468-470.

[4] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, p. 31.

[5] Schrader, F. C., Preliminary report on a reconnaissance along Chandlar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 472-474.

## METAMORPHIC ROCKS IN KNIK ARM REGION.

### CHARACTER AND DISTRIBUTION.

The geologic map (Pl. IX, in pocket) shows that in the southeast corner of the region there is a small area of metamorphic rocks here provisionally assigned to the Paleozoic. These rocks have been described by several geologists, but the following account is taken chiefly from the most recent report by Paige and Knopf.[1] This belt is made up largely of graywacke, slate, and phyllite, with some greenstone, rhyolites, and tuffs. The graywackes are highly indurated rocks containing small angular fragments of slate. Petrographic study shows them to consist largely of quartz in angular fragments, feldspar, usually rounded, and hornblende and augite, together with the fragments of slate already mentioned. Argillaceous rocks are prevalent in this series, which also contains various fine-grained slates and phyllites. The igneous rocks include greenstones largely made up of secondary minerals, together with greenstone tuffs, rhyolite, and rhyolitic tuffs. In regard to this series Paige and Knopf state: "The various rock types—graywacke, greenstone tuffs, and rhyolite tuffs—are characterized by the presence of numerous small angular slate fragments. Metamorphism has not proceeded far enough to mask the clastic origin of the typical members nor to cause a marked development of new minerals."

These metamorphic rocks form a belt which embraces the high ranges lying north of Turnagain Arm and southeast of Matanuska River. They occur also on the south side of Turnagain Arm.[2]

### STRUCTURE.

The general trend of these metamorphic sediments is easterly and northeasterly parallel to the axis of the Chugach Mountains. Most of the dips recorded are high, ranging from 20° to 90°. Both northerly and southerly dips occur, but the southerly dip probably dominates. The rocks are characterized throughout by a well-developed cleavage system, which is most commonly parallel to the bedding, so far as observed. Close folding, probably accompanied by considerable faulting, characterizes the succession throughout. There are no data at hand to permit even an approximate estimate of the thickness of these rocks. In view of the fact, however, that they, or at least their eastern extension, as will be shown below, form a belt some 50 or 60 miles wide, it is probable that their thickness is to be measured in thousands of feet.

### AGE AND CORRELATION.

Mendenhall[3] was the first to describe the rocks here under consideration and grouped them together under the name Sunrise series. His investigations showed that rocks of the same types occur throughout the northern portion of the Kenai Peninsula. He traced them as far southward as Resurrection Bay and eastward to Portage Bay, an arm of Prince William Sound. Moffit,[4] who later covered some of the same region that Mendenhall had, describes the Sunrise "series" as made up of slate and arkose, all of which have well-developed cleavage. Neither Mendenhall nor Moffit noted the presence of any igneous rocks in the Sunrise "series," with the exception that Moffit makes mention of a little granite. It would seem, therefore, that the greenstones and rhyolites of this group occur only in the Knik Arm region. There are, however, known to be granitic intrusive rocks in the graywacke series near Resurrection Bay.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 12-16.

[2] In 1910 the writer examined the exposures in the railway cuts along the north side of Turnagain Arm. There massive graywackes and feldspathic grits are interbedded with siliceous slates and argillites. The entire series is closely folded and the less resistant beds are intensely sheared. Several thrust faults were noted.

[3] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 305-307.

[4] Moffit, F. H., The gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 16-19.

The strike of these metamorphic rocks carries them into Prince William Sound, where they were first recognized by Mendenhall. Schrader,[1] on the basis of his first season's work in this part of Prince William Sound and on lower Copper River, divided the rocks of this field into two groups. The lower, which he called the Valdez series, comprises quartzite, quartz schist, arkose, and conglomerate. To the upper group he gave the name Orca series and included in it sandstones, limestones, arkoses, shales, and slates, and a little conglomerate. Two years later Schrader and Spencer[2] continued work in the Prince William Sound region. In regard to the Valdez "series" they say: "It is a series which, on the whole, is of a uniform composition in which there are no lithologic differences sufficient to make any special division. In a large way it is homogeneous rather than heterogeneous, since throughout its thickness there is a constant repetition of alternating thin bands of arkoses, sandstones, and shales in various stages of metamorphism. The series in general may be characterized as a schist, although it does not show the extreme metamorphism of many rocks for which the term has been used." They note also that the Orca "series" is in general less metamorphosed than the Valdez, and is therefore probably considerably younger.

In 1905 Grant[3] began the studies which are being continued at this writing in the Prince William Sound region. His provisional conclusions are that the sedimentary rocks of Prince William Sound can be separated into at least two unconformable groups of very similar lithologic character. In the older—the Valdez group—the rocks are a little more altered, more schistose, and more closely folded than those of the younger or Orca group, and interbedded lava flows are nearly or quite absent, the only representative of volcanic rocks being some greenish schists which may be altered tuff. The Orca group differs from the Valdez group in carrying much black slate, conglomerate, and many interbedded lava flows. Grant notes also that the lava flows are particularly abundant near the base of the Orca.

The easterly extension of the trend of the Prince William Sound and Copper River metamorphic rocks would carry them into the Controller Bay region, where Martin[4] has noted similar strata. These rocks consist of black slate with well-developed cleavage, graywacke, chert, greenstone, and other igneous rocks, together with some fine-grained rocks of uncertain origin.

At Yakutat Bay, which orographically lies in the same province and probably contains the same formations as the Controller Bay region, Tarr[5] found metamorphic rocks which he has described as belonging to two groups. The older of these includes mica schist, slate, and argillite conglomerate, together with large masses of intrusive rocks. The younger, which, following Russell, Tarr has termed the Yakutat group, includes thin-bedded black shales, gray sandstone, and black shale conglomerate, together with a massive rock which is probably a tuff. In addition to these there are some lesser amounts of a coarse conglomerate and crystalline limestone. The entire series is very closely folded and faulted.

Blackwelder[6] carries the Yakutat group southeastward to the Alsek. He divides it roughly into two subdivisions—a lower, consisting of black shale and slate, with interspersed bowlders, and an upper, consisting of slate or graywacke, with local beds of coarse and fine conglomerate. He notes that some of the graywacke members are from 200 to 500 feet thick. On the Alsek, Blackwelder also noted an older metamorphic series lying in vertical isoclinal folds. This, so far as his field observations showed, is made up of quartzose schist phyllite, the metamorphic derivative of alternating graywackes, quartzites, and slates.

The studies of Fred. E. and C. W. Wright have shown that a more or less broken belt of rocks resembling those described in the previous pages skirts the western part of the Alexander Archipelago, in southeastern Alaska. These includes slates, greenstones (chiefly lavas),

[1] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 404-423.

[2] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska, a special publication of the U. S. Geol. Survey, 1901, pp. 34-40.

[3] Grant, U. S., Copper and other mineral resources of Prince William Sound: Bull. U. S. Geol. Survey No. 284, 1906, pp. 79-80.

[4] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: Bull. U. S. Geol. Survey No. 335, 1908, pp. 26-27.

[5] Tarr, R. S., Yakutat Bay region: Prof. Paper U. S. Geol. Survey No. 64, 1909, pp. 146-160.

[6] Blackwelder, Eliot, Reconnaissance on the Pacific coast from Yakutat to Alsek River: Bull. U. S. Geol. Survey No. 314, 1907, pp. 82-84.

conglomerates, and tuffs, together with breccias, interbanded with argillaceous graphitic slates. These rocks are closely folded and have been rendered schistose. They have been recognized on the west coast of Chichagof Island, on Baranof Island near Sitka, and on Gravina Island. Similar rocks also occur on Cleveland Peninsula—a portion of the mainland—and on Douglas Island near Juneau.

The foregoing statements can be briefly summarized as follows: A well-defined belt of more or less metamorphosed rocks stretches parallel to the Pacific shore line from Turnagain Arm eastward and southeastward to the Alsek. Certain lithologic and structural features are persistent throughout this belt. These rocks are characterized by the presence of graywacke, feldspathic sandstone, and slate. Conglomerates are also present in most parts of the belt, and in a few places some thin-bedded limestone has been observed. At Prince William Sound there is evidence that this group can be subdivided into two unconformable formations and that only the upper one carries any extensive volcanic rocks. At Knik and Turnagain arms the two formations were not differentiated, though the Knik Arm region differs from that of Kenai Peninsula, to the south, in containing the volcanic rocks which in the Prince William Sound region are characteristic of the upper member of the group. At Controller Bay the rocks include the greenstones which appear to be characteristic of the Orca or upper group of Prince William Sound. In the Yakutat and Alsek regions no considerable amount of greenstone has been recognized associated with these rocks, the greenstones in these regions appearing to be older than the Yakutat. In these regions there are also two groups which are probably unconformable.

The extension of the strike of the metamorphic rocks of the Alsek River region would carry them into southeastern Alaska, and here, too, a group of beds has been found which resembles in many ways those described above. These include arenaceous and argillaceous sediments, with some conglomerates and a large amount of volcanic material. These rocks form a broken belt on the outer margin of the Alexander Archipelago, and terranes which have been correlated with them are also found in a few other localities in southeastern Alaska.

The metamorphic rocks which have been described are characterized throughout by sharp folding which in some places has amounted to a complete kneading of the softer strata. They are all well foliated and some are altered to schist. The structure is so complex that, though more than a dozen geologists have studied them in half a dozen different localities, not one has ventured to express an opinion on even their approximate thickness. All appear to be agreed in believing that there are many duplications by folding and also by faulting.

The age of the belt of metamorphic sediments of which the rocks of Knik and Turnagain arms above described form a part is one of the most puzzling problems that has developed in Alaskan stratigraphy. The stratigraphic evidence in Kenai Peninsula and the Matanuska region indicates that these rocks are certainly older than the Middle Jurassic and probably older than a part of the Triassic. In the Knik and Turnagain arm regions they have yielded no fossils of any kind.[1]

In the Prince William Sound region, so far as known, there are no formations present other than the Orca and Valdez groups, and hence the stratigraphic relations throw no light on the age of the rocks. The Valdez group has yielded no organic remains of any kind, but in the Orca group Schrader[2] found a few fragmentary plant remains, which are practically indeterminable but suggest that these rocks may be of lower Tertiary or Upper Cretaceous age. In the same field the Harriman expedition found a few obscure fossils that have been referred to the Jurassic by Ulrich.[3]

In the metamorphic rocks of the Controller Bay region Martin[4] found some poorly preserved Globigerina of indeterminate species. If this determination is correct, it indicates a post-Paleozoic age for those rocks.

[1] Moffit, F. H., The gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 18-19. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 15.

[2] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 406.

[3] Ulrich, E. O., Fossils and age of Yakutat formation: Harriman Alaska Expedition, vol. 4, 1902, pp. 125-146.

[4] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: Bull. U. S. Geol. Survey No. 335, 1908, p. 26.

In the Chitina Valley, on the north side of the Chugach Mountains, the Valdez group is found in close association with the Triassic, and the evidence, as pointed out by Schrader and Spencer,[1] indicates that it is older than the Triassic rocks. It should be noted that in the Chitina district, below the oldest known Mesozoic beds, there is a large development of greenstone volcanic rocks which in many ways resemble those of the Orca group. These volcanic rocks, termed the Nikolai greenstone, appear to underlie conformably the Chitistone limestone, which was formerly believed to be upper Carboniferous but is now known to belong in the Triassic system. These relations suggest at least that the Nikolai greenstone represents the transition stage between the Paleozoic and the Triassic, and the same may be true of the greenstone found at the base of the Orca group.

No fossils have been collected in the Yakutat Bay region except those procured by the Harriman expedition in 1899 and described by Ulrich, and a few imperfect plant remains and indeterminable invertebrates, found by Tarr.

Stratigraphic evidence throws little light on the age of the occurrences of these rocks in southeastern Alaska, though it suggests that they are probably early Mesozoic.

Most of the earlier workers on this problem were inclined to assign these rocks to the Paleozoic era, with the exception of the Orca and Yakutat groups. Mendenhall, Schrader, Spencer, and Moffit assigned the Sunrise and Valdez groups to different parts of the Paleozoic sequence, from the Silurian to the Carboniferous. The writer,[2] in summing up the evidence bearing on this problem in 1904, was inclined to regard the Valdez as probably of Mesozoic age. At that time little evidence had been presented to prove that there was a distinct stratigraphic break between the Orca and the Valdez groups, and as the work of various geologists had led to the assignment of the Orca and Yakutat (with which the Valdez can be provisionally correlated) to the Mesozoic, it seemed plausible to think that the Valdez was for the most part also Mesozoic. Since that time, however, Grant and Higgins[3] have shown that the Orca rests unconformably on the Valdez and exhibits certain differences in lithology and structure. The age of the Orca therefore does not necessarily determine the age of the Valdez. Additional evidence has been furnished indirectly by the establishment of the Mesozoic sequence, from the lowest Triassic to the Upper Cretaceous, in this part of Alaska. The sequence being established, if the Valdez is Mesozoic it should find its equivalent somewhere among the Mesozoic terranes. It will be shown later, however, that the Mesozoic rocks are of an entirely distinct type from the Valdez, with the exception of Jurassic beds in the Alaska Range, which resemble in some degree the rocks of the Valdez group. As, however, it has now been proved that the Valdez is probably pre-Triassic in age, it can not be correlated with the Jurassic rocks of the Alaska Range.

All this appears to point to the conclusion that the metamorphic rocks forming the Chugach Mountains and stretching eastward as far as Controller Bay and possibly as far as Alsek River are of pre-Triassic age. In this connection it is interesting to note that rocks of similar types are found in formations assigned to the Silurian or Devonian (Tonzona group) which occur along the inland front of the Alaska Range and also in the Yukon-Tanana region. The age of the Orca and Yakutat groups (if the two are to be correlated) can be determined only by more detailed investigations. It seems probable to the writer, however, that they may represent the oldest member of the Mesozoic. Their lithologic similarity to the Valdez may be due to the fact that the material of which they are composed was derived directly from the erosion of the Valdez group. The correlation of the greenstones of the Orca group and those of the Knik Arm region with the Nikolai greenstone has already been suggested. If these prove to be equivalent in age and to represent the transition zone between the Paleozoic and Mesozoic, they can perhaps be correlated with some of the greenstones which occur near the top of the

[1] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska, a special publication of the U. S. Geol. Survey, 1901, p. 36.

[2] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 229-230.

[3] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Bull. U. S. Geol. Survey No. 443, 1910, pp. 20-26.

Carboniferous or at the base of the Triassic in southeastern Alaska. It is worthy of note that copper deposits are associated with the greenstones both of the Orca group and of Chitina River (Nikolai greenstone).

#### SCHISTOSE ROCKS OF WILLOW CREEK BASIN.

Paige and Knopf[1] have described a narrow belt of schist which lies between the lower Matanuska and the main Susitna Valley. On the accompanying geologic map these schists are correlated with the Birch Creek schist. They are much more highly crystalline than the metamorphic rocks of Knik Arm and are believed by Paige and Knopf, who have studied them, to be an older formation. These rocks include garnetiferous mica schist and chlorite-albite schist. The belt is about 3 miles wide and strikes northeastward, the dip being both north and south. It has been traced from a locality near the head of Willow Creek westward to the region where it passes underneath the Pleistocene gravels of the Susitna Valley. The age of these schists is unknown, but from the degree of metamorphism they appear to be older than any other rocks in the province. In degree of metamorphism these rocks resemble in some measure those described by Mendenhall[2] under the name Dadina schist.

#### SLATES AND SCHISTS OF THE SUSITNA AND TALKEETNA VALLEYS.

Little is known of the geology of the east side of the Alaska Range and the adjacent portions of the Susitna basin. Eldridge explored Susitna River in 1898 and obtained some general data on the distribution of the various types of bed rock. In 1906 Paige encircled Talkeetna Mountain and the eastern part of this region. In addition to the facts ascertained by these men, some notes have been furnished by various prospectors and by Robert Dunn.

The dominating type of rock in this region appears to be a schist or slate which in some ways resembles the type rocks of the Knik Arm region. This rock was termed by Eldridge[3] the Susitna slate. The following description is quoted from his report: "The beds are essentially quartzitic, varying in coarseness of material from an extremely fine homogeneous rock to one of granular structure. In addition to quartz, there are occasional orthoclase, plagioclase, biotite, muscovite, scattered grains of iron oxide, and minute fragments of slate, apparently of the same nature as the fine-grained slates of the series itself. The entire series has been extensively sheared and the sand grains crushed, producing thus the partial schistose or slaty structure that so generally prevails." He also notes that the formation is as a rule highly folded and that where crumpling has taken place there are a large number of quartz seams, some of which show mineralization and sulphide of iron and are believed to be the source of the gold found in the bars of the Susitna. From the description it will be noted that these rocks do not differ essentially from the sedimentary types of rock found in the Knik Arm region. For this reason and because the Susitna slate is known to be pre-Jurassic the rocks of the two areas are here provisionally correlated. It is not improbable, however, that they include also some younger rocks which have not been differentiated in the hasty explorations made in this field.

Paige and Knopf noted that similar rocks occur along the lower course of Talkeetna River, where they are associated with various microcrystalline schists. The latter under the microscope prove to be composed largely of hornblende, together with quartz, chlorite, epidote, and biotite. With these are finely foliated rocks made up chiefly of quartz, biotite, and some carbonaceous material. It should be noted that this entire group of rocks shows less evidence of sedimentary origin than those of the Knik Arm region. However, some of the schists are interbedded with clay slates, and it was suggested by Paige and Knopf that some of the fine-grained varieties are altered dolomite.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 10–11.

[2] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, pp. 27–28.

[3] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 15–16.

## PALEOZOIC ROCKS.

### OUTLINE.

Paleozoic rocks are known to be widely distributed in the central Alaska province, though details regarding their occurrence are scanty. The presence of Ordovician, Silurian, and Devonian strata has been established on paleontologic evidence, and the occurrence of middle Carboniferous rocks is inferred from stratigraphic correlations with adjacent provinces. No Cambrian rocks have been recognized within the province, though it is quite possible that such may occur in the terranes mapped as metamorphic, which are, in part at least, believed to be of pre-Ordovician age. In addition to the areas mapped as Paleozoic (see Pl. IX, in pocket), the extensive areas of metamorphic rocks of the Susitna basin and of the Knik and Turnagain arms region already described are probably for the most part Paleozoic, though direct evidence of their age is lacking.

The route of travel through the Alaska Range along the valley of the Kichatna traversed a belt of argillites, with some graywackes, which are succeeded by Jurassic rocks toward the axis of the range. These rocks stretch parallel to the mountains and are of unknown age, but are here provisionally assigned to the Paleozoic. At the head of the Susitna Eldridge found slate, with some limestone, also of undetermined age, but believed to be Paleozoic. Beyond the watershed the Jurassic rocks were found to rest on a series of phyllites, with some interbedded graywackes associated with cherts. Still farther west and apparently lower in the series is a considerable belt of blue limestone and black carbonaceous slate, some of which carries Ordovician graptolites. From this belt the line of travel turned northeastward and for about 200 miles followed the foothills and the adjacent piedmont plateau of the high range to the southeast. In this field there is an abundance of excellent exposures, and had there been time it would have been possible to work out the detailed stratigraphic succession and structure. Here the carbonaceous slate and blue limestone series was found in close association with thin-bedded siliceous limestone and calcareous slate, and the younger phyllite series was found to include slate and shales of variegated colors, together with considerable chert and in places heavy-bedded graywackes. Here also occurs a heavy blue cherty limestone which at one locality yielded Devonian fossils. These Devonian and older beds are unconformably overlain by a conglomerate, sandstone, and slate series which in some places includes a large amount of volcanic material.

Four stratigraphic units have been recognized in the Paleozoic rocks of the inland front of the range. The oldest includes the blue limestone and carbonaceous slates carrying Ordovician fossils associated with thin-bedded siliceous limestone and calcareous slate of undetermined age, but also provisionally correlated with the Ordovician. These rocks have been here termed the Tatina group. They are succeeded by varicolored slates and cherts, together with graywackes, which have yielded no fossils but are provisionally assigned to the Silurian or Lower Devonian, here called the Tonzona group. The Devonian is represented by a massive blue siliceous limestone carrying fossils which are probably of Middle Devonian age.

These rocks are unconformably overlain by the Cantwell formation, which is made up of heavy conglomerates, red sandstone, and clay slate, with volcanic material, and is provisionally assigned to the middle Carboniferous. As will be shown, these Paleozoic formations are intricately folded and profoundly faulted, hence no complete measurements of thickness could be made. It seems probable that the entire Paleozoic succession of the Alaska Range includes 10,000 to 11,000 feet of strata.

The distribution of the Paleozoic rocks in the Alaska Range will be clearer if it is recalled that they occur along the two arms of a broad synclinorium the inner boundary of which is marked by a belt of Jurassic rocks, and that the whole is broken by numerous stocks of granite. The Paleozoic strata of the southeastern arm of the syncline have not been definitely correlated with any of the terranes on the west side, but probably represent the same horizons. Profound faulting has taken place along the inland margin of the mountains, and the stratigraphic succession is not as definitely established as the cartographic representation of it (see

Pl. IX, in pocket) might appear to show. It seemed best, however, to draw the boundaries of the various formations in this field, and these boundaries at least indicate the structural types, though the geographic distribution of the cartographic units may not be altogether correctly shown. Intricate folding and faulting characterize the structure of these rocks. The types of structure are closed folds overturned to the west, accompanied by thrust faulting. All the Paleozoic rocks of the Alaska Range are cut by diabase dikes and intruded by granites and granodiorites. Some considerable areas of volcanic rocks are found in association with them, but these may in part be younger.

North of the Tanana these Paleozoic rocks are differentiated, though only two divisions are shown on the map. The older includes fine conglomerates, graywackes, and slates. With these occur some limestones which have yielded a few fossils provisionally assigned to the Silurian. This group is too ill defined to permit of cartographic representation and is included in the undifferentiated Paleozoic. On the basis of the fossils, all these rocks have been referred to the Silurian. The second Paleozoic group includes red, green, and black argillites and some fine conglomerates and cherts, and all these rocks have been provisionally correlated with the Tonzona group. A heavy Devonian limestone with which some slate and greenstone are associated constitutes the third Paleozoic terrane recognized in the Yukon-Tanana region. All these strata are folded and are cut by granitic and other intrusive rocks, though these are not very abundant.

### UNDIFFERENTIATED PALEOZOIC ROCKS OF THE YENTNA BASIN.

#### CHARACTER AND DISTRIBUTION.

On the lower Kichatna a belt of argillite was traversed which has a width of about 5 miles. It is composed chiefly of black carbonaceous slate and phyllite, with some heavier beds of fine graywacke and grit. The foliated rocks are much more abundant than the massive types. Among the characteristic features of the slates are the general presence of iron pyrite in them and the two systems of jointing by which they are broken into pencil-shaped fragments. Many diabase dikes and some granitic intrusive rocks cut these slates. Quartz stringers are not uncommon, following the joint planes of the argillites. Some of these are iron stained. It will be shown that these slates probably form the country rock of the Yentna gold-placer district, and it seems probable that the quartz veins are the source of the gold. On the northwest the phyllites are overlain by the slate, sandstone, and grit of the Tordrillo formation (Middle Jurassic). The contact between the two belts of rocks is not exposed, but it seems most likely that the Tordrillo rocks are unconformable with the Paleozoic slates. On the southeast the slates are mantled by Pleistocene gravels. The southwestern extension of the strike should carry these rocks into the Skwentna River valley, but they were not observed by Spurr and are probably there buried by the volcanic rocks of the Skwentna group. The contact between these two formations lies in the unmapped area between the Skwentna and the Kichatna. An extension of the strike of these argillites would carry them into the Yentna placer district, where similar rocks are reported to occur by prospectors and by R. W. Porter. On a western tributary of the Chulitna, Robert Dunn found argillites which lie in the extension of the trend of this series, parallel to the main axis of the range.

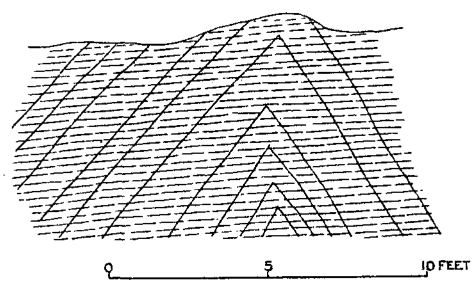



FIGURE 1.—Diagram showing exposure of slates in cliff near the camp of July 5, on Kichatna River, exhibiting relation of jointing to bedding planes.

#### STRUCTURE AND THICKNESS.

Where seen by the writer these slates are closely folded and somewhat faulted. The strikes vary from 40° to 55° east of north and are parallel to the main axis of the range. It appears that the Kichatna cuts across the axis of an anticline whose northwestern arm dips under the Tordrillo formation. Within this large structure there are many secondary folds, one of which is illustrated in figure 1. This diagram shows the nearly horizontal jointing which appears to prevail. More or less movement has taken place along bedding planes, and this, with the horizontal jointing, has yielded the pencil-shaped fragments so characteristic of the formation. Jointing parallel or nearly parallel to the bedding was also observed at some localities.

It will be shown that the top of the formation has not been definitely determined, nor is the bottom of it exposed, and hence no measurement of thickness could be made. The thickness is probably not less than 2,000 to 3,000 feet.

#### AGE AND CORRELATION.

The slates above described are overlain by rocks assigned to the Middle Jurassic. They resemble somewhat the argillites on the west side of the Alaska Range which form a part of the Tonzona group and are assigned to the Silurian or Devonian. They are also somewhat similar to the metamorphic sediments of the Knik Arm region which have been described on page 61. The structure of the cross section of the Alaska Range between the Kichatna and the Kuskokwim is that of a synclinorium whose center is occupied by the Mesozoic beds. (See section *A–B*, Pl. IX, in pocket.) The above facts all point to the conclusion that these slates are of Paleozoic age, and if a more definite assignment should be made they would probably be correlated with a part of the Tonzona group of the Kuskokwim Valley. As the slates have yielded no organic remains, their age can not now be more definitely determined. It should be noted, however, that these supposed Paleozoic slates are not very different lithologically from some of the overlying Jurassic beds, and it is by no means impossible that they may be Mesozoic. They differ from the Jurassic rocks in being somewhat more altered and in the fact that the fragmental beds, such as graywackes, form only a small percentage of the bulk of the material, whereas in the Tordrillo formation the grits and sandstones are more abundant than the slates.

It has been shown that the northeastern extension of this belt would carry it parallel to the Alaska Range, and slates have been reported by prospectors in this general region. Similar rocks were observed by Eldridge along the headwaters of the Susitna, though these are associated, as will be shown, with some heavy limestone. It is probable that the slates of the Kichatna section are synchronous with some of the rocks found by Eldridge near Broad Pass, but at present no more definite correlation can be made.

### *UNDIFFERENTIATED PALEOZOIC ROCKS IN THE HEADWATER REGION OF THE SUSITNA.*

The exploration of the Susitna made by Eldridge in 1898 was carried out under great difficulties, and of necessity the geologic conclusions were rather indefinite. Though he correlated under the name Susitna slate all the sedimentary rocks of the part of the Susitna Valley traversed by him, it would appear from Paige's more recent investigation that a part of these rocks are considerably altered, and hence they have been classed here with the metamorphic rocks. A study of Eldridge's field notes has led the writer to the conclusion that there is a belt of sedimentary rocks between Jack River, tributary to the Susitna, and the head of the Nenana which is properly separable from the metamorphic rocks lying to the southeast. These have here been mapped as undifferentiated Paleozoic rocks. Eldridge's field notes show that they include black, red, and green argillites, probably some cherts, and a heavy limestone, together with some igneous rocks. His description suggests that they include some of the same formations as are found along the inland front of the Alaska Range, notably part of the Tonzona group. These interpretations of Eldridge's notes are borne out by the stream gravel noted by the writer along the northern margin of this area. The evidence at hand would therefore seem to justify the provisional assignment of this belt of rocks to the Paleozoic.

These rocks are bounded on the north by what Eldridge calls the Cantwell conglomerate, which is here termed the Cantwell formation and provisionally assigned to the Carboniferous. The Cantwell rests unconformably upon the older supposed Paleozoic rocks. On the south the rocks continue to the point where they pass under the alluvial floor of the upper Susitna. It has already been suggested that these rocks are in part equivalent to the slate of the Kichatna Valley. They appear to form the eastern limb of the great synclinorium of the Alaska Range. (See section *C–D*, Pl. IX, in pocket.)

### TATINA GROUP (ORDOVICIAN).

#### CHARACTER AND DISTRIBUTION.

The Tatina group embraces a series of sediments, dominatingly calcareous but including considerable argillaceous and some arenaceous material, which forms the oldest known Paleozoic terrane of the province. The typical exposures of this group are in the upper basin of Tatina River (formerly called Rohn River). Blue limestones, usually argillaceous and in places carbonaceous, occurring in beds from 6 inches to 20 feet or more in thickness and interbedded with carbonaceous argillites in the form of shales, slates, or more rarely phyllites, constitute one phase of this group of rocks. Intimately associated with these carbonaceous sediments is a series of thin-bedded sandy gray limestones, which grade into calcareous flags and are interbedded with calcareous sandy shales and slates and calcareous shaly sandstones. It is by no means certain that these two phases of this group form an unbroken sedimentary succession, but the evidence at hand does not permit a subdivision. So intricate is the structure that it is impossible to state definitely whether the carbonaceous or the sandy phase of the group is the older, but it seems probable that the former constitutes the lower part of the group. It will be shown that this lower member, comprising the blue limestone and carbonaceous slates, carries Ordovician fossils, but that the upper sandy limestones and shales have not yielded any organic remains and may be found to be of post-Ordovician age. One of the best examples of the supposed lower member of the group occurs near the camp of July 21. (See Pl. IX.) Here a highly contorted series of limestones and shales is exposed in a cliff. (See fig. 5, p. 71.) The calcareous layers, made up of blue and black limestone which is somewhat sandy and from 1 to 2 feet in thickness, are separated by bands of carbonaceous shales, usually not more than 1 inch thick. On Tatina River a more complete section is exposed. Here the series, embracing 1,000 to 1,500 feet of sediments made up of blue limestones, locally sandy and carrying carbonaceous matter, occurs in layers from 1 to 20 feet thick interbedded with argillaceous and carbonaceous slates, in beds for the most part not over 1 foot in thickness but in places reaching 50 feet or more. These rocks also are highly contorted and have been intricately penetrated by diabase dikes. (See figs. 4 and 7, p. 71.) It appears that in the upper part of this lower member sandy limestones begin to appear, and this suggests that there is a gradual transition into the upper arenaceous member, but no complete section of the group came under observation. The upper sandy division of the Tatina group was observed at several localities, but the most complete section that was studied is about 2 miles west of the camp of July 24. Here a belt about a mile wide is made up of closely folded series of alternating thin bands of gray siliceous limestone, flaggy calcareous sandstone, and sandy calcareous shale. A fault separates this belt on the east from the slates and cherts of the younger Tonzona group. The western limit of the belt was not determined, but the rocks extend at least a mile beyond the area actually traversed. In this section the massive rocks, including some of the limestones and sandstones, are 2 to 10 feet thick and are separated by thinner beds of foliated rocks. Many igneous rocks, chiefly intrusive diabase, are found in association with this series.

As has been shown, diabase intrusives are plentiful among the Tatina rocks. Most of these appear to be dikes, but some may be sills or ancient interbedded lava flows. About 2 miles southeast of the camp of July 27 and well within the high mountains there are extensive exposures of a limestone breccia in a matrix of diabase. The limestone fragments range from a few inches to 2 or 3 feet in diameter. They form probably 50 per cent of the rock, are as a rule angular, and show little evidence of metamorphism, though there is considerable veining by secondary calcite. The limestone resembles that of the Tatina group. It appears from the drift that there is a large area of this breccia extending toward the crest line of the range, to the southeast of the exposure described.

Granite, both in stocks and dikes, cuts the Tatina rocks. The dikes are confined chiefly to marginal zones of the larger stocks. Quartz veining is not uncommon, following the foliation of the argillites and the jointing of the massive beds. These veins are not known to be mineralized.

The Tatina rocks were traced from Tatina River to the east fork of the Toklat and appear to constitute most of the inland slope of the mountains. Along the Kuskokwim the group is bounded on the east by the overlying Tonzona sediments. The mountains west of the Kuskokwim were not examined, but from their general appearance and some notes by Spurr they are believed to be made up of Tatina sediments and diabase intrusive rocks. The easterly boundary of the broken belt of the Tatina group which skirts the mountain front was not determined, but from the evidence furnished by the glacial wash they are believed to be here also overlain by the Tonzona group.

###### STRUCTURE AND THICKNESS.

Extreme deformation characterizes the Tatina group of sediments throughout. As a rule, two structural systems can be recognized. One, which runs parallel to the main axis of the range, is characterized by profound faulting accompanied by overthrusts; the other has produced minor crenulations about at right angles to the system of faulting. In general it can be said that the formation is bounded by fault lines rather than by lines marking zones of deposition. At different localities the Tatina group rests on sediments belonging to the Tonzona (Silurian or Devonian), Devonian, Carboniferous, and Eocene. There is no measure of the extent of these thrust faults, but in several places they cut out the intervening strata, which must aggregate many thousand feet in thickness. Cross faults of any considerable throw seem to be comparatively scarce, though there is one striking example which is shown on the map (Pl. IX, in pocket). The upper Kuskokwim Valley appears to be incised along the axis of an anticlinal fold which trends from north to N. 10° W. Near the point where the river emerges from the mountains the strike swings abruptly to about N. 30° E., and at this locality (near the camp of July 20) the drag has brought about cross faulting and the Tatina rocks on the north abut directly against the younger Tonzona rocks on the south. The trend of this fault line is uncertain, and the movements that have taken place between the two blocks of strata are impossible of determination with the present incomplete evidence. It may be noted, however, that rocks lying northeast of the fault line have moved northwest and in many places are known to have overridden younger strata. It is possible that the structure can be explained by supposing that there was an unyielding buttress lying west of the upper Kuskokwim which held these strata in place while the strata of the main range to the northeast were moved inland by a thrust from the Pacific.

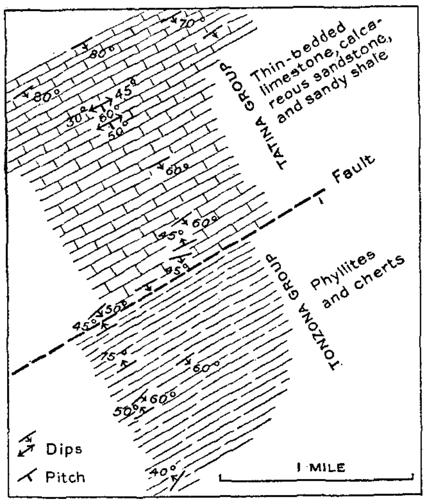
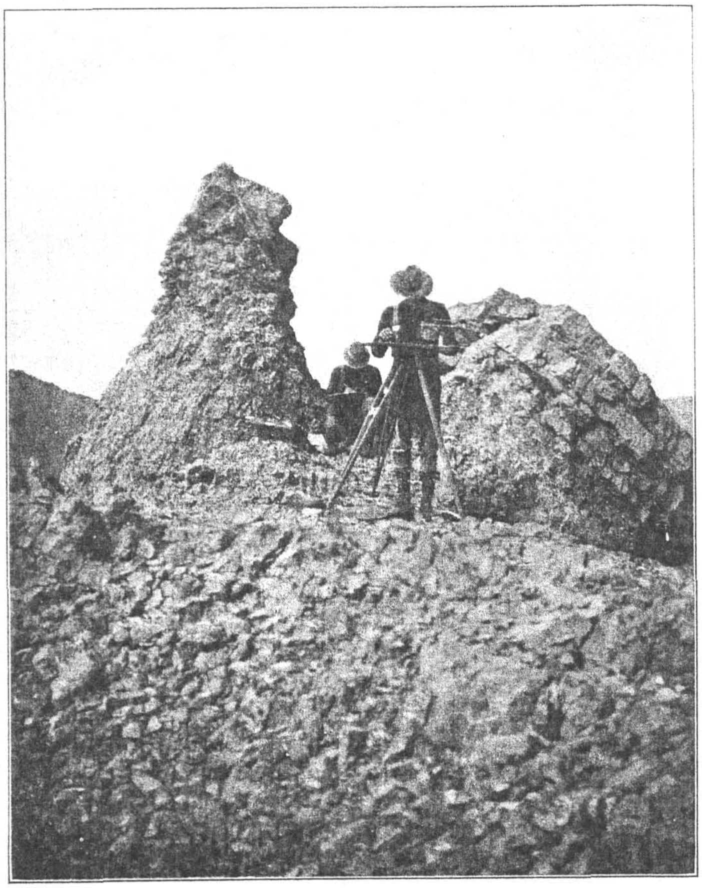


FIGURE 2.—Sketch map showing relation of pitch and of cross folding to dominant structural lines 1 mile west of the camp of July 24.

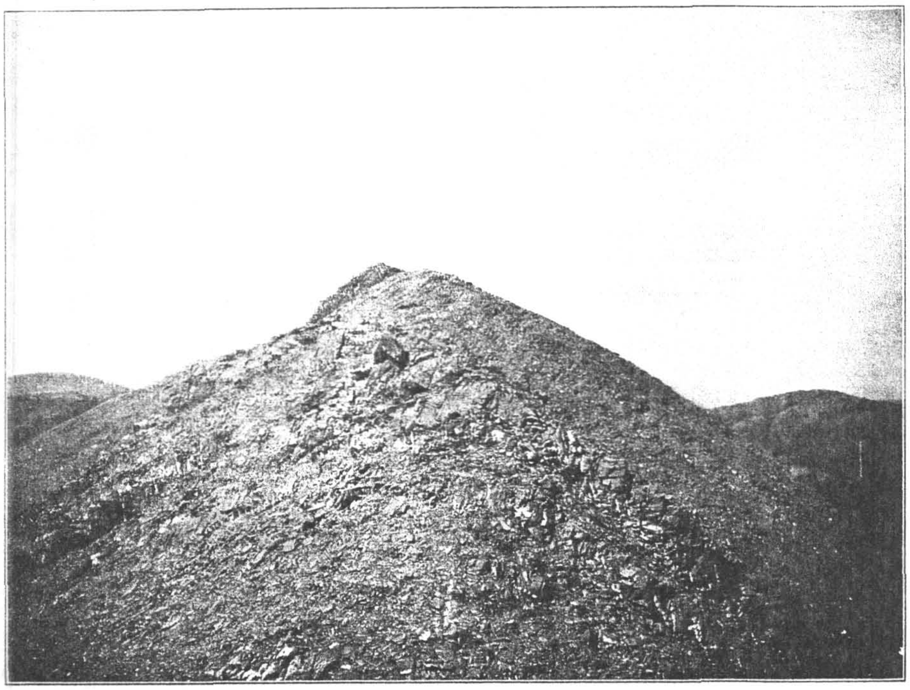
The overthrust faults all strike parallel to the axis of the range, the direction being about N. 20° to 40° E. The dip of the fault planes is to the southeast at unknown angles but apparently in the main at 60° or more. The faulting has affected all the strata from the Ordovician to the Tertiary and will receive further consideration when the general structure of the province is discussed.

The cross folding found in the Tatina rocks manifests itself in sharp plication, forming anticlines and synclines the pitch of whose axes is parallel to the larger structures. This feature is brought out in Plate X, *B*, and in the accompanying sketch map (fig. 2). The figure shows that in the northern part of this area there is an anticlinal arch, as indicated by the double-headed arrows, and that this pitches to the southeast parallel to the general trends. This cross



A. BEDDED AND JOINTED SILICEOUS DEVONIAN LIMESTONE.

Near camp of July 24. See page 77.



B. ANTICLINAL FOLD IN SANDY LIMESTONE AND SHALES OF THE TATINA GROUP.

Near camp of July 24. See page 71.

arching is shown in Plate X, *B*, and in the diagram forming figure 3, taken from a field sketch which also illustrates the joints that traverse the massive beds and are filled with calcite veins. The east slope of the upper Kuskokwim Valley exhibits some fine examples of cross folding. Here the major structures trend about north and south and the axis of the cross folds strikes nearly at right angles, parallel to the structures north of the cross fault which has been described. The section in figure 4 is reproduced from a field sketch.

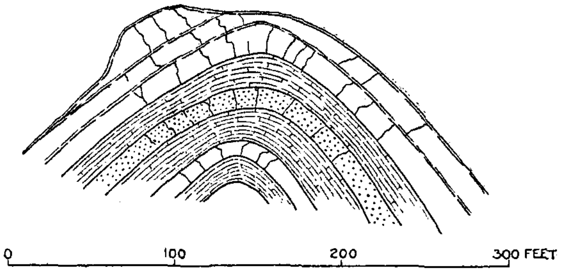



FIGURE 3.—Diagram showing cross folds in limestone and sandstone interbedded with calcareous shales near the camp of July 25. This section shows also calcite veins following the joints of the massive beds.

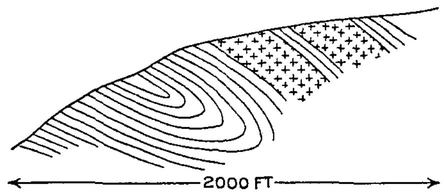



FIGURE 4.—Section showing cross folding on east slope of Kuskokwim Valley near the camp of July 19. The major structural lines are nearly at right angles to these folds.

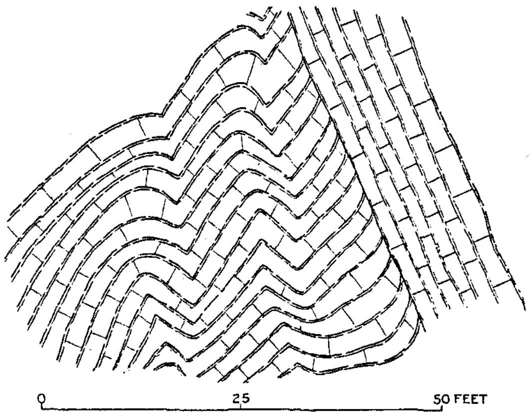



FIGURE 5.—Diagram showing exposures in cliff 1 mile east of the camp of July 21, exhibiting cross folding and faulting of limestones and shales of Tatina group.

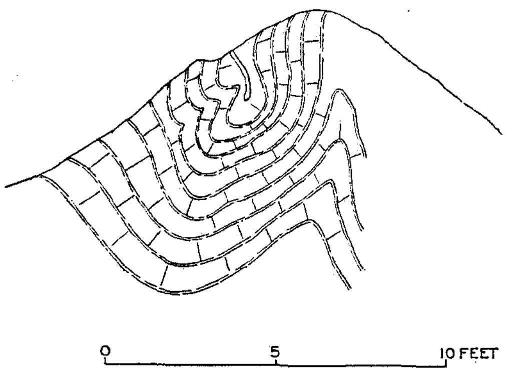



FIGURE 6.—Diagram showing folding of sandy limestone interbedded with carbonaceous shales 2 miles north of the camp of July 30.

The extreme deformation of the limestone and carbonaceous shale member of the Tatina has been referred to as one of its most characteristic features. The diagram in figure 5 is reproduced from a field sketch. In the cliff shown in this figure the limestone beds are from 1 to 2 feet in thickness and are separated by shale layers from 1 to 3 inches thick.

Another example of the crenulated character of the folding is shown in figure 6, which is taken from a field sketch. The locality shown, near the camp of July 30, is about 50 miles northeast of the one shown in figure 5.

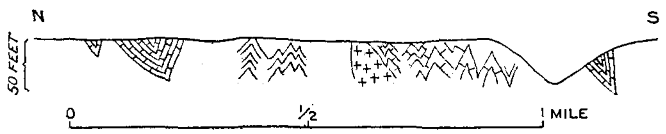



FIGURE 7.—Section along east side of river near the camp of August 11, showing limestone and carbonaceous shales of Tatina group, with diabasic intrusive rocks.

Figure 7, which is reproduced from a section drawn in the field, indicates the character of the folding of the Tatina group near the northeasterly limit of its occurrence. It will be noted that the folds are mostly overturned toward the north.

It will be evident from the foregoing account of the structure and distribution of the Tatina group that a much more detailed survey than was made would be required to determine the thickness of the entire series. It was estimated that from 1,500 to 2,000 feet of the limestone and carbonaceous shale member of this group is exposed along the Kuskokwim. It is probable that the upper limestone and calcareous sandstone member is at least 2,000 feet thick. It should be remembered that the base of the Tatina has nowhere been recognized, and it is fair, therefore, to assume a minimum thickness of 4,000 to 5,000 feet for the entire succession.

###### AGE AND CORRELATION.

In the streams tributary to Dillinger River fragments of black carbonaceous shale were found, in some of which Mr. Prindle discovered the remains of graptolites. This occurrence is near the camp of July 22 (see map, Pl. IX, in pocket), but, although diligent search was made for the source of the fossil remains, they were not found in place. It was established, however, that the fragments carrying the graptolites were derived from the interbedded limestones and shales, which it has been shown form a member, probably a lower member, of the Tatina group. These fossil-bearing shale fragments were found in two localities; one (No. 10) was near the camp of July 21 and the other (No. 11) about 5 miles to the northeast. Prof. Charles Schuchert has kindly furnished the following statement in reference to these fossils:

> Localities 10 and 11 have the same fauna, consisting of graptolites, as follows: *Climacograptus bicornis* (Hall) (10 and 11), *Climacograptus* sp. undet. (10), *Dicranograptus* cf. *ramosus* (Hall) (11).
>
> In eastern North America these fossils are regarded as marking a horizon about Utica. These species, however, have a greater range, but it is the absence here of others marking a lower horizon than Utica that leads me to refer localities 10 and 11 to about the Utica (Ordovician).

Mr. Prindle also found some fossil fragments on the mountain slope about a quarter of a mile east of the camp of July 17 (locality 9), and on these Professor Schuchert reported as follows:

> Locality 9 is Ordovician, but the fossils are too indefinite for exact age determination. It is either that of localities 10 and 11 or of a zone in the middle Ordovician. There are present a fragment of a graptolite, a bivalve, apparently of *Ambonychica*, and long, slender tubes, possibly worm tubes, similar to those of serpulites. The latter fossils resemble *Endoceras*, but no septa can be seen.

The structure would appear to indicate that the beds at locality 9, from which these fossils were derived, are either at the same horizon as the fossiliferous beds at localities 10 and 11 or, if anything, a trifle higher in the Tatina group. As these localities are, however, some 30 miles apart, and in view of the profound faulting in the region, these statements in regard to the stratigraphic position of the fossil-bearing beds can be regarded as little more than suggestive. The evidence in hand, however, indicates that the blue limestone and black shale member of the Tatina group is of Ordovician age.

The supposed upper member of this group, including the sandy limestones, sandstones, and shales, has yielded no fossils of any description, and it is by no means certain that it also is Ordovician. Spurr[1] grouped all the rocks lying west of the Tordrillo formation (now known to be Jurassic) together under the name Terra Cotta series. This "series" could therefore include the Tatina group as here defined and also as much of the Tonzona group as occurs in the section studied by Spurr. He was inclined to correlate the Terra Cotta with the Skwentna group, which is the natural interpretation of the structure. The similarity which he recognized between the Skwentna and the Terra Cotta was due to the large number of diabase dikes which occur in the latter; the weathering products of these dikes, when viewed from a distance, resemble the volcanic rocks of the Skwentna. In the following table the equivalency between Spurr's stratigraphic units for this field and those of this report is indicated:

| Spurr, 1898. | Brooks and Prindle, 1902. |
|---|---|
| Tordrillo series | Tordrillo formation. |
| Terra Cotta series | {Tonzona group.<br>{Tatina group. |

Ordovician rocks have been recognized at only two other localities in Alaska. In Seward Peninsula there is a heavy semicrystalline limestone named the Port Clarence,[2] which is referred

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 156–157.
[2] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 73–79.

to either the Ordovician or the Silurian. Kindle[1] has also found on the Porcupine a heavy bluish-gray magnesian limestone which has yielded fossils determined by Ulrich to be Ordovician. In this connection it is of interest to note that there is a graptolite-bearing formation on the Porcupine which is lithologically identical with that of the lower division of the Tatina group, but whose fossils have been referred to the Silurian by Ulrich.[2] (See correlation table, p. 52.) The black shales interbedded with limestone described by Dawson[3] as occurring on Dease River in British Columbia carry graptolites of the following species, referred by Lapworth to the Middle Ordovician:

Diplograptus englyphus Lapworth.
Climacrograptus cf. antiquus Lapworth.
Cryptograptus tricornis Carruthers.
Gossograptus ciliatus Emmons.
Dichymograptus cf. sagittarius Hall.
New form allied to Cænograptus.

Regarding the stratigraphic position of these fossils, Dawson quotes Lapworth as follows:

The graptolite-bearing rocks are clearly of about middle Ordovician age. They contain forms which I would refer to the second or Black River–Trenton period—that is, they are newer than the Point Levis series and older than the Hudson and Utica groups. * * * The rocks in Canada and New York with which these Dease River beds may best be compared are the Marsoin beds of the St. Lawrence Valley and the Normans Kill beds of New York. The Dease River beds may perhaps be a little older than these. * * * The specific identification of the Dease River fossils I regard as provisional.

### TONZONA GROUP (SILURIAN OR DEVONIAN).

#### CHARACTER AND DISTRIBUTION.

A series of argillites, in part interbedded with graywacke and associated with cherts, is here classed together under the name Tonzona group. The name is taken from the river in whose basin these rocks typically occur. The Tonzona group has at least one striking difference from the older Tatina group in its marked lack of limestone. It is made up of sediments which, as a rule, are coarser grained than those of the Tatina, being derived chiefly from clays and sands. It includes, however, considerable masses of chert.

The argillites, which predominate in this group, vary from shales to slates and phyllites. One of their characteristic features consists in their variegated colors, which include black, red, green, and blue. Fragmental rocks are represented by gray indurated feldspathic sandstone or graywacke, some of which in the field was mistaken for igneous rock. The cherts, which occur in association with the fine-grained argillites, are also varied in color, including black, greenish-white, green, and red varieties.

The facts in hand suggest that the Tonzona group may be divisible into two members—(1) a lower, made up largely of bluish phyllites and black slates, some interbedded with massive graywacke, with which are also associated some black cherts, and (2) an upper, which is dominatingly made of black, red, and green slates, locally grading into shales and cherts of various colors. This subdivision can not be carried throughout the field, and it has been necessary, therefore, to map all these rocks as a stratigraphic unit.

A reference to the map (Pl. IX, in pocket) will show that the Tonzona group forms a broken belt stretching along the inland front of the Alaska Range and has also been recognized along the lower Tanana and north of the Tanana. In general, it is true that in the southern part of the field the lower phyllite and graywacke member is most abundant, whereas in the northern part the upper slate and chert member is the prevalent type.

The belt of Tonzona rocks which lies east of the Tatina group and is bounded in the heart of the range by the Tordrillo formation affords a good typical section of the older member of the group. A blue-black phyllite of irregular cleavage, which in places weathers out into knotty fragments, is the dominating rock type in this section. Some of these phyllites are highly

[1] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 322-324.
[2] Kindle, E. M., op. cit., pp. 325-326.
[3] Dawson, G. M., Report on an exploration in the Yukon district, Northwest Territory, and adjacent northern portion of British Columbia: Ann. Rept. Geol. Survey Canada for 1887-88, vol. 3, new ser., pt. 1, 1888, pp. 94B-95B.

carbonaceous and nearly all carry considerable pyrite. Near the top of this phyllite succession a few thin beds of impure limestone were observed and represent the only calcareous rocks found in association with the Tonzona group. Interbedded with the phyllites, especially toward the lower part of the series, are some arenaceous beds, in part recognizable as indurated feldspathic sandstones, in part forming close-grained bluish-gray rocks whose fragmental character was recognized only under the microscope. These proved to be graywackes and are made up of detrital quartz with subordinate feldspar grains included in a fine-grained aphanitic cement. In one place a bed was observed in which the fragmental material was worn enough to warrant terming the rock a conglomerate, and this contained some small rounded pebbles of limestone. These graywacke beds range from 2 to 10 feet in thickness. No chert was observed in this section, but some black siliceous cherts were found in association with similar rocks near the camp of July 19, in the Kuskokwim Valley.

Diabase dikes are very plentiful, cutting the phyllites and as a rule injected parallel to the bedding planes. Quartz veins are also common, and some of these carry iron pyrites. It appears that the total thickness of this group exposed between the Tatina group on the west and the Tordrillo formation on the east is not less than 3,000 to 4,000 feet.

West of the route of travel between the camps of July 24 and 28 there is an extensive area of this lower member of the Tonzona. In this area, which is broken by other formations (see geologic map, Pl. IX), the argillites vary from slates to phyllites and from gray to blue and black in color. Interbedded with these rocks are coarse feldspathic sandstones and graywacke, some of which reach 20 to 30 feet in thickness. Siliceous slates interbedded with black cherts also form an important element in this series. Diabase dikes are present but are not so plentiful as in the section to the south. These rocks are closely folded and in general more highly altered than their equivalents in the Kuskokwim basin. Though no measurement of their thickness could be made, it probably is at least as great as that of the rocks described above—3,000 to 4,000 feet.

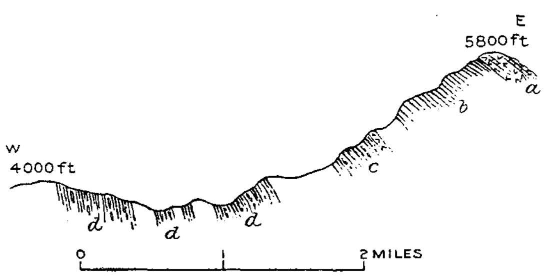



FIGURE 8.—Section of Tonzona group near the camp of July 26. By L. M. Prindle. *a*, Diabase with limestone fragments; *b*, black clay, shale, and slate with some beds of green and red shale and slate; *c*, diabase dike, black paper clay, shales, sandy shales, and thin-bedded grits with some limestone; *d*, black and gray cherts interbedded with black and pale-green shales and slates.

In the northern part of the field, between the camps of August 19 and 20, is a narrow belt of black phyllites and black and green cherts, which are correlated with the rocks described above. These are overlain unconformably on the south by conglomerates of the Cantwell formation and on the north probably rest on the Birch Creek schist. In these rocks there is a noticeable absence of the graywackes noted above, and they appear to represent the transition between the lower and upper member.

Rocks belonging to the upper member of the Tonzona group were found at various localities in the Tonzona River basin. The best section seen was one studied by Mr. Prindle, extending about 4 miles eastward from the camp of July 26, and the following description and the diagram in figure 8 are taken from his field notes:

Cherts and shales make up the western half of the section, being exposed at intervals for about 2 miles. The cherts are thin bedded, occurring in layers up to 4 inches in thickness, and are black and gray in color. They usually form knobs along the ridges, the saddles being occupied by the argillites. The latter, which include shales and slates, are black, red, gray, and green. When weathered the shales have a buff color. A few thin beds of grit were found in association with these rocks. East of the chert-shale series lies a belt of grits and shales. Here thin layers of fine grits are interbedded with black paper shales and a few layers of impure limestone. To the east of these and above them topographically and probably stratigraphically are beds of black shale and slate, with some interbedded layers of green and red slates. The thickest beds of green and red shale are about 10 feet thick. At the top of the ridge is an exposure of diabase, along the margin of which are included some large angular slabs of limestone. These inclusions show very little evidence of metamorphism. The whole series shows many minor crenulations, and there are probably many duplications by folding and faulting. Mr. Prindle estimates the thickness of the upper shale member at about 1,000 feet, and the other beds must aggregate more.

While exploring the Tanana in 1898 the writer[1] traversed a belt of rocks similar to those described above exposed in the ridge lying between the Tolovana Flats and the valley of Baker Creek, and described them as the Nilkoka formation. These rocks include a series of highly contorted red and green slates and sandstones and fine conglomerates. The conglomerate is made up of fine vitreous quartz grains averaging less than a quarter of an inch in diameter; the cement is siliceous and carries considerable iron. The slate is commonly red in color, but some is green; it occurs in beds of 50 feet or more in thickness. Most of the slates are argillites, but some are siliceous. As a rule, they have an even fracture, but some cleave irregularly. Quartz veins cut the sandstone, but none were observed in the slate. In 1906, on the route from Fairbanks to Rampart, a similar formation was found along the western margin of the Birch Creek schist. In this region the exposures are very poor, but it appears that the same red and green slates and sandstones occur and that with them are associated some gray and black cherts.

On the evidence above outlined several areas of the Tonzona group have been mapped (see Pl. IX, in pocket) in the region north of the Tanana. It must be confessed that the evidence for correlating these rocks with those of the Alaska Range is far from conclusive, but the lithologic resemblances are so strong that it seemed advisable to so interpret the facts. There are, moreover, certain stratigraphic facts which support this conclusion. Rocks of the same types also occur north of the Tanana in the areas mapped as undifferentiated Paleozoic.

It will be clear from what has been stated that the Tonzona group includes (1) a phyllite series interbedded with graywackes and with some associated cherts and (2) a series of grits or graywacke, slates, and cherts. The entire group occurs along the inland front of the Alaska Range; the upper member and possibly the lower also are found north of the Tanana.

Diabase dikes are common in the Tonzona group, and there are some rocks of diabasic composition which may be lava flows extruded while the sediments were deposited. Granitic intrusive rocks are also found in the sediments of this series. In the upper Nenana basin some gneissoid rocks, consisting chiefly of augen gneisses, were found in intimate association with cherts and slates that have been assigned to the Tonzona group. The areal distribution of the gneisses is only approximately indicated on the map (Pl. IX). The augen are quartz or feldspar (chiefly orthoclase), have a lenticular cross section, and are embedded in a fine crystalline groundmass consisting chiefly of quartz and mica. There is a marked parallel structure throughout the rock, which is finely foliated, the longer axis of the augen being parallel to the foliation. The gneiss everywhere exhibits evidence of having undergone intense deformation. In the gneissic areas traversed the exposures were poor and no fresh material came under the observation of the writer. In the field it appeared that this rock represented a basal conglomerate resting on an Archean complex, but further field studies and detailed microscopic investigations by Mr. Prindle proved that it was of igneous origin and probably a deformed rhyolite (pp. 149–150).

Similar rocks are known to occur in the Yukon-Tanana region and have been usually regarded as gneissoid porphyritic granite. In some respects they are not unlike the gneissoid phases of the Klondike group.[2] Like them, the rocks of the Nenana basin are seamed with quartz stringers, and there is evidence that some of these are metalliferous.

#### STRUCTURE AND THICKNESS.

Much of what has been said about the deformation of the Tatina rocks applies with equal force to those of the Tonzona group. The Tonzona rocks have, however, apparently suffered

[1] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 472.

[2] McConnell, R. G., Report on the Klondike gold fields: Ann. Rept. Geol. Survey Canada for 1901, vol. 14, pt. B, 1905, pp. 15B-22B.

somewhat less deformation than the older series and present but little evidence of the folding transverse to the main axis of the range which is so conspicuous a feature of the Tatina sediments. The dominant structure running parallel to the mountains and manifesting itself chiefly by close folding and faulting is as typical of these rocks as of the Tatina group. Probably over half of the boundaries of the Tonzona group are fault lines, and on many of them there is some evidence of overthrusting. The strikes along the Kuskokwim Valley trend north as far as the cross fault which has already been described. North of the fault the structures swing to northeast and maintain this general direction to the limits of the area mapped. North of the Tanana these rocks also strike northeastward. The dips are variable but are prevalently steep and to the southeast. Many closed folds overturned to the northwest were noted. The argillites in places exhibit many minor crenulations, but in the more massive graywacke and grits the movement has been taken up by shearing along the bedding planes. Apparent monoclinal structures such as are exhibited in figure 8 are on closer study usually found to be made of a series of overturned closed folds. In the region north of the Tanana the folding appears to be somewhat more open. Here, however, the exposures are so poor that there is little evidence to be obtained. The section shown in figure 9 represents the structure of some exposures (red and green slates and sandstone) on the lower Tanana. The section is generalized from a sketch made in the field.

No complete measurement of the rocks of the Tonzona group has been made. It appears that the lower member of the group may be 2,000 to 3,000 feet thick and the upper member somewhat less. The best evidence indicates a total thickness of 4,000 to 5,000 feet.

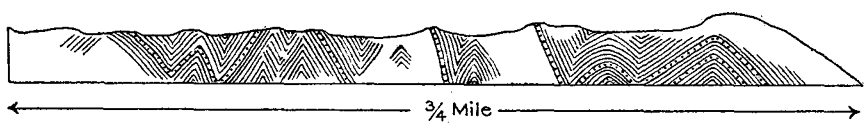



FIGURE 9.—Section of red and green slates and sandstones exposed along north side of Tanana River 2 miles below the mouth of the Tolovana.

### AGE AND CORRELATION.

No fossils of any description have been found in the Tonzona group, although the lithology of the rocks suggests that a more careful search would result in the finding of organic remains. It will be shown that they are overlain, probably unconformably, by a limestone of Middle Devonian age. Their relation to the older Tatina group is not definitely established, as most of the contacts between the two groups have become lines of movement. In any event they are without doubt younger than the Tatina, which is, in part at least, Ordovician. These facts have led the writer to assign these rocks provisionally to the Lower Devonian or to the Silurian. In the Rampart region there is a group of rocks somewhat like the Tonzona in lithology which carry Silurian fossils. These organic remains occur in a heavy limestone. Such a member is unknown in the group under discussion, and a correlation with them is therefore not justified. It is probable, however, that these supposed Silurian rocks of the Rampart region are older than most of the Tonzona group.

Spurr,[1] in subdividing the rocks of the Yukon district, grouped together under the name Rampart series greenstones, lavas, and tuffs, with gray slates, impure limestones, cherts, etc. It will be shown that the limestones are of Middle Devonian age and that the volcanic rocks probably for the most part belong to the same period. The cherts and slates are probably synchronous with some of the deposits here described. Above Circle on the Yukon cherts and slates similar to those here assigned to the upper member of the Tonzona occur in association with large amounts of greenstone.[2]

[1] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 101-166.
[2] Brooks, A. H., and Kindle, E M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, p. 279.

### LIMESTONE (MIDDLE DEVONIAN).

#### CHARACTER, DISTRIBUTION, AND STRUCTURE.

In the region drained by Dillinger and Tonzona rivers two narrow belts of siliceous limestone were found which are assigned to the Middle Devonian. This limestone has a thickness of probably not exceeding 200 feet. It is blue to white in color, very siliceous, semicrystalline, and usually much fractured. (See Pl. X, *A*, p. 70.) In the belt lying just north of the camp of July 26 the limestone appears to lie in a closed synclinal both arms of which rest on the phyllites of the Tonzona group. It differs from the limestone of the Tatina group in being much heavier bedded and in carrying a very large percentage of silica. Its massive character has also prevented the close folding characteristic of the thin-bedded limestones of the Tatina.

The second area of limestone, which lies just east of the camp of July 24, is bounded on both sides by fault lines. Here the blue-white siliceous limestone is overlain by a ferruginous limestone, and both carry Devonian fossils. White quartz conglomerate (Carboniferous?) bounds the limestone on both sides, and the limestone is exposed along the axis of an anticline. The structure is exceedingly complex, but the best interpretation appears to be that the supposed Carboniferous conglomerate and the Devonian limestones are overthrust on the Tertiary and these in turn have been overridden by the Ordovician (Tatina) rocks. This interpretation is shown in the section forming figure 23 (p. 98). Somewhat similar relations are shown in figure 10. Here the Devonian is seen resting on top of the Carboniferous, which is faulted up on the Tertiary beds. Rocks of the Tonzona group succeed the Devonian limestone. The structure may be interpreted as close folding overturned to the northwest or a series of thrust faults.

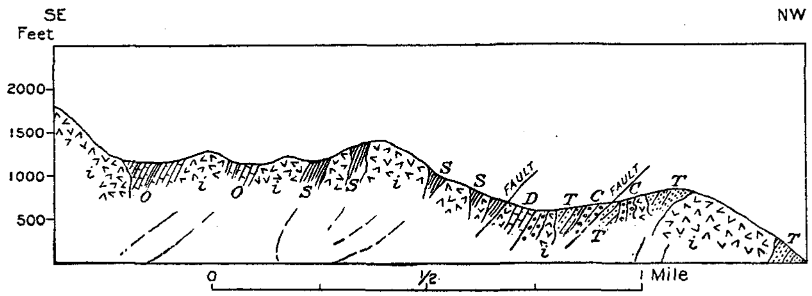



FIGURE 10.—Section showing folding of Devonian and Carboniferous rocks 3 miles southeast of the camp of August 4. *T*, Kenai formation (carbonaceous sandstone and shale), Eocene; *C*, Cantwell formation (white quartz conglomerate and slate), Carboniferous (?); *D*, massive siliceous semicrystalline limestone, Devonian; *S*, Tonzona group (black slates, chert), Silurian or Devonian; *O*, Tatina group (thin-bedded sandy limestone and carbonaceous slate), Ordovician; *i*, intrusive.

Similar limestones occur along the north front of the range south of the Tanana Valley, but these are in small areas and have not been mapped, being included in the areas of Tonzona group. A broad belt of this limestone was crossed between Tanana and Yukon rivers, and several other areas are indicated in the Rampart region. Detailed mapping will probably show that there are many others. In these occurrences north of the Tanana the limestone is blue and not crystalline, as in the southern areas. Nor is it as much deformed. Some slates are associated with it which may belong to the same formation or may be older. The total thickness of the rocks mapped as Devonian north of the Tanana may aggregate several thousand feet.

#### AGE AND CORRELATION.

A few fossils were obtained from this limestone at a number of places, as follows:

Locality 13. One mile south of camp of July 24.
Locality 16. Near camp of July 25.
Locality 25. Two miles west of camp of September 6.
Locality 26. Near camp of September 11.

Prof. Charles Schuchert reports as follows on this material:

Localities 13, 16, 25, and 26 seem to represent one general horizon toward the top of the Middle or of the lower portion of the Upper Devonian. There is nothing sufficiently diagnostic to indicate with certainty the Upper Devonian, while the general facies is rather that of the upper part of the Middle Devonian.

Locality 13:

- Cyathophyllum sp. undet.
- Dendropora, probably new.
- Favosites, a small ramose species similar to F. clausus Rominger.
- Orthothetes, a small species reminding one of O. arctostriatus.
- Cyclonema, like C. multilira and C. hamiltoniæ Hall.
- Euomphalus or Straparollus.
- Bellerophon, very much like B. mæra Hall of the Chemung.
- Aviculopecten.

Locality 16: Diphyphyllum n. sp.

Locality 25: A large species of compound Cyathophyllum.

Locality 26:

- Phillipsastrea sp. undet.
- Crinoidal fragments.

This limestone appears to be at the same horizon as that found in association with the volcanic rocks of Spurr's Rampart "series." It has been identified on the upper Yukon[1] and on the Porcupine,[2] where Kindle called it the Salmon-Trout limestone. Spurr[3] found on the middle Kuskokwim a heavy gray limestone carrying what are probably Middle Devonian fossils, which probably represents the same horizon. It is associated with argillaceous limestones and slates, together with black calcareous shales and arkoses. All these rocks were grouped together under the name "Tachatna series." It is possible that the shales and arkoses of this series may be synchronous with some of the deposits of the Tonzona group.

### CANTWELL FORMATION (CARBONIFEROUS?).

#### CHARACTER AND DISTRIBUTION.

The Cantwell formation includes a series of heavy conglomerates interbedded with a few shale layers and succeeded by finer conglomerates and red sandstones interbedded with gray and black clay shales. Eldridge first described a part of this formation as a series of conglomerates and coarse sandstones outcropping along the head of Nenana (then called Cantwell) River. The writer traced these rocks westward from Eldridge's locality and found them associated with a great series of shales and sandstones. It would seem best to include these in the same map unit. In any event reconnaissance work was not sufficient to differentiate the upper shale and sandstone series from the lower sandstone and conglomerate series, and it does not seem likely that this can be done, even with more detailed study.

The basal conglomerate of this formation is made up chiefly of well-rounded white quartz and chert pebbles, the largest of which are 2 inches in diameter. The basal character of the conglomerate is well illustrated in several localities where it rests unconformably on the older rocks and also contains rounded fragments of them. That part of the formation seen by Eldridge contained only the basal beds of the series. On being traced to the north and west these are found to be succeeded by reddish sandstone and gray, drab, and black shales. The sandstones are in some places bright red, but grade from this into a reddish-brown to medium-brown color. The shales are both argillaceous and arenaceous, the latter phase grading into a shaly sandstone. Some of them carry a large amount of carbonaceous matter, and coal seams are interbedded with these rocks, but those seen by the writer appear not to have any commercial importance. In this connection it is interesting to note that the Nation River formation of the Yukon, which, as will be shown, is correlated with the Cantwell formation, also carries some thin coal beds.

[1] Bull. Geol. Soc. America, vol. 19, 1908, pp. 280-291.
[2] Idem, p. 327.
[3] Spurr, J. E., A reconnaissance in southwestern Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 157-159.

A typical section near the camp of August 9, on the West Fork of the Toklat, showed a basal conglomerate about 20 feet in thickness resting unconformably on the upturned edges of Paleozoic slates and limestones. This bed contains pebbles of the underlying rocks. Above it is exposed about 20 feet of carbonaceous shale, and this in turn is overlain by a heavy quartz and chert conglomerate containing sandstone lenses which probably has a thickness of 100 to 200 feet and passes upward gradually into a grit and sandstone series with local conglomerate layers. This upper member is made up of heavy sandstone and grit, thin-bedded sandstone, and sandy shales which on weathering have an iron stain, together with considerable carbonaceous clay shale. The sandstone and shale member probably aggregates 1,200 feet in thickness at this locality. One small area of these rocks, made up chiefly of conglomerate and red sandstone, was found on the Tonzona, where they formed a syncline resting on the cherts and slates of the Tonzona group. (See fig. 11.) The most extensive exposure of them occurs in a belt of unknown width stretching from the McKinley Fork of the Kantishna to the Nenana Valley and probably beyond. In this area, especially toward the Nenana, lava flows interbedded with the conglomerate are very prevalent. In some localities these volcanic rocks form over half of the thickness of strata exposed belonging to this formation. These lavas appear to be chiefly andesites, but also include rhyolites and basalts. That they were surface flows is indicated both by their stratigraphic relations and by the amygdaloidal and columnar structure that some of them exhibit. Some tuffaceous beds also occur in this formation. The Cantwell formation is cut by diabase dikes and some granitic stocks.

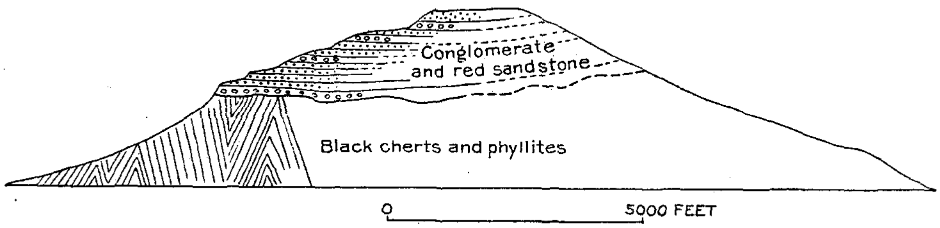



FIGURE 11.—Diagrammatic section near the camp of July 28, showing supposed relation of conglomerate of Cantwell formation to phyllites and cherts of the Tonzona group.

#### STRUCTURE AND THICKNESS.

The dominant strike lines of the Cantwell formation are all parallel to the main axis of the range. They swing from northeastward near the west end of the conglomerate on the McKinley Fork of the Kantishna to eastward on the Yanert Fork of the Nenana. The typical structure of the formation is that of broad, open folds accompanied by faulting. The massive conglomerate and sandstone beds have yielded but little in the lines of movement and the stress seems to have been taken up largely by faulting, but the interbedded shales are considerably deformed. It appears that the physical character of the formation has played a dominant part in determining the structure, for the series as a whole has been subjected to many of the stresses that have affected the older rocks. This must be so, for the younger Tertiary strata have been involved in the complex deformation of the province. If, therefore, the Cantwell formation is not as sharply folded as the older rocks, it is probably in large part because the massive beds were able to resist the movement, some of which has been taken up by lines of shearing that have followed the shale beds and the lines of parting between the shales and the massive beds. It should be noted, however, that where thinner beds of conglomerates have been found, particularly in the region near Mount McKinley and to the southwest, these are involved in all of the complex structure of the area. The older beds are thrust up over the conglomerate and the conglomerates themselves are much faulted.

The infolding and faulting of the conglomerate are shown in figure 9 and also in figure 23 (p. 98). In the section shown in figure 23 the conglomerate bed is less than 50 feet in thickness. Less intricate relations of the conglomerate horizon are shown in figure 11, an interpretation of the field data not actually to be seen in any one group of outcrops. In this section the conglomerate is probably somewhat faulted, though the data at hand are not sufficient to indicate the lines of movement.

In the belt of the Cantwell formation that stretches from the McKinley Fork to the Yanert Fork open folding is the rule, and here a series of anticlines and synclines are well marked. A beautiful example of this structure was observed in the valley in which the camp of August 10 was located. This valley occupies an anticlinal arch, in the center of which the older rocks have been exposed and on both slopes of which the conglomerate beds of the succeeding sandstones and shales dip away from the axis of the valley. These features are illustrated in the accompanying sketch map and section (fig. 12), which are based on foot traverses made in the field.

The section shows a synclinal valley cut through the Cantwell formation, which here rests on the upturned edges of limestones and carbonaceous slates of Ordovician age (Tatina). The northern limb of the anticline forms the southern limb of a syncline whose northern arm rests on the upturned edges of phyllites and cherts of the Tonzona group. There has been some faulting along the central limb of the two folds. To the east the syncline flattens out, as is shown in figure 13, which is reproduced from the field notebook. In this sketch the Cantwell formation

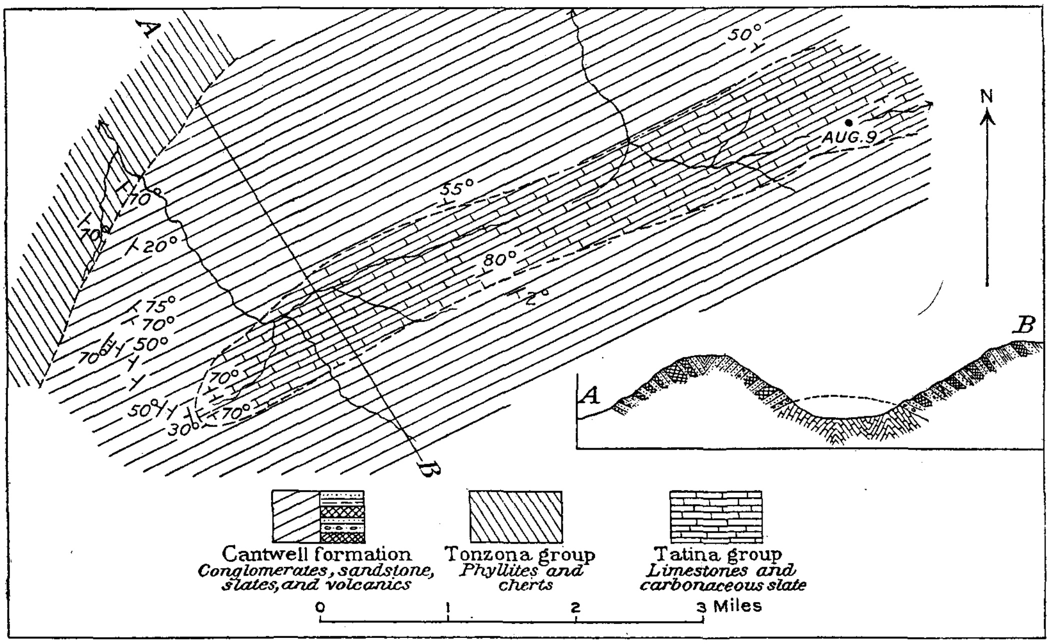



FIGURE 12.—Sketch map and section showing stratigraphic relations of Cantwell formation in the upper Toklat basin near the camp of August 10.

is seen as a broad syncline forming a high mountain mass. The southern arm of the conglomerate rests on the limestone and slates of the Tatina group, which are cut by intrusive rocks. The section also shows something of the irregular distribution of the volcanic rocks, as well as the large percentage of the formation made up of them. It seems probable that closer study would have shown similar structural features in other parts of this belt. Yanert Fork appears to occupy such an anticline, and south of this is a broad syncline one arm of which rests on the upturned edges of the older rocks. The ridge north of Yanert Fork appears to be made up of a sharp syncline which on the north side is faulted against the Paleozoic beds.

One feature of the folding of the Cantwell formation is not easy to explain. Although the conglomerates are faulted and the shales show evidence of having suffered deformation, the associated lava beds are as a rule fairly massive. As these lavas are believed to be contemporaneous with the conglomerates and shales, it is difficult to understand why they should not show evidence of deformation. In some places intrusive rocks of later age have been mistaken for lavas, but there are many which are undoubtedly lavas. It may be that the lavas were competent to resist the movement and have also been protected by the conglomerate beds, which are very massive, and that the latter have taken up the strain of the deformation. It must be confessed, however, that this explanation is far from satisfactory, and further work will have to be done before this question can be definitely settled.

No complete section of the Cantwell formation has been measured, so it is impossible to make definite statements in regard to its thickness. In the headwater region of the Toklat basin, near the camp of August 13, however, partial measurements were made, and these were supplemented by estimates, giving a total thickness in this region of at least 2,000 feet. Of this the lower 400 or 500 feet consists chiefly of massive cherts and quartz conglomerate, with one basal bed carrying fragments of the underlying metamorphic rock, having a thickness of 20 feet. Above the conglomerate member occurs about 1,200 to 1,500 feet of massive sandstone interbedded with black and gray shales.

To the east of this locality there is so much volcanic material that the thickness is probably much greater, but it varies greatly from place to place. It should be remembered that the Cantwell formation in most places represents the top of the stratigraphic column with the exception of the Quaternary deposits. Therefore any statement in regard to its thickness will simply represent the amount that has been left by erosion, and will not indicate the total thickness of strata deposited when the formation was laid down.

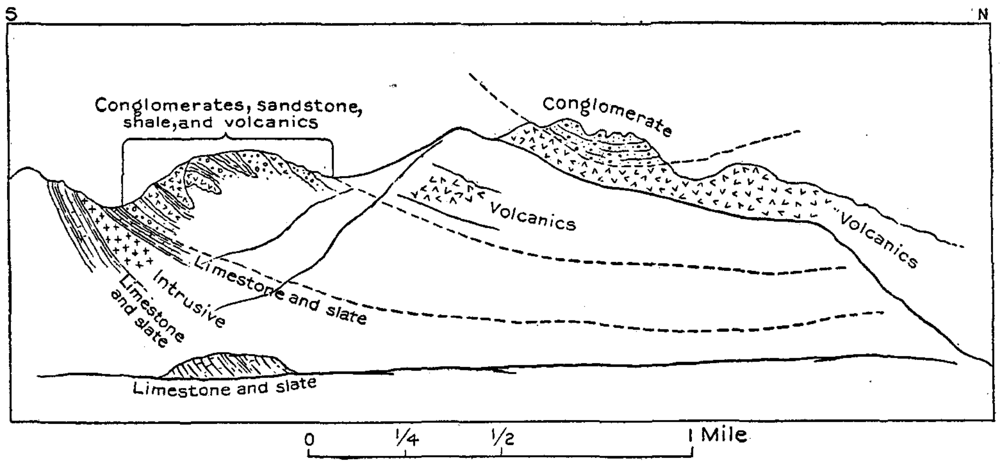



FIGURE 13.—Section west of the camp of August 10, showing limestones and slates (on the left) overlain by the conglomerates, sandstones, and volcanic rocks of the Cantwell formation.

#### AGE AND CORRELATION.

No definite statement in regard to the age of the Cantwell formation can be made on the basis of present knowledge. As has been shown, it rests unconformably on various members of the Paleozoic, the uppermost of which is probably Middle Devonian, and it may be said, therefore, to be younger than the Middle Devonian. In the opinion of the writer it is of pre-Eocene age, but this admits of less definite proof. It can not be denied that the Cantwell formation resembles lithologically and structurally certain phases of the Kenai found in the Yukon basin. For example, on Seventymile River Mr. Prindle found a series of highly tilted heavy conglomerates interbedded with some shales carrying Kenai (Eocene) plant remains, and these beds closely resemble the Cantwell formation. It is also somewhat similar to the Kenai formation of the Matanuska basin. On the other hand, it will be shown that the typical Kenai of the province under consideration is very much less indurated and as a rule much less deformed than the Cantwell formation. Nowhere in Alaska has any belt of known Kenai rocks as extensive as the area occupied by the Cantwell been found, for the Kenai, as will be shown, is made up chiefly of fluviatile and lacustrine deposits which, originally laid down in basins of moderate size, now remain only in small isolated areas or in broken, rather narrow belts. Still it should be recorded that the expedition found some shale beds which carried Kenai plants in close association with the Cantwell formation. The locality is near the camp of

August 12, in the upper basin of Toklat River. The accompanying section (fig. 14) indicates the relations at this locality. It will be noted that the plant remains occur in the black shales, which are interbedded with layers of impure coal, and that these are separated from the conglomerate, which is believed to belong to the Cantwell, by a fault. The shales carrying the plant remains, however, resemble lithologically the shales which are interbedded with the conglomerate. Had these plant remains proved to be of pre-Eocene age, they would probably have been accepted as evidence of the age of the Cantwell formation; but in view of the fact that the other evidence points to the pre-Eocene age of the Cantwell this occurrence of Kenai (Eocene) plants in rocks closely associated with the conglomerate of the Cantwell formation is not considered a conclusive indication of the Eocene age of that formation. In this connection it should be noted that no such development of coal beds was found in the Cantwell as is usually associated with the Eocene plant-bearing beds.

No other fossils of any kind were found in the region occupied by the Cantwell rocks. The possibility of its being of Mesozoic age has been carefully considered. As a matter of fact, however, the Mesozoic section of this part of Alaska has been well determined, and nowhere in it have any formations been recognized that resemble in any degree the Cantwell formation. Moreover, the Mesozoic of central Alaska is almost universally fossiliferous, whereas the Cantwell is without fossils. These considerations, together with certain correlations made with terranes of adjacent regions, have led the writer to the opinion that the Cantwell is of pre-Mesozoic age, and if this is so it would be most likely to fall in the Carboniferous. It will be shown below that the Nation River formation of the Yukon, known to belong to the Carboniferous, resembles in many ways the Cantwell, and it is on this basis of lithologic resemblance, supplemented by certain facts of stratigraphic occurrence, that the Cantwell formation has been tentatively assigned to the Carboniferous.

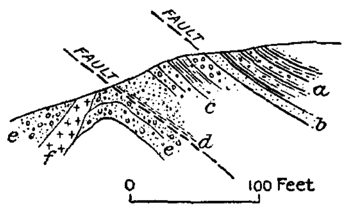


FIGURE 14.—Section showing structural relations at locality where Kenai fossil plants were found, 3 miles east of the camp of August 12. *a*, Carbonaceous shale and coal beds with siliceous nodules carrying Kenai plants; *b*, fine micaceous sandstone; *c–d*, Cantwell formation (?); (*c*, white quartz conglomerate and ferruginous sandstone; *d*, carbonaceous shale); *e*, conglomerate and sandstone; *f*, intrusive (?).

The extension of the strike of the Cantwell formation from the head of the Yanert Fork of Nenana River, where it was last seen by the writer, would carry it across Delta River into the Chistochina area, tributary to Copper River. Mendenhall[1] has described a series of heavy quartzitic conglomerate, tuff, arkoses, and quartzite, together with a large amount of igneous material and some calcareous beds, which occur in the headwater region of the Chistochina. This group of deposits he named the Chisna formation and correlated with certain tuffaceous beds observed by him on Delta River in a previous expedition. In some of the calcareous beds Mendenhall found some crinoid stems, but the formation has yielded no other fossils.

The Chisna is separated from the Permian lying to the north by a fault of several thousand feet throw. On the south it is mantled by the Quaternary silts of the Copper River valley. Mendenhall had little to guide him in determining the age of this formation, but provisionally assigned it to the upper Paleozoic, considering that it was probably younger than his Tetelna volcanics, which are largely composed of altered andesite. Both the Tetelna and the Chisna he regarded as pre-Permian in age. He also provisionally correlated these rocks with the Wellesley formation of the upper White and Tanana basins.

The Wellesley formation occurs in a series of isolated hills through the broad alluvial flat which separates the central part of the White River basin from the Chisana or east fork of Tanana River and which lies in the extension of the strike of the Chisna beds. The Wellesley formation consists of a lower member made up of coarse massive conglomerate interbedded with a few layers of clay slate and an upper member which is made up largely of clay slates. The studies by the writer[2] indicate that the Wellesley may at its type locality have a thickness of 1,000 to 2,000 feet. It rests unconformably on some greenstone schists which are regarded as part of the Birch Creek schist. A few igneous rocks cut the Wellesley formation.

[1] Mendenhall, W. C., Geology of the central Copper region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, pp. 33–34.

[2] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 470–472.

The data at hand when the report just cited was written indicated that the Wellesley belonged in the upper Paleozoic, being either Devonian or Carboniferous. A few invertebrates were found in the slates interbedded with the conglomerates, and these were provisionally assigned to the Devonian or Carboniferous by Charles Schuchert.[1]

It will be observed that the Wellesley has closer lithologic similarity to the Cantwell than has the Chisna. The Chisna, however, is not unlike that part of the Cantwell which carries a large amount of igneous material. The volcanic rocks associated with the Cantwell may in part represent the same outburst as those of the Tetelna. The facts at hand, therefore, seem to justify the provisional correlation of these three formations and their assignment to the post-Devonian and pre-Permian part of the Paleozoic column.

In 1906 the writer, in company with E. M. Kindle,[2] studied the upper Yukon section and there noted a formation made up of conglomerate, sandstones, and shales which in many ways corresponds stratigraphically and lithologically with the formations above described. This group of arenaceous deposits, which was called the Nation River formation from the locality of its type exposures, includes about 3,700 feet of gray clay shale and some clay slate intercalated with heavy beds of conglomerate and some sandstone. There are two noteworthy conglomerate beds. One occurs at the base and is very massive; the other, which is not quite so heavy, is about 1,000 feet above the base. This 1,000 feet is made up of shales with some fine conglomerate and sandstone; the upper 500 feet is chiefly gray shales. No igneous rocks of any kind were found in association with this formation.

The Nation River formation succeeds the lower Carboniferous limestone (Mississippian?), upon which it probably rests unconformably. It is in turn overlain by a massive limestone which is probably also unconformable, and this has been proved by paleontologic evidence to belong to the upper part of the Carboniferous. A few beds of bituminous coal occur in the Nation River, and some of these contained a few fragmental plant remains which David White has provisionally assigned to the Carboniferous. The Nation River formation is, then, definitely known to be Carboniferous and later than the Mississippian. It therefore represents about the same time as the Pennsylvanian.

It is with this formation that the Cantwell formation is provisionally correlated. There is considerable lithologic similarity between the two, and the stratigraphic relations of the Cantwell, so far as they have been determined, correspond to those of the Nation River. Both of these formations appear to rest unconformably on the older rocks—a fact which, if they are to be correlated, indicates a widespread period of erosion.

#### UNDIFFERENTIATED PALEOZOIC ROCKS OF YUKON-TANANA REGION.

In the region north of the Tanana the pre-Tertiary rocks include, besides the Birch Creek schist, the slate, cherts, and sandstone of the Tonzona group, and Devonian limestone, also a considerable area of undifferentiated Paleozoic rocks. These sediments in part belong to the Tonzona and in part are Middle Devonian, but the hasty character of the work in this field has not made it possible to extend these differentiations over the entire area.

There also appears to be in this area a pre-Tonzona formation which is not represented in the region to the south. This is made up of graywackes, fine conglomerates, slates, and some massive limestone. Mr. Prindle also reports that it contains some cherts. Except for the massive limestone, this formation resembles the lower member of the Tonzona, and such it may prove to be. For the present, however, it is considered a distinct formation. In this limestone Mr. Prindle has found some fossils, upon which E. M. Kindle has reported as follows:

7AP277 (Quail Creek). This lot contains several species of corals and fragmentary representatives of a large lamellibranch and a gasteropod. They are referred provisionally to the following genera:

| | |
|---|---|
| Cladopora? | Diphyphyllum. |
| Syringopora. | Megalomus?? |
| Amplexus? | Pleurotomaria? |
| Streptelasma? | |

[1] Brooks, A. H., A reconnaissance in the White and Tanana River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 472.

[2] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 294-295.

The minute characters used for specific limitation in corals are not well enough preserved in these specimens to justify any attempt at specific determination. As the genera noted above are all common to both Devonian and Silurian horizons, they afford no definite evidence as to which of the two the corals represent. The chief interest o the collection lies in the lamellibranch fragments, which represent a very large thick-shelled form that appears almost certainly to be specifically identical with a shell occurring in the limestones of Glacier Bay and similar beds at Freshwater Bay, in southeastern Alaska. This southeastern Alaska shell has been referred to the genus *Megalomus* and considered to belong to a late Silurian fauna.

The distribution of the Tonzona in this field has already been discussed (pp. 75–76). It should be added, however, that in the opinion of the writer the extensive areas of black slates and phyllites which occur in the Baker Creek region should probably be assigned to this group.

The Middle Devonian is represented by a blue fossiliferous limestone, which is in places associated with extensive bodies of greenstones, chiefly ancient lava flows. It is impossible to state, with only the present knowledge, whether all the greenstones belong to this same period of extrusion, but it seems probable that there are some which are older than Middle Devonian. These greenstone eruptives were all classified together by Spurr under the name Rampart series. Carboniferous rocks occur to the northeast of the area here discussed,[1] and some beds of this age may be included in the undifferentiated Paleozoic rocks. The rocks to the northeast are made up of black, gray, and green shales, and the contained faunas, according to Girty, belong to the upper part of the Carboniferous system.

## MESOZOIC ROCKS.

### OUTLINE OF OCCURRENCE.

Though Mesozoic rocks cover large areas in the southern part of the central Alaska province, the era is chiefly represented by two terranes which belong to the Middle Jurassic, but Cretaceous rocks have also been found. The Skwentna group is the lower of the two and in the Alaska Range is made up chiefly of volcanic rocks of varied lithologic character. It appears that the same horizon is represented in the Matanuska and Talkeetna basin by volcanic rocks which contain some interbedded sediments. The latter are supposed to be unconformable to the metamorphic rocks. In the type area of the Skwentna group, in the basin of Yentna River, the base of the series has not been studied; hence its relation is unknown. It is probable, however, that these rocks rest unconformably upon the Paleozoic strata.

In the Alaska Range the Skwentna group is succeeded unconformably by a considerable thickness of slates, grits, and sandstones, with subordinate limestone masses, which are referred to the Middle Jurassic and have been termed the Tordrillo formation. The same general horizon is also represented in the basin of Matanuska River. The Tordrillo occurs in the great synclinorium infolded in the heart of the Alaska Range and probably constitutes a considerable part of the bed rocks in the unexplored portions of the range. Another Jurassic sedimentary formation, which is somewhat younger than the Tordrillo, is found in the Matanuska basin.

Near the eastern margin of the area mapped (Pl. IX, in pocket), at the head of the Matanuska, is a small area of Lower Cretaceous limestone, which is more extensively developed in the adjacent areas farther east. This limestone has not been recognized in any other part of the province.[2] The Upper Cretaceous is represented by small areas of conglomerates, sandstones, and slates in the northern part of the province, between the Yukon and the Tanana. These rocks rest unconformably on Paleozoic rocks and have been cut by granite.

The aggregate thickness of the Mesozoic terranes of the Mount McKinley province is probably between 3,000 and 7,000 feet. It is possible, however, that the Skwentna group of volcanic rocks locally exceeds this thickness.

The great masses of granite and granodiorite which occur in the province were probably intruded during Mesozoic time. The granodiorites of the Alaska Range and the Talkeetna

[1] Prindle, L. M., The Fairbanks and Rampart quadrangles: Bull. U. S. Geol. Survey No. 337, 1908, pp. 22-23.

[2] Martin's recent studies in the Matanuska region show that there is a Mesozoic horizon chiefly made up of shales and probably of Cretaceous age which is widely distributed in the coal field.

Mountains cut the Middle Jurassic rocks. In the southern part of the province, therefore, the granite can probably be assigned to a time later than Middle Jurassic. To the north some granites cut Upper Cretaceous rocks, and there are others which may be older.

### TRIASSIC ROCKS.

No Triassic rocks have been identified within this province, though a considerable thickness of sediments belonging to this system has been identified in adjacent areas. Stanton and Martin[1] have described some 2,000 feet of cherts, limestones, and shales carrying invertebrate Triassic fossils which occur in the Alaska Peninsula. These are unconformably overlain by rocks of Lower Jurassic age—a horizon which has not been recognized in the Mount McKinley region.

In the Copper River region, to the east, Schrader and Spencer[2] noted the presence of about 4,000 feet of thin-bedded limestone and black shales, which are referred to the Triassic. These rest conformably on the Chitistone limestone, which is 2,000 feet or more in thickness and has been found by Moffit and Maddren[3] to carry Triassic fossils. The Chitistone limestone rests apparently conformably on the Nikolai greenstone, whose age is uncertain, but which probably represents the top of the Paleozoic or the base of the Mesozoic column. A reference to the table opposite page 52 will show that Triassic beds have been found also in the White River country, on the upper Yukon, and in southeastern Alaska. In all these localities the Triassic rocks consist either of limestone or of fine argillaceous sediments indicating deep-sea conditions. As there is a considerable thickness of Triassic beds on both sides of the Mount McKinley region, it is most likely that sediments of that period originally covered this area also. They may have been removed by erosion or may be buried underneath some of the younger deposits.

### SKWENTNA GROUP (LOWER MIDDLE JURASSIC).

#### CHARACTER AND DISTRIBUTION.

In the journey from Cook Inlet, after traversing a broad gravel-floored plain, the party entered a foothill belt which differs in topography and geology from the main range lying to the west. These foothills, which include mountains up to an altitude of 4,000 and 5,000 feet, have an extremely irregular topography. The crest lines are very sinuous, the ridges and peaks sharp, and the valleys steep-walled. (See Pl. XI, *B*, p. 88.) The bed rock was found to consist chiefly of a complex of igneous rocks which are largely volcanic. Dacites predominate among these volcanic rocks, which include both lavas and tuffs. (See p. 153.) Some basalts were, however, also noted. With the volcanic rocks are associated some arkoses, but these were not studied in detail in the field, for they were identified only after microscopic investigation. A few cherts and one small belt of black limestone were also found intermingled with the volcanic rocks. The whole series is cut by many intrusions which include some acidic rocks, classed by Mr. Prindle as alaskites (p. 141), and granite and diabase dikes are very common. In the hand specimens the volcanic rocks are chiefly of a greenish and reddish color. Locally they carry considerable pyrite. The whole series is entirely distinct from anything else which was found in the province.

Spurr,[4] who first described this belt of rocks, traversed them in 1898 along the valley of Skwentna River. He described them as basaltic glass, lavas, tuffs, andesite, trachyte, and chloritic and feldspathic slates, together with some arkoses. He also noted the presence of carbonaceous cherts.

Spurr termed these rocks the Skwentna series, which he defines as a series of volcanic rocks interstratified with tuffs and derived slates and with some arkoses, all of which have been

[1] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, p. 410.
[2] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of the Copper River district, Alaska, a special publication of the U. S. Geol. Survey, 1901.
[3] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: Bull. U. S. Geol. Survey No. 374, 1909, pp. 27–28.
[4] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 149–152.

highly folded and in parts cut by dikes. These rocks are here placed in one group, but more detailed surveys may resolve them into different formations.

The Skwentna group as here defined forms a northeastward-trending belt lying between the Quaternary gravels of Cook Inlet and the high range made up of the later Mesozoic sediments. Some evidence obtained by Spurr indicates that these rocks also form Mount Yenlo, east of Yentna River. Their southwestern extension has not been determined, but from the topographic appearance of the country the writer is inclined to think that they extend at least as far as Mount Spurr, and they have been so indicated on the map (Pl. IX, in pocket).

Considerable areas in the Matanuska and Talkeetna basins are mapped on Plate IX as belonging to the Skwentna group, but the correlation of these rocks with the Skwentna group is not definitely established. They have been studied by Paige and Knopf,[1] from whose report the following description is taken. They comprise andesitic greenstone, quartz porphyries, tuffaceous sandstone, shales, and conglomerates, and the sediments include some beds of coal. The greenstones are the most characteristic members and are widely distributed. They are described as being chiefly andesitic and of extrusive origin. With the greenstones also occur rhyolites and dacites, including their tuffs. Some of the rhyolites are flinty looking. While volcanism was active in one part of the region sedimentation was going on in the other part and some feldspathic sandstones were laid down. With these occur some shales carrying numerous limestone nodules.

It will be noted from the above description that the rocks of the Talkeetna and Matanuska basins which are correlated with the Skwentna group are very similar to those of the type locality of the Skwentna, with the exception that the lavas appear to be chiefly andesites rather than dacites. It also appears that in the eastern area considerable amounts of sediment were laid down during the volcanic outburst. These facts appear to justify the correlation of these two groups of volcanic rocks. It is of interest to note that all who have studied this complex have reported evidence of mineralization, though so far no workable ore bodies have been found. This subject will be further discussed in the section on mineral resources.

### STRUCTURE AND THICKNESS.

The general trend of the Skwentna group along the Alaska Range is northeasterly, parallel to the axis of the mountains. Spurr notes the fact that the rocks have undergone a considerable amount of folding and faulting, and this statement is borne out by the observations of the writer, though few details were determined. In the eastern part of the region Paige and Knopf appear to have found less complexity of structure. Here the trend is a little east of north and the folding is rather gentle, but there are numerous faults.

No data whatever as to the thickness of the Skwentna were obtained by the writer, but in the Matanuska and Talkeetna area Paige and Knopf have determined it as approximately 2,000 feet. The volcanic rocks which constitute the lower part of the group in this area are estimated to have a thickness of over a thousand feet, and the upper member, made up of sandstone, shales, and conglomerates and some coal, is estimated to have a thickness of a thousand feet, more or less. It appears probable that the thickness of the group in the western part of the region is greater than this, but there is no definite evidence at hand, and the amount of volcanic accumulation is likely to have differed greatly in different parts of the region.

### AGE AND CORRELATION.

In the type area of the Skwentna group no conclusive evidence of age was obtained. The westerly contact of the belt was not studied, and no other series was found in contact with the volcanic rocks except in one place, where they were overlain unconformably by some Eocene coal-bearing beds. The direct evidence, therefore, indicates only that they are of pre-Eocene age. Spurr, however, had previously determined that the Skwentna rocks are overlain by the Tordrillo formation, which has since been determined to be of Middle Jurassic age. It also seems

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 16–19.

likely that the Skwentna group rests unconformably on the Palezoic rocks of the Kichatna Valley. This would appear to give the Skwentna a place in the lower Mesozoic or upper Paleozoic.

Fortunately, in the Matanuska basin some more direct evidence is available, for Paige and Knopf obtained some fossils from the sediments which form a part of the Skwentna group in that region. On this point their report is cited as follows:[1]

The fossils found in tuffs associated with the greenstones were submitted to T. W. Stanton, who reports as follows: "6 A. K. 201. Fossiliferous tuffs, associated with lavas and coarse pyroclastics, from the head of Matanuska River.

| | |
|---|---|
| Rhynchonella. | Astarte? |
| Lima. | Protocardia. |
| Pecten. Smooth species. | Pleuromya. |
| Pecten. Species of Vola type. | Sonninia? |
| Trigonia. | |

"The Jurassic age of this lot is clearly shown by the form of the *Trigonia* and of the ammonite (*Sonninia?*). The general aspect of the fauna is that of the lower part of the Enochkin,[2] though it may be somewhat older than the fauna in lots 88A and 88B. With the exception of the *Vola*-like species of pecten, there is nothing in it to suggest the lower Jurassic fauna of Seldovia."

According to this determination the age of the greenstones is lower Middle Jurassic.

In general the sandstones and shales are barren of fossils, though belemnites are rather common. The following species, however, were found and were submitted to Mr. Stanton, who reports as follows:

"6 A. K. 88A. Caribou Creek, tributary to Matanuska River.

| | |
|---|---|
| Inoceramus cf. lucifer Eichwald. | Phylloceras. |
| Pleuromya. | Stephanoceras. |
| Pleurotomaria. | Oppelia? |

"6 A. K. 88B. Same locality as preceding, but found in float bowlder in stream bed.

| | |
|---|---|
| Inoceramus. | Stephanoceras. |
| Natica. | Sonninia? (two species). |
| Phylloceras. | Belemnites. |

"The two lots are evidently from the same horizon, and nearly all the species occur in the lower part of the Enochkin at Snug Harbor."

The age of these sandstones and shales is therefore substantially the same as that of the greenstones—lower Middle Jurassic.

The evidence at hand would appear, therefore, to justify the statement that the Skwentna group belongs to the lower part of the Middle Jurassic.

In seeking for possible terranes to correlate with the Skwentna group it is natural to turn to the most complete Mesozoic section which has been worked out in this part of Alaska, namely, that of Cook Inlet and Alaska Peninsula. In that region the Enochkin formation, which it will be shown is equivalent in age to the Tordrillo, the formation unconformably overlying the Skwentna, rests on sandstone, tuffs, and lavas of Lower Jurassic age. It would appear, therefore, that in the Alaska Peninsula region the Skwentna is not represented unless it is to be correlated with these Lower Jurassic rocks, and the paleontologic evidence is against this correlation. Nor has any other equivalent formation been found in other parts of the adjacent provinces, unless the greenstones of the Orca group and the Nikolai greenstone may be so considered. In the upper White River region there are also some volcanic rocks which are provisionally assigned to the Mesozoic and which may prove to represent this same horizon. It may be, however, that this outburst of volcanism was confined to a comparatively small area and that its equivalents in adjacent fields must be sought in sedimentary beds.

#### TORDRILLO FORMATION (MIDDLE JURASSIC).

##### CHARACTER AND DISTRIBUTION.

The Alaska Range where traversed by the party along the valley of Kichatna River is made up of a broad synclinorium of Middle Jurassic rocks, here termed the Tordrillo formation. This formation consists of a series of closely folded and faulted grits, sandstone, and fine conglomerate, together with argillites and a few layers of limestone. Although no continuous section was found, it appears that the rocks of the lower part of the formation are coarser than those of the

[1] Op. cit., pp. 18–19.

[2] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, pp. 391–410.

upper part. In this lower part massive grits and sandstones predominate, with some argillite, mostly in the form of slates but in places altered to phyllite. The upper part of the formation is made up chiefly of argillite, with subordinate sandstone members and a few layers of limestone. (See Pl. XI, *A*.)

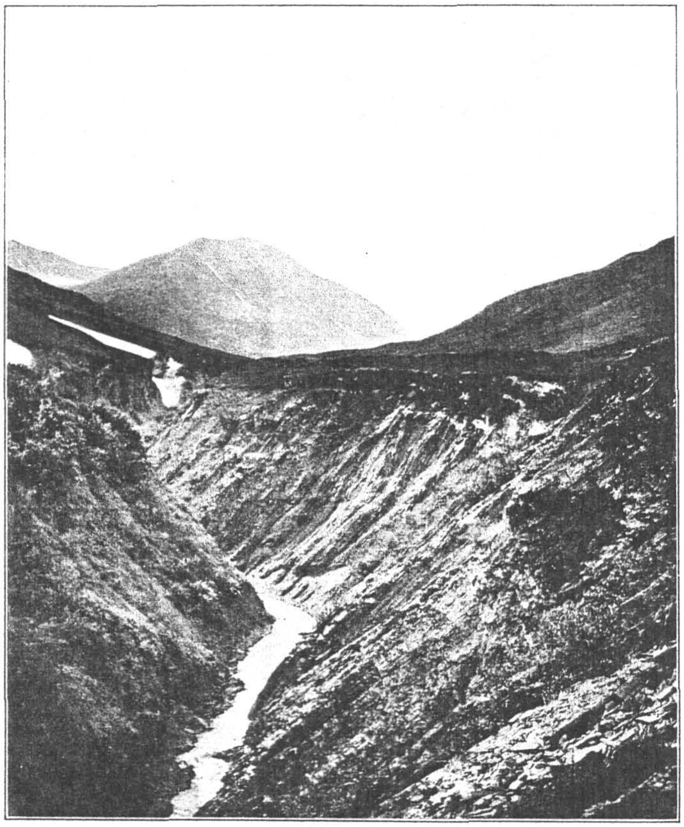
The lower arenaceous beds are typically 10 to 30 feet in thickness and are interbedded with the argillites. The conglomerates are mostly very fine, the pebbles usually not exceeding a quarter of an inch in diameter. These fine conglomerates pass into grits and these in turn into a sandstone. The grits, conglomerates, and sandstones in many places carry some feldspar among the pebbles. The cement, which is argillaceous and siliceous, is as a rule of a dark-gray or blue color. These rocks are well jointed and grade into flags which are largely composed of siliceous material. The argillites include slates and phyllites in about equal proportions. The slates are of the typical bluish color and are well cleaved. The phyllites carry a small amount of sericite. Some of the argillites carry a great deal of carbonaceous matter. Interbedded with the argillites are siliceous slates, which generally carry considerable pyrite and are locally seamed with small stringers of quartz. Limestones were found at only a few localities and apparently occur only in thin lenses. Where observed, the limestone is of a bluish color and entirely unmetamorphosed.

One phase of these sediments deserves special mention. This includes some conglomerates which have the appearance of being basal. The pebbles of these conglomerates, some of which are an inch or more in their longest diameter, are identical in character with the rocks of the older series upon which the Tordrillo formation is believed to rest unconformably. The pebbles are made up in part of chert, in part of phyllite, and in part of slate, with a siliceous cement which locally carries some calcareous matter. Slate or phyllite layers are interbedded with these conglomerates. Rocks of this type were noted in the drift at several localities near the western margin of the formation but were found in place at only one locality, near the camp of July 15, in the basin of Tatina River. Here the outcrop was not very extensive, but it appeared that there was at least 10 to 20 feet of this conglomerate, and the strike lines were at variance with those of the older phyllites that outcrop close at hand. It appears, therefore, that this is the basal bed of the series. If this is the case, it is not unlikely that these basal beds may be exposed at other places in the heart of the range where the folding may have brought up the older series but which have been overlooked in the hasty reconnaissance. In the absence of evidence to the contrary the whole belt in the heart of the range is mapped as the Tordrillo formation. (See geologic map, Pl. IX, in pocket.)

The Tordrillo formation occupies a belt 25 to 30 miles wide in the heart of the Alaska Range. On the west there appears to be pretty definite evidence that these rocks rest unconformably on the slates and phyllites of the Tonzona group. On the east the Tordrillo formation succeeds the slates and phyllites, which are also provisionally assigned to the Paleozoic but which in lithologic character do not differ very materially from the Tordrillo. Spurr has shown that the Tordrillo overlies the volcanic rocks of the older member of the Skwentna groups along Skwentna River.

The extension of the strike lines to the northeast would carry the Tordrillo into the heart of the Alaska Range north and east of the route of the expedition here recorded, into a region that is unexplored except where traversed by prospectors and by the members of the two Cook expeditions. Slates are said to occur in this area, and it seems most likely that this formation is present. As the Paleozoic slates resemble in many ways the rocks of the Tordrillo formation, however, it is impossible to state which horizon the slates on the western tributaries of Susitna River represent.

Intrusive rocks are very common in the Tordrillo formation. The largest areas of such rocks are those occupied by the granites and granodiorites, which occur in considerable masses as well as in small stocks and dikes. More basic rocks are also intruded in small stocks and dikes; they include monozonite and rocks of kindred types. (See Mr. Prindle's petrographic description, p. 139.) In addition to these rocks, fine-grained diabase dikes are not uncommon in the formation and are as a rule intruded at an angle to the bedding.



*A*. HEAD OF MORRIS RIVER, LOOKING TOWARD SIMPSON PASS.

Showing recent canyon and typical topography of Tordrillo formation. Near camp of July 10. See page 88.

*B*. SOUTHEASTERN PART OF ALASKA RANGE.

Showing topographic character of Skwentna group. Near camp of June 15. See page 85.

STRUCTURE AND THICKNESS.

As already stated, the Tordrillo formation occupies a broad synclinorium whose western arm rests unconformably on the Paleozoic rocks, and the same relation probably exists on the eastern arm also. The strike lines, though locally variable, in general trend northeastward, parallel to the main axis of the range. Within this synclinorium are numerous minor folds. (See section *A–B*, Pl. IX, in pocket.)

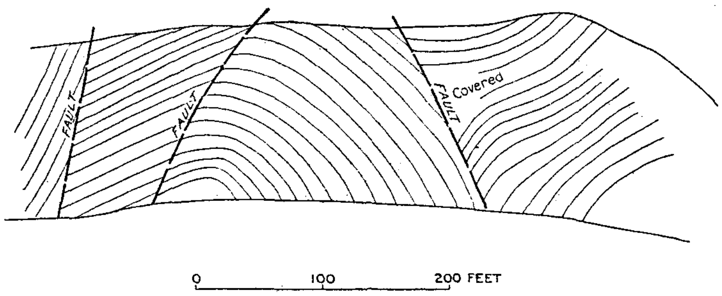



FIGURE 15.—Diagrammatic section showing character of folding and faulting in flaggy sandstone and grits of Tordrillo formation half a mile south of the camp of July 12.

The characteristic structure of the Tordrillo beds is one of sharp folding accompanied by considerable faulting. Many minor faults were noted and evidence of a few larger ones was obtained. It seems probable that detailed work will show a very large amount of faulting which was overlooked in the hasty examination. In general the folds seem mostly to dip toward the axis of the synclinorium. In the eastern arm the dips are generally toward the axis of the range; on the west side easterly dips prevail near the contact of the older rocks, though here there are also some sharp minor flexures. In the center of the range, especially along the watershed between the Kichatna and the Kuskokwim, the folding has been exceedingly intense and there is much faulting. In addition to the folding of the strata, slaty cleavage is developed in all the argillites, and the more massive beds are usually jointed.

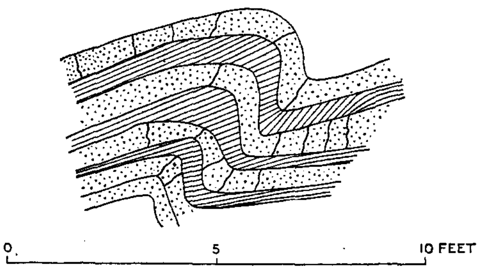



FIGURE 16.—Fold in sandstone and slate of Tordrillo formation, showing relation of cleavage in slate and jointing in sandstone to bedding planes 1 mile southeast of the camp of July 12.

The character of the deformation of the more massive beds is shown in the accompanying diagram (fig. 15), which is based on a field sketch of a cliff exposure. It was noted at this locality that, in addition to the faults which break the bedding planes, there was evidence of much movement along the planes themselves. The cleavage of the slate may be parallel or at right angles to the bedding, in accordance with its position in the fold. This relation is shown in figure 16 reproduced from a field exposure. The section also shows the radial character of the jointing in the massive beds along the apex of a fold. In this exposure the joints are filled with quartz veins.

The movement accompanying the deformation appears to have been taken up in part by faulting along margins of the massive beds. This is shown by the accompanying section (fig. 17) reproduced from field notes, which shows a massive bed of indurated feldspathic grit bounded by fault planes. The massive bed is traversed by a double system of joints which form angles of about 45° with the bedding planes.

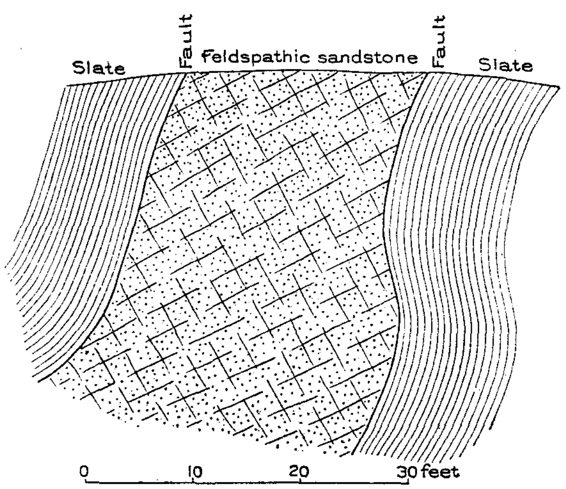



FIGURE 17.—Section showing jointing of massive bed and faulting along margin 3 miles west of the camp of July 15.

The strike and dips in this formation noted by Spurr to the south of our route of travel indicate a rapid closing in of the syncline and suggest that it may pinch out within 10 or 15 miles to the south. Along the western arm of the syncline there is some suggestion of profound faulting of an overthrust character, but the stratigraphic succession is not sufficiently well established to determine the amount of the dislocation. A cliff exposure near the base of the formation, if not actually at the base, showed very remarkable discordance of planes of stratification, which can only be interpreted as due to faulting. This exposure was not accessible, but figure 18 is a reproduction of a sketch of it made at a distance of 200 yards.

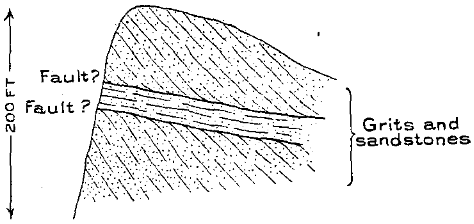


FIGURE 18.—Cliff exposure 2 miles southwest of the camp of July 15.

There is so much duplication by folding and faulting that it was impossible to obtain any exact measurements of thickness. It seems probable, however, that the aggregate thickness of the Tordrillo formation is between 2,000 and 3,000 feet. Of this the more massive lower member of the formation constitutes about a third.

### AGE AND CORRELATION.

Stanton and Martin, as a result of their investigations on Cook Inlet and Alaska Peninsula, described under the name Enochkin formation some shales and sandstones, with conglomerate, having a thickness of 1,500 to 2,500 feet. This formation carried Middle Jurassic fossils. It is overlain by the Naknek formation, made up of conglomerates, arkoses, sandstones, and shales, with some andesite flows, the whole 5,000 feet thick, referred to the Upper Jurassic. A few invertebrate fossils were found by Mr. Prindle in the slates of the Tordrillo formation near the camp of July 14. Although these fossils were rather fragmentary, they were sufficient to enable Dr. Stanton to refer the rocks in which they occur to the same horizon as the Enochkin. It does not follow, however, that the Tordrillo formation as here described is the exact equivalent of the Enochkin. The subjoined statement is quoted from Dr. Stanton's manuscript report:

The following localities yielded Mesozoic fossils:

No. 2. Kichatna River, opposite camp of July 9, Alaska Range: Imprint of a fragment of a large *Inoceramus*.

No. 4. About 3 miles southeast of Simpson Pass, Alaska Range, near camp of July 10: *Inoceramus eximius* Eichwald, several specimens; *Inoceramus lucifer* Eichwald?, two specimens; spine of an echinoid.

No. 6. Near the pass, camp of July 14, Alaska Range: *Inoceramus eximius* Eichwald.

No. 7. Near the pass, camp of July 14: *Inoceramus eximius* Eichwald?, fragmentary imprint.

The above are probably from a single horizon which is believed to be Upper Jurassic. When Eichwald described these species of *Inoceramus* with several others from "Tukusitnu Bay," Cook Inlet, he referred them to the Lower Cretaceous.

Associated with the plants at locality 21 there are two imperfect specimens of invertebrates in the form of small annulated tubes. These are probably either marine worms or the tubes of burrowing mollusks.

Under date of April 11, 1905, Dr. Stanton writes as follows:

I have again examined the Mesozoic fossils collected by your party near the Alaska Range in 1902, and am now able to give a more definite opinion as to their age. They consist chiefly of *Inoceramus eximius* Eichwald, with possibly other species of the same genus. There can be little doubt that the horizon represented is the Enochkin formation, which we now refer to the Middle Jurassic. Since my original report was written we have visited the locality of Snug Harbor, where Eichwald obtained the species in question, and their stratigraphic position is now well established.

It will be shown that the Jurassic sediments of the Matanuska region are assigned by Stanton to the Upper or upper Middle Jurassic and hence are younger than the Tordrillo formation. Hence it seems probable that the Tordrillo may never have been deposited over the area east of the Alaska Range. The coarseness of the material suggests a land mass near by when these sediments were laid down. On the other hand, the equivalent Enochkin formation on the Alaska Peninsula, to the southwest, is made up of finer sediments and includes some limestones. These facts indicate that during Tordrillo time there may have been a shore line somewhere near the present Susitna Valley, from which an ocean extended to the southwest. In the upper Copper basin, on the north side of the Wrangell Mountains, are some volcanic rocks which may be synchronous with the Tordrillo sediments.

### UPPER JURASSIC AND UPPER MIDDLE JURASSIC ROCKS OF MATANUSKA BASIN.

In the southeastern part of the Mount McKinley province Paige and Knopf found an extensive series of shales, sandstones, conglomerates, tuffs, and arkoses which, for the most part, represent a somewhat higher horizon than the Tordrillo and are therefore given a distinct color on the map (Pl. IX, in pocket). As the Tordrillo has yielded but few fossils, however, it is quite possible that it may include Upper Jurassic as well as Middle Jurassic beds. The following description of this higher formation is an abstract from the report of Paige and Knopf.[1]

These rocks rest unconformably on the lower Middle Jurassic of the same areas. Their lowest beds include a basal conglomerate with sandstones and shales. The formation is made up largely of blue shales locally carrying fossiliferous limestone nodules. With these occur sandstone conglomerates and some tuffs and arkoses. The sandstones are in the main yellow in color and highly fossiliferous. Along Nelchina River there are some heavy conglomerate beds which belong in this formation, interlayered with sandstones and shales. This conglomerate carries some large bowlders and consists largely of granitic rock.

Paige and Knopf noted that an unconformity occurs below these Upper Jurassic rocks and that, although the rocks below this unconformity are badly shattered and folded, the Jurassic beds above the unconformity are but little deformed. This, then, is another important element of difference between the Jurassic of the Alaska Range and that to the east. The beds of the Matanuska basin are believed to include 2,000 feet of strata, of which about 1,100 feet belongs to the conglomerate member of the formation.

The following statement in regard to the age of this formation is quoted from Paige and Knopf's report:

> The age of these strata has been determined from the following invertebrates, identified by T. W. Stanton:
>
> "Lot 6 A. K. 156. Headwaters of Nelchina River of Copper River drainage: *Cadoceras* sp., many immature specimens; belemnites, fragments. The horizon is that of the *Cadoceras* zone, which forms the upper third of the Enochkin formation.
>
> "Lot 6 A. K. 185. Nelchina River: *Pleuromya; Cadoceras?*, fragmentary imprint doubtfully referred to the genus; belemnites. The horizon is probably in the upper part of the Enochkin formation.
>
> "Lot 6 A. K. 136. Billy Creek: *Aucella* cf. *bronni* Rouiller. The same species occurs in similar rock in the Naknek formation of Kamishak Bay."
>
> The fossils indicate faunas of both late Middle Jurassic age and Upper Jurassic age. It is interesting to note that the Upper Jurassic rocks of this region, which are faunally allied to those of the Naknek formation on the west coast of Cook Inlet, show a certain lithologic similarity in the presence of interstratified tuffs and arkose.[2] Furthermore, an accumulation very similar to the remarkable andesite-granite conglomerate occurring on the headwaters of Susitna River is found at the base of the Naknek formation.[2]

Collier[3] has described some coal-bearing beds in the Cape Lisburne region which, on the evidence furnished by fossil plants, are assigned to the Upper Jurassic. They constitute the Corwin formation and have a thickness of some 15,000 feet. This formation consists of thin-bedded shales, sandstones, conglomerates, and coal beds, which are thrown up in gentle folds. It is worthy of note that both these beds of the Cape Lisburne region and the Upper Jurassic beds of the Matanuska region carry coal.

### GRANITE (POST-MIDDLE JURASSIC).

The rocks here classified as granite embrace granular intrusives varying in composition from diorites to granites and including some monzonites. To about the same period of intrusion belongs the more acidic phase—alaskite. These several rock types are described by Mr. Prindle on pages 136–147. The granites and granodiorites are the most abundant of the granular rocks, occurring as extensive batholiths in the Alaska Range and in the Talkeetna Mountains. These batholiths cut rocks as young as the Middle Jurassic. Wherever seen by the writer

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 20–23.

[2] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: Bull. U. S. Geol. Survey No. 250, 1905, p. 44.

[3] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: Bull. U. S. Geol. Survey No. 278, 1906, pp. 27–30.

these granular rocks are massive except for certain systems of jointing, which will be referred to in the section on structure. It will be shown that the last extensive earth movement took place in Tertiary time and that the absence of secondary structures in these rocks is not because they have not been subjected to stress. It seems probable that these stresses were compensated by movements which took place along the margin of the granitic stocks. It is noteworthy that the highest peaks of the range are made up of granitic rocks and probably represent areas of higher uplift than the adjacent tracts.

Martin's recent studies have shown that the granites of the southern part of the Talkeetna Mountains are intensely deformed. Here the granite has been crushed and rendered gneissoid and also has been thrust over the sedimentary rocks. This deformation took place since the deposition of the Tertiary beds.

The map (Pl. IX, in pocket) shows that one line of granitic intrusion follows the main axis of the Alaska Range. A second broad zone of intrusive rocks lies in the central part of the Susitna basin. The line of intrusion along the axis of the Alaska Range extends to the east and southeast beyond the limits of the area mapped, and finally merges with that of the Coast Range of southeastern Alaska. This suggests a general synchrony of this belt of intrusion, which parallels the Pacific seaboard throughout British Columbia and Alaska. In fact, this belt is but a northern extension of the great batholithic intrusions of the Sierra Nevada, and a similar extension is traceable to the southeast into Mexico. This belt of batholiths, traceable with some breaks for over 4,000 miles, forms one of the longest lines of intrusions known in the world.

Stocks of granitic rocks occur in the region lying north of the Tanana; some of these, as has been shown, are as young as Upper Cretaceous, and all are probably Mesozoic. More of these granitic rocks occur east of the area mapped, in the Yukon-Tanana region. Of these Prindle has said: "This region is regarded as one of large batholithic masses of intrusive rocks, now mantled by a comparatively thin shell of sedimentary rocks. Intrusion has taken place at different periods." [1]

The distribution of the granite is a matter of some economic importance, for it is along the margins of the intrusive rocks that mineralization has taken place in southeastern and in other parts of Alaska. This matter will be further discussed under the caption "Mineral resources" (pp. 160–161).

### LOWER CRETACEOUS ROCKS.

No strata assignable to the Lower Cretaceous [2] have been found in the Alaska Range or in the region to the north included on the accompanying map (Pl. IX). The map, however, shows some rocks of this age [3] which occur in the upper Matanuska basin and have been described by Paige and Knopf.[4] The Lower Cretaceous beds of this area include a massive bed of limestone some 300 feet thick which rests conformably on Upper Jurassic strata. These rocks were first described by Mendenhall,[5] who discovered in them some fossils, notably *Aucella crassicolis* Keyserling, referred by Stanton to the Lower Cretaceous. This limestone, like the rocks to which it is conformable, has been very little disturbed.

Though Lower Cretaceous rocks have not been recognized elsewhere in the province under discussion, they form one of the most widely distributed series in Alaska. (See correlation table, p. 52.) Spurr's Holiknuk series,[6] which occurs in the middle Kuskokwim Valley and is composed of arkoses, sandstones, and carbonaceous shales, may belong to this horizon. It carries some plant remains and fragments of *Inoceramus*. Spurr also described some similar

[1] Prindle, L. M., Occurrence of gold in the Yukon-Tanana region: Bull. U. S. Geol. Survey No. 345, 1908, p. 185.

[2] Martin's detailed survey in the Matanuska Valley has revealed the presence of a shale formation which is Mesozoic and may be of Cretaceous age.

[3] The rocks here called Lower Cretaceous belong to a horizon which may be Upper Jurassic.

[4] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull U. S. Geol. Survey No. 327, 1907, p. 24.

[5] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 309.

[6] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 159–161.

sediments farther down the Kuskokwim, carrying a large amount of andesitic lavas and tuffs, under the name "Kolmakof series" and provisionally correlated them with the "Holiknuk."[1] A more definitely recognizable Lower Cretaceous group was found by Spurr in the "Oklune series,"[2] which covers a considerable area in the vicinity of the Ahklun Mountains, near Bering Sea. These rocks are made up of shales, cherts, tuffs, andesites, basalts, arkoses, and conglomerates, and contain some fossils which Stanton determined as *Aucella crassicolis* Keyserling(?).

Lower Cretaceous rocks are represented in the Alaska Peninsula region by shales of unknown thickness and on the upper Yukon by closely folded siliceous slates and quartzites, with some tuffs and limestones. It is a noteworthy fact that the Lower Cretaceous beds of the upper Yukon and the Bering Sea region are closely folded and more or less altered, whereas those of the Alaska Peninsula and Matanuska basin are comparatively little disturbed.

#### UPPER CRETACEOUS ROCKS.

The only Upper Cretaceous beds found in the Mount McKinley province are some lying north of the Tanana, about 20 miles southeast of Rampart, on the Yukon.[3] These have been studied and described by Prindle,[4] from whose report the following statement is derived. These beds lie high on the flanks of Wolverine Mountain (Pl. VII, *B*, p. 48), about 1,000 feet above the base, and may comprise several hundred feet of strata. They include massive carbonaceous sandstones and shales. The rocks are folded and are intruded by dikes of granitic material, as well as seamed by small quartz veins, many of which are ferruginous. These also contain some fragmental dicotyledonous leaves and invertebrate fossils. The following is quoted from Stanton's determination of these fossils:

> While the fossils are fairly well preserved, they have been considerably distorted, so that it is not practicable to make specific determination. The better-preserved forms appear to be undescribed. The following list will show the forms recognized in each lot:
>
> 4278. 7AP271 (spur of Wolverine Mountain):
>
> | | |
> |---|---|
> | Hemiaster? sp. | Lucina sp. |
> | Pecten sp. | Pleuromya sp. |
> | Inoceramus cf. labiatus Schloth. | Pachydiscus sp. |
> | Cucullæa sp. | Pachydiscus? sp. |
>
> 4279. 7AP278 (ridge on left limit south fork of Quail Creek):
>
> | | |
> |---|---|
> | Hemiaster? sp. | Pachydiscus sp. |
> | Cucullæa sp. | Pachydiscus? sp. |
>
> 4280. 7AP279 (right limit south fork of Quail Creek):
>
> Pachydiscus sp.
>
> These fossils evidently all belong to practically a single horizon which is confidently referred to the Upper Cretaceous. * * * The species of *Inoceramus* is very likely one that has been previously found on the Yukon, but the specimens in the present collection are too imperfect to serve as the basis for a positive identification. The most important forms are ammonites, which make up the bulk of the collection and which I have referred, in some cases doubtfully, to the genus *Pachydiscus*. These are unquestionably Upper Cretaceous types.

Prindle found some massive quartzite beds underlying these known Upper Cretaceous rocks, and these quartzites, while they may belong to the underlying Paleozoic, possibly represent the Lower Cretaceous horizon in this field.

Upper Cretaceous rocks, chiefly limestone and shales, are abundant on the lower Yukon, where they carry coal.[5] No Upper Cretaceous beds have been found on the upper Yukon, though they may occur among those rocks which have been correlated with the Eocene. Atwood[6] has found Upper Cretaceous conglomerates, sandstones, and shales, with some coals, on

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 161-163.
[2] Idem, pp. 163-169.
[3] Martin's recent detailed survey of the western part of the Matanuska coal fields indicates that some of the sediments previously mapped as Tertiary may be of Cretaceous age.
[4] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 23-24.
[5] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903.
[6] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, p. 113.

the Alaska Peninsula, and these have an estimated thickness of about 600 feet. The same horizon is also probably represented in southeastern Alaska.

## TERTIARY SYSTEM.

### OUTLINE.

It has become almost an established practice in Alaskan reconnaissance surveys to assign all lignite-bearing beds to the Kenai formation (Eocene). Moreover, where the lignitic formations have yielded plant remains, most of such age assignments have been supported by the paleobotanic determinations. In this report also the coal-bearing sediments of the province are all provisionally referred to the Kenai formation. It will be shown, however, that some beds of friable sandstone, shales, and lignite here included in the Kenai may be of Miocene or Pliocene age. There is also a possibility that some of the deposits here assigned to the Pleistocene, such as the deep gravels at Fairbanks, the high bench gravels of Minook Creek, or the terrace gravels on both sides of the Alaska Range, may prove to be Pliocene.

It is possible, therefore, that the Tertiary sediments may be represented by three formations in this province. (1) The oldest is represented by the lower 2,000 feet of coal measures in the Matanuska Valley, the coal measures at Tyonek, and much of the coal-bearing series along the Nenana. These beds carry Eocene plants and therefore represent the true Kenai. (2) A younger formation embraces the upper conglomerate of the Matanuska coal measures and the upper part of the coal-bearing beds in the Nenana basin. Plants have been found in this formation only at the latter locality, and these indicate a post-Eocene age.[1] (3) Some of the gravels and sands here included with the Pleistocene may constitute a third and uppermost member of the Tertiary sediments. Such a triple subdivision of the Tertiary would be in general accord with the stratigraphic sequence determined by Dawson[2] in British Columbia. It is also a suggestive fact that in Alaska Peninsula Atwood[3] has found evidence of a triple subdivision of the Tertiary rocks.

It is not possible with the facts in hand to subdivide the rocks here classed as Kenai. Some of them have yielded plant remains, though for the most part fragmental, which Mr. Knowlton has, with a single exception, provisionally assigned to the Kenai. (See pp. 99–102.)

In addition to these sediments, the post-Eocene lavas of the Talkeetna-Matanuska region are here also provisionally included in the Tertiary. The diabase intrusive rocks are probably of Eocene age.

### KENAI FORMATION (EOCENE).[4]

#### CHARACTER AND DISTRIBUTION.

The Kenai formation is typically made up of a succession of conglomerates, sandstones, and shales, with lignitic and in the Matanuska Valley bituminous coals. Two phases have been recognized. In one the rocks are but slightly indurated, include only lignitic coals, and have been but little deformed. Some plant remains have been found in these rocks. This phase of the formation is the most widely distributed, occurring in small areas throughout the Mount McKinley province and over much of Alaska.

In a second phase of the Kenai, also carrying plant remains, the strata, though composed of the same materials, are indurated. The argillites are slates, the sandstones are hard, and the conglomerates are tough, while some of the included coals are bituminous. This phase of the Kenai is much folded and faulted.

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[1] Since this was written Martin has divided the Tertiary rocks of the Matanuska Valley into three formations: (1) A lower, made up of arkoses with some shales; (2) a middle, consisting chiefly of shale with coal beds, and (3) an upper, made up of conglomerate.

[2] Dawson, G. M., On the later physiographical geology of the Rocky Mountain region in Canada: Trans. Royal Soc. Canada, vol. 8, 1890, sec. 4, pp. 1-24; Geological record of the Rocky Mountain region in Canada: Bull. Geol. Soc. America, vol. 12, 1900, pp. 79-84. In the writer's opinion Dawson's "Laramie" is to be correlated with the Kenai.

[3] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 111-115.

[4] The Kenai formation was first named and described by W. H. Dall (Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 234-252). The type locality has been studied in detail by R. W. Stone (The coal fields of the Kachemak Bay region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 57-59).

The unconsolidated phase of the Kenai finds its widest distribution in the lower Susitna Valley and in the region tributary to Cook Inlet. It is quite possible that this phase floors the entire Cook Inlet and Susitna trough, for it has been traced almost continuously around the margins of the depression. It also occurs extensively in the Nenana basin, where it is in part mantled by Pleistocene gravels, and it is present in small patches along that part of the Yukon Valley included in this discussion. The harder Kenai rocks occupy an extensive belt in the lower Matanuska Valley and occur in small areas infolded with the Paleozoic strata along the inner margin of the Alaska Range. Most of both phases of these beds have yielded some plant remains, which have been referred by Knowlton to the Eocene, or Arctic Miocene, as it is sometimes called.

Some of the typical exposures in each district are next described, the various areas being taken up in geographic order from south to north. A further account of those Kenai beds which carry commercial coal beds is to be found in the discussion of mineral resources (pp. 184–192).

Within the Mount McKinley province the Kenai is everywhere separated by an erosional interval from the older rocks, be they Paleozoic or Mesozoic. On the lower Yukon Collier[1] found the Kenai in apparent stratigraphic conformity to the Upper Cretaceous beds. In Alaska Peninsula the Kenai has been found resting unconformably on Upper Cretaceous rocks.[2]

About a mile below Tyonek there is a series of cliff exposures of friable sandstone, fine conglomerate, shales, and lignitic coal beds, covered by a heavy bed of stratified sands and gravels. The attitude of these beds is shown in the accompanying section (fig. 19), taken from the note books of G. H. Eldridge,[3] who examined these exposures in 1898. These beds strike N. 10° to 15° E. and dip southeastward at angles varying from 15° to 60°. About 1,000 feet of strata are exposed. The conglomerate pebbles are well rounded and are held in a very loose cement. The sandstones, also very friable, are made up of white micaceous sand with intercalated layers of clay, in places sufficiently indurated to be called shale. The coal has a woody fiber and appears to be chiefly a low-grade lignite.

Atwood,[4] who has studied these beds in detail, reports the occurrence of a heavy conglomerate made up of lignitic pebbles and suggests that there may be two unconformable series of lignite-bearing beds. He also visited an extension of this belt which outcrops along Beluga River about 10 miles from the coast. At this locality the character and attitude of the beds are about the same as at Tyonek. The Beluga River locality also gave evidence of two formations which are possibly unconformable.

Friable conglomerates and sandstones with interbedded shales and lignites have been found at several localities in the Yentna basin. Some of these have been described by Spurr[5] under the names Yentna beds and Hayes River beds, but they all seem to belong to the same general horizon as the rocks at Tyonek here referred to the Kenai. Eldridge[6] noted the presence of similar rocks at various places along the Susitna up as far as the mouth of Chulitna River, and prospectors report the occurrence of

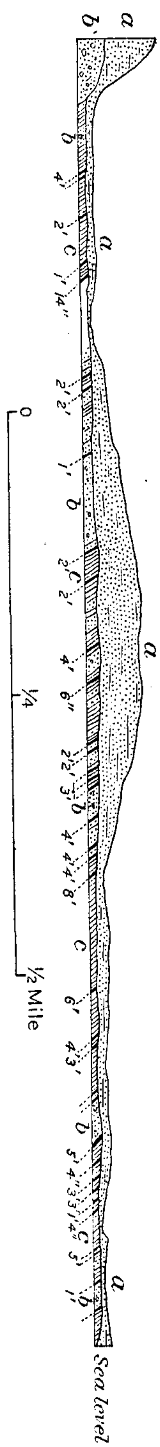



FIGURE 19.—Section of bluff along beach 1 mile below Tyonek, at the camp of June 1. By G. H. Eldridge. *a*, Stratified sands and gravels with bowlders and some till (Pleistocene); *b*, friable sandstones, with some fine conglomerates; *c*, sandy and clay shales, and shaly sandstone (Kenai formation, Eocene). Heavy line shows lignitic coal beds. Thickness in feet and inches.

[1] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903, pp. 15–18.

[2] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and the Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, pp. 391–410. Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 113–115, 129, 136–137.

[3] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 21–22.

[4] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 118–121.

[5] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 172–173.

[6] Eldridge, G. H., A reconnaissance in the Sushitna and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 16–17.

lignite on the Chulitna, in the Kahiltna basin, and along the western base of the Talkeetna Mountains. Similar rocks have been recognized along the eastern shore of Cook Inlet, south of Turnagain Arm, and at Point Campbell, at the entrance to Knik Arm. (See geologic map, Pl. IX, in pocket.)

The striking features of all these Kenai deposits of the eastern flank of the Alaska Range are the unconsolidated condition of the sediments, their comparatively slight deformation compared with the indurated phases, and the fact that they invariably carry some lignitic coal seams. In most places sufficient fragmentary plant remains have been obtained from the beds to indicate that they belong to the same general horizon. They are interpreted as being remnants of a larger deposit, probably of fluviatile origin. Eldridge's conclusion that these rocks probably underlie the entire Cook Inlet depression seems to be borne out by the later observations.

A broad belt of Kenai rocks[1] flanks the northern slope of the Matanuska Valley and stretches northeastward up Chickaloon Creek. This belt[2] is made up of shales, sandstone, arkoses, beds of bituminous coal, and conglomerate. These rocks are well indurated and are totally unlike the Kenai of the west side of Cook Inlet, in some respects resembling the Carboniferous coal measures of the Appalachian region. The sandstone is very hard and tough. The shales are dark blue and fissile and are interstratified with sandstones and arkoses in irregular beds. The conglomerate is massive and aggregates 1,000 feet in thickness. The beds of conglomerate are separated by thin bands of shaly sandstone, and its pebbles are chiefly greenstone porphyry but include some quartz porphyry and a little granite and vein quartz. Diabase dikes and sills and large stocks of dioritic intrusive rocks are prominent features in this belt of rocks.

It is clear that the Kenai of the Matanuska region is strikingly different from that of the west side of the Susitna basin. In fact, these Kenai beds resemble in some ways the Cantwell formation, which has been provisionally assigned to the Carboniferous. (See p. 78.)

The Kenai beds of the northwestern front of the Alaska Range occur in several small belts which are infolded with the older rocks. Some of these are represented on the geologic map (Pl. IX), but many are too small to be indicated on so small a scale. They are made up chiefly of carbonaceous and argillaceous shales and slates which carry plant fragments. In places they include some carbonaceous and ferruginous sandstones. At some localities the supposed Kenai is overlain by Paleozoic strata—a relation brought about, it is believed, by thrust faulting. (See figs. 14, p. 82; 23, p. 98.) All the Kenai in this part of the field is closely folded and probably much faulted. Lithologically these beds bear little resemblance to any of the deposits which have been previously described under this formation, but the plant remains are such as to indicate Kenai age.

The Tertiary rocks of the Nenana basin occupy a considerable area lying between Wood River on the east and the Nenana on the west. They are also known to occur in the Delta River basin, but this part of the field has not been surveyed.[3] In most of this area the Tertiary beds are buried under heavy gravel deposits, being exposed only along the stream cuttings. These beds are made up of white incoherent conglomerate and sandstone and soft clay shales, with many layers of lignitic coal. Both conglomerates and sandstones are so loosely cemented as to be little more than gravels and sands. The almost snow-white color of the arenaceous rocks intermingled with the black of the coaly beds forms a striking feature of the landscape. (See Pl. XVI, *B*, p. 170.) On Healy Creek, in the Nenana basin, a section of 425 feet of these rocks was exposed.[4] At this locality the basal bed is a white quartz conglomerate 200 feet thick resting on the upturned edges of metamorphic rocks (Birch Creek schist). The well-washed character and white color of this conglomerate suggest an old beach deposit. Above the conglomerate are incoherent sandstones and lignitic beds, with some clay shale. All these beds dip northward, away from the mountains, at angles of 5° to 10°.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 24–28.

[2] Martin's surveys of 1910 show that this belt of Tertiary rocks is interrupted by areas of Mesozoic shale. The Tertiary and Mesozoic are intricately interfolded. Therefore the areas marked as Tertiary on the geologic map (Pl. IX) are in part Mesozoic.

[3] It was surveyed in 1910 by S. R. Capps.

[4] This section, together with the Quaternary gravels, is included in the section given in the discussion of the Nenana coal field (pp. 189–190).

Near the camp of August 22, on the main Nenana River, a section is exposed showing perhaps 200 feet, chiefly of white friable sand, with some shale and considerable lignite. Similar deposits have been found by Prindle[1] in the basins of Kantishna River to the west and Wood River to the east. (See Pl. XVI, *A*, p. 170.) Lignite-bearing beds are also reported from Delta River near the rapids and from the headwaters of Jarvis Creek, a tributary of the Delta. Conglomerates and sandstones, probably of the same general horizon, have been found by Prindle and Katz[2] on the north slope of the Fairbanks Creek valley, and similar rocks, with some lignite, are reported to occur on Little Salchaket River. Both these localities are north of the Tanana.

The facts presented show that this lignite-bearing formation has a wide distribution in the Tanana Valley. It seems quite probable that if the alluvium could be swept away it would be found that much of the floor of the Tanana depression is covered with this typical deposit. In other words, the conditions here are probably the same as in the Cook Inlet and Susitna depression.

The Kenai formation is widely distributed along the Yukon Valley. Within the area shown on the map (Pl. IX, in pocket) it occurs a few miles above Rampart, on the east bank of the Yukon. Here the Kenai is represented by white flat-lying incoherent conglomerate and sandstones, with interbedded shales that have yielded some plant remains. Heavy brown sandstones and massive conglomerates with green shales, also referred to the Kenai, outcrop for several miles along the west bank of the Yukon about 5 miles above the mouth of the Tanana. These beds are folded and considerably faulted. If judged solely from their degree of induration and extent of deformation, these beds would appear to be much older than the white conglomerates occurring near Rampart.

#### STRUCTURE.

Three general types of structure have been recognized in the Kenai formation. The simplest phase is that in which the beds are only gently folded and faulted. To this type of structure belong most of the small patches of Kenai in the Cook Inlet and Susitna depression. In a second type the Kenai beds are sharply folded and faulted. Its best example occurs in the lower Matanuska Valley, but this type of folding is also found on the Yukon. In the third structural type the Kenai beds have been involved in a very complex system of folding accompanied by thrust faults. This phase of structure has been recognized only in the zone of extreme folding along the inland front of the Alaska Range.[3]

The simplest type of deformation merits no special description. In this class are included strata which are practically undisturbed except for small faults as well as strata which show dips up to 60°. In the section of the Tyonek exposures (fig. 19, p. 95) the beds dip from 30° to 60° NE. Some small faults were noted at this locality, and there may be large ones, as a part of the section is covered. On the Nenana the deformation of the Kenai is of about the same magnitude but has manifested itself chiefly in broad, open folds accompanied by faulting. The character of this deformation in the Nenana coal field is illustrated in figure 20, reproduced from a field sketch. This figure also shows the relation of the Kenai to the Pleistocene gravels, a matter which will be referred to later.

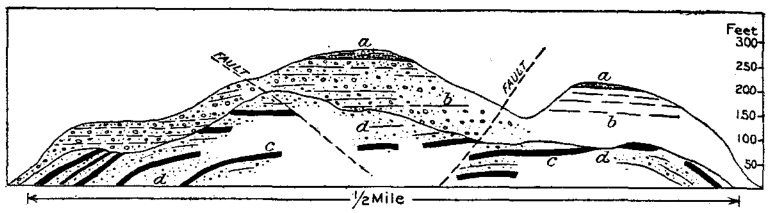



FIGURE 20.—Section of bluff of Nenana River 3 miles below the camp of August 23. *a*, Gray micaceous silt; *b*, reddish gravels and sands containing some bowlders; *c*, lignite coal beds; *d*, gray friable sandstone, with some white friable conglomerate (Kenai formation). (White areas covered by talus.)

[1] Prindle, L. M., The Bonnifield and Kantishna regions: Bull. U. S. Geol. Survey No. 314, 1907, pp. 205-207.
[2] Prindle, L. M., and Katz, F. J., The Fairbanks gold-placer region: Bull. U. S. Geol. Survey No. 379, 1909, p. 185.
[3] In 1910 Martin found similar structures along the northern margin of the Tertiary of the Matanuska Valley.

The more extensive folding and faulting of the indurated phases of the Kenai is shown in the accompanying section by Paige and Knopf (fig. 21). In this section the massive hard conglomerate of the Kenai formation is broken up into a series of fault blocks with extensive throws.

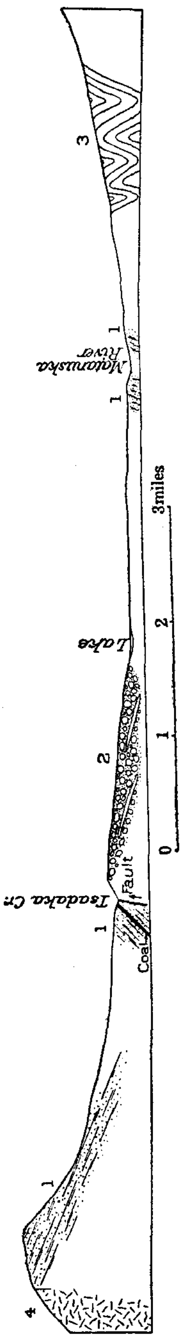



FIGURE 21.—Section across Matanuska River at Conglomerate Mountain. By Sidney Paige and Adolph Knopf. 1, Sandstones, shales, arkoses; 2, conglomerate with sandstone lenses; 3, graywackes and slates; 4, quartz diorite.

Though this type of Kenai folding is known only in the Matanuska basin south of the Alaska Range, similar deformations occur north of the mountains in the Yukon basin. This is illustrated by the section (fig. 22) made by Collier at the Drew coal mine, about 10 miles north of Rampart, beyond the limits of the area shown on Plate IX (in pocket).

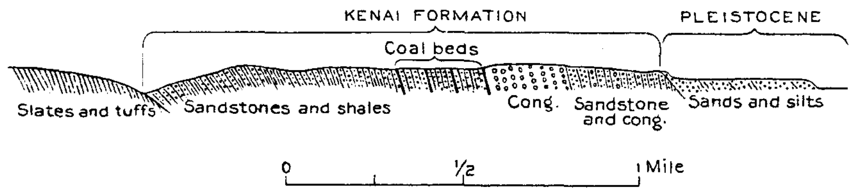



FIGURE 22.—Section showing structure of Kenai formation at Drew mine, Yukon River. After A. J. Collier.

Here the Kenai consists of sandstones and shales, with fine conglomerate, together with some heavy beds of conglomerate. The coal-bearing series rests on metamorphic rocks of unknown age.

The infolding of the Kenai beds with the Paleozoic rocks is shown in the section in the upper basin of Toklat River (fig. 14, p. 82), where the Carboniferous conglomerate appears to have been thrust up over the Tertiary sandstones and shales. A better example of thrust faulting which involved the Tertiary is afforded by the section near the camp of July 24 (fig. 23), where the closely folded Tertiary beds dip under Carboniferous and Devonian strata that have been brought into superposition by a thrust fault.

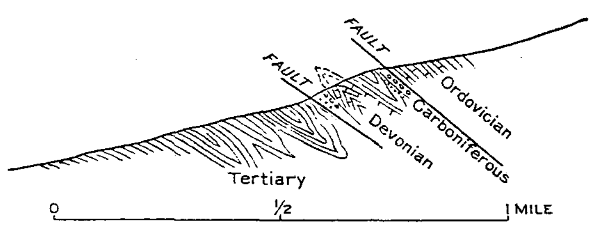



FIGURE 23.—Section near the camp of July 24, showing faulting of Paleozoic over Tertiary beds.

The data presented are sufficient to indicate the widely divergent character of the post-Kenai diastrophism. If the folding of all the Kenai rocks of Alaska were described, similar conditions would be noted. This clearly shows that the crustal movement which followed the deposition of the Kenai, though epeirogenic in extent, differed greatly in intensity in different parts of the province.

*THICKNESS.*

The Kenai formation is much thinner in some parts of the province than in others. These differences are due in part to irregularities of original deposition, in part to the fact that in most places it forms the topmost member of the bed-rock column and hence has been subject to erosion. The unconsolidated phases of the Kenai are especially subject to rapid erosion. It is probable that much of the Kenai was laid down as fluviatile and lacustrine material in areas of subsidence, and it is to be supposed, therefore, that the deposits originally had the outline of elongated lenses, thinning out rather abruptly in cross section.

1 80 34



The thickness of the Kenai deposits at various localities in central Alaska is shown in the following table:

*Thickness of Kenai formation in central Alaska.*

| Locality. | Character of unit. | Thickness (feet). | Authority. |
|---|---|---|---|
| Kachemak Bay, Cook Inlet | Soft sandstones, clay shales, and coal beds | 10,000± | R. W. Stone. |
| Tyonek, Cook Inlet | Soft sandstone, sandy and clay shales, with some conglomerate beds and numerous coal beds. | 5,000+ | Eldridge and Brooks. |
| Matanuska Valley | Sandstones, arkoses, and shales, numerous coal beds, and massive hard conglomerate (1,000 feet). | 3,000+ | Paige and Knopf. |
| Hayes River, Susitna basin | Soft conglomerates and shales, with coal beds | 150+ | Spurr. |
| Kichatna Valley, Susitna basin. | Soft conglomerates, sandstones, and shales, with coal beds | 200± | Brooks and Prindle. |
| Junction of Susitna and Chulitna. | Clays and sandstones, with coal beds | 100-300+ | Eldridge. |
| Upper Chistochina, Copper River basin. | Massive hard conglomerate (500 feet), with fissile clay shales, gravel, and sand and coal beds. | 2,000+ | Mendenhall. |
| Upper Nenana Valley | Friable white conglomerate and sandstone, clay, and coal beds | 500-1,500 | Brooks and Prindle. |
| Drew mine, Yukon River | Sandstones, shales, and conglomerates, with coal beds | 5,000± | Collier. |
| Washington Creek, Upper Yukon. | Friable sandstones and some conglomerates, with coal beds | 2,000 | Collier and Brooks. |

If the Kenai beds are fluviatile deposits, as seems most probable, it is likely that the Cook Inlet and Susitna depression was occupied by one of these rivers and that the heaviest deposits indicate the approximate position of the main stream, while the lighter deposits mark the margins of this old valley or the position of its tributary streams. A somewhat similar explanation will probably account for the variation in thickness of the Kenai of the Yukon-Tanana Valley. The wide distribution of this formation suggests an extensive drainage system whose main artery may have corresponded approximately with the present valley of Yukon and Tanana rivers. It is not improbable that the lower Yukon and Tanana, as well as Cook Inlet, may have been estuaries during Kenai time. This subject, which will receive further consideration in the discussion of the recent geologic history, is here introduced for the purpose of explaining the great variations in the thickness of the formation.

#### AGE AND CORRELATION.

The age assignment and correlation of the Kenai formation have been based on the evidence of fossil plants and invertebrates and of stratigraphic sequence and relations. Physiographic evidence has thus far been neglected. Indeed, the study of the genesis of land forms in Alaska has leaned somewhat heavily on the stratigraphic investigations rather than contributed anything toward the solution of the problems involved in correlation.

The age determinations and correlations of the Kenai made up to the present time are based almost wholly on fossil plants, which are, geographically at least, widely distributed and fairly abundant in the formation. With the exception of a few fresh-water gastropods, no invertebrate fossils have been found in the Kenai rocks here described. The Kenai of Herendeen Bay has, however, yielded a marine fauna of Eocene age. In the absence of any detailed investigation of structure, succession, and distribution in the Mount McKinley region, little weight can be given to the stratigraphic evidence.

Alaska Kenai beds have yielded a large flora, all of which has received a preliminary examination by F. H. Knowlton. His familiarity with the key fossils has made it possible for him to pass a more or less definite opinion on the rather fragmentary plant remains which have been found in the Kenai formation here described. The following fossil determinations and age assignments have been made by Mr. Knowlton. The reports not otherwise credited are from unpublished material.

*Fossil plants from Kenai formation.*

**Tyonek, Cook Inlet.**

[Collected by W. W. Atwood and C. E. Weaver, 1906.]

One-half mile south of Tyonek on cliff exposed along beach. Age, Kenai.

Taxodium tinajorum Heer.
Corylus macquarrii (Forbes) Heer.
Fragments of dicotyledons.

**Matanuska Region.**

[Collected by Sidney Paige and Adolph Knopf,[1] 1906.]

This material, consisting of six small lots, is in the main very poorly preserved and insufficient in quantity to make the report of fullest value. The various localities and the forms detected at each are as follows:

Tsadaka Creek, 25 feet above 11-foot coal seam. Age, Kenai.
- Sequoia langsdorfii (Brgt.) Heer.
- Ficus? grönlandica? Heer.
- Magnolia inglefeldi Heer.
- Fragments of other dicotyledons.

Kings Creek coal. Age, apparently Kenai.
- Ficus? grönlandica Heer.
- Populus arctica? Heer.
- Rhamnus eridani Heer.
- Viburnum sp. cf. V. nordenskiöldi Heer.

Arkose Ridge, north of Tsadaka Creek. Age, apparently Kenai.
- Taxodium distichum miocenum Heer.
- Taxodium tinajorum Heer.
- Populus sp.?
- Ficus? grönlandica? Heer.
- Paliurus colombi Heer.
- Fruits, cf. Leguminosites sp.

Chickaloon coal strata, Watson's camp. The age indicated is Kenai.
- Sequoia langsdorfii (Brgt.) Heer.

**Matanuska Region.**

[Collected by G. C. Martin, 1905.[2]]

Chickaloon coal strata, Watson's camp. The age indicated is Kenai.
- Taxodium distichum miocenum (Brgt.) Heer.
- Salix varians Heer.
- Populus arctica Heer.
- Corylus macquarrii (Forbes) Heer.
- Juglans nigella Heer.

Kings Creek, collected by W. A. Langille, of Forest Service. The specimens are small and the plants fragmentary. With some uncertainty the species named below have been recognized. If determinations are correct, the beds are probably Kenai.
- Taxodium tinajorum Heer.
- Sequoia langsdorfii (Brgt.) Heer.
- Populus arctica Heer.
- Corylus macquarrii (Forbes) Heer.

**Mount McKinley Region.**

[Collected by A. H. Brooks and L. M. Prindle, 1902.]

1. Branch of Kichatna River, camp of July 5, east side of Alaska Range.
   Minute plant fragment, without character.
3. Kichatna River, one-half mile below camp of July 9, east side of Alaska Range.
   Fragments of stems and bark, without character.
5. About 3 miles southeast of Sampson Pass, Alaska Range, near camp of July 10.
   Minute plant fragments, with a single very small fragment of a dicotyledon, not determinable.
12. Dome Stream, about 1,000 feet from camp of July 23, west slope of Alaska Range.
   Chondrites heerii Eichwald.
14. Above camp of July 24, east side of canyon 20 to 30 miles southwest of Mount McKinley.
   Fragments, apparently of bark, without character.
15. Camp of July 24, southwest of Mount McKinley, west slope of Alaska Range.
   Stems and minute fragments of a dicotyledon, not determinable.
17. Four miles southeast of camp of August 3, foot of Mount McKinley, west slope of Alaska Range.
   Minute fragments, without character.
18. Creek bed at base of hill S. 30° E. from camp of August 3, west slope of Alaska Range.
   Plant stems, possibly rachis of ferns, not determinable.
19. Two miles north of camp of August 8, about 30 miles north of Mount McKinley.
   Stems and bits of vegetable matter and two minute fragments of a dicotyledonous leaf, not determinable.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 26.
[2] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, p. 14.

20. Camp of August 9, 30 to 40 miles northeast of Mount McKinley, west slope of Alaska Range.
    Chondrites heerii Eichwald.
21. South side of main valley, about 3 miles south of camp of August 9.
    Carpites sp., probably new.
    Grass leaves?
    Fern rachis?
22. South side of divide one-half mile from camp of August 12, west slope of Alaska Range, N. 15° E. (magnetic) from Mount McKinley.
    Fragment of a large dicotyledonous leaf, not determinable.
23. Four miles east of camp of August 12, Toklat River basin.
    Taxodium tinajorum Heer.
    Sequoia langsdorfii (Brgt.) Heer.
    Populus arctica Heer.
    Populus sp.
    Large leaf, apparently new.
24. About three-fourths of a mile east of camp of August 24, 5 miles north of Nenana River. Bowlder in drift.
    Probably Sequoia langsdorfii (Brgt.) Heer.
27. Southeast of camp of September 12, on ridge about 2 miles east of Little Minook River.
    Chondrites heerii Eichwald.
28. Four miles southwest of camp of August 20, at headwaters of a creek flowing northward to Nenana River.
    Fragments of stems, without character.

From localities 12, 20, 23, 24, and 27 the following spines have been identified:

Chondrites heerii Eichwald.
Taxodium tinajorum Heer.
Sequoia langsdorfii (Brgt.) Heer.
Populus arctica Heer.

These spines are all enumerated by Heer and others as belonging to the so-called "Arctic Miocene," now pretty generally regarded as belonging to the upper Eocene. Although the material in hand is scanty and in part obscure, it is probably safe to assume that these localities should be referred to the upper Eocene.

Locality 21, in the collection from which I find a *Carpites*, grass leaves, and rachis of a fern, appears to represent the same horizon as that affording the other named species—that is, the upper Eocene.

The collections from localities 5, 15, and 19 show minute traces of the presence of dicotyledons and are presumably of the same age as those from other localities with a dicotyledonous flora, but obviously it is impossible to be certain of this with the data at hand.

Locality 22 shows the presence of a large dicotyledonous leaf. The remarks in the preceding paragraph apply to this also.

Localities 1, 3, 14, 17, 18, and 28 are represented by material upon which it is not possible to venture an opinion.

**Foothills of Alaska Range, 50 Miles South of Fairbanks, Alaska.**

[Collected by L. M. Prindle and C. S. Blair, 1906.]

L. M. Prindle, No. 31. California Creek, tributary of Totatlanika. This is one of the finest and most satisfactory small collections of fossil plants from Alaska that I have examined. Although embracing less than 20 specimens, each individual is so far determinable that I have been able to distinguish a full dozen forms. They are as follows:

Taxodium tinajorum Heer.
Populus leucophylla? Unger.
Populus arctica Heer.
Quercus pseudocastanea Göppert.
Quercus? sp.
Myrica?, probably new.
Betula prisca Ettingshausen.
Betula grandifolia Ettingshausen.
Betula cf. grandifolia or n. sp.
Juglans nigella Heer.
Hedera auriculata Heer.
Vitis crenata Heer.

Nearly all of these species are enumerated and figured in Heer's "Flora fossilis Alaskana," and I do not hesitate to refer them to the Kenai or so-called "Arctic Miocene," now generally considered Eocene.

C. S. Blair, No. 10. Roosevelt Creek, mouth of Tatlanika. This collection of only about a dozen specimens is interesting, although the material is not nearly so well preserved as the last. I do not recognize any species in this collection, but I note the genera *Betula*, *Alnus*, *Corylus*, *Andromeda*, etc. While I am not positive about it, my impression is that this material is younger, much younger, than the baked material from locality 31. In any event there is not a single thing in common to the two localities, and this material appears much more modern.

**Yukon River.**

[Collected by W. W. Atwood and H. M. Eakin, 1907.]

XIV. Drew mine, about 35 miles upstream from Rampart. Age, Kenai.
Populus arctica Heer.
Populus latior Heer.
Juglans sp.?

XV. Left bank of Yukon, above Rampart. Age, Kenai.
Sequoia langsdorfii (Brgt.) Heer.
Populus latior Heer.
Populus arctica? Heer.

Mr. Knowlton's determinations indicate that all the plants except those from Roosevelt Creek belong to the same horizon. The question may be raised whether the plant-bearing beds do not constitute a definite formation with the sequence here referred to the Kenai, and whether there may not be a younger terrane not assignable to this formation, as appears to be the case at Roosevelt Creek. In the absence of detailed sections at the localities where plants have been collected, it is impossible to prove or disprove such an assumption. The following facts bear on this question:

The plants collected at Kachemak Bay[1] all come from the lower 2,000 or 3,000 feet of the exposed beds. Hence the paleontologic evidence from this locality definitely determines the age of only the lower part of the succession.

In the Matanuska Valley, where the Kenai has a thickness of some 3,000 feet, plants have been collected near the base of the formation and from a bed which lies below the upper 1,000 feet (p. 96) of conglomerate. This conglomerate may therefore be younger than Kenai.

The Kenai plants from California Creek, in the Nenana coal field, come from a bed believed by Prindle to be near the base of the coal measures. On the other hand, the plants from Roosevelt Creek, 10 miles to the east, are provisionally assigned by Prindle to a bed near the top of the coal-bearing series. These are the plants which Knowlton regards as possibly younger than the Kenai. It seems certain, therefore, that in the Nenana coal field at least 200 or 300 feet of the beds must be definitely assigned to the Kenai, while the upper 100 or 200 feet may belong to a younger formation.

The other plant collections are from localities where there is either only a small thickness of Kenai exposed or the folding of the plant beds is so intricate as to make any determination of stratigraphic sequence impossible.

Martin[2] found some gastropods in an ironstone exposed on Chickaloon Creek, in the Matanuska region. These fossils, which occur stratigraphically not far from some of the plant-bearing beds already referred to, have been described by T. W. Stanton as follows:

> This lot (No. 3316) consists entirely of fresh-water gastropods, of which all but one specimen belong to a single species of *Viviparus* of a type that occurs in both the upper Cretaceous and the Tertiary. The other specimen is a more slender form, too imperfect for generic determination. These fossils are apparently an undescribed species, at least they are new to Alaska, and they do not fix the horizon more closely than is above indicated.

Atwood[3] has found that the Kenai formation of the Alaska Peninsula carries a marine fauna pronounced by W. H. Dall to be of upper Eocene age. This corroborates the paleobotanic evidence as to the age of the Kenai already presented. Furthermore, the Kenai of the Alaska Peninsula rests on rocks carrying upper Cretaceous fossils and is overlain by sediments which have yielded a Miocene fauna. There can therefore be no question as to the Eocene age of that part of the Kenai which has yielded fossil evidence. It has been shown that little is known of the stratigraphic succession within the Kenai formation. Although at most of the localities of its typical occurrence there is, so far as determined, a marked lithologic similarity and a stratigraphic continuity throughout the sequence, yet certain exceptions to these conditions have been noted. At Tyonek and at Beluga River Atwood found some evidence of a

[1] East side of Cook Inlet, 100 miles south of Tyonek. The Kenai rocks of this locality and their flora are similar to those of Tyonek. See Stone, R. W., The coal fields of the Kachemak Bay region: Bull. U. S. Geol. Survey No. 277, 1906.

[2] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, p. 12.

[3] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, p. 114.

stratigraphic break between an upper and a lower member. Again, in the Matanuska region Paige and Knopf found a well-defined conglomerate member 1,000 feet thick, forming the top of the Kenai as mapped. The Matanuska region has also yielded some physiographic evidence bearing on this point. In their report on this region Paige and Knopf[1] state:

At the close of the Eocene the strata were uplifted and sharply folded. Peneplanation, however, was far advanced in the Talkeetna area, especially on the flanks of the region. Broad rivers whose beds were filled with well-rounded gravels flowed over its surface.

* * * * * * * *

The early Tertiary history of the Talkeetna area has already been sketched. It was shown that, coeval with the deposition of the Kenai, a peneplain of considerable perfection was developed over the region of the Talkeetna Mountains. The older age limit of this planation is fixed by the fact that the surface is in part cut across a lower Cretaceous limestone. The later limit is determined by the fact that the fluviatile conglomerates resting upon the peneplain appear to represent the similar conglomerates occurring at the top of Kenai or in the Matanuska basin. According to this view the conglomerates at the top of the Kenai represent the period at the close of lacustrine conditions and the conglomerates in the Talkeetna area are the fluviatile accumulations of the rivers which transported the materials of the Kenai sediments.

In the Tanana Valley, on the other hand, Prindle finds no stratigraphic break between the beds carrying the Eocene plants and those carrying a flora pronounced by Knowlton to be probably of post-Kenai age. These two series of beds are identical in lithology and in character of deformation. Mr. Prindle has suggested to the writer, however, that the fact that the younger beds probably derived their material directly from older beds would suffice to account for the lithologic identity of the two members of the formation even if there had been an erosional interval between the two. (See Pl. XVI, *A*, p. 170.)

The evidence presented, though far from conclusive, suggests that the Kenai as here mapped and described probably includes an upper member which is considerably younger, also that this member is separated by an erosional unconformity from the Kenai proper.

As already stated, the Kenai is widely distributed in Alaska, the various phases of this formation, as here described, being found in different parts of the Territory. As the Kenai of the interior is believed to have been laid down in rivers and lakes and that along the coast in rivers and estuaries, the conditions of deposition must have varied greatly. It is not to be expected, therefore, that correlations can be established between beds or a group of beds except over small areas. Nearly every considerable area of Kenai rocks in Alaska has yielded some of the plants referred by Knowlton to this terrane. It is not improbable, however, that younger beds are included with the Kenai in many localities, as is believed to be the case in the Mount McKinley province.

There are but few facts on which to base correlations between the Kenai and the Eocene of adjacent provinces. In their lithologic character and in the physical conditions under which they were deposited the Kenai beds resemble the rocks of the Puget group.[2] They also appear to be deposits synchronous with Dawson's "Laramie,"[3] being fresh-water plant-bearing beds succeeding the marine Upper Cretaceous. It is also true, however, that the Kenai formation bears many resemblances to the Cold Water group (Oligocene)[4] of British Columbia. These facts lend some support to the hypothesis that the Kenai may include some beds younger than Eocene.

#### VOLCANIC ROCKS.

The only known volcanic rocks in the Mount McKinley province that are referable to the Tertiary period are the basalt flows on the eastern flank of the Talkeetna Mountains. With these are correlated certain volcanic rocks near the mouth of Susitna River described by Spurr and Eldridge. Extensive bodies of volcanic rocks occur also along the inland front of the Alaska Range. These are believed to be mostly of Cantwell age and have been described in connection with that formation (pp. 78–85). Some are, however, closely associated with the Kenai and may prove to be of Tertiary age.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 33, 38.

[2] Willis, Bailey, and Smith, G. O., Tacoma folio (No. 54), Geol. Atlas U. S., U. S. Geol. Survey, 1899.

[3] Dawson, G. M., Geological record of the Rocky Mountain region of Canada: Bull. Geol. Soc. America, vol. 12, 1900, p. 79.

[4] Idem, p. 80.

#### POST-KENAI LAVA FLOWS IN THE TALKEETNA MOUNTAINS.

Paige and Knopf[1] have described and mapped a series of basalt flows which occur in the Talkeetna Mountains. These include lavas and pyroclastic rocks and have a thickness of about a thousand feet. They appear to rest on a plain of rather gentle relief cut across the upturned edges of the older rocks. In one place the volcanic rocks rest on a bed of conglomerates of unknown age about 200 feet thick.

The basaltic outflow appears to have been confined chiefly to this region, for there is no evidence of its occurrence farther west except at the mouth of the Susitna. Tertiary volcanic rocks are widely distributed in Alaska. They are known to occur in the Wrangell region and are probably found on Alaska Peninsula and in the Aleutian Islands. Basaltic flows that are probably of Quaternary age are still more widespread, being found almost throughout Alaska. It is possible that the deposits above described may be correlated with some of these Quaternary rocks rather than with those of Tertiary age.

#### VOLCANIC ROCKS OF LOWER SUSITNA.

On the geologic map (Pl. IX, in pocket) some small areas of basalts are indicated in the region lying adjacent to the Susitna delta. These localities are mapped on the authority of Spurr[2] and Eldridge.[3] Spurr describes these rocks as basalts and refers them to the Tertiary or Pleistocene. They are here provisionally correlated with the basalts of the Talkeetna region.

#### INTRUSIVE ROCKS.

In the foregoing pages it has been noted that basic intrusive rocks occur throughout the sediments of the geologic column described, including the Kenai. The age of these intrusive rocks is therefore considered to be Tertiary, though it may be younger. It is not improbable that they may represent the same period of igneous activity as that of the post-Eocene basalts of the Talkeetna region, to which they are similar in composition.

The commonest type of these basic intrusive rocks is a fine-grained green rock which is in places porphyritic and can be classed as a diabase. Another representative of what is apparently the same period of intrusion is a coarser-grained rock to be classed as a gabbro. Descriptions of these rocks as well as of variations from the two types will be found in Mr. Prindle's petrographic notes (pp. 147–148).

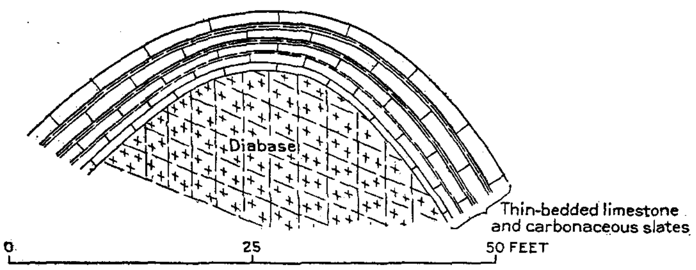



FIGURE 24.—Section showing arching of strata by intrusive diabase and jointing of igneous rock near the camp of August 9.

It has been shown that the other intrusive rocks, here termed diabases, cut the rocks of Kenai age.[4] A number of the sections which have been presented also show that this diabase invasion took place after the latest period of extensive earth movement, for the intrusive rocks almost invariably cut across the major structures. (See figs. 10, p. 77; 14, p. 82.) In some places an arching of the strata around the intrusive rock was noted. An example of this structure is presented in figure 24, which is taken from a field observation. The intrusion here is probably a laccolith, but its floor was covered. Other examples of similar disturbances due to intrusion were noted. The intrusive rocks themselves are all massive, except in some places where jointing is shown, as in the section given in figure 24. Diabase intrusives such as are here

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 29–30.

[2] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 105–226.

[3] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Idem, p. 18.

[4] Martin's recent investigations show that stocks, dikes, and sills of basic rocks are abundant in the Tertiary sediments of the Matanuska Valley.

described are common phenomena throughout Alaska. Most of these are probably of Tertiary age or later. The presence of Quaternary basalts in many parts of the Territory suggests that some of these diabase dikes may represent the feeders of such outflows.

## QUATERNARY SYSTEM.

### OUTLINE.

Much of the Mount McKinley region is mantled by a heavy covering of Quaternary alluvium. (See Pl. IX, in pocket.) This unconsolidated material may be divided into two general groups. The older group, provisionally assigned to the Pleistocene, includes (1) the terrace gravels, which are conspicuous features of the lowland areas south of the Tanana, and (2) the silts and the high bench gravels, which occur within the physiographic province termed the Yukon-Tanana upland (p. 48). (See Pl. XII, *A*, p. 108.) It is possible that some of the deep gravels of the Tanana basin may be found to form a third type of the Pleistocene. The second and younger Quaternary group, here mapped as Recent, is made up chiefly of the fluviatile deposits of the present watercourses. There is also a layer of white tuff which occurs in the Cook Inlet region immediately underneath the soil. There are no lithologic differences to characterize the two groups of the Quaternary, but many of the older deposits show a greater degree of oxidation. As a matter of fact, the differences in the lithology of the various phases of the Pleistocene are greater than those between them and the Recent deposits. This is natural, for most of the Recent alluvium is made up of the re-sorted débris derived from the dissection of the older gravel sheet. Much of the region is believed to have been glaciated before the deposition of the terrace gravels, and in some places the material deposited by the floods that accompanied the ice retreat was overridden by readvances of the ice sheet. South of the Tanana the Pleistocene gravels include a large percentage of glacial material. The existing glaciers have also contributed débris to the Recent deposits. The mapping of the Quaternary on Plate IX is only in part based on field observations by geologists. In the mapped areas the topographic expression of the Quaternary deposits is so strikingly regular as to appear to justify the extension of the Pleistocene and Recent coloring beyond the limits of actual geologic field observation on the basis of the contouring alone. Without this explanation it might be inferred that far more field work had been done on the Quaternary deposits than on the hard-rock formations.

### PLEISTOCENE DEPOSITS.

The deposits here of necessity grouped as Pleistocene embrace bodies of alluvial material of widely divergent character and origin. Though the study of isolated sections indicates that the terrace gravels will probably be subdivided when detailed surveys are made, subdivision is not now possible. Genetically the Pleistocene deposits, though here mapped as a unit, are divisible into at least two groups, which were probably synchronous. In one group fall the glacial terrace gravels, which are of fluviatile origin and were laid down during the ice retreat;[1] in the other are the silts and bench gravels, which lie for the most part beyond the influence of glacial activity. The latter were deposited chiefly under lacustrine conditions, probably brought about by changes in drainage and uplift and depression. They also include, however, some fluviatile deposits.

Although there is little direct evidence as to the age of these deposits—for no fossils have been found in them—they have been found resting unconformably on Eocene and older terranes and are for the most part younger than the time of maximum glaciation. Some Pleistocene

[1] S. R. Capps, who in 1910 made a reconnaissance of the northern base of the Alaska Range, from the Nenana to the Delta, considers that the high gravels of this region are of preglacial origin.

fossils have been found at several localities in the Yukon Valley, in silts which resemble and are probably of the same age as the silts of the northern part of the area here described. It is by no means impossible that some of the heavy terrane gravels may be of Tertiary age. The deep gravels at Fairbanks, some of which may be Pleistocene, are known only through the mine workings, and no evidence of their age has been obtained. As these deep gravels are everywhere buried under Recent deposits, they are not represented on the geologic map.

In the following pages the Pleistocene deposits of each physiographic province are considered in turn. The genesis of these deposits is treated in a later section of the report (pp. 134–136), together with an account of the glaciation.

### COOK INLET AND SUSITNA REGION.

Under this heading all the Pleistocene deposits of the river draining to Cook Inlet are described. Much of the land area within the Cook Inlet and Susitna trough is covered by gravels here referred to the Pleistocene. These have been dissected by streams, the larger of which have entrenched broad valleys in the gravel covering. Along the coast wave action has cut into these sediments, leaving seaward-facing escarpments (Pl. IV, *B*, p. 44).

These Pleistocene gravels, sands, and silts underlie the low plateaus which stretch inland on both sides of Cook Inlet to the foot of the high ranges and reach far up the Matanuska and Susitna valleys and their tributaries (Pl. IV, *A*). The topographic expression of these deposits is of the same general type throughout. They form a broad gravel terrace which slopes up from Cook Inlet or from the main waterway toward the highland rim. Where incised by river cutting or by wave action, as along the shore at Cook Inlet, these benches end in steep escarpments from 75 to 125 feet in height. From the top of these escarpments the surface slopes up gradually toward the foothills of the bordering ranges, reaching altitudes of 1,000 to 1,200 feet. An extension of these gravel plateaus is represented within the mountains by steeply sloping benches which are in the main well defined and which reach altitudes of 2,000 feet. Smaller well-defined benches occur up to the limit of glaciation, which on the Pacific slopes of the ranges is approximately 2,500 feet above sea level.

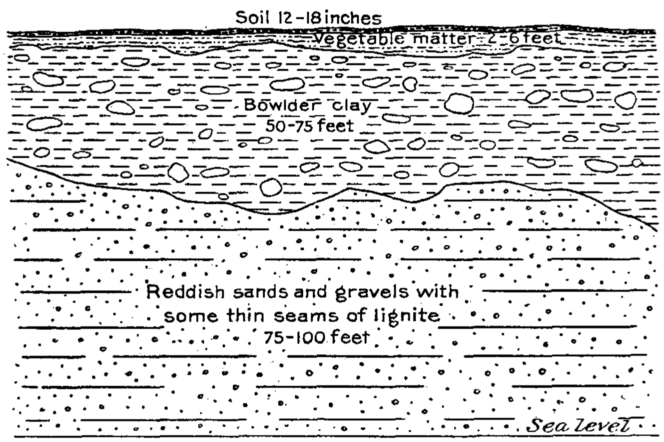



FIGURE 25.—Section of Pleistocene deposits near Tyonek, at the camp of June 1.

The material of these Pleistocene terraces is chiefly stratified sand and gravel, with some silt near the outer margins of the deposits. Large angular bowlders, some of which are 20 feet in diameter, are not uncommon in these deposits. Bowlder clay was observed in association with the gravels at a few localities. About 2 miles south of Tyonek the Pleistocene gravels and sands, carrying some large granitic bowlders, rest uncomformably on the Kenai formation. (See fig. 19, p. 95.) In some sections along this coast line bowlder clay was seen underneath and in others on top of the stratified deposits, indicating recurring advances of the ice sheet. The relations of bowlder clay and gravels near Tyonek are shown in figure 25. Only at this one locality were Pleistocene gravels that carried any lignite seen by the writer. This can be considered the type of several sections, though the thickness of individual deposits differs greatly. In some places the bottom of the bowlder clay is at or below sea level and the underlying gravels are not exposed. In others the bowlder clay rests on 100 feet or more of stratified gravel. The sands and gravels are usually red from oxidation and some are cemented by iron or manganese. Three miles north of Tyonek is exposed a section showing 75 feet of stratified gravels overlain by a white tuff 2 feet thick, and this in turn by soil. A section exposed near Beluga River shows the red or oxidized gravel unconformably overlain by gray gravel.

Though the character of the topography clearly indicates that the Pleistocene gravel sheet stretches inland from Cook Inlet, there was no opportunity to study any detailed section of these deposits after leaving tidewater. Broad terraces were observed stretching up the lower courses of Skwentna and Kichatna rivers, and these merge, at the mouths of the valleys, with the gravel sheet of the Susitna.

Moffit,[1] in describing the Pleistocene deposits on the east side of Cook Inlet, notes a section of gravel 75 to 100 feet thick at the settlement of Kenai. Of this the lower two-thirds is made up of bluish-black silt containing some gravel, overlain by sand and gravel. The upper third is in part firmly cemented with iron oxide and resembles a weathered ferruginous sandstone. Along the beach there are many large granite bowlders, some of which reach 8 or 10 feet in diameter; these were probably derived from the Talkeetna Mountains.

The Pleistocene deposits of the Knik Arm region,[2] made up of gravel, sand, and silt, are coextensive with the bench gravels of the Matanuska Valley, which have a measured thickness of at least 300 feet. The gravels of the Matanuska are well waterworn and contain but few if any glacial bowlders such as are present around Knik Arm.

Eldridge's account[3] of the Pleistocene of the Susitna Valley is rather general and includes no detailed sections. He notes, however, deposits of two distinct periods—a lower deposit, made up of bluish-gray clay-carrying pebbles and small bowlders, and an upper deposit, consisting of gravels becoming finer toward the coast and coarser toward the headwaters of the river.

On the west side of the Susitna Valley these gravel terraces merge along the watercourses with bench gravels which extend up the valleys of tributary streams for greater or less distances. As observed along the Kichatna, the benches are made up chiefly of coarse gravels, with some bowlder clays. The exposures are not very plentiful, and it was impossible to determine whether there was more than one period of deposition, as in the plateau gravels of Cook Inlet. If there was a preglacial gravel sheet, it was probably removed by the advance of the ice. If, on the other hand, the glaciers left deposits of till, these may have been removed by the floods which attended the ice retreat. It is therefore not likely that evidence of an older Pleistocene terrane could have been preserved in these mountain valleys. Some of these Pleistocene bench gravels are difficult to differentiate from the glacial benches of recent data. The upper limit of the well-marked gravel terraces of the larger watercourses is about at the limit of glaciation—that is, between 2,200 and 2,500 feet above the sea.

Moffit[4] has described similar benches along the valleys of Kenai Peninsula, which are common up to altitudes of 1,600 feet. He also makes mention of stream gravels on the mountain slope west of Quartz Creek, on Turnagain Arm, nearly 2,000 feet above sea level, and describes a still higher gravel occurring at an altitude of 3,000 feet which he interprets as a deposit laid down along the margin of a glacier.

These Pleistocene deposits differ greatly in thickness. On Cook Inlet the maximum depth observed was about 200 feet, but in the Matanuska Valley 300 feet of gravel is reported. At other localities the deposits have a depth of 50 to 200 feet. It is probable that the Pleistocene of the Cook Inlet region was laid down in a rather deep basin whose rock floor may be many hundred feet below the present surface. In the center of the basin these deposits may be 1,000 feet or more in thickness. As the alluvium probably mantles an irregular surface, however, great variation in thickness is to be expected, and in fact this is shown to exist by the few measurements that have been made.

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, p. 23.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 30–31.

[3] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey pt. 7, 1900, pp. 17–18.

[4] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 25–26.

PIEDMONT PLATEAU.

The plateau terrace which masks the inland front of the Alaska Range, from the Kuskokwim northward and eastward into the Tanana Valley, has been described as the piedmont plateau. It has been shown that the surface of this plateau slopes away from the mountain and is cut by numerous streams, some of which have chiseled out broad valleys (Pl. VI, *B*, p. 46). Along that part of the plateau lying close to the mountains between the Kuskokwim and McKinley Fork of the Kantishna the Pleistocene deposits consist of sands and gravels, with some glacial till. No measurement of thickness of these deposits was obtained, for there are no good exposures of the Pleistocene in this part of the field. It seems probable, however, that the whole plateau is underlain by gravels and sands, with probably some bowlder clay, and that these deposits extend out into the Kuskokwim lowland. At the base of the mountains the material is coarse, but away from the highlands it seems to become finer. Prospectors report the occurrence of silt and sand bluffs in the Lake Minchumina region, and these probably belong to the same terrane. Many erratic bowlders were seen along the mountain front, but these were undoubtedly deposited by the existing glaciers, whose fronts are close at hand.

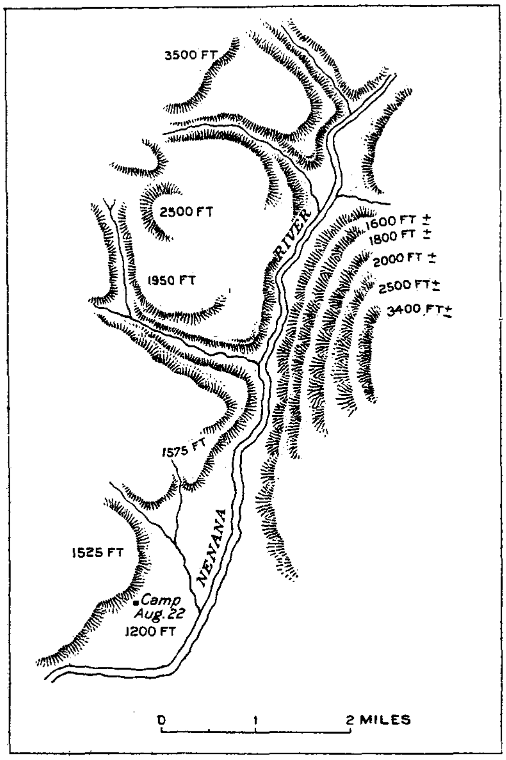



FIGURE 26.—Sketch map showing gravel terraces on Nenana River. Figures show approximate elevation above sea level.

Along the southern margin of the Tanana Valley there is a gravel sheet 2,000 feet or more in thickness. In this the Nenana and other rivers have incised sharply cut trenches (see fig. 26), along whose walls the character of the deposits is well seen. The material is chiefly coarse washed gravel, much of it having a reddish color, with some heavy beds of coarse sand. The writer's observations indicate that this deposit rests unconformably on the eroded edges of the friable conglomerates and sandstones assigned to the Kenai formation, from which it is sharply differentiated. Mr. Prindle, however, in studying the eastern extension of this belt, found that both the gravel of the Kenai formation and those lying above it appeared to be conformable, and in many places it was impossible to differentiate the two formations. A section exposed about 2 miles below the mouth of Healy Fork, on the Nenana, showed the unconformable relation of the Pleistocene gravels to the Tertiary beds. At this locality about 150 feet of roughly stratified gravels containing bowlders 3 to 4 feet in diameter were observed resting unconformably on a friable sandstone of Kenai age. Above these gravels there is about 5 feet of gray sand and silt with a few pebbles up to 2 inches in diameter. These gravels where exposed to weathering have a red color. The section in figure 20 (p. 97) shows the relation of the gravels to the faulted Kenai beds. Along the mountain front, at the contact with the metamorphic schists, these Pleistocene deposits dip northward at angles of 5° to 10°. This fact indicates that there has been uplift since their deposition.

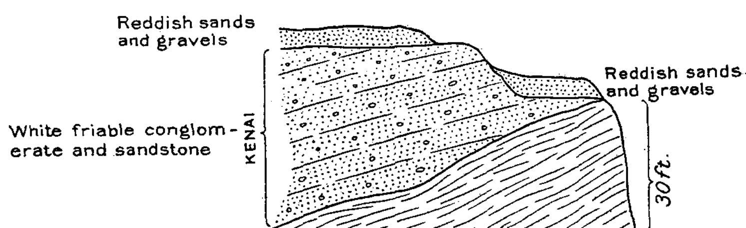
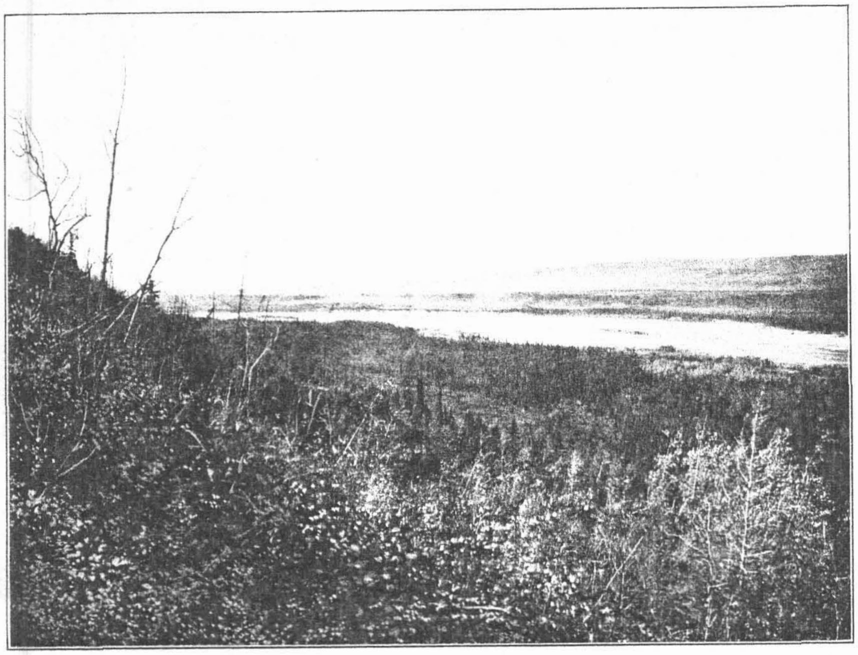
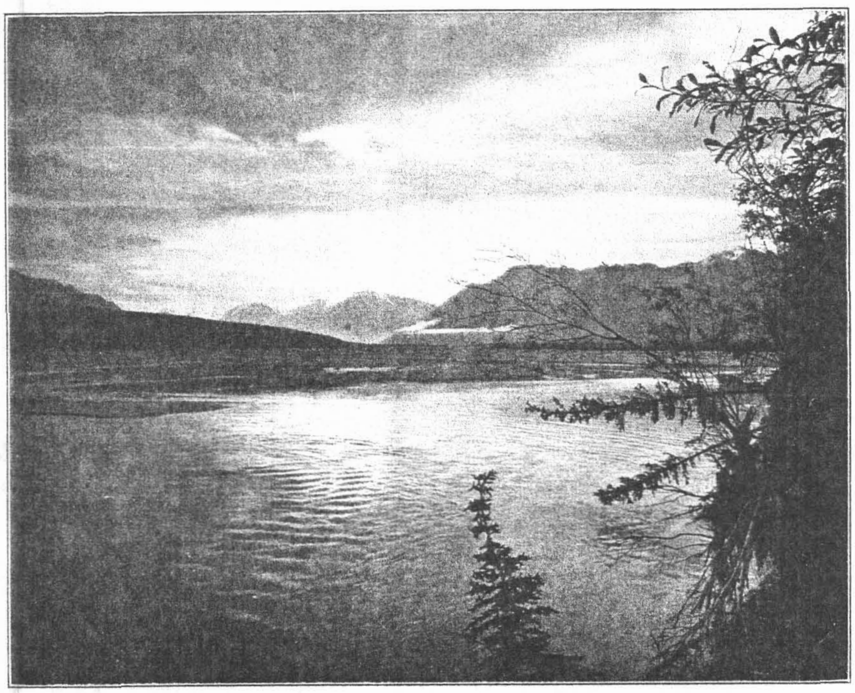



FIGURE 27.—Section on Nenana River near the camp of August 22, showing the relation of terrace gravels to Kenai formation and of Kenai formation to metamorphic rocks.



*A.* VIEW LOOKING UP NENANA VALLEY.

Three different gravel terraces are shown. Near camp of August 22. See page 109.



*B.* YANERT FORK, LOOKING UPSTREAM.

Showing flood-plain deposits in basin lowlands above canyon of Nenana River. From camp of August 18. See page 110.

Many of the valley walls in this part of the field are broken by a series of benches which represent deposits of a later date than those forming the main gravel sheet. This is well illustrated in the sketch map of the upper Nenana (fig. 26, where the benches are diagrammatically indicated) and in Plate XII, *A*. At the locality shown in the view five terraces are clearly recognizable, standing at altitudes estimated at 1,000 to 3,400 feet. The gravels of these terraces appear to be entirely undisturbed, resting horizontally on the upturned and eroded edges of the Kenai beds or on the older gravels. Their relations to the Kenai are shown in the accompanying section (fig. 27), which is reproduced from a field sketch.

The Pleistocene gravel sheet above described occupies the southern part of the Tanana lowland. Its northern limit is marked by an escarpment which is roughly parallel to and from 30 to 50 miles south of Tanana River. On the lower Tanana, beyond the area of the map, the Pleistocene sediments mantle a much larger part of the Tanana lowland, and at the mouth of Cosna River they reach within a few miles of the north wall of the Tanana Valley. Here the sediments are notably finer, indicating deposition in quiet waters and transportation much farther than those described above.

### YUKON-TANANA UPLAND.

The Pleistocene deposits of the Yukon-Tanana upland have been in part mapped and studied in some detail since 1902. To the reports resulting from these investigations the reader is referred for details, for they will here only be briefly summarized.

Prindle and Katz [1] have mapped a fine gray silt which occurs as a terrace deposit in the Fairbanks placer district. The material forms a well-defined bench at an altitude of about 1,000 feet. It appears that similar deposits occur in the Tolovana Basin, but less is known of them. All these silts were probably deposited in sluggish streams or in standing water.

Reference has been made to the possibility that some of the deep gravels of the Fairbanks district are as old as Pleistocene, if not even of Tertiary age. These gravels[2] vary from 3 to 50 feet in thickness and are overlain by 10 to 160 feet of sandy clay and humus. They are all derived from the drainage basins in which they now occur. The gravels themselves are of undoubted fluviatile origin, but the overlying fine sediments are in part contributions from talus slopes and in part may be of lacustrine origin.

A high bench gravel which occurs on the east side of Minook Creek valley, some 800 feet above the valley floor, has been described in some detail by Prindle and Hess.[3] This deposit slopes down steeply toward the west till its height above the stream is only about 500 feet. The lower part is made up of coarse rounded gravels. The thickness of these gravels has nowhere been determined, but it is probably as a rule not over 50 feet. This peculiar deposit is unique in the district, though bench deposits at lower altitudes are not uncommon, one occurring, for example, a few miles north of the town of Rampart, on the east side of the Yukon, where a bed of well-rounded gravel rests unconformably on the sandstone of the Kenai formation, about 30 feet above the river.

As shown on the geologic map (Pl. IX, in pocket) there is an extensive area of Pleistocene deposits along the valley of Stephens Creek, a few miles southwest of Minook Creek. These deposits define a well-marked bench some 400 feet above the river and are made up essentially of fine buff-colored and yellow silt interstratified in places with a few beds of gravel. The silts are at least 200 feet thick. They are very like the silt deposits of the upper Yukon,[4] which, however, are believed to be closely related to the overwash deposits of the glacial epoch.

There are some benches along the Yukon below the mouth of Stephens Creek, and these are probably covered with gravel, though they have not been examined. On the west bank of the Yukon, opposite the mouth of the Tanana, there is a broad bench which extends inland for several miles and is covered with fine silt. These are similar to the deposits found on the lower Tanana and are probably extensions of them.

[1] Unpublished manuscript.

[2] Prindle, L. M., and Katz, F. J., The Fairbanks gold-placer region: Bull. U. S. Geol. Survey No. 379, 1909, pp. 181–192.

[3] Prindle, L. M., and Hess, F. L., The Rampart gold-placer region, Alaska: Bull. U. S. Geol. Survey No. 280, 1906, pp. 30–31.

[4] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 309–310.

### CORRELATION.

The known facts do not permit a definite correlation between all the deposits here described as Pleistocene. There seems to be little doubt that the terrace gravels found on the two sides of the range are synchronous deposits,[1] but there is less certainty in the correlation of these gravels with the silts of the Fairbanks region and Stephens Creek or the high gravels of Minook Creek. The silts which occur along the Lewis and Yukon valleys have been described by Spurr[2] as the remnants of a continuous deposit under the name Yukon silts. Russell[3] had previously referred these deposits to lacustrine origin, while Dawson[4] regarded them as estuarian. Spurr argued that they were in part estuarian, in part lacustrine. Some fresh-water fossils have since been found at various localities, indicating that most of the silts are nonmarine. In the opinion of the writer, most of these silts are overwash deposits laid down by the floods which accompanied the ice retreat. This explanation is supported by the fact that the silts occur up the Lewis Valley only to the northern limit of glaciation.

### RECENT DEPOSITS.

The Recent deposits consist of the alluvial material along the present watercourses (Pl. XII, *B*), including some low benches, and also some beach sands along Cook Inlet. Many of these deposits are not sufficiently extensive to be represented on the accompanying map. In this subdivision must also be placed the recent ejectamenta of Redoubt Volcano which were found in the vicinity of Cook Inlet. In the Fairbanks district there are some extensive deposits of silt, clay, and humus, also of Recent age.

The alluvial deposits have no striking peculiarity that merits detailed description. Near the mouths of the southward-flowing larger streams, like the Susitna, the flood plains consist chiefly of fine silts and muds. With these muds are found here and there bowlders and pebbles, some of which are clearly ice borne and were evidently deposited during the freshets which accompanied the spring break-up. In an upstream direction the flood-plain deposits gradually become coarser, and along the smaller tributaries they consist chiefly of heavy wash. On the streams having glacial sources there is a large percentage of glacial bowlders in the fluviatile matter. All the southward-flowing streams of the region are overloaded and are building up their flood plains.

The upper parts of the tributaries to the Kuskokwim all have steep gradients, and their flood plains are made up of coarse gravels and a large proportion of glacial bowlders. From the best information available it appears that all these streams change their character before they join the Kuskokwim, becoming more or less sluggish watercourses with only fine material in the flood plains.

The flood plains of the tributaries of the Tanana are of two types. The rivers flowing from the south have steep gradients and their deposits are chiefly coarse gravel. Moreover, they are turbulent muddy streams which are rapidly aggrading. The northern tributaries of the Tanana, on the other hand, are sluggish clear-water streams whose flood plains are built up largely of fine sediments almost to the sources of the small tributaries. It has been shown that this fine material also goes to considerable depths and that the bed-rock floors of the valleys lie far below the present surface.

The subject of ground ice is worthy of mention. It appears that on the south side of the Alaska Range the ground thaws out to bed rock every season. North of the range ground ice is nearly everywhere present under 1 to 2 feet of soil and humous matter. This layer remains frozen throughout the year. Usually where the alluvial material is undrained the permanent frost extends to bed rock, in one place 318 feet of frost having been measured. Locally, however, where loose gravels are encountered, the material is not frozen.

[1] Recent studies of S. R. Capps have raised the question whether the heavy gravels on the south side of the Tanana are of postglacial age. If they are preglacial the heavy gravels on the two sides of the range may not be synchronous deposits.

[2] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 200–221.

[3] Russell, I. C., Notes on the surface geology of Alaska: Bull. Geol. Soc. America, vol. 1, 1889, p. 146.

[4] Dawson, G. M., On the later physiographical geology of the Rocky Mountain region in Canada: Trans. Royal Soc. Canada, vol. 8, sec. 4, 1891, p. 43.

The white tuff already referred to is the result of an eruption from Redoubt Volcano, 60 miles southwest of Tyonek, which took place January 18, 1902. This deposit, which appears to be of andesitic character according to local report, accumulated to a depth of about one thirty-second of an inch. It was observed by the writer as far north as Skwentna River and is said to have been carried as far to the northeast as the Matanuska. This would make the most distant deposit about 150 miles from the center of eruption. Near the periphery of the deposit the material was little more than an impalpable dust which could be seen only on the foliage.

## STRUCTURE.

The structure of each stratigraphic unit represented in the Mount McKinley province has been described in the discussion of the geologic sequence. It remains to consider the interrelation of these structures and, so far as the data permit, to present the salient tectonic features of the province as a whole, as well as to trace the sequence of diastrophic events.

Attention is here again directed to the marked parallelism of the major structural axes of central Alaska to one another and to the crescentic sweep of the southern coast line. This parallelism of structural lines holds not only for central Alaska but also for the entire northwestern part of the continent. It finds topographic expression in the crest lines of the principal ranges of both the Pacific and the Rocky Mountain systems. Variations from the general trend, which occur here and there, serve but to emphasize the general tectonic law of the province, which is in effect that east of a line bisecting mainland Alaska the major structures trend northwest and southeast, while west of such a line they trend northeast and southwest.[1] The former trend is but an extension of the structures of the western part of the North American continent; the latter is Asiatic in direction.

In Kenai Peninsula and west of Cook Inlet the dominant strike lines range from N. 10° E. to N. 20° E. These trends curve eastward, and at about the one hundred and fifty-second meridian the strike is N. 60° E. and at the one hundred and forty-eighth meridian nearly east and west. From thence it gradually curves to the southeast, so that near the one hundred and forty-sixth meridian the strike lines trend N. 60° W.

These strikes are typical of the Mount McKinley province, which includes the western part of what is here termed central Alaska. The trend of the great synclinorium of the Alaska Range is the most striking example of the direction of the dominating structural lines, but this is paralleled by the strike lines of the Paleozoic and metamorphic rocks of the Tanana upland, as well as by the folds in the Tertiary beds of the Matanuska Valley. There is some divergence from these general trends around the flanks of the Talkeetna Mountains, due both to the disturbances caused at the time of the intrusion, when the mountains were formed, and to the physical effect of the great mass of igneous rocks, during the subsequent deformation. Another markedly discordant element in the strike lines has been produced by an east-west fault, which was noted near the intersection of the one hundred and fifty-third meridian with latitude 63° 30′. More detailed studies will probably develop many other divergencies from the normal strike lines, but these are not likely to affect the truth of the statement as to the direction of the major structural features. The stratified and schistose rocks of the Mount McKinley region, where closely folded, most commonly dip to the east, southeast, and south. There are, however, many variations from this direction. In the closely folded rocks of the Chugach Mountains southeasterly dips prevail, but northwesterly dips are not uncommon. In the Matanuska and Talkeetna regions the folds are in part open and the dips vary in direction from place to place. The faults along the southern margin of the Talkeetna Mountains dip toward the north.

East of the central axis of the Alaska Range synclinorium the strata in many places dip toward the major axis of the folding. Along the inland front of the range the dips are almost universally to the southeast, and—perhaps a more significant fact—the fault planes also dip in the same direction. In the Tanana upland southeasterly dips prevail, but northwesterly dips have also been noted.

[1] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, Pl. XXI.

Seven tectonic subdivisions have been made of the Mount McKinley region. Named from south to north, they are (1) the Chugach zone of close folding, (2) the Matanuska [1] and Susitna province of open folding, (3) the Alaska Range synclinorium, (4) the piedmont zone of overturned folds and thrust faulting, (5) the Tanana Valley province of gentle folding, (6) the Birch Creek schist area of intense deformation, and (7) the Paleozoic area of close folding. Each of these subdivisions, as indicated by the designations, is characterized by structural types differing from those of the adjacent provinces. As will be shown, these differences can only in part be accounted for by the effects of the pre-Mesozoic epochs of diastrophism. The facts in hand clearly indicate that these tectonic provinces are in a large measure the result of differential post-Paleozoic deformation, which was to a considerable extent localized along certain well-defined zones.

Only the western part of the Chugach Mountains is here considered, where the component strata are known to be closely folded, with dips ranging from 40° to 90°.[2] The monoclinal succession of steeply dipping strata is interpreted as due to repetitions by close folding. Moffit,[3] in describing the southern extension of this belt, notes the presence of many faults, though he was unable to determine their magnitude.

The Mesozoic and Tertiary beds of the Matanuska and Talkeetna basins, which lie in the second tectonic province, are, with exceptions of those lying adjacent to granite batholite of the Talkeetna Mountains, only gently folded, and hence are in strong contrast to the intensely deformed rocks to the southeast. Some of the coal-bearing rocks of this area, however, have suffered greater deformation, which has manifested itself chiefly in the presence of numerous faults.[4] It was undoubtedly the massive character of the conglomerate involved in these movements (see p. 96) which caused the compressive stresses to be taken up by dislocations rather than by folding. (See fig. 21, p. 98.) The Tertiary rocks of the Susitna basin, here included in the same tectonic province, are but little disturbed.

The Alaska Range synclinorium includes a broad belt of closely folded rocks, in which, however, the synclines and anticlines are recognizable. (See section *A–B*, Pl. IX, in pocket.) Many minor faults and some of considerable throw were observed in the heart of the range, but no measure of the amount of the displacement was made. There are also some local irregularities, caused by the presence of large stocks of intrusive rock, but on the whole these masses of igneous rocks appear to have had little effect on the structure.

As already indicated, the piedmont zone of faulting, which extends along the western base of the Alaska Range, is a locus of most intense crustal disturbances. (See Pl. X, *B*, p. 70.) In this zone practically all the folds are overturned toward the west, and hence the dips are to the southeast. In the less resistant beds the deformation has been such that it is in few places possible to make out details of structure, but the dominating type is that of thrust faulting. The older Paleozoic rocks are thrust up on the Kenai formation, indicating displacement which must be measured in thousands of feet, if not in miles. It is not impossible that the entire front of the range between the Kuskokwim and McKinley Fork of the Kantishna is a zone of overthrust where the older rocks have risen over younger series. This overthrusting has been accompanied by some cross faulting, and there is a suggestion that these zones of cross faulting are lines of weakness to erosional agencies and are marked by topographic scarps. At Farewell Mountain (see Pl. IX) and in the region adjacent to the east there is a well-defined northeastward-trending scarp, which from the stratigraphic evidence appears to lie in a line of movement. Similar topographic features have been observed that may also mark cross faulting, of which there is in places some stratigraphic evidence. In the whole belt the only rocks that appear to have resisted the intense deformation are the massive conglomerates of the Cantwell forma-

[1] Since the above was written Martin has found a zone of close folding and overthrust faulting extending along the northern margin of the Matanuska Valley. This was probably caused by the thrusting of the sediments against the buttress formed by the Talkeetna Mountain intensive rocks.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Talkeetna and Matanuska basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 15.

[3] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, p. 18.

[4] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 41.

tion, which, where it finds its full development, has been thrown up into easily recognizable anticlines and synclines. The folding of all the older rocks, which are made up chiefly of less massive beds than the Cantwell, has been so intense that the details of structure will defy analysis except after very minute studies.

The Kenai beds of the Tanana Valley, constituting the fifth tectonic province, are only gently folded and faulted; indeed, in some places they are practically undisturbed. The significance of this fact will be made clearer if it is remembered that if the stratigraphic correlations are correct the Kenai rocks are also involved in the intense movements of the piedmont zone of faulting.

The area of Birch Creek schist adjacent to the Tanana on the north forms the sixth tectonic province. These rocks have been deformed to such an extent that in many places all evidence of bedding is destroyed. The quartzites of this series are broken by faults and closely folded and the less massive schists have been fairly kneaded; as a result there are an infinite number of minor flexures. The strike lines trend uniformly to the northeast, but the planes of schistosity usually dip to the southeast.

The Paleozoic rocks lying adjacent to and northwest of the schists and forming the seventh tectonic province are also intricately folded and faulted. The deformation, however, has not been so intense as to obscure the larger structural features. Although closed folds with southeasterly dip predominate, some more open structures with northwesterly dips have been noted. The strike lines are prevailingly to the northeast, but there are some exceptions.

It is shown in the next chapter that the structures of the Mount McKinley province are the result of recurrent epochs of diastrophism during a period extending from pre-Ordovician to Tertiary time. The parallelism of the structural lines is therefore of greater significance than if they were the result of only one epoch of mountain building. Of equal importance to the tectonic history is the peculiar distribution of the zones of intense deformation, separated, as they are, by zones characterized by only moderate folding. With regard to the older rocks, such as those of the Chugach Mountains and the Birch Creek schist, this can be explained by the fact that the deformation took place before the younger rocks now occupying the intervening areas were laid down. Such an explanation can not be given for the extreme deformation along the inland front of the Alaska Range as compared with the gently folded belts lying to the north and south, for in this belt the same Mesozoic and Tertiary beds are involved in both types of structure. The structures indicate that the thrust which caused these deformations came from the direction of the Pacific, and it appears that along certain zones of weakness, which appear to have been loci of previous deformation, the strata were intensely disturbed. One such zone of folding would be easy to account for, but where there are two or more parallel and separate zones, as there appear to be in the Mount McKinley region, it is difficult to conceive how the thrust could have been transmitted.

The explanation of these phenomena must be sought in the fundamental concepts bearing on the evolution of the northwestern part of the continent. At present there is no adequate background of facts to warrant any final analysis of these problems.

## GEOLOGIC HISTORY.

*Means of interpretation.*—The descriptive geology of the Mount McKinley region indicates the lack of many data essential to a fundamental analysis of the evolution of the province. It seems worth while, however, to utilize the evidence in hand for a discussion of the geologic history and to present in outline at least what is believed to be the sequence of events by which this part of the continent was formed. In doing this many assumptions will have to be made, and many ideas that are advanced can be regarded as little more than speculation. To simplify the presentation it will be necessary to accept as definitely proved certain interpretations of the known facts on the correlations, structure, and stratigraphy that have been advanced in the foregoing descriptions solely as suggestions.

The stratigraphic subdivisions presented and the correlations suggested in the foregoing pages have been based chiefly on the evidence of lithology, sequence of beds, and fossils; in other words, the discussion has been primarily an interpretation of the sedimentary record. Relatively less weight has been given to the subdivisions of geologic time marked by crustal disturbances and consequent epochs of erosion. A time scale determined by periods of diastrophism, though it may not always lead to the same subdivisions as one based on the evidence of sedimentation and of organic life, takes into account phenomena of first importance to an understanding of the geologic history—the ultimate aim of all geologic investigations. Geologic science has perhaps not yet advanced far enough to determine to which line of evidence shall be given greatest weight in attempting a rational subdivision of the geologic time scale, but it is certain that the paleogeographer can not afford to ignore either the sedimentary and paleontologic record, on the one hand, or the epochs of diastrophism and erosion, on the other.

*Tabular statement.*—On page 55 the salient features of the geologic sequence of Mount McKinley region have been summarized in tabular form. This summary is amplified and supplemented by the subjoined statement of the chief events of the dynamic history as well as the record of sedimentation. As it is the time scale and not the sequence of strata which is here presented, the table begins with the oldest records. For the sake of making this section complete the entire geologic history will here be considered. A more detailed discussion of the post-Cretaceous history, however, will be found in the account of the geomorphology (pp. 118–137).

*Statement of geologic history of Mount McKinley province.*

1. *Pre-Ordovician sedimentation* (Birch Creek schist). Deposition of great thickness of arenaceous and argillaceous sediments, with some calcareous material and igneous rocks.
2. *Pre-Ordovician diastrophism.* Intense deformation under heavy cover, accompanied by some intrusion.
3. *Ordovician sedimentation* (Tatina group). Deposition of several thousand feet of argillaceous and calcareous material, with much carbonaceous matter.
4. *Silurian (?) and Devonian (?) deposition.* Sedimentation on a sinking sea floor, first of argillaceous material (Tatina group), followed by cherty and calcareous material (Middle Devonian), the whole series measuring several thousand feet in thickness. In the Yukon region calcareous deposition accompanied by extravasation of a large amount of andesitic and basaltic volcanic material.
5. *Pre-late Devonian folding.* Epoch of folding, possibly followed by period of erosion.
6. *Late Devonian and early Carboniferous sedimentation.* An unbroken period of sedimentation on a lowering sea floor. Earliest deposits argillaceous, followed by deposition of calcareous material. These sediments on the Yukon aggregate some 2,000 feet in thickness, but have not been recognized in the Mount McKinley province.
7. *Middle Carboniferous erosion and sedimentation.* A period of erosion followed by deposition of coarse arenaceous material, with some argillaceous material (Cantwell formation). Aggregate thickness at least 2,000 feet. In the Alaska Range there was an outburst of volcanoes during this epoch.
8. *Late Carboniferous and early Triassic deposition.* A rapid depression followed by deep-sea sedimentation of calcareous material. Sedimentation continued unbroken from Carboniferous into Triassic time. No deposits of this epoch have been found in the Mount McKinley region.
9. *Early Middle Jurassic volcanism.* Extensive extravasation of volcanic material in southeastern part of Mount McKinley province (Skwentna group).
10. *Middle Jurassic sedimentation.* Accumulation of several thousand feet of coarse arenaceous sediments, with some argillaceous and calcareous material (Tordrillo formation).
11. *Post-Middle Jurassic diastrophism.* Widespread crustal disturbances accompanied by the intrusion of large amount of granitic and dioritic material. As a result a land mass was exposed and erosion followed.
12. *Late Jurassic and early Cretaceous sedimentation.* Deposition of probably several thousand feet of conglomerates, sandstones, arkoses, and volcanic rocks in the southern half of the province. During late Cretaceous time deep-sea conditions prevailed in the eastern part of the Matanuska region; but elsewhere in the province the deposits of this period were chiefly of terrestrial origin.
13. *Post-early Cretaceous folding.* Intense crustal disturbances throughout the province, accompanied by some intrusion. A land mass was probably revealed at the end of this epoch and erosion followed.
14. *Late Cretaceous sedimentation.* A part of the Mount McKinley province was submerged and, locally at least, arenaceous sediments were deposited.
15. *Eocene erosion and deposition.* An uplift inaugurated a cycle of erosion which was of sufficiently long duration to permit the development of an extensive drainage system. Deposition of fluviatile deposits was widespread during this cycle (Kenai formation).
16. *Post-Eocene deformation and subsequent erosion and uplift.* A widespread crustal movement during which the entire province was elevated several thousand feet and intense local deformation took place along the zones marked by the high ranges. This was followed by erosion and then by renewed uplift.

*Pre-Ordovician sedimentation.*—The oldest record of sedimentation in the Mount McKinley province is contained in the metamorphosed rocks termed the Birch Creek schist, here assigned to pre-Ordovician time. The rocks of this formation in the province are chiefly argillaceous and fine arenaceous sediments, with a little calcareous matter and some igneous rocks. It has been suggested that the amount of calcareous matter increases farther east, but this has not been proved. It has been shown that similar rocks extend southeastward into Yukon Territory and that the same horizon has been recognized on Porcupine River in a series of quartzite slates, with some limestone. This horizon may also be represented by the Kigluaik group of Seward Peninsula,[1] which includes a considerable thickness of limestone as well as schists and gneisses. There is some evidence that the Kigluaik group is pre-Cambrian. These facts point to the conclusion that deposition was widespread during this epoch, and it seems probable that the sea in which these sediments were laid down covered a large part of central Alaska and adjacent portions of Canada.

There is only slight evidence as to the thickness of these strata, but it must be measured in thousands of feet. If this terrane or any part of it is found to be of Cambrian age, the body of water in which it was laid down may have been coextensive with the Cambrian sea of southern British Columbia. All these facts go to show that in pre-Ordovician and possibly in pre-Cambrian time there was an extensive body of water in the northwestern part of the continent. The character of the sediments laid down in the Yukon-Tanana region indicates that there were also some land masses not remotely distant. Beyond these facts there is little clue to the geologic history of this epoch. Whether deposition went on continuously until this whole great mass of strata was laid down or whether it was interrupted by periods of elevation and erosion can not be determined from the facts at hand.

It should be noted that there is a possibility that the metamorphic rocks forming the Chugach Mountains and occurring in the upper part of the Susitna basin may in part be contemporaneous with the Birch Creek deposits. If this is the case, it suggests that there was a land mass in this direction, as these rocks contain a far greater amount of fragmental material than the typical Birch Creek schist.

*Pre-Ordovician diastrophism.*—The rocks here assigned to pre-Ordovician time are characterized by intense deformation and metamorphism and are thus strongly contrasted to those which are definitely known to be of Paleozoic age. The metamorphism is of such a character as to indicate that the rocks were under a heavy cover when they were subjected to deformation and alteration. This crustal disturbance was accompanied by the intrusion of igneous rocks. There is no criterion as to when it took place, but it was probably before the deposition of the Ordovician sediments.

It seems quite probable that this epoch of mountain building resulted in elevating the province above the sea and that a period of erosion followed. The Ordovician beds have, however, not been found in contact with the metamorphic rocks, so that the stratigraphic relations have not been established. As indicated, however, the metamorphic rocks are so much more highly altered than the later sediments as to indicate that their history was widely different from that of the recognized Paleozoic rocks. It is fair to assume, therefore, that they were folded and altered before Ordovician time.

*Ordovician sedimentation.*—Sedimentation began again in the Mount McKinley province some time during the Ordovician period and continued until several thousand feet of limestone cherts and argillaceous sediments (Tatina group) were accumulated. The sequence of beds, so far as known, indicates that deep-sea conditions were followed by those of shallower water, when finer detrital material was laid down. If the Ordovician of the Mount McKinley region is the same as that of the Porcupine and of Seward Peninsula, it indicates widespread marine conditions. It appears possible that the Tatina sedimentation may have been interrupted by elevation and erosion, or perhaps by some folding. This, however, is in doubt, as there is no

[1] Collier, A. J., Hess, F. L., Smith, P. S., and Brooks, A. H., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 66-69. Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, 1910, pp. 19-22.

positive evidence in this province of an unconformity between the Ordovician Tatina group and the succeeding Silurian or Devonian Tonzona group.

*Silurian (?) and Devonian (?) deposition.*—A long period of sedimentation began during late Silurian or early Devonian time and appears to have continued unbroken into the Middle Devonian. The deposits of this age seem to have been laid down on a sinking sea floor, the land sediments (Tonzona group) of the first part of the epoch being followed, apparently without break, by limestone known to be of Middle Devonian age. Deposition continued until at least several thousand feet of strata were accumulated. In the Yukon-Tanana region the later part of this epoch was characterized by volcanic outbursts.

Limestones of Middle Devonian age, which are widely distributed over Alaska, are characterized both by marked lithologic similarity and by the same faunas. This indicates similarity of physical conditions and suggests that most of the northwestern part of the continent was submerged during Middle Devonian time. Locally, as indicated, there was extensive extravasation of volcanic material, which is intimately associated with the limestones of this epoch.

*Devonian folding.*—In the Yukon Valley there is evidence that Middle Devonian was separated from late Devonian time by an epoch of deformation, probably followed by a period of erosion. In general it may be said that the Middle Devonian limestone, so widely distributed in Alaska, is sharply differentiated from the later sediments both by degree of metamorphism and by unconformity, and similar conditions may have prevailed in the Mount McKinley province, though of this there is no direct evidence.

*Late Devonian and early Carboniferous sedimentation.*—On the upper Yukon there is evidence of an unbroken sedimentary record extending from late Devonian to early Carboniferous time. This record began with the laying down of at least 1,000 feet of fine terrestrial sediments, that toward the top gradually became more calcareous and finally passed into a limestone and shale series (Calico Bluff formation) which accumulated to an unknown thickness—at least 1,000 feet. The increase of calcareous matter was accompanied by the invasion of a Carboniferous fauna. This formation has not been recognized in the Mount McKinley province. Its absence may be due to erosion in the period which followed, for it appears that marine conditions prevailed in much of Alaska during early Carboniferous time.

*Middle Carboniferous erosion and sedimentation.*—On the Yukon there is an abrupt change in character of sediments from the Calico Bluff formation to the Nation River formation. The former is made up of rocks which originated as deep-sea and offshore deposits; the latter is composed of conglomerates and sands strongly suggestive of fluviatile origin. In the Alaska Range the middle Carboniferous is represented by the Cantwell formation, which is similar to the Nation River in lithologic character. A period of erosion is known to have preceded the deposition of the Cantwell and is believed to have preceded that of the Nation River. The beds in other parts of Alaska that are provisionally correlated with these two formations all bear unconformable relations to the rocks which they overlie. Moreover, the sediments are as a rule of a continental character and the included conglomerates are made up of well-washed quartz pebbles. The character of these rocks indicates that they originated after a long epoch of subaerial denudation.

It is fair to assume, therefore, that after the deposition of the early Carboniferous limestones there was a crustal movement by which much of central Alaska was laid bare to the agencies of denudation. There is some evidence that during a long period of erosion much of the land was reduced to a surface of low relief and that during this period or after a second uplift which revived erosion extensive fluviatile deposits were laid down. These fluviatile sediments were accumulated in some localities to a thickness of at least 4,000 feet. In the Alaska Range this sedimentation was accompanied by volcanic outbursts, and extensive lava flows were poured out.

*Late Carboniferous and Triassic deposition.*—On the Yukon the Nation River formation is succeeded by heavy limestones of upper Carboniferous age, which in turn are overlain by Triassic limestones. The abrupt transition from the conglomerate and sandstone of the Nation River to shale and limestone suggests that there was an important earth movement in late Carboniferous time. Although there is no direct evidence of structural unconformity between the two formations, there must have been a marked change in physical conditions from one to the other. The facts may be accounted for by a rapid lowering of the land and the bringing about of deep-sea conditions, which appear to have prevailed without break into Triassic time. In the Mount McKinley province the Paleozoic record of sedimentation closed with the deposition of the Cantwell formation, and the Triassic is also lacking. Hence there is no evidence as to the conditions which prevailed in this province during late Carboniferous and early Triassic time.

In the upper Copper basin, east of the Mount McKinley province, there are some 7,000 feet of upper Carboniferous sediments, chiefly limestones and volcanic rocks, and in the southeastern part of the Copper basin there are about 6,000 feet of Triassic limestones and shales resting on a great thickness of volcanic rocks (Nikolai greenstone), which may be of Carboniferous age. These facts point to the conclusion that during late Carboniferous and early Triassic time marine conditions prevailed over much of Alaska. The Carboniferous deposition of calcareous rock and shale was locally accompanied by the extrusion of lavas and tuffs.

*Middle Jurassic volcanism.*—Volcanism began in the southern part of the Mount McKinley province during early Jurassic time, or possibly as early as the Triassic, and continued until a great complex of lavas and tuffs (Skwentna group) was accumulated. Contemporary with the outpouring of these rocks was some normal sedimentation. Some folding and possibly erosion apparently followed, but of this there is little direct evidence. It seems probable that during this epoch the northern part of the province was above water, though this is little more than a supposition.

*Middle Jurassic sedimentation.*—However the cycle of volcanism may have terminated, whether by the beginning of deformation or of erosion, it was followed by an epoch of littoral deposits, when the material of conglomerates, sandstones, and slates was laid down to a thickness of 2,000 feet or more. Oscillations of the sea floor or adjacent land masses during this epoch are suggested by abrupt changes of material. Some limestones are found among the deposits of this age. These sediments have been recognized only in the southern part of the province—a fact which suggests that at this time the northern part was above the sea.

*Post-Middle Jurassic diastrophism.*—Sometime after the Middle Jurassic period there was a widespread crustal movement which was accompanied in certain areas by the intrusion of large masses of igneous rocks. It was chiefly during this epoch that the great batholiths of the Coast and Alaska ranges and the Talkeetna Mountains were injected. Many of the granitic and dioritic rocks of other parts of Alaska are believed to belong to this epoch also. Although it is known that intrusions of rocks of this type continued locally until late Cretaceous time, most of the intrusions are believed to have taken place during this epoch.

Deformation at this time was intensified along the axes of the present mountain ranges. In fact, this epoch of folding can be considered the beginning of the modern dynamic history. Later earth movements appear to have followed the zones of weakness which became well established during this epoch.

These disturbances probably laid bare to erosion much of the province, especially near the centers of maximum intensity. Erosion followed, but there is no means of determining its duration or the extent of the land mass exposed.

*Late Jurassic and early Cretaceous sedimentation.*—A widespread inundation followed the cycle of disturbance just described and sedimentation began again over much of Alaska. Most of the sediments of this epoch include enough detrital material to suggest the proximity of land masses. Probably the most logical interpretation of the facts at hand indicates an archipelago or a deeply fiorded coast line over what is now Alaska. In some parts of the province sedimentation appears to have continued unbroken from Jurassic to early Cretaceous time. During the early Cretaceous marine deposits were laid down in the Matanuska and Kuskokwim regions, indicating deep-sea conditions, but in the rest of Alaska the sediments of this period are chiefly fragmental, indicating near-by land masses.

*Post-early Cretaceous folding.*—The sedimentation cycle was closed by a period of folding, locally accompanied by intrusions. This crustal movement was both widespread and intense.

It was the last disturbance in which any considerable metamorphism took place. There is some reason to believe that it was followed by a period of erosion.

*Late Cretaceous sedimentation.*—In late Cretaceous time a general subsidence took place in the region west of the one-hundred and fiftieth meridian, accompanied by an invasion of the sea. It is not possible to trace the shore line of this epoch from the evidence in hand. It is known that sedimentation was going on over Alaska Peninsula and on the Yukon as far as Rampart. It seems probable that the northeastern part of the Mount McKinley province was not submerged at this time. Sedimentation was closed, in this province at least, by an uplift accompanied by local folding and intrusion of granitic rocks. This movement appears to have resulted in elevating the entire province above the sea.

*Eocene erosion and deposition.*—Erosion, begun after the crustal disturbances which followed the Upper Cretaceous sedimentation, continued for a long period of time, extending into the Eocene. An extensive system of valleys was then developed, and in these valleys a large amount of fluviatile deposits (Kenai formation) was laid down.

*Post-Eocene deformation and subsequent erosion and elevation.*—The period of diastrophism which followed Eocene deposition was the last one of intense folding. It has already been shown in the discussion of structure (pp. 111–113) that the later epochs of folding were most intense along certain zones now marked by the mountain ranges. This is especially true of the post-Kenai deformation.

As a result of these movements the whole province was uplifted far above sea level, and then stability was maintained for a sufficiently long time to permit the peneplanation of extensive areas. Differential uplift followed and the present drainage system was carved out. This later history is discussed in greater detail in the section devoted to geomorphology.

## GEOMORPHOLOGY.

The sequence of stratigraphic events, more especially with reference to the history up to the close of the Lower Cretaceous, has been presented above. It remains to consider in more detail that part of the geologic history which has left its impress on the present topography. For this purpose it is necessary to describe the land forms with reference to their origin and in greater detail than was done in the section devoted to general geography (pp. 42–48). Therefore a genetic classification of the land forms is attempted, followed by a statement of the period of glaciation, which has been one of the most important agencies in molding the surface. This forms the introduction to a statement, as systematic as the data in hand permits, of the sequence of events by which the present topography was evolved.

### GENETIC CLASSIFICATION OF LAND FORMS.

#### MOUNTAINS.

Ranges of two types have been recognized in this province. Those of one were carved out of masses of deformed rocks, in which the major structural lines have determined, to a very large extent, the present topography. Those of the other were formed by the dissection of uplifted crustal blocks whose surfaces represent old peneplains. In the second class erosion has been controlled primarily by drainage inherited from previous erosion cycles and only secondarily by bed-rock structure.

The Alaska Range is the best example of the first class. Its component strata have been thrown up into a broad synclinorium profoundly faulted on the west side. (See sections, Pl. IX, in pocket.) The range has a well-defined crest line, which varies from 6,000 to 8,000 feet in height and is traceable with but few breaks for several hundred miles. Numerous peaks, composed chiefly of the relatively more resistant intrusive masses, tower above the crest line, with altitudes of 9,000 to over 20,000 feet. On the northwest the range for 200 miles falls off by an abrupt descent to the piedmont plateau, only 3,000 feet in altitude. On the inland slope the distance from the crest line to the front of the range is only 3 to 10 miles, and foothills are almost entirely absent. The coastal slope is far less abrupt, for here the crest line is separated from the mountain front by a number of subordinate ranges and foothills, together forming a rugged area some 20 to 40 miles wide. This asymmetrical cross section is due in part to the character of the crustal movement by which the western area of the syncline was uplifted higher than the eastern area and in part to subsequent dissection. The coastward-flowing streams, because of the greater precipitation, had the advantage over the inland-flowing streams. For the same reason glacial erosion was also greater on the coastal side.

Certain topographic features suggest that a part of the southeastern frontal margin of the range may havè once been peneplaned. On the upper Skwentna there is a marked accordance of summit levels at altitudes of about 5,500 feet. Similar features have been noted to the northeast, in the Yentna basin. The evidence is far from conclusive, but it seems possible that the peneplanation of the Kenai and Talkeetna mountains (see p. 132) may have beveled the southeastern part of the Alaska Range also. This feature is in marked contrast to the main crest line of the range, where the variation in altitude is from 6,000 to 20,000 feet.

Little is known of the structure or topography of the mountains which form the backbone of Kenai Peninsula (see Pl. II, p. 42), and these, like the Alaska Range, may be predominatingly of structural origin. In these mountains, however, a marked accordance of summit levels at altitudes of about 5,000 feet has been interpreted by Gilbert, Moffit, and Atwood as evidence of peneplanation. Even less is known of the Chugach Mountains, whose west end lies close to the Mount McKinley province. They appear to be made up of an irregular aggregate of peaks and connecting ridges, with a very sinuous crest line, but farther east a peneplain has been recognized by Spencer and others in the accordance of summit levels of the Chugach Range.

The Talkeetna Mountains afford the best example of a range whose topography has been controlled primarily by the erosional features of a previous cycle, modified by differential uplift, the influences of bed-rock structure having been only of secondary importance. This highland mass is made up of a roughly circular rugged group of mountains from 5,000 to 6,000 feet in altitude, above which tower some individual peaks that reach 7,000 to 9,000 feet. The Talkeetna Mountains have no well-defined axial crest, owing probably in large part to their genesis but also to the uniformity of their component rocks, which are largely granitic intrusives. Paige and Knopf[1] have described these mountains as having been carved out of an uplifted peneplain, remnants of which are still recognizable. The old peneplain, which is in part capped by basalt, falls off to the east and appears to dip under the Quaternary gravel sheet of the Copper River Plateau.

## PLATEAUS.

There are two types of plateaus in the Mount McKinley region—(1) those formed by deposition and uplift and (2) those which are uplifted plains of erosion. The gravel sheets of Pleistocene age that fringe the high ranges are the most extensive and numerous examples of the first type. With this type must also be classed some small basalt-capped plateaus or mesas in the eastern part of the Talkeetna Mountains.

The gravel plateaus have been fully described in the account of the Pleistocene sediments. It has been shown that they stretch inland from wave-cut escarpments on both shores of Cook Inlet, sloping up to the bases of the high mountains at a grade of about 50 feet to the mile (Pl. IV, p. 44). In the Susitna Valley occurs a gravel sheet which is similar to these but has been more dissected. The surfaces of these plateaus also slope perceptibly toward the central axis of the depression. The Copper River Plateau, which is of a similar character, lies to the east of the area here under discussion. (See Pl. II, p. 42.)

The piedmont plateau along the inland front of the Alaska Range is of the same genetic type (Pl. VI, *B*, p. 46). Near the mountains its surface slopes away from the highlands at an angle of about 5°, but this grade decreases until, at a distance of 10 or 15 miles, the angle of slope is imperceptible to the eye. Whatever may be the form of the bed-rock floor underneath the gravels, the present plateau surface is clearly due to the deposition of gravel.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 38–39.

The area here described as the Yukon-Tanana upland (p. 48) forms a part of the great Yukon Plateau—a feature generally interpreted as an uplifted and dissected peneplain. At the international boundary the plateau surface has an altitude of about 4,000 feet, but toward the west it falls off and in the Fairbanks region (see topographic map, Pl. III, in pocket) is only 1,200 to 2,000 feet in altitude. The plateau region as a whole is characterized by remarkably flat-topped ridges and irregular interstream areas, some of which do not vary more than 200 feet in altitude for 20 miles. This summit level truncates the bed-rock structures, which are in the main nearly vertical. Many flat-topped interstream areas embracing several square miles appear absolutely smooth and level to the eye. Broad drainage channels traverse the plateau, and many domes and some sharp peaks and isolated mountain masses rise above the general level. As a rule, the plateau summit level falls off toward the axis of the larger watercourses, whose valleys therefore possibly occupy positions inherited from the previous cycle.

Near the town of Fairbanks the old plateau surface has an altitude of about 1,200 to 1,400 feet, and 15 miles to the north it rises to 2,000 feet.[1] In this region the old erosion surface declines toward the wide drainage channels. This is shown by flat-topped sloping spurs which make out from the main ridges. From the ends of these spurs the fall is abrupt to the valley bottom. These facts suggest that the present drainage channels, in part at least, occupy valleys whose positions were determined by the previous peneplain conditions.

The uplifted peneplain surface continues westward at about the same altitude to the vicinity of the Yukon near Rampart. Here it is less distinctly recorded but appears to rise to an altitude of over 3,000 feet, and above this level stand some high rugged masses, such as Wolverine Mountain (Pl. VII, *B*, p. 48), reaching 4,600 feet.[2] Near the junction of the Tanana and the Yukon the peneplain surface appears to be recorded in flat-topped ridges 1,200 to 1,400 feet high.

The peneplain level has not been recognized south of the Tanana, where the Alaska Range falls off directly to the Pleistocene gravel-floored plateau, and hence in this part of the province the relations of the peneplain to the mountains are not established. Farther to the southeast what is believed to be the same peneplain abuts directly against the escarpment that marks the inland front of the St. Elias Range.[3]

In most of the area the upland surface bevels the edges of complexly folded rocks, and therefore can not be explained as a structural feature of the bed rock. As the surface cuts across both the hard and the soft rocks, no appeal can be made to lithologic uniformity or equality of resistance to weathering to account for the plain. The plateau surface is typically developed in a region where neither relief nor structure permits any explanation of this feature by a theory of block adjustment, to which the subequality of summit level in some of the high ranges has been ascribed. The plateau is found both above and below timber line, and therefore timber line can have nothing to do with its development. As it occurs in a region which has never been affected by ice action, the theory of planation by ice or glacial sapping is equally untenable. There is no evidence of marine invasion in any part of this province since Upper Cretaceous time, and the plateau is therefore not a plain of marine denudation. It thus appears that subaerial denudation alone can be suggested to account for this feature.

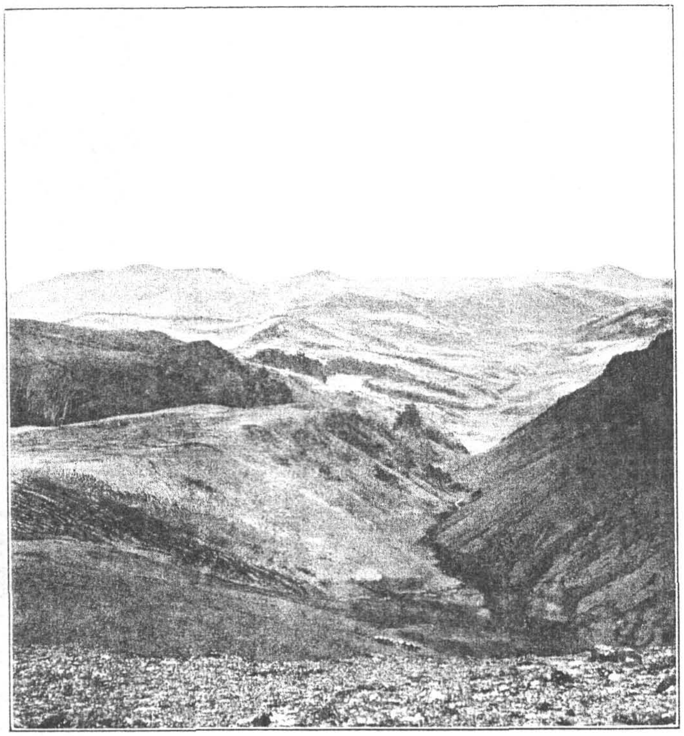
There must have been a long cycle of stability during which erosion reduced the land to low relief. The local irregularities of the surface of the plateau indicate that this erosion stopped far short of base-level, for there are variations in relief believed to be of erosional origin amounting to hundreds and possibly a thousand feet. At the close of this cycle there were, without doubt, ridges rising at least several hundred feet above the broad valley floors and having gentle slopes. There were also peaks and mountains which, either because of their position relative to watercourses or because they were formed of more resistant rocks, were left standing high above the lowland.

This cycle of erosion was closed by differential uplift, the amount of which is in places to be measured in thousands of feet. There is some evidence that this uplift was intermittent

[1] See Fairbanks special map, U. S. Geol. Survey, Alaska sheet No. 642A.

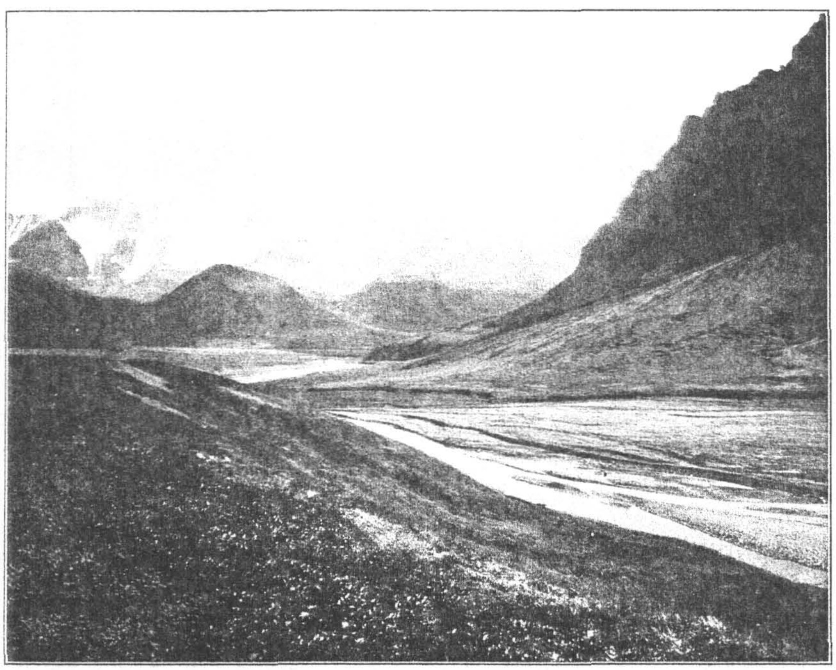
[2] See map of Rampart quadrangle, U. S. Geol. Survey, Alaska sheet No. 643; map of Fairbanks quadrangle, Alaska sheet No. 642.

[3] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 347.



*A.* FOOTHILLS AT INLAND FRONT OF ALASKA RANGE, IN UPPER TONZONA RIVER BASIN.

Near camp of July 24. See page 128.



*B.* GLACIAL CIRQUES AT HEAD OF EAST FORK OF TONZONA RIVER.

Near camp of July 25. See page 126.

and that the present altitude of the plateau was reached by series of uplifts interrupted by periods of stability during which there was some stream cutting. The evidence at hand is not sufficient, however, to correlate definitely certain flat-topped spurs and benches which may represent stream erosion. It is possible that many of these could be accounted for by differential uplift.

It has been shown that near Rampart the old peneplain was elevated several thousand feet higher than in the region to the east. This local doming brought the plateau level to such an altitude that its character has been almost destroyed by subsequent erosion. Few details of this uplift are yet known, but it is pretty definitely established that the old surface was more or less warped. It seems probable, however, that the position of watercourses on the plateau surface was determined in a large measure by the drainage systems of the previous cycle rather than by the warping.

During this new cycle the streams cut broad valleys and over much of the area a large part of the plateau was destroyed. A rough measurement in the Fairbanks district,[1] which is the only region mapped in detail, indicates that only 10 per cent of the area of the old peneplain in that district is still preserved. In the region adjacent to Rampart the area of the peneplain remnants probably forms a still smaller percentage of the whole. On the other hand, in the Yukon Plateau region as a whole probably at least 20 per cent of the old peneplain can still be recognized.

In the description of the Talkeetna Mountains (p. 119) mention has been made of the peneplain preserved as a summit level and dipping off under the Copper River Plateau. It has also been shown that, according to Paige and Knopf, there are conglomerates filling channels in this plain and that these are provisionally correlated with a conglomerate resting conformably on the Kenai plant-bearing beds (pp. 103–104). This indicates that the peneplain is of post-Kenai age. In the Yukon region the peneplain bevels Kenai beds and can therefore be provisionally correlated with the Talkeetna summit level. In the Cook Inlet region Atwood[2] recognizes two peneplains—an older one, marked by the summit of the Kenai Mountains and of pre-Kenai age, and a lower one, which is of post-Kenai age. He also presents facts pointing to three peneplains in the Yukon region—one marked by the summit of the Coast Range, one by the plateau level here described, and a third which has only a local development.

Dawson,[3] the first to describe the inland plateau region, recognized one extensive epoch of base-leveling. This took place after the folding of the "Laramie." This "Laramie" has already been correlated with the Alaskan Kenai (p. 103), so that Dawson's peneplain can be provisionally correlated with the one here described.

### LOWLANDS.

The only two extensive lowland areas of the Mount McKinley province are those of the lower Susitna and lower Tanana valleys, which have many features in common. Both have a roughly wedge-shaped outline, with the apex of the angle upstream. The Susitna lowland is bounded on both sides by broad gravel terraces sloping up to high ranges; the Tanana lowland has a similar feature on the south, but on the north abuts against the escarpment which marks the southern edge of the highlands. (See Pl. XIII, *A*.)

The surface of the Susitna lowland slopes toward Cook Inlet at a grade of 5 or 6 feet to the mile. There is also a somewhat steeper slope from the bounding escarpments toward the axis of the basin, which is approximately the position occupied by Susitna River. The gradient of the Tanana lowland between the gravel escarpment on the south and the base of the upland on the north is about 10 feet to the mile, while its downstream slope toward the Yukon is less than 2 feet to the mile. As a consequence Tanana River closely hugs the north wall of the valley and its southerly tributaries are madly rushing, overloaded streams, while those from the north are sluggish and clear.

[1] See Fairbanks special map, U. S. Geol. Survey, Alaska sheet No. 642A.

[2] Atwood, W. W., Working hypothesis on the physiography of Alaska: Science, new ser., vol. 27, 1908, p. 730.

[3] Dawson, G. M., On the later physiographical geology of the Rocky Mountain region in Canada: Trans. Royal Soc. Canada, vol. 8, sec. 4, 1891, p. 11.

Both these lowlands appear to occupy broad basins of the soft Kenai sediments. Although it has not been established, the Kenai formation probably underlies the alluvium in the central parts of the lowlands. These Tertiary sediments are of lacustrine, estuarian, or fluviatile origin. The erosion of the basins must therefore be assigned to Tertiary time, and they were then partly filled with Kenai sediments. These rocks, being relatively soft, were later in part removed by subaerial and glacial erosion and then replaced to some extent by Pleistocene or Recent alluvium.

There is reason to believe that the Susitna basin has been more or less scoured by glacial ice. Its bed-rock floor is undoubtedly a continuation of that of the Cook Inlet depression. There is no positive evidence that the entire Tanana lowland was ever occupied by ice, but it is undoubtedly true that during the period of maximum glaciation some of the glaciers of the northern slope of the Alaska Range reached completely across the Tanana Valley. There is no evidence as to whether or not such glaciers had any considerable effect on the bed-rock floor of the valley, but as only the margin of the ice sheet extended into the lowland its excavating power must have been relatively small.

### SHORE LINE.

The Mount McKinley province touches tidewater only at Cook Inlet, which exhibits shore topography of two types. Along both shores of the main inlet gravel bluffs face the sea, and from their bases broad gravel beaches slope down gently toward the water (Pl. IV, *B*). This slope is continued out from the shore, thus forming a broad marginal shelf of shallow water. As a result, there are broad tidal flats, and these are very extensive at the wide delta of Susitna River. In strong contrast to this shore line are the steep rock walls and deep waters which characterize Turnagain Arm. Here gravel terraces and beaches are lacking and the land rises to considerable altitudes directly from the water. Turnagain Arm is essentially a fiord.

The origin of these two types of topography has not been worked out in detail. The general features of the inlet indicate that the most recent movement has been downward and that an invasion of the sea has taken place. Submarine glacial erosion may in part account for the drowned character of the inlet, but it will be shown that there is no reason to believe that a large amount of erosion was accomplished in this province by ice action. There can be no doubt that the sea has transgressed on the land and that the estuary marks an old river valley. The presence of the terraces suggests that there may have been a recent uplift.

Like the Susitna lowland lying to the north, Cook Inlet occupies a Tertiary basin. The easily eroded Kenai sediments have in part been removed and reveal a pre-Tertiary topography which has subsequently been scoured by a large glacier from the north. Preceding or during the glacial epoch there were a marked subsidence of the land and an accompanying invasion of the sea, since which there may have been some differential uplift.

The receding glaciers deposited an enormous amount of débris and filled in the depression to an unknown depth. The well-marked terrace along the shore of the inlet (see Pl. IV, *B*, p. 44) may mark a recent elevation or may be a marginal glacial deposit.

### DRAINAGE.

Most of the drainage of the province is received by four rivers—the Susitna and Matanuska, flowing into Cook Inlet, the East Fork of the Kuskokwim, and the Tanana, the largest tributary of the Yukon. These rivers and all their tributaries except those joining the Tanana from the north are overloaded with sediments and have swift, often torrential, currents. The streams of the coastal slope have steeper gradients than those tributary to the Kuskokwim and the Tanana.

The Susitna, which rises in an unsurveyed part of the Copper River Plateau, traverses a mountainous belt by a westerly course, here flowing, it is said, through a narrow, steep-walled, rocky canyon, and then bends sharply to the south. Below this bend its valley gradually widens out and finally, 60 miles from tidewater, merges with the Susitna lowland. The mouth of the river is marked by a broad delta with extensive tidal flats. The silt-laden waters of the Susitna are rapidly extending this delta into Cook Inlet.

The genesis of the lower Susitna Valley, which occupies a basin carved out in Tertiary time, has already been described. The canyon above the lowland is probably a very recently incised trench. Data are lacking to determine whether this is an entirely new course for the river or whether it is a canyon cut in an older valley floor. Its similarity to the Matanuska Valley makes it probable that the latter explanation is the true one.

The Talkeetna, the largest easterly tributary of the Susitna, flows round the north end of the Talkeetna Mountains. Its valley is glaciated throughout and in most places steep walled. A number of smaller tributaries to the Susitna have their sources in the same high mountain mass. These are turbulent streams to points within a few miles of the main valley, where their gradients abruptly flatten and their courses become winding. These flats are coextensive with the surface of the gravel terrace which fringes the eastern margin of the Susitna Valley. Below these flats the streams descend by abrupt slopes to the Susitna Valley level.

The Chulitna, the largest westerly tributary of the Susitna, rises on the southern slope of Broad Pass and flows in part through canyons, in part through a wide valley. Broad Pass, which is about 5 miles in width and stands some 2,000 feet above sea level, forms the watershed between the Cook Inlet drainage on the south and that of the Tanana on the north. Jack River, a tributary of the Nenana, which joins the Tanana, lies just northeast of Broad Pass and appears formerly to have flowed into the Chulitna. This stream diversion was probably caused by some phase of glaciation. The Chulitna receives a large unnamed tributary from the west which is said to rise near the western front of the Alaska Range and to flow through a narrow rock-walled canyon for the lower 20 miles of its course.

Most of the westerly tributaries of the Susitna have glacial sources within the Alaska Range. Their valleys are probably all steep-walled and glacier-scoured. Toward the mouths of these streams glacial benching is noticeable along the valley walls.

The topography of a part of the upper basin of Yentna River, tributary to the Susitna from the west, is quite different from that described above. While most of the other streams flowing from the Alaska Range head in high snow-covered divides, some of the branches of the Yentna are separated by only low passes from Kuskokwim waters. Thus the Kichatna heads in Simpson Pass, only about 4,000 feet high. Still lower are the passes through the range at the head of the Skwentna. Rainy Pass, at the head of Happy River, traversed by the expedition, though a rather narrow defile, is only about 2,800 feet high. The broadest gap in the range, at the head of Portage Creek, discovered by Spurr in 1898, is about 3,000 feet in altitude.

Matanuska River rises near the western margin of the Copper River Plateau and flows through a depression 4 to 5 miles in width which separates the Talkeetna Mountains on the north from the Chugach Mountains on the south. Throughout much of its course the Matanuska flows in a canyon whose steep walls rise 300 to 400 feet above the present water level to the broad floor of an older valley. This older valley floor has a steeper gradient toward the sea than the present river dissecting it—a fact which, as Mendenhall points out, indicates a tilting of the land toward the sea.

A part of the Matanuska trench is occupied by Kenai sediments, and it seems probable that this depression, in part at least, is due to erosion of the comparatively soft Tertiary rocks. It is probable that during Kenai time a large river occupied approximately the position of the present Matanuska Valley. As the Kenai sediments are closely folded, however, it is not likely that the present valley is an inheritance from Tertiary time. Erosion removed much of the Tertiary deposits, and later glaciation has played a part in sculpturing the valley. Recent elevation and accompanying dissection are indicated by the old valley floor already described.

The tributaries of the East Fork of the Kuskokwim in this province emerge from the inland front of the Alaska Range through U-shaped gravel-floored valleys. Beyond the mountain front these valleys are incised in the Quaternary gravel sheet, but in few of them has the incision gone deep enough to uncover bed rock. The gradients of all these streams decrease as they approach the East Fork.

The main Kuskokwim, below the mouth of Hartman River, meanders through a broad gravel-filled valley with steep slopes broken to heights of about 200 feet by alluvial terraces. For some 5 miles above the mouth of Hartman River the Kuskokwim traverses a box canyon. The river has not been explored above this canyon, but seems to follow a rather broad north-south valley and probably has its source near Lake Clark. Hartman River occupies an extension of the main valley of the Kuskokwim below the canyon. This valley is broad and flat, with gentle slopes, and seems to be separated by only a low divide from waters flowing southward.

Knowledge of the topography of the southern part of the Alaska Range is meager but indicates that there are in that area a number of old north-south valleys. With this system may be classed those of the Skwentna above Portage Creek, the Kuskokwim Valley above the canyon, and its northern extension, the Ptarmigan Creek valley, also the Hartman-Kuskokwim valley. Big River, which enters the Kuskokwim just below the main forks, also has a north-south valley. These valleys are all parallel to the main structural lines, and the Kuskokwim below the canyon follows an anticlinal axis. The valleys of the north and south are connected by some broad passes like that at the head of Ptarmigan Creek, which are evidently part of an old topography, and also by recently cut canyons, such as that of the Kuskokwim above the mouth of Hartman River.

The Tanana rises in the Wrangell Mountains, far to the east of the area under discussion. Its two chief headwater streams traverse the Nutzotin Mountains through narrow valleys and debouch on a broad lowland, where they unite to form the Tanana. Below this junction the valley walls gradually contract, and as far down as the mouth of Delta River the Tanana flows through a series of connected steep-walled basins having a rectangular outline. Below the Delta the south wall of the Tanana Valley rapidly recedes, and thence to the Yukon the river traverses the broad lowland already described.

The Delta has its source in the northern margin of the Copper River Plateau and traverses the Alaska Range to join the Tanana. It is separated from the Copper River drainage basin by a broad gravel-filled gap some 3,600 feet high. Within the mountains it has a broad steep-walled valley, with some glacial terraces. Nenana River, also a tributary of the Tanana, has a valley similar to that of the Delta, for one of its forks rises in Broad Pass, south of the Alaska Range. It flows through the mountains in a narrow rock-walled canyon 200 to 400 feet deep, above which is the remnant of an older valley floor. North of the mountains the Nenana has deeply dissected the Quaternary gravel sheet (fig. 26, p. 108) and exposed the Tertiary rocks lying below (fig. 27; Pl. XII, *A*, p. 108). Along this part of its course there are numerous gravel benches.

The probable development of the broad depression occupied by the lower Tanana in Tertiary time has already been discussed. A similar history is probable for the lowland of the upper Tanana, a region which lies beyond the province here discussed. The narrower and steeper-walled parts of the Tanana Valley are believed to be of more recent date, but there is little evidence of this. The broad gaps through the Alaska Range, such as Mentasta Pass and the Delta and Nenana valleys, are also believed to have been largely cut during Tertiary time.

The northern tributaries of the Tanana, including the Chena, Tolovana, and Baker Creek, all flow through broad valleys deeply filled with alluvium. The topography of these valleys, with their gentle slopes and broad floors, is in sharp contrast to the sharply cut valleys of the streams entering the Tanana from the south.

The tributaries of the Yukon here included are mostly small streams deserving no special mention. Worthy of note is the remarkably straight and steep-walled valley occupied by Minook Creek. The high bench on this stream has already been described (p. 109). It appears probable that the many large drainage features of the Tanana upland are inheritances from the previous cycle, during which peneplanation took place. It is not impossible, however, that some may have a history similar to that of the Tanana Valley and represent the result of erosion along former Tertiary drainage channels.

## GLACIATION.

Although during Pleistocene time probably over two-thirds of the area lying south of the Tanana was covered by ice, glaciers are now confined to the high ranges and valleys within the mountains, where they are fed by the perennial snow fields. (See Pl. XIII, *B*, p. 120.) A rough estimate indicates that less than 1 per cent of the area formerly covered by ice still remains buried under glaciers and perpetual snow. The present glaciers appear to be rapidly retreating and represent the lingering remnants of the larger Pleistocene ice sheets.

### PRESENT GLACIERS.

The glaciers of the region all occur within three areas of high relief—the Chugach Mountains, the Talkeetna Mountains, and the Alaska Range. (See Pls. III, XV, in pocket.) All the ice streams are of an alpine character and, compared with the glaciers of the seaward slope of the St. Elias Range, are small. Here, as in other parts of Alaska, there is a striking contrast in the extent of the glaciers between the coastal slope of the mountains, with its abundant precipitation, and the inland slope, where drier conditions prevail. On the coastal slope some glaciers discharge at tide water and the fronts of many are only 200 to 800 feet above the sea, but no glacier of the inland slope reaches a lower altitude than 2,500 feet. The distribution of the perennial snow, though less well known, appears to be similar. For example, on the Susitna slope of the Talkeetna Mountains the snow line is between 6,500 and 7,000 feet above the sea, but on the inland slope of the Alaska Range it lies between 8,000 and 8,500 feet.

The only considerable glacier in that part of the Chugach Mountains here described is one drained by Knik River, and only the front of this has been mapped. This glacier fills a broad, flat valley some 4 miles in width. Its front is only 15 miles from the coast and less than 200 feet above sea level. Some smaller glaciers which discharge into Port Wells, an arm of Prince William Sound, are included within the area of the map (Pl. III). Matanuska River springs from a glacier of the same name whose front has an elevation of about 1,800 feet above sea level. A survey of the Chugach Mountains would undoubtedly reveal many other glaciers as well as extensive névé fields.

The central unsurveyed part of the Talkeetna Mountains is known to be occupied by extensive snow fields and glaciers. These glaciers discharge at altitudes between 4,200 and 5,000 feet along the periphery of the mountain group.

The largest glaciers of the Alaska Range are on its southern slope, which is exposed to the moisture-laden winds of the Pacific. On the Pacific side of the crest line a number of glaciers are known which are 20 to 30 miles in length, but the largest glacier on the inland side is only about 12 miles long. The largest glaciers of the Pacific slope lie in the basins of Yentna and Chulitna rivers, which drain the highest parts of the range. (See Pl. XV, in pocket.) These glaciers occupy steep-walled valleys, and most of them have their sources in the unexplored snow fields in the heart of the range. Prominent among these is the Kahiltna Glacier, measuring some 4 miles at its front, standing 600 feet above the sea, and having a length of at least 15 miles. Two large glaciers discharge into the Tokichitna, a westerly tributary of the Chulitna, at an altitude of about 800 feet. The western of these has a frontal width of about 2 miles and has been traced into the mountains for about 20 miles. The eastern glacier expands to some 4 miles at its mouth and is said to fill a winding valley extending far back toward the crest line of the range and to receive a tributary glacier from the coastal slope of Mount McKinley. Its length must therefore be over 30 miles.

All the largest northward-flowing glaciers of the Alaska Range rise on the slopes of Mount McKinley and Mount Foraker (Pls. I, p. 11; VI, *A*, p. 46). Of these the largest are the Herron, having its source in the névé fields of Mount Foraker; the Peters, which encircles the northwest end of Mount McKinley; and the Muldrow, whose front is about 15 miles northeast of Mount McKinley and whose source is in the unsurveyed heart of the range. The fronts of all these glaciers for a distance of one-fourth to one-half a mile are deeply buried in rock débris.

Along the crest line there are numerous smaller glaciers, including many of the hanging type. Both slopes of Mount McKinley and Mount Foraker are ice-covered. On the north slope these glaciers override the ridges above an altitude of 7,000 feet. The photographs reproduced in Plate XIV showing glaciers of this type were taken on the ridge between Peters Glacier and the front of the range, near the camp of August 3–4. On the south slope of Mount McKinley the glaciers are said to come down much lower.

The glaciers that came under the observation of the writer all appeared to be receding rapidly. There is, however, little proof of the rate of recession. Spruce trees about 6 inches in diameter were seen in the old path of the Muldrow Glacier about 5 miles from the present ice front. If the age of these trees is estimated at fifty years, this fact, so far as it goes, indicates an average annual recession of about one-tenth of a mile.

On the inland front but little morainic material is left along the old tracks of the glaciers, and it appears that most of the frontal débris is removed by the streams as fast as it is laid down. Such a process would be accelerated in this northern latitude by the freshets which accompany the spring break-up. The glaciers are as a rule not badly crevassed and many of them afford, beyond the frontal lobes, excellent routes of travel.

## PAST GLACIATION.

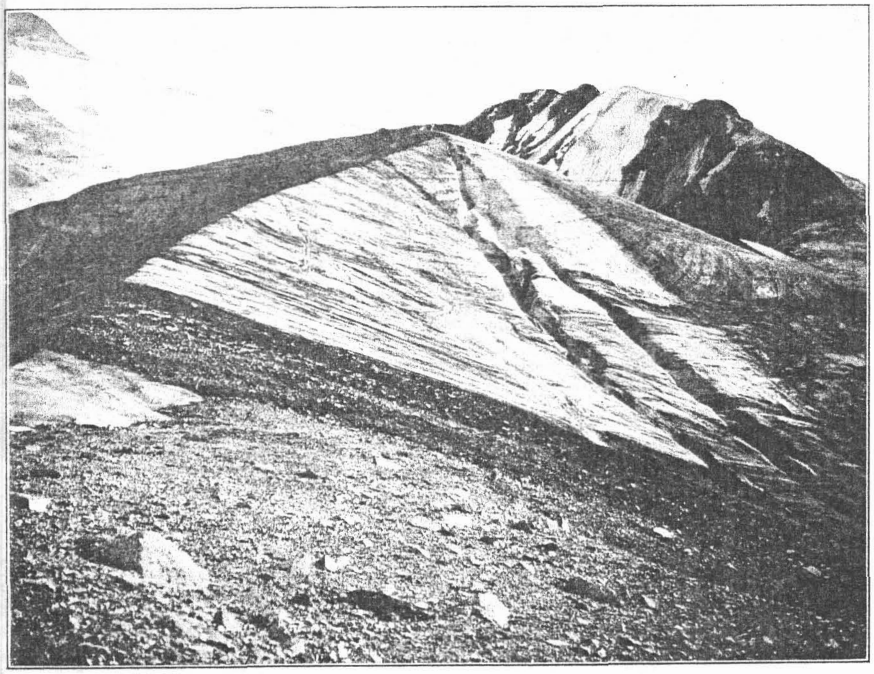
Most of the valleys and lowlands lying south of the Tanana were during Pleistocene time filled with glacial ice. This ice also overrode some of the lower foothills, while in the high ranges were the extensive névé fields which fed the ice streams.

There were three centers of ice accumulation from which glaciers radiated into the valleys and lowlands. The névé fields of the Chugach Mountains were the source of ice which on the south filled Prince William Sound and on the north and west flowed into the Matanuska Valley, Knik Arm, and Turnagain Arm. These northerly and westerly ice streams united with other glaciers to fill Cook Inlet. From the Talkeetna Mountains the ice flowed into the Copper River basin and the Matanuska and Susitna valleys. The southern slope of the Alaska Range was the gathering ground for the most extensive ice sheet of the province. Innumerable glaciers filled the southerly valleys and coalesced into one great ice sheet which moved over the Susitna lowland and far down the Cook Inlet depression. This ice sheet was augmented by the glaciers which had their source on the west slope of the Kenai Mountains. The inland slope of the Alaska Range was also the collecting ground for many glaciers. These, though not comparable in size to those of the Pacific slope, moved far out into the lowland. The position of the northern front of the ice in the Kuskokwim basin has not been determined, but there is reason to believe that it extended as far as Lake Minchumina, or about 30 miles beyond the mountain front. In the Tanana Valley also the exact limit of glaciation is not known but was in places probably 15 to 20 miles north of the mountain, and it is not impossible that much of the lowland above the mouth of the Nenana was filled with ice.

The upper limit of glaciation in the main valleys along the route of travel on the southern margin of the Alaska Range was found to be about 2,400 feet. It rises toward the heart of the range and along Happy Valley was found to be as high as 3,600 feet. Toward the western margin of the range, near the Kuskokwim, the main valleys appear to have been filled with ice only to a height of about 2,600 feet. Farther to the northeast, where the range attains its maximum altitude, the upper limit of glacial action lies at an elevation of about 3,000 feet. (See Pl. XIII, *B*, p. 120.) In the upper Nenana basin the valleys have been glacier-filled only to about 2,500 feet.

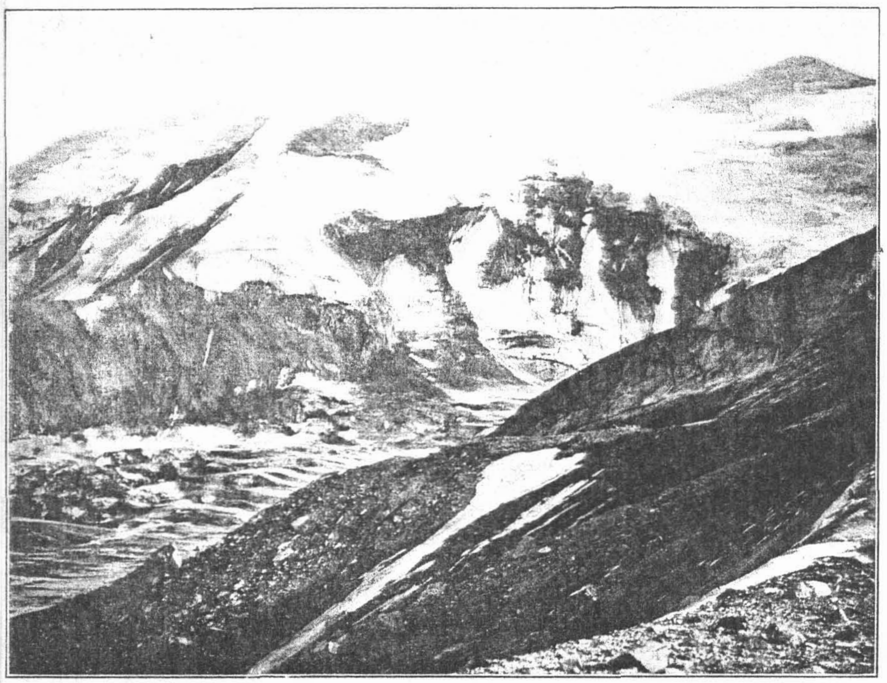
The figures just given refer only to the main valleys. The smaller tributary valleys which head in the high ranges bear evidence of having been ice-filled throughout their extent. In fact, many of them still carry small glaciers. It goes without saying that, except for individual peaks, the high mountain masses were entirely buried in snow and ice during the glacial period.

Glaciation in the other mountain ranges was of a similar character. In Kenai Peninsula Moffit found evidence of glaciation in the main valleys as high as 1,200 to 1,400 feet above sea level. In the tributary valleys and high up on the slopes of the ranges which formed the centers



A. GLACIER OVERRIDING RIDGE OF ALASKA RANGE 9 MILES NORTHWEST OF MOUNT McKINLEY

Near camp of August 4. See page 126.



B. GLACIER-COVERED RIDGE BETWEEN PETERS GLACIER AND MOUNTAIN FRONT, 9 MILES NORTHWEST OF MOUNT McKINLEY.

Near camp of August 4. See page 126.

of ice accumulation the glaciation went very much higher. In the Matanuska and Talkeetna region Paige and Knopf observed evidences of glaciation as high as 2,500 feet.

Direct evidences of glaciation are relatively rare in this province. For a region so much of which has been covered by ice within recent time there is a remarkable absence of glacial grooving and moraines, till, and other typical glacial features. The upper limit of the valley glaciers is usually marked by irregular gravel terraces, and the former distribution of the ice has been largely determined by these features. In the high ranges, however, cirques are abundant.

It appears probable that only in the larger valleys was the ice thick enough to exert the pressure necessary for deep rock grooving. As nearly all the bed-rock floors of these valleys are deeply buried in gravels, whatever striations may exist are not now exposed. The lesser ice scorings which may have been produced at higher levels are not likely to have been preserved, because they lay in the zone of rapid rock disintegration. The absence of striæ has not prevented the determination of the general direction of ice movement, which, as already set forth, is known to have followed the present drainage system.

The present studies also indicate that englacial and superglacial deposits are not at all abundant. Some glacial till has been found along the shores of Cook Inlet and some morainic deposits occur in the Tanana Valley, but aside from these little is left of the deposits of the ice invasion except those of extraglacial origin. The deposits left by the ice have either been swept away by the floods resulting from the recession of the glaciers or now lie deeply buried in the alluvium-filled valleys.

Glacial erratic material is relatively abundant on the south side of the range and has furnished valuable confirmatory evidence of the direction of ice movement. For example, large angular bowlders of the granitic rock typical of the Talkeetna Mountains occur along both shores of Cook Inlet as far south as Kenai. These indicate at least one source of the ice stream which filled Cook Inlet. Many of the erratic bowlders are, however, so intimately associated with the extraglacial deposits as to indicate the probability of their having been carried by floating rather than by glacial ice.

The most characteristic features of the glaciated portion of the Yentna basin are the terraces and benches along the Kichatna Valley, near the camp of July 8. Here the uppermost terrace, which is the best developed, has an altitude of about 2,400 feet and marks the upper limit of the glacier formerly occupying the valley. This terrace can be traced along both sides of the Kichatna and is bounded by steep talus slopes. Below the talus the valley slope is broken by a number of grass-covered terraces, which are, however, irregular and can be traced for no great distance. All these terraces slope with the present valley floor and, where wide enough to permit a determination, also fall off toward the axis of the valley.

Similar features are prominently developed on the east side of the upper part of Happy Valley, near the camp of July 13, 1909. At this place half a dozen terraces can be traced along the valley wall, the highest of which, about 3,600 feet above the sea, marks the upper limit of glaciation. Some of these terraces are well defined for nearly a mile, but most of them fade away within 200 to 300 yards. Their surfaces have only a general parallelism, but all slope downstream. One measurement was made of a terrace which sloped at an angle of 5°. These terraces occur irregularly one above another along the valley wall. For example, one can be traced unbroken for a quarter of a mile, ending abruptly at that level, being continued by another perhaps 50 feet lower, which in turn fades away. It was found impossible to trace any one bench level for any considerable distance or even to recognize it on opposite sides of a valley, as would be the case if these were normal stream terraces. The outer margins of the terraces toward the axis of the valley are in many places irregular and broken and present none of the features of regularity usually found in stream terraces.[1] There was little opportunity to examine the material of which these terraces were formed, but it appears that they are built up chiefly of gravels with a good deal of glacial erratic material. Some appear to be rock-cut benches with very little gravel on them. These terraces are believed to have been formed

[1] Spurr (A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 249) ascribes these features of Pleasant Valley to marine benching—a theory which the facts presented above appear to make untenable.

by streams which flowed along the margins of the ice in the glacier-filled valleys. The uppermost is usually the best preserved and indicates a longer condition of stability than the later terraces formed at lower levels during the different stages of the ice retreat. As already stated, these terraces are too irregular to be of the normal stream type, and, furthermore, they occur only in the glaciated parts of the valleys. Similar terraces in process of formation have come under the observation of the writer along some of the present Alaskan glaciers.

Lateral terraces are also present in some of the valleys on the north side of the Alaska Range, but their glacial origin is not so well marked. An example of one of these is shown in Plate XIII, *A* (p. 120), reproduced from a photograph taken in the upper part of the Tonzona basin.

The fluvioglacial terraces of this type are not to be confounded with the stream terraces which have been so extensively produced in the province as the result of the dissection by streams of the alluvium deposited during the recession of the ice. Terraces of the latter type are very widely distributed in the province but are especially well developed in the Nenana basin. (See p. 108.) The great Pleistocene gravel sheets have been fully described (pp. 105–109) and are believed to represent the extraglacial deposits laid down chiefly during the recession of the ice. Detailed surveys will probably indicate that the recession was interrupted by some advances. Evidence of this has been found in the occurrence of glacial till overlying fluviatile glacial material on Cook Inlet and by moraines in the Tanana basin formed after the deposition of the terrace gravels.

It will be evident from the above description that the former ice sheet of the province was essentially a system of Alpine glaciers which in the lowlands expanded to large piedmont glaciers. While some of these glaciers overrode hills of considerable altitude, the ice streams were confined chiefly to the valleys and the higher mountain slopes, and even during the maximum extension of the ice there was probably one-third of the area which was not covered. There is a striking contrast in the topography of the glaciated region south of the Tanana and that of the unglaciated region lying to the north. This is due not so much to the degradation of ice, which is believed to have been relatively slight, but to the absence of products of weathering and to the extensive deposits of extraglacial gravels in the glaciated areas. These occur also in the valleys beyond the limit of glaciation, but are most prominent in the areas reached by the ice.

This system of glaciers differs, then, very markedly from the great Cordilleran, Keewatin, and Labrador ice sheets. Although it is reasonable to suppose that the accumulation of ice in Alaska was contemporaneous with that in other parts of the continent, yet the evidence indicates that the recession of the glaciers is a comparatively recent phenomenon. It has been shown that the present glaciers are but the remnants of the former larger ice streams. If the rate of recession in the past is comparable to that of the present, the time of maximum extension may not have been more than a few centuries and can not have been more than a few thousand years ago. It is quite probable, however, that the rate of recession has not been uniform and may have been very much accelerated in recent times. There is some reason to believe that there were two or more advances of the ice. Therefore the measurements of the present rate of recession of the glaciers may have no bearing on the time interval which has elapsed since Pleistocene glaciation.

## RECENT GEOLOGIC HISTORY.

### OUTLINE.

The close of the Lower Cretaceous epoch has been chosen as the beginning of the recent geologic history for the purpose of discussing the genesis of the topography. Such a line of demarcation between recent and ancient history must of course be more or less arbitrary. Sedimentation, volcanism, and diastrophism, even of the earliest epoch, must necessarily have had some influence on the present topography in determining the relative susceptibility of the rocks to erosion, either through differences in lithology or through lines of weakness due to structure. These forces have, however, had a subordinate effect on the land sculpturing compared with the more recent geologic agencies, especially those of elevation and depression. Obviously, therefore, a genetic discussion of the land forms can be complete only if it is based on a comprehensive knowledge of all the facts of the geologic history. Such a groundwork is of course lacking for the Mount McKinley region, so that only the larger features of the geomorphology can be considered and many of the conclusions must be regarded as tentative. It appears that in the present relief there are certainly no remnants of any topographic forms older than the crustal disturbances which followed the deposition of the Lower Cretaceous sediments. Hence this period of diastrophism can be conveniently chosen as the datum for the discussion of the geomorphology. The chief events of the recent geologic history may be outlined as follows:

1. Early Cretaceous sedimentation was closed by widespread crustal movements which deformed the strata and elevated the entire province above the sea. A long period of erosion followed.

2. Depression in late Cretaceous time brought about an invasion of the sea and marine sedimentation was begun. The shore line of this sea—probably irregular and believed to have lain within or close to the Mount McKinley region—has not been traced.

3. In early Eocene time marine sedimentation was closed by a gradual uplift, which finally brought the entire province above the sea. A long period of erosion and fluviatile deposition followed. During this period an extensive river system was developed and the Kenai sediments were laid down.

4. Kenai sedimentation was closed by a period of diastrophism whose intensity differed greatly in different parts of the province. During this epoch there was extensive folding and faulting in certain zones now marked by the high ranges and the whole region was uplifted many thousand feet. There followed a long period of erosion, during which the Tanana upland and probably a part at least of the mountains to the south were reduced to a peneplain.

5. Differential uplift by a series of elevations amounting in all to at least 4,000 feet renewed the activities of the rivers. The carving out of the present drainage system followed.

6. Next came probably a period of general elevation. Ice and snow then accumulated on the high ranges and glaciers moved down the valleys and far into some of the lowlands.

7. After what was probably a long period of time the glaciers receded and the accompanying floods spread an extensive gravel sheet over the lowlands. There were probably some ice advances since the disappearance of the main ice sheet.

8. The disappearance of most of the glacial ice renewed the eroding power of the streams, which began the dissection of the Pleistocene gravel sheet—a process that is still going on.

### CONDITIONS ANTERIOR TO LATE CRETACEOUS SEDIMENTATION.

It has been shown that the diastrophism which followed the deposition of the Lower Cretaceous beds was widespread in Alaska, locally produced considerable metamorphism, and was accompanied by some intrusions of holocrystalline rocks. All this indicates that the Lower Cretaceous sediments, now exposed, were buried by considerable thicknesses of strata during this period of deformation.

This crustal disturbance probably brought the entire area above sea level, and it is to be supposed that the land presented many irregularities of contour and had a strong relief. Be that as it may, a period of erosion followed that was long enough to remove the strata to the depth of at least several thousand feet. There are no facts to indicate the character of the land mass at the close of this period. The axes of the present mountains were the scene of the most intense folding during all of Mesozoic time and probably during late Paleozoic time. It seems probable that these mountains were elevated above the general level by the folding, but they may have been planated during the cycle of erosion which followed.

LATE CRETACEOUS SEDIMENTATION.

The cycle of erosion was terminated by a depression which carried much of the land below the sea. In the Yukon basin this invasion of the sea extended as far as Rampart, where slates and sandstones carrying an Upper Cretaceous fauna have been found. (See p. 97.) The character of these sediments indicates littoral deposits and suggests that the shore line was not far distant. There appears to have been no marked deepening of the sea from this point toward the lower Yukon, for near Nulato [1] the Upper Cretaceous beds include shales carrying marine fossils, sandstones, arkoses, and conglomerates. Similar Upper Cretaceous rocks occur on Alaska Peninsula,[2] all of which suggests that during late Cretaceous time the continental margin may have been broken by deep embayments or that there may have been an archipelago in this region.

The Cretaceous sediments at Rampart are cut by large granite stocks, indicating that there was formerly a considerable covering of beds that have since been removed and that these surface strata were probably also Upper Cretaceous. This goes to show that much the larger part of the Upper Cretaceous has been removed and that these beds may have originally been spread over much of the region.

EOCENE EROSION AND SEDIMENTATION.

Marine sedimentation was closed in late Cretaceous or early Eocene time by elevation, since which time there has been no invasion of the province by the sea. As a result of this movement the sea receded westward [3] and probably southward. Erosion began on the newly exposed land and was accelerated by upward movements which continued for a long period of time. These movements may have been continuous or intermittent; they may have been interrupted by depressions; but the algebraic sum of all the oscillations was an elevation of the land above the sea amounting to thousands and possibly to tens of thousands of feet.

This upward movement was differential, and it appears probable that the present mountain ranges were then, as in the other periods of diastrophism, the loci of maximum uplift. Such at least seems to be the most plausible explanation for the drainage adjustments of the period. The sediments derived from this period of erosion were for the most part carried far beyond the area here under discussion and are probably to be sought in what is now the Pacific Ocean and Bering Sea.

There is no criterion to determine the time of maximum uplift, but as the Kenai sedimentation immediately followed, it probably occurred near the beginning of the Eocene. This epoch of deposition marked the commencement of a general depression of the land. Here again the movement was probably intermittent and may have been interrupted by minor uplifts. All that can be definitely stated is that there was an epoch of fluviatile deposition long enough to permit the accumulation of strata which, locally at least, aggregated over 10,000 feet in thickness.

This change from degradation to aggradation by the watercourses was gradual and, because of differential movement, was not synchronous throughout the area. With the depression of the land near the sea, flood-plain deposition went on while headwater erosion continued. In this way there was a gradual headwater growth of the flood plains, until eventually fluviatile deposits hundreds of miles in their longer dimensions and thousands of feet in thickness were accumulated.

The Kenai drainage has by no means been traced out,[4] but the facts in hand are possibly sufficient to indicate some of its larger features. It seems likely that there was a system of southward-flowing streams which united in a large river near what is now the head of

[1] Collier, A. J., The coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, p. 15.
[2] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, p. 113.
[3] On the lower Yukon there seems to have been no interruption to sedimentation between the Cretaceous and the Eocene.
[4] Martin's subdivision of the Matanuska Tertiary into three formations, the uppermost of which is a conglomerate, suggests that the drainage system here described was developed near the close of Tertiary time. If such proves to be the case, the early Tertiary history of the province may have been quite different from that here postulated.

Cook Inlet. This river discharged into the sea south of what is now the entrance to Cook Inlet and probably as far south as Kodiak Island.[1] Its largest tributary is believed to have been from the east, probably paralleling and possibly in part following the present course of the Matanuska Valley, and this river may have drained a large part of the Copper River basin. Another of the Eocene rivers probably followed about the present course of the lower Susitna, but its headwaters have not been traced.

It appears probable that the divide between the southward and the inland flowing waters was, in Eocene time as now, formed by a highland mass similar to the present Alaska Range. Unless they are valleys of Tertiary watercourses no explanation has been found of the wide passes which now break the range at the heads of the Skwentna and the Chulitna, flowing into the Susitna, and Delta River, a tributary of the Tanana. In view of the extensive deformation that has taken place along the axis of the range since Tertiary time, it is hard to believe that these rivers would have maintained their courses across the zones of the disturbance.

The remnants of the Kenai fluviatile deposits in that part of the Kuskokwim basin which is here described are too fragmentary to permit the tracing of the drainage system they represent. Coal-bearing rocks are reported by W. E. Priestly[2] to occur adjacent to and west of the mountains which bound the upper Kuskokwim. The occurrence of this coal and of the Kenai formation to the northeast suggests that a Tertiary river may have flowed parallel to the inland front of the Alaska Range. As a part of this belt of Kenai rocks lies in a zone of extreme deformation, however, it is improbable that the course of this river can be traced.

There can be no question that the basin now occupied by the Tanana lowland was in part eroded during Tertiary time, but the heavy alluvial filling makes it impossible to trace the actual drainage lines. In the opinion of the writer, this trench and that occupied by the upper Tanana and upper White rivers, as well as the series of old northwest-southeast valley systems of adjacent parts of Canada, were all eroded during the Tertiary period. This opinion is borne out by McConnell's interpretation of the coal-bearing sediments of the Finlay River region.[3] Some remnants of the deposits of the Tertiary river system occur along the Yukon above the mouth of the Tanana, and what may be an extension of the same old drainage channel has been described as paralleling the upper Yukon from Circle to the international boundary.[4]

The above outline indicates something of the distribution of the Tertiary drainage lines, but it will require much more investigation to work out the details. The plant remains of this period indicate that the climate then was more equable than that which prevails at present in the region and far milder than that of the glacial epoch which followed, and this suggests that there have been extensive movements of the land mass since these conditions prevailed. The milder Tertiary climate may have been due to the nonexistence of the Aleutian barrier, so that the warm waters of the Pacific swept up into Bering Sea. These warm ocean waters may have penetrated along an embayment which then occupied the lower Yukon Valley as far up as the mouth of the Tanana.

In speculating on the geographic conditions which may have existed in Eocene time, it is necessary to take into account the fact that the Kenai plant-bearing beds have been found along the shores of the polar sea as far north as Wainwright Inlet, on Colville River to the east, and at many places inland north of the Arctic Circle. It seems likely, therefore, that the warm waters of the Pacific then penetrated into the Arctic Ocean. If wider passages then existed through the Aleutian Islands and at Bering Strait, and northern Bering Sea was deeper, such a deflection of the Pacific warm-water current might have taken place. If such warm waters of the Pacific flowed into the Bering Sea and the Arctic Ocean and the crest line of the coastal barrier of mountains stood below the line of perennial snow, much of northern Alaska would have had a higher precipitation and a higher mean annual temperature.

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[1] No marine fossils have been found in the Kenai except on Alaska Peninsula, where they are associated with fresh-water plant-bearing beds. See Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 108-160.

[2] Information kindly furnished by Mr. Priestly, who visited this region during the winter of 1909.

[3] McConnell, R. G., Report on an exploration of the Finlay and Omenica rivers: Ann. Rept. Geol. Survey Canada, new ser., vol. 7, 1896, p. 36c.

[4] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 307-309.

## POST-KENAI FOLDING AND EROSION.

The diastrophism which closed Kenai sedimentation was characterized by broad continental uplifts as well as by intense local deformation. Marked orogenic disturbances assigned to this period have been recognized along the western front of the Alaska Range and the southern base of the Talkeetna Mountains. (See p. 112.) In both these zones the post-Kenai folding was accompanied by extensive faulting. On the other hand, in the Susitna and Tanana lowlands the Kenai beds are only gently folded and in some places entirely undisturbed.

As a result of this movement the entire region was elevated to an unknown height above sea level. There is no measure of the amount of elevation, but the resulting land surface must have been one of rather strong relief, on which the Alaska Range and some other mountain masses were probably conspicuous features.

The relations of land and sea established by this uplift were maintained long enough to allow much of the region to be reduced to a gently rolling plain. It has already been shown that the summit levels of the Yukon-Tanana region mark a peneplain, which has been correlated with the peneplain in Yukon Territory and British Columbia described by Dawson and others. Both these peneplains bevel the coal-bearing series (the Kenai and the Canadian "Laramie;" see p. 103).

There is little definite evidence on the interrelation of the Yukon peneplain and those which have been recognized by various observers in the summit levels of some of the ranges of the Pacific mountain system. Spencer,[1] who was the first to attempt a systematic genetic classification of the larger physiographic features of Alaska, suggested the correlation of the peneplains of the Chugach and Coast ranges with the Yukon plateau summit level, accounting for the differences of altitude by warping and faulting. The writer[2] has been inclined to accept this correlation, while Schrader[3] and Atwood[4] have maintained that there were two or more epochs of planation. Mendenhall, though he does not agree with all of Spencer's conclusions bearing on the history of the Copper River region, recognized only one epoch of base-leveling. Gilbert[5] described three peneplain remnants which he noted at several localities along the Pacific seaboard of Alaska. Moffit[6] ascribed the accordance of summit levels in the Kenai Mountains to peneplanation but did not definitely determine its age relations to Kenai sedimentation.

Martin's analysis of the topography of the Controller Bay region[7] includes an account of ten distinct epochs of erosion, but only a few of these were of sufficient duration to planate any considerable areas. According to Tarr,[8] there is a subequality of summit levels in the Brabazon Mountains of the Yakutat Bay region, but he does not accept this as evidence of peneplanation.

The peneplain described by Paige and Knopf[9] as truncating the Talkeetna Mountains is the only one in Alaska of which sedimentary as well as topographic evidence has been found. The sedimentary record consists of some fluviatile deposits which are believed to mark the position of river channels on the old land surface. These channel gravels are correlated with the heavy conglomerate forming the topmost member of the Kenai formation. It is significant that the deformation of this conglomerate has here been assigned to post-Kenai diastrophism. If this assignment is correct, the peneplain, which is older than the conglomerate, can not be correlated with the Yukon epoch of base-leveling, which is believed to be post-Kenai.

The Talkeetna peneplain falls off gently to the east and appears to pass underneath the Quaternary deposits of the Copper River Plateau. This fact lends support to Mendenhall's theory that the Copper River basin is a depressed area, or "graben," and that its bed-rock surface is to be correlated with the peneplain marking the summit level of the Chugach Mountains.

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[1] Spencer, A. C., Pacific mountain system in British Columbia and Alaska: Bull. Geol. Soc. America, vol. 14, 1903, pp. 117-132.
[2] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 286-290.
[3] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 42-45.
[4] Atwood, W. W., Working hypothesis on the physiography of Alaska: Science, new ser., vol. 27, 1908, p. 730.
[5] Gilbert, G. K., Alaska—Glaciers and glaciation: Harriman Alaska Expedition, vol. 3, New York, 1904, pp. 166-186.
[6] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 28-31.
[7] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: Bull. U. S. Geol. Survey No. 335, 1908, pp. 64-65.
[8] Tarr, R. S., The Yakutat Bay region, Alaska: Prof. Paper U. S. Geol. Survey No. 64, 1909, pp. 28-29.
[9] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 38-39.

It is evident, then, that it is impossible to harmonize the numerous interpretations of Alaskan topography. This is emphasized by the fact that there are a number of later investigators in this field who are disinclined to accept the subequality of summit level in the Pacific ranges as proof of former planation.

However the accordance of summit levels in the high ranges may have originated, the Yukon Plateau appears to be one of the best examples of a dissected peneplain which has been recorded in geologic literature. This does not preclude the possibility that there was an older peneplain in this province, as suggested by Atwood.

If the Alaska Range was also base-leveled at this time, there is no record of such an event in the existing topography. It appears more likely that an area of considerable relief separated the inland peneplain from the Pacific slope. In all probability other parts of the province were reduced to areas of low relief during this long cycle of erosion. It will, however, require further investigation to establish definitely the relations between the peneplains recognized in the Pacific mountains and those of the interior.

### ELEVATION AND EROSION.

The post-Kenai cycle of erosion was closed by a general elevation amounting to at least 4,000 feet in the Yukon basin and probably many times that in the bordering mountain ranges. As indicated, this uplift was differential and had its maximum effect along the mountain axes, then long established in geologic time as loci of the most intense diastrophism. Atwood's recognition of a peneplain below the summit level of the Yukon Plateau indicates that this uplift had at least two stages, and it is quite possible that more detailed study will discover other periods of stability which interrupted the general elevation.

The high gravels of the Minook Creek region (see p. 109) may mark an interruption to the general uplift. These gravels are extensive enough to suggest that they belong to a well-developed river system, and they are certainly younger than the Kenai sediments. No deposits which could be correlated with them have been found in other parts of the province.

The differential character of this uplift, though emphasized in the mountain ranges, is recognizable throughout the plateau region, where the warping has produced many domes and basins. It is probable that the Yukon basin as a whole was marked by a long depression which extended from Bering Sea northeast and then southeast far into British Columbia. In addition to these irregularities resulting from warping, there must also have been shallow valleys of the drainage system on the old land surface of the previous cycle. Within the Pacific mountains there may have been broad areas which remained at low altitudes while the surrounding mountains were uplifted.

On this land surface thus exposed to active erosion the positions of the main drainage channels were determined by the constructional topography. In fact, many of the major watercourses followed the old Kenai valleys which had been almost obliterated during the previous cycle of planation. This was due in part to the fact that many of the areas covered by Tertiary fluviatile deposits seem to have been loci of minimum uplift, but also to the fact that certain of the drainage lines of previous cycles seem to have maintained themselves along these zones of relatively softer material.

In any event many of the larger rivers follow antecedent courses, their cutting power having been rejuvenated by uplift. As erosion continued the waterways that were incised along the old Tertiary valleys had the advantage over other streams because they were working on the friable conglomerates and sandstones and soft shales which make up a large part of the Kenai formation. Even where the upwarps were transverse to the drainage lines of the former cycles, certain streams have maintained their old courses, cutting steep-walled trenches. Such appears to have been the history of the Ramparts of the Yukon, between the flats and the mouth of the Tanana. Here the river has cut its valley across one of the highest domes in the deformed peneplain, and there has been a depressed area to the north, now the basin lowland known as the Yukon Flats.

If this is the history of the Yukon Flats, it is analogous to the probable genesis of the Copper River basin as described by Mendenhall. According to Spencer, however, the Copper River depression may owe its origin to headwater erosion by an antecedent stream during a succession of uplifts. He also suggests that headwater erosion may have been accelerated because of the presence of softer materials. This theory is borne out by what is known of the distribution of the Tertiary beds. (See p. 94.) If such is the origin of the broad depression including the Copper River Plateau, it is probable that Delta River played an important part in the erosion. This stream appears to have maintained its course through the Alaska Range during the uplift. There may also have been an ancestor of the present Nenana flowing northward through Broad Pass, whose headwater tributaries also helped to erode the Copper River basin in soft Tertiary beds. These explanations, in the absence of exact information, must be regarded only as working hypotheses.

While these various stream adjustments were going on in the region of less relief erosion was still more active in the high ranges. Here the conditions were exceptionally favorable for rapid degradation. Elevation in these areas was far more rapid than erosion. A measure of its extent is to be found in the present relief of the mountains, though these have been much reduced by erosion. It is probable that although the lithologic character of Mount Foraker, Mount McKinley, and certain of the Talkeetna Mountains, which are composed of a hard granitic rock, has had much to do with the present altitude of these high peaks, yet they also represent points of maximum elevation.

At the close of this cycle the configuration of the land surface was probably very similar to what it would be to-day if the Pleistocene sediments were removed. The present drainage system was established and the mountain ranges had much of their present rugged character. Glaciation, which followed, simply modified to a small degree the older topography, deepening the valleys and cutting extensive cirques in the high ranges and rounding and smoothing off other areas of lesser relief.

It is evident from the above discussion that the data in hand do not permit an entirely consistent interpretation of the present drainage system. The fact that there is some evidence of a Tertiary formation younger than the Kenai (see p. 103) may account for a part of the apparent discrepancies. It is possible that the Tertiary drainage system, remnants of which have been described, may be of post-Kenai age and that the fluviatile deposits of these rivers may be later than the epoch of diastrophism which deformed the Kenai of the Matanuska Valley and of the inland front of the Alaska Range. If this is so, the extensive erosion represented by the Matanuska trench, the Copper River basin, the valleys of Delta River and the lower Tanana, and other valleys, passes, and lowlands may have occurred in post-Kenai Tertiary time. Under such an hypothesis it will remain to determine what the age of this cycle of erosion is relative to the Yukon peneplain. These suggestions are made to indicate clearly that the final word on the recent history of this region must be deferred until far more detailed information is available.

### ICE ACCUMULATION AND ADVANCE.

The causes of ice accumulation in this province are obscure. It is fair to suppose that the land, or at least the mountain ranges, stood at considerably higher altitudes than they now do and than they did at the close of the previous cycle of erosion. It would not take much of an elevation to produce a marked climatic effect on the areas of high relief, and yet such an elevation of the coastal barrier should increase the aridity of the inland province to the extent of preventing any considerable accumulation of ice. It is possible, however, that if at this time Bering Sea and the Pacific Ocean were one body of water the uplift might increase the precipitation on the inland slopes of the mountains sufficiently to account for the glacial accumulation. On the other hand, the presence of the warmer waters of the Pacific might raise the mean annual temperature to such a point as to prevent the accumulation of ice. It is an interesting fact, however, that even at the present time ice which lasts nearly all summer often accumulates along the streams of inland Alaska and Seward Peninsula. It appears, therefore, that it would require no great change from the present conditions to cause the formation of ice fields in favored localities. It is also true that the present precipitation in Seward Peninsula is not sufficient, even with a lowering of the mean summer temperature, to account for the glaciers which formerly existed in this part of the province. Paradoxical as it may seem, therefore, the absence of the Aleutian chain may have been one of the important causes of the glaciation, as it possibly was also of the temperate conditions of the Kenai epoch. (See p. 131.) The governing factor would appear to be the altitude of the coastal barrier.

In summing up the evidence it seems necessary to conclude that parts of the region, if not the whole, stood higher during the ice advance than they do now. This theory also receives support from the fact that there is evidence of glacial erosion throughout the length of Cook Inlet, indicating that this depression was then probably a river valley and not an arm of the sea. The reason for this conclusion lies in the probable depth, far below the present sea level, of the bed-rock floor of Cook Inlet and its tributary streams. Although Gilbert and others have shown that glacial degradation below sea level has taken place along the Pacific seaboard, such work was probably not done by the Cook Inlet glacier. There is no reason to suppose that this glacier at Kenai, for example, was more than a few thousand feet thick, and such an ice sheet would not exert pressure enough to counteract the buoyancy of the water and also do any considerable scouring, nor would it excavate the tributary valleys. On the whole, therefore, it seems to be a reasonable assumption that during the glaciation the Cook Inlet region was higher than now, possibly as much as a thousand feet higher. It can not be too strongly emphasized, however, that Alaska as a whole has been the scene of many earth movements since Tertiary time and that these movements have been differential. While, therefore, the Cook Inlet province may have been higher than at present, some parts of the adjacent regions may have been lower.

As the epoch of glaciation has been fully described, it will be necessary here only to call attention to some of its larger effects. The ice masses which radiated from the highland were, as has been shown, by no means of the same magnitude. The coastal slopes have been much more extensively degraded by ice than the inland slopes. The ice mass from the Alaska Range, uniting with that of the Talkeetna, Chugach, and Kenai mountains, covered all the Pacific drainage basins below altitudes of 2,500 to 3,000 feet. On the inland slope, however, only the cirques and their draining valleys were ice-filled, though some large piedmont glaciers stretched out across the Kuskokwim and Tanana lowlands.

There is little evidence of the amount of erosion effected by these ice sheets, but it is believed to have been relatively small. There was no such concentration of ice action as took place along the fiorded coast of southeastern Alaska, nor was there any such bulk of ice and snow back of the glaciers as existed in the névé fields of the St. Elias and Coast ranges. No deep grooving like that along the steep slopes of Portland Canal has been found in the Mount McKinley region. The chief work of these glaciers was the removal of the loose material accumulated during the long epoch of subaerial erosion which had immediately preceded. In other words, the Pleistocene glaciers followed the valley systems established in the previous cycle and probably deepened them to a certain extent.

### ICE RETREAT AND DEPOSITION.

The causes of the retreat of the ice are as obscure as those which brought about the advance. If the changing of ocean currents and elevation of mountain barriers were the chief factors which brought about the ice advance, crustal movements of similar magnitude probably brought about the retreat. In any event the cycle of retreat is practically that of the present day, for the recession of the present glaciers is but a continuation of the recession of the Pleistocene ice sheet.

The chief influence on land forms brought about by this recession is the sedimentation accomplished by the accompanying floods. These sediments, as has been shown, were deposited as extensive gravel sheets[1] throughout the area south of the Tanana. With them can be grouped

[1] The recent studies by S. R. Capps along the northern margin of the Alaska Range have led him to the opinion that these heavy gravels are of preglacial age. This opinion is of course not in accord with the theories set forth in the text of this report.

also the gravel terraces that occur along many of the valley slopes. These are in part remnants of a dissected valley filling, in part the result of deposition along the margin of glaciers. The first class are for the most part of later date than the second, but the two can be differentiated only after detailed surveys.

### PRESENT EPOCH OF EROSION.

With the disappearance of the ice sheet the watercourses gradually lost their overloaded character and erosion took the place of deposition. The sheet of Pleistocene gravels was rapidly dissected and much of it has been removed. This process of dissection was accelerated to a certain extent by uplift. In the Cook Inlet region the top of the gravel sheet is 100 to 200 feet above sea level, suggesting an uplift, though this may be a marginal deposit along a glacier. It does not seem likely, however, that a central tongue of ice was preserved long enough for the deposition of this gravel sheet. In the Tanana Valley the Pleistocene gravels have a perceptible dip to the north, and there must have been here an uplift of several hundred feet along the front of the range. In the Tanana upland there are some silt terraces which indicate recent uplift in this area. It is, however, impossible to correlate them with the glacial gravels to the south. This cycle of erosion is the one of the present. The rivers are still continuing the work of removing the Pleistocene gravels and in the mountain valleys are working on bed rock. Grades have not yet been established.

There is evidence that some of the glaciers have made a considerable advance since the dissection of the gravel sheet and later retreated to their present positions. This movement is believed by the writer to have been comparatively local, however, and in no sense comparable to that of the Pleistocene ice sheet.

## IGNEOUS ROCKS.

By L. M. Prindle.

### INTRODUCTORY STATEMENT.

The facts observed and material collected during the journey here recorded were necessarily of a fragmentary character. There was little opportunity for the study of contacts, and material was often obtained in intervals snatched from other duties. With the ever-present impossibility of visiting many localities, stream gravels and talus slopes were carefully scanned, and the results indicate the kind of material occurring in the area but give scant information regarding its areal distribution and geologic relations. They have qualitative rather than quantitative value. The following report, therefore, by no means represents a minute petrographic investigation. It is unsupported by detailed field evidence or by chemical analyses and includes only what seem to be the most salient facts regarding the lithologic character, distribution, and general relations of the igneous rocks of this province.

A part of the area was traversed by Spurr [1] in 1898 and a detailed classification and description of the rocks observed by him appear in his report.

Igneous rocks constitute a large part of the bed rock in the region traversed by the party. They are found in discontinuous masses from Cook Inlet to the Alaska Range, throughout that range, and in the Rampart region. They include intrusive and volcanic rocks and some of them are highly metamorphosed.

The phenomena of intrusion are manifested on a most extensive scale. There are large masses cutting the inclosing rocks, penetrating them with a fringe of apophyses, and in many places inducing contact metamorphism, and there are many small dikes remote from the large masses and not referable directly to any parent body. These rocks, as a rule, contrast strongly in form and color with the sedimentary rocks and largely make up the most prominent mountains, including Mount Foraker and Mount McKinley.

No volcanoes, either active or extinct, were observed along the route of travel. There is much volcanic material, however, and float in many streams bore witness to the presence of

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 188–234.

volcanic rocks in areas not covered by the party. Volcanic rocks occur in great abundance in the mountains north of Skwentna River and along the western base of the Alaska Range, particularly between Mount Foraker and Mount McKinley and between Muldrow Glacier and Nenana River. There are small areas of them in the northern foothills of the Alaska Range, and they are also present in the Rampart region.

In composition the igneous rocks show a wide range of variation. At one extreme are rocks high in silica and the alkalies and so low in iron, magnesia, and lime as to contain relatively small amounts of plagioclase and negligible amounts of the ferromagnesian minerals; at the other extreme are a few rocks composed mostly of ferromagnesian minerals. Some individual types also exhibit a wide variation in the proportions of their essential constituents. The region in general is characterized by siliceous rocks of intermediate composition, and, although there are variations in both the acidic and the basic directions, the number of extreme types is small, and quantitatively also these form but a small proportion of the whole assemblage.

The granular intrusive rocks include essentially granitic, monzonitic, and dioritic rocks, with isolated occurrences of more basic types and a considerable amount of coarse diabase. There are many gradational types between acidic granites and quartz diorites and from quartz monzonites through olivine-pyroxene monzonite to basic rocks. Porphyritic rocks are common either in close association with the large masses of granular rocks or as independent masses of considerable extent or dikes of minor importance, and these are described in connection with the groups to which they are most closely related. The volcanic rocks include rhyolites, andesites, and basalts, and these, like the intrusive rocks, merge into one another through gradational types. Tuffaceous rocks are associated with the volcanic rocks.

Most of the igneous rocks are unmetamorphosed, but some of them have been subjected to metamorphism and have become gneisses. Moreover, there are zones in the sedimentary rocks on the composition of which the igneous rocks have exerted a modifying influence, with the production of metamorphic minerals.

The rocks are in general similar throughout the region and are not separable into provinces distinctly different in petrographic character. They are of different ages and form the continuation of the masses which extend throughout the western part of the United States and Canada into Alaska.

## INTRUSIVE ROCKS.

### GRANITIC ROCKS.

#### ALASKITE.

This province contains rocks similar to those of adjacent areas, described by Spurr [1] under the term alaskite. These are granitic rocks composed essentially of quartz and feldspar and characterized most commonly by the graphic texture. The ferromagnesian minerals are present in these rocks only as accessory constituents.

The most common type is light gray or pinkish and ranges from a finely granular rock to one with a diameter of grain averaging about 2 millimeters. Small miarolitic cavities containing quartz and feldspar crystals and pyrite more or less altered to limonite are common in this rock at some localities. The rock is composed of quartz, alkali feldspar, and soda-lime feldspar. Biotite occurs in some specimens. Zircon is a common accessory, and here and there are needles of apatite. Fine grains of iron mineral, presumably magnetite, are scattered through the rock, and epidote and chlorite are among the alteration products. The quartz has many liquid inclusions, some of them 0.2 millimeter in diameter. Many of these contain movable bubbles and small cubic crystals. Some of the cavities in basal sections of quartz are hexagonal in outline. The feldspar is mostly orthoclase and microcline; both are much altered and contain in perthitic intergrowth considerable soda-lime feldspar. The soda-lime feldspar occurs to a minor extent also as automorphic individuals slightly zoned, with extinctions on sections cut parallel to the plane 010, ranging from $-4°$ in the interior to $+12°$ in

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 189, 195-196.

the outermost zones, indicating an oligoclase. The biotite, where present, is mostly altered, and rows of magnetite grains indicate its former distribution. There are porphyritic varieties of the rock containing a few scattered alkali feldspar phenocrysts up to 5 millimeters in diameter in a fine groundmass of quartz and feldspar mostly in the graphic relation.

The most prominent textural characteristic of these rocks is the graphic intergrowth. It is visible in some hand specimens but in other rocks is so minutely developed as to require the higher powers of the microscope. This texture and the perthitic character of the feldspar, which suggests a larger proportion of soda-lime feldspar than is present as individuals, are somewhat indicative of the chemical composition of these rocks.

These acidic granitic rocks occupy a considerable area in the eastern foothills of the Alaska Range south of Skwentna River. They have been glaciated and have furnished a large proportion of the glacial bowlders scattered over the greenstones of these hills.

Dikes of similar composition, ranging in thickness from a few inches to 100 feet or more, occur at widely scattered localities in the Alaska Range, either in close association with granitic or dioritic rocks or isolated in the sedimentary rocks. They are conspicuously light colored from the absence of ferromagnesian minerals, and where altered are in many places of a chalky whiteness. They are composed of quartz, alkali feldspar, and soda-lime feldspar, mostly oligoclase. Some of them are very pure examples of quartz-feldspar rocks. Locally they contain considerable muscovite. The rocks are in many places porphyritic, quartz and both feldspars appearing as phenocrysts. The prevailing texture is granular.

Dikes of this character are common in the Jurassic slates along Kichatna River, and the moraines along the west side of the range abound in material illustrating the intrusive nature of the alaskite in the granitic and dioritic rocks. Transitional rocks to muscovite granite and to biotite granite are common.

#### MUSCOVITE GRANITE.

The moraine material derived from the western base of Mount McKinley contains fragments of muscovite granite. The rock is composed essentially of quartz, much alkali feldspar, a small amount of soda-lime feldspar, and considerable muscovite.

#### BIOTITE GRANITE.

The most common granite in the region is light gray in color, flecked with black. Quartz, feldspar, and biotite are visible in the hand specimen, and the first two minerals predominate. The rock is generally of an uneven grain, being in places a finely granular mass of the constituent minerals with a slight interstitial development of the graphic texture and in places a rather coarse rock in which the feldspars attain a diameter of 1 centimeter. The observed constituents are quartz, alkali feldspar, plagioclase, biotite, zircon, and magnetite. The abundant quartz is medium to fine grained and is in places colored with lines of inclusions. The feldspar occurs in larger grains than the quartz; in some localities it is mostly orthoclase, but at others microcline is more abundant. Perthitic intergrowths are common. Soda-lime feldspar is rather abundant and many of the zoned individuals contain cores of andesine. The proportion of biotite is generally small; it is pale brown, occurs in irregular patches and slivers, and is generally fresh; at some localities, however, it is largely chloritized. Magnetite and zircon are present in about the usual proportions. The composition of the rock is fairly uniform.

This rock occurs at widely scattered localities. Mount Susitna is in part composed of it, and there are scattered areas of it between Cook Inlet and the hill country to the west. Small dikes of it cut the volcanic rocks in the hills south of Skwentna River. The same rock forms a large part of the morainal material derived from sharp precipitous peaks at the head of the Kichatna and strewn for miles along the stream and high on the sides of the valley. It is found also on the west side of the Alaska Range, in the morainal material coming from Mount Foraker and Mount McKinley, and forms perhaps a large part of these peaks.

Wherever the contact relations were observed the rock was found to be intrusive, and some of the occurrences at least are probably intrusive in rocks as young as the Jurassic.

#### AMPHIBOLE GRANITE.

A yellowish-gray medium-grained granite occurs abundantly in the hills near the camp of August 8. It is composed of quartz, alkali and soda-lime feldspars, hornblende, biotite, apatite, magnetite, and zircon. The quartz occurs intergrown with the alkali feldspar, which is perthitic and mostly kaolinized, and is present in much larger quantity than the plagioclase. The plagioclase exhibits albite and Carlsbad twinning and zonal development. One section studied cut parallel to the 010 plane showed an interior of basic labradorite inclosed by a broad zone of andesine and a narrow exterior of oligoclase. The rock contains considerable biotite and a somewhat larger amount of greenish-brown, strongly pleochroic hornblende. Magnetite and apatite are plentiful.

#### PYROXENE GRANITE.

A granite that occurs in the Rampart region in Wolverine Mountain and vicinity is composed of quartz, much alkali feldspar, soda-lime feldspar, and a small proportion of dark constituents of which biotite is the most abundant. The biotite is accompanied by a small amount of hornblende and diopsidic pyroxene.

### MONZONITIC ROCKS.

The monzonitic rocks of this province have so wide a range of variation that at one extreme they are closely related to granitic rocks and at the other are with difficulty separable from gabbros. The series of gradational rocks may be grouped about three types—quartz monzonite and associated porphyries, quartz-pyroxene monzonite, and olivine-pyroxene monzonite.

#### QUARTZ MONZONITE.

The Shell Hills are composed partly of a rather coarse, uneven-grained rock showing in the hand specimen all the essential constituents. These are pink feldspar, white feldspar, quartz, and hornblende. The pink alkali feldspar is the most abundant constituent. It attains a diameter of 1 centimeter and is largely kaolinized. There is much soda-lime feldspar, which is fresher and attains a diameter of 2 millimeters. It is in places poikilitic in the alkali feldspar, several individuals of the plagioclase occurring in one of the other feldspar. It is twinned according to both albite and Carlsbad laws and is locally zoned. In composition it ranges from labradorite to oligoclase. Alteration has produced considerable secondary quartz and epidote. The primary quartz is distributed in minor quantity irregularly through the section. The color range of the hornblende is from a dull yellowish green to brown. There is considerable of it present and in some of the rock it crystallized subsequently to the plagioclase. It is somewhat chloritized. Magnetite is abundant, and in places considerable pale-brown titanite is associated with it. Some apatite is partly included in the hornblende.

An estimate of the mineral and chemical composition of this rock based on Rosiwal's method of linear measurement[1] and reduction to weight percentages and on the methods set forth in the "Quantitative classification of igneous rocks," by Cross, Iddings, Pirsson, and Washington, is as follows:

*Approximate mineral and chemical composition of quartz monzonite from the Shell Hills.*

| | | | |
|---|---|---|---|
| Quartz | 19.00 | $SiO_2$ | 65.00 |
| Orthoclase | 38.00 | $Al_2O_3$ | 16.00 |
| Plagioclase | 30.00 | $Fe_2O_3$ | 2.50 |
| Hornblende | 8.00 | FeO | 1.75 |
| Magnetite | 3.00 | MgO | 1.00 |
| Titanite | 1.50 | CaO | 4.00 |
| Apatite | .25 | $Na_2O$ | 2.25 |
| | 99.75 | $K_2O$ | 7.00 |
| | | $TiO_2$ | .75 |
| | | $P_2O_5$ | .20 |
| | | | 100.45 |

[1] Rosiwal, A., Verhandl. Wien. geol. Reichsanstalt, vol. 32, 1898, pp. 143 et seq.

A specimen taken from a point 4 miles distant contains the same constituents, but the proportions are reversed. There is considerably more plagioclase in the rock than orthoclase. In composition the rock apparently ranges both ways from one containing a nearly equal amount of both feldspars, approaching the granites in one direction and the granodiorites in the other.

A porphyritic rock of similar composition occurs in the same general area in the hills south of the Skwentna. It is a light-gray medium-grained rock showing in the hand specimen slightly porphyritic pinkish feldspars, white feldspars, quartz, and hornblende. Under the microscope the rock exhibits a well-defined porphyritic character, with phenocrysts up to 3 millimeters in diameter and a size of grain in the groundmass of about 0.06 millimeter. The phenocrysts are feldspar, hornblende, and quartz. A granular mass of quartz and altered feldspar, with perhaps a greater proportion of feldspar, make up the groundmass. The quartz occurs in angular somewhat corroded grains up to 5 millimeters in diameter and contains many liquid inclusions with movable bubbles. The feldspar is largely altered. It generally shows zonal development and albite twinning. The composition varies from that of andesine to that of a feldspar which gives a lower index of refraction than the balsam and which in places shows albite twinning. A section was observed nearly normal to the positive bisectrix which gave an extinction angle of 17° to 19°; this would indicate albite. The hornblende is yellowish green to brown in color. It occurs in stout, irregularly terminated forms up to 4 millimeters in length and is largely altered. Magnetite is present in grains of considerable size and abundance. Chlorite and epidote are abundant secondary constituents.

North of Tanana River, in the hills near the headwaters of the Tolovana, occurs a similar rather coarse, unevenly grained rock, with porphyritic alkali feldspars over a centimeter in length. The rock consists of these larger alkali feldspars, which are mostly kaolinized; plagioclase nearly equal in amount to the alkali feldspar; quartz, hornblende, biotite, apatite, magnetite, and zircon. The alkali feldspar appears to have been uniform in composition and was probably orthoclase. The plagioclase is up to 2.5 millimeters in length, is twinned according to both Carlsbad and albite laws, is somewhat zoned, and ranges in composition from a basic andesine to oligoclase. The quartz is subordinate in amount, filling the spaces between the feldspars. The dark constituents, hornblende and biotite, make up a large proportion of the rock. The hornblende is strongly pleochroic, varying from bluish green to yellowish brown. It reaches 3 millimeters in length. The clear-yellow biotite is less abundant than the hornblende and occurs in foils of variable size up to 2 millimeters in length, some of them inclosing hornblende. Considerable apatite is generally associated with the biotite and hornblende. In composition this rock is similar to that of the Shell Hills, but it differs in the presence of biotite and in an apparently greater proportion of hornblende.

#### QUARTZ-PYROXENE MONZONITE.

In close association with the rock of the Shell Hills is a dark-gray fine-grained rock composed of an unevenly grained hypautomorphic mass of quartz, feldspar, biotite, and diopsidic pyroxene. The quartz is abundant and occurs in irregular grains up to half a millimeter in diameter. The orthoclase is interstitial between automorphic plagioclase which exhibits albite and to a lesser degree Carlsbad twinning. A section normal to the negative bisectrix gave an extinction angle of 76° and one normal to the positive bisectrix 2°, indicating the composition of an acidic andesine. The biotite occurs in small quantity and is much interrupted in its development; the same cleavage and extinction may persist through rather widely separated fragments. It shows only a slight alteration to a chloritic substance. The pyroxene is of a pale-green color and is very abundant. It occurs in irregular xenomorphic fragments ranging in size from individuals as large as the other constituents to minute grains. The largest diagnostic angle of extinction observed on the plane 010 was 37°. Magnetite is present in considerable quantity, as well as some apatite and here and there a small crystal of zircon. Chlorite and pyrite are among the secondary products.

In the Rampart region near Wolverine Mountain is a gray porphyritic rock with tabular feldspar phenocrysts 2 centimeters or more in diameter. The rock contains abundant quartz and soda-lime feldspar, alkali feldspar, and a large proportion of brown biotite and diopsidic pyroxene. The quartz is interstitial in the other minerals. The alkali feldspar forms the largest phenocrysts. The plagioclase is automorphic, is zoned, and ranges in composition from labradorite to oligoclase. The pyroxene is nearly colorless, automorphic, with prismatic development, and largely altered. The rock is transitional in that region to pyroxene granite.

#### OLIVINE-PYROXENE MONZONITE.

A rock similar to those from other regions described as olivine monzonite, kentallenite, shonkinite, gabbro-syenite, etc.,[1] occurs at several places in this province. The essential constituents are alkali and soda-lime feldspar, biotite, monoclinic pyroxene, and olivine. Hypersthene is present in places and there is some apatite and considerable magnetite. The constituents vary greatly in proportion in different varieties of the rock and the most basic type is composed almost entirely of pyroxene. The relationship of the rock to the quartz-pyroxene monzonites is very close, and at some of the localities a single thin section will show small amounts of primary quartz and olivine.

The most extensive body of this rock observed in the eastern foothills of the Alaska Range is near the head of the Kichatna Valley, where it forms a massive reddish-weathering intrusion in the Jurassic slates. It is dark gray, with an oily luster and a greenish or reddish tinge. It is hard and tough and of an uneven medium to fine grain. The finer varieties have a conchoidal fracture. Biotite in plates of interrupted continuity 15 millimeters or more in diameter, distributed irregularly through the rock, presents a striking appearance. The material collected is roughly divisible into four varieties. The geologic relations between them are not known. One variety is a medium-grained rock of greenish-gray color mottled with a few large flakes of the brown biotite. Under the microscope are seen thickly crowded phenocrysts of olivine and pyroxene and some biotite in a mass of alkali and soda-lime feldspar in which the other constituents are poikilitically embedded. The alkali feldspar has a lower index of refraction than the balsam, shows no twinning of any kind, and on a section nearly normal to the negative bisectrix gave an angle for the plane of the optic axes to the 010 cleavage of about 87°. The composition is not uniform. The mineral presents a watery appearance and under the higher powers shows a peculiar intergrowth of another substance in a manner similar to that of the graphic texture. A difference of composition is also shown by alternating irregular layers similar to perthitic intergrowths. The feldspar is in places considerably altered. Lines of serpentinous substances run out into it from the olivine, connect with other olivine individuals or here and there with pyroxene, and give to the feldspar a streaky and finally a yellowish-green opaque appearance. In some feldspars the alteration proceeds along the cleavage planes. There is but little plagioclase (labradorite) and it occurs in the automorphic relation to the alkali feldspar. The pyroxene occurs interstitially between olivine grains and also as automorphic, stout, nearly colorless prisms up to 2 millimeters in diameter. It shows some twinning parallel to the plane 100, a slight parting to 010, and a basal parting. The largest angle of extinction observed was 42°. Many of the prisms inclose small olivine grains and some biotite. The olivine occurs in rounded forms, attaining a diameter of 1.5 millimeters. Magnetite is rather abundant along the fractures, but otherwise there is little alteration. A small amount of a bright bluish-green substance is present along some of the fractures, and also a substance with high birefringence, like that of talc. The biotite occurs in splintery foils up to 2 millimeters in length. It is very fresh and of a deep reddish-brown color. Little magnetite is present except in the olivine. There is a small amount

[1] Brögger, W. C., Die Eruptivgesteine des Kristianiagebietes, pt. 2, 1895, p. 21.
Teall, J. J. H., British petrography, 1888, Pl. XVI, fig. 1; Ann. Rept. Geol. Survey Great Britain, 1898, pp. 22, 23.
Hill, J. B., and Kynaston, H., On kentallenite and its relations to other igneous rocks in Argyllshire: Quart. Jour. Geol. Soc. London, vol. 56, 1900, pp. 531–558.
Pirsson, L. V., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 479–488.
Tarassenko, B., Ueber die Gesteine der Gabbrofamilie in den Kreisen Radomysl u. Gitomier der Gouv. Kiew u. Volhynien, 1895.

of apatite. A rough approximation of the mineral composition, based on linear measurement, is as follows:

*Mineral composition of olivine-pyroxene monzonite from Kichatna Valley (No. 1).*

| | |
|---|---|
| Alkali feldspar | 20 |
| Soda-lime feldspar | 5 |
| Pyroxene | 29 |
| Olivine | 37 |
| Biotite | 9 |
| | 100 |

Another variety is intimately associated with this rock and contains similar large biotite plates. The grain is uneven, with phenocrysts of the same mineral as were found in the other rock, in a finely granular mass of feldspar and pyroxene. Both alkali and soda-lime feldspar are present. The former occurs in xenomorphic grains up to 0.5 millimeter in diameter. It is very fresh and limpid, shows no twinning, and has a lower index or refraction than the balsam. Sections nearly normal to the positive bisectrix gave angles of 6°, 9°, and 12° to the basal cleavage. Almost invariably this feldspar shows a peculiar faint striation visible only under the higher powers of the microscope and an intergrowth of another material having a slightly higher index of refraction, which occurs as faint finger-like processes spreading out into the substance of the feldspar. Some grains are full of this material, which gives rise to a texture resembling the graphic texture. This texture is especially well developed in some places where the ends of the soda-lime feldspar individuals come into contact with the alkali feldspar. Besides this intergrowth, there are minute crystals of a soda-lime feldspar embedded in the alkali feldspar. The finger-like processes are probably soda-lime feldspar. Black hairlike inclusions are very common. These range in length up to 0.10 millimeter and in places the clear feldspar substance is almost entirely filled with them. Besides the inclusions above mentioned, which are characteristic constituents of this feldspar, there are many poikilitic grains of pyroxene. The composition of the feldspar was assumed to be that of a soda orthoclase with a proportion of orthoclase to albite of 1:1. The soda-lime feldspar occurs in automorphic individuals with tabular development parallel to the plane 010 and 2 millimeters or more in thickness. It is twinned according to the albite, Carlsbad, and pericline laws, and zones are prominently developed. Study of the albite and Carlsbad twinning combinations and 010 sections with zonal development showed a composition ranging from that of basic labradorite to that of oligoclase. The soda-lime feldspar is free from the inclusions and intergrowths so common in the alkali feldspar. The ferromagnesian constituents are biotite, pyroxene, and olivine. The biotite occurs in plates up to a centimeter in diameter. It shows a skeleton-like development and is in many places discontinuous, with the same orientation, however, throughout the disconnected areas. It is strongly pleochroic, the color varying from a pale straw to a deep reddish brown. There are phenocrysts of pyroxene like that of the rock variety first described up to about 1.5 millimeters in diameter, but automorphic development is not so common as in the other variety. The pyroxene crystals are generally irregular in shape, with frayed, ragged edges and detached grains. Around the edges of many of these monoclinic pyroxenes are to be found small prisms of hypersthene. The olivine is not so abundant as in the other rock. It is very clear and fresh and has an irregular outline bordered by granular pyroxene. There is little magnetite in the rock aside from that along the fractures of the olivine. A small proportion of apatite is present.

The quantitative mineral composition of this rock is approximately as follows:

*Mineral composition of olivine-pyroxene monzonite from Kichatna Valley (No. 2).*

| | |
|---|---|
| Alkali feldspar | 34 |
| Soda-lime feldspar | 22 |
| Pyroxene | 26 |
| Biotite | 14 |
| Olivine | 3 |
| Apatite and magnetite | 1 |
| | 100 |

The third variety is a porphyritic rock containing phenocrysts of olivine, monoclinic pyroxene, and beautiful skeleton forms of biotite, like those of the rock just described but more delicately developed. The groundmass is composed of finely granular pyroxene and feldspar. There are forms transitional to the second variety, the olivine decreasing and the biotite losing its prominence and being dispersed in minute flakes throughout the rock.

The fourth, most basic variety contains phenocrysts of the nearly colorless monoclinic pyroxene, many of which are bordered with biotite in a finely granular mass composed mostly of rounded pyroxene grains. Some of the pyroxene phenocrysts have become a granular mass containing in places spongy pyrite.

In the first variety described the rather coarsely granular texture resulting from crystallization is perfectly preserved. All the other varieties have suffered deformation and recrystallization. Deformation has manifested itself most prominently in the granulation of the pyroxene, automorphic individuals becoming broken, bordered with granular pyroxene, and finally reduced to a granular mass.

Composition was calculated from measured sections, one of which represented an acidic type and the other a more basic type. The average of both analyses is given below:

*Approximate chemical composition of olivine-pyroxene monzonite from Kichatna Valley.*

| | | | |
|---|---|---|---|
| $SiO_2$ | 52.50 | $H_2O$ $H_2O+$ | 0.70 |
| $Al_2O_3$ | 10.50 | $TiO_2$ | .60 |
| $Fe_2O_3$ | 2.00 | $P_2O_5$ | .20 |
| $FeO$ | 6.00 | $CO_2$ | .10 |
| $MgO$ | 14.00 | | 100.60 |
| $CaO$ | 7.50 | | |
| $Na_2O$ | 3.00 | | |
| $K_2O$ | 3.50 | | |

Similar rocks occur in the Rampart region but do not show so wide a range of composition. They are found in Lynx Mountain and in the hills at the head of Glenn Creek, a tributary of Baker Creek. The proportion of olivine is less, some sections containing none, and a few grains of primary quartz are present. The texture is essentially the same as in the rock of the Kichatna Valley and the biotite has an equally prominent development.

In association with these rocks east and southeast of Little Minook Creek are a few dikes, ranging up to 20 feet in thickness, of a dark-gray medium-grained rock with large individuals of biotite and pyroxene in a mass of small biotites and interstitial feldspar. The rock is generally much decomposed. The feldspar forms a comparatively small proportion of the rock and in one section was found to be orthoclase. The biotite is very abundant in laths up to 4 millimeters in length, most of them bordered by dark rims and many having faded interiors. It is largely altered to chlorite and locally includes many minute rutile needles. The colorless pyroxene occurs in forms up to 2.5 millimeters long and 0.75 millimeter wide and has undergone considerable alteration peripherally and along fractures. Much chlorite, kaolin, and calcite and some quartz are alteration products, and here and there pyrite is present in considerable quantity.

## DIORITIC ROCKS.

The dioritic rocks of the Mount McKinley region are separable into granodiorite and quartz diorite, of which the latter is the more common.

### GRANODIORITE.

In the hills west of Mount Susitna is a medium-grained rock containing quartz, alkali feldspar, plagioclase, biotite, a little hornblende, magnetite, apatite, zircon, and titanite. Quartz and plagioclase are the most abundant constituents. The plagioclase occurs in more or less automorphic individuals up to 4 millimeters in length. Zonal development is common, and in composition the mineral ranges from andesine within to a narrow zone of albite on the outside. The proportion of alkali feldspar present is rather small. The section studied had the composition of granodiorite, and the rock is an intermediate type between the granite of Mount Susitna and the head of the Kichatna and the quartz diorite of the Alaska Range.

### QUARTZ DIORITE.

The numerous moraines which protrude from the valleys along the western base of the Alaska Range are composed largely of intrusive material from the peaks within the range, and most of it is granitic in appearance. This material, so far as it is represented by the fragmentary collections, is separable into granite and quartz diorite, and the latter is the more abundant. Associated with these granular rocks are porphyries of about the same composition occurring as apophyses or as independent masses of considerable prominence. The most general characteristic of all these rocks is the presence of abundant quartz and the predominance of soda-lime feldspar. The rock is composed essentially of quartz, alkali feldspar, soda-lime feldspar, biotite, and hornblende, with apatite, magnetite, zircon, and rarely allanite as accessories. There is a greater proportion of the salic constituents. The biotite and hornblende generally occur in close association, forming masses 12 millimeters in diameter, which gives the rock a somewhat patchy appearance. The largest size of grain observed was 10 millimeters. Fine-grained varieties occur but are not abundant. The composition varies with the proportion of dark constituents, and these vary with respect to one another, giving rise to dark-gray rocks with much biotite and little or no hornblende and those in which hornblende is the most abundant ferromagnesian mineral. The material is separable into three varieties.

An example of the first and most common variety was collected from the moraine about 5 miles southeast of the camp of August 5, opposite the base of Mount McKinley. In texture and composition it agrees with the description already given. The quartz is clear, contains minute liquid inclusions, some of which are arranged in lines, and occurs in interlocking areas and in irregular grains between the feldspars. Undulatory extinction is common and some of the quartz has been somewhat crushed. The rock contains a few fragments of altered orthoclase. The plagioclase occurs in stout, lath-shaped, more or less automorphic forms up to 3.5 millimeters in diameter. It is comparatively fresh and clear, containing minute dustlike inclusions and showing a fine development of zonal growth. Inclusions of various nature are especially abundant between successive zones. Twinning is common according to both the Carlsbad and the albite laws and in some places according to the pericline law. In composition the plagioclase ranges from labradorite to oligoclase. The average composition was assumed to be $Ab_3An_2$. There is but little alteration. Some of the interiors have become a more or less opaque mass which seems to contain some sericite mixed probably with calcite and kaolin. The biotite occurs in foils up to 1.5 millimeters in diameter, varies in pleochroism from a clear yellow to brownish black, and has suffered considerable alteration to chlorite. The lamellæ are commonly bent and in places faulted, showing that the rock has undergone some deformation. The hornblende is black in the hand specimen and dark green in the section, varying in pleochroism to a greenish brown. It ranges in diameter up to 1.5 millimeters, is partly automorphic, and is generally in close association with the biotite. Apatite occurs in small crystals and much of it is inclosed in the biotite foils. There is little magnetite and zircon.

A specimen collected from an intrusive mass on the western slope of the ridge at the western base of Mount McKinley, about 6 miles southeast of camp No. 56, is a rather fine, evenly grained rock containing only a few grains exceeding 1 millimeter in diameter. In the hand specimen the rock is light gray, showing a greater proportion of light constituents. The essential minerals are quartz, soda-lime feldspar, and biotite, with possibly a little alkali feldspar. There is a little apatite and zircon and secondary chlorite, kaolin, sericite, and epidote. The quartz contains many minute inclusions, fills the spaces between the feldspars, and locally forms large masses of granular quartz. The individual grains attain a diameter of 2 millimeters. A little filling material of a doubtful character is present in many places between the plagioclase grains, and this was considered to be alkali feldspar. The soda-lime feldspar occurs in more or less automorphic equidimensional forms up to 1.5 millimeters in diameter. Its most prominent feature is the zonal development. Sections cut parallel to the plane 010 exhibited a range of composition from basic labradorite with an extinction of − 31 to an acidic oligoclase with an extinction of + 13. In the sections studied the interiors were more basic than the outer zones, but there were numerous alternations of composition toward the surface. The average composition was taken to be $Ab_3An_2$. The feldspar is twinned according to the Carlsbad, albite, and pericline laws. The biotite is similar to that already described. It is considerably chloritized and there is some epidote. The rock also contains apatite and zircon.

Half a mile above camp No. 54 is the termination of a moraine composed of material part of which has probably been derived from Mount Foraker. A specimen taken from this moraine is a dark-gray, fine, evenly grained rock containing a large proportion of dark constituents. The essential constituents are quartz, soda-lime feldspar, biotite, and hornblende. There is possibly a little alkali feldspar. The rock contains considerable apatite, magnetite, and pyrite and a little zircon. Chlorite, kaolin, muscovite, and epidote are secondary products. The quartz fills the spaces between the other minerals, contains the usual inclusions, and in the larger individuals contains poikilitic feldspar laths. Few of the grains exceed 0.7 millimeter in diameter. The soda-lime feldspar occurs mostly as more or less automorphic lath-shaped crystals about 1 millimeter long, twinned according to the Carlsbad, albite, and pericline laws. Zonal development is very prominent. A study of 010 sections showed a variation in composition from basic labradorite to oligoclase. The contacts between the feldspar and quartz are generally sharp. The feldspar is not only poikilitic in the quartz but here and there has the same relation to biotite. The biotite is clear yellow to brown in color and occurs in foils up to 1 millimeter in diameter. The plates are locally bent and broken. It shows only a slight alteration to chlorite. The hornblende occurs in more or less automorphic forms, varying in size from fragments of 0.5 millimeter to minute grains, scattered irregularly throughout the section. In color it varies from brown to green. It is in places closely intergrown with the biotite. Apatite is abundant, the crystals attaining a diameter of 0.07 millimeter.

By using the composition of the biotite from the granodiorite of El Capitan, Yosemite Valley,[1] and of the hornblende from a quartz diorite 4.6 miles south of Table Mountain, California,[2] chemical analyses were calculated for each of the three varieties above described and an average for the series. The soda-lime feldspar was considered as $Ab_3An_2$ and doubtful material in the measurements was distributed equally between that and orthoclase, giving perhaps a greater percentage of orthoclase than is really present in the rock.

A comparison of the approximate mineral and chemical composition is given in the following table, in which the numbers 1, 2, and 3 represent the three varieties in the order of the foregoing descriptions:

*Approximate mineral and chemical composition of quartz diorite of the Alaska Range.*

| | 1. | 2. | 3. |
|---|---|---|---|
| Quartz | 27.00 | 32.00 | 11.00 |
| Alkali feldspar | 4.50 | 5.00 | 1.30 |
| Soda-lime feldspar | 47.00 | 52.00 | 56.00 |
| Biotite | 9.00 | 10.00 | 13.00 |
| Hornblende | 11.00 | ......... | 16.00 |
| Apatite | .60 | .20 | 1.30 |
| Magnetite | .80 | ......... | .40 |
| Pyrite | ......... | ......... | .10 |
| Zircon | .20 | .10 | .10 |
| | 100.10 | 99.30 | 99.20 |

| | 1. | 2. | 3. |
|---|---|---|---|
| $SiO_2$ | 66.00 | 70.00 | 58.00 |
| $Al_2O_3$ | 16.00 | 17.00 | 19.00 |
| $Fe_2O_3$ | 1.50 | .50 | 1.50 |
| FeO | 2.50 | 1.50 | 3.00 |
| MgO | 2.75 | 1.00 | 4.00 |
| CaO | 5.50 | 4.50 | 7.00 |
| $Na_2O$ | 3.50 | 3.75 | 4.25 |
| $K_2O$ | 1.60 | 1.80 | 1.50 |
| $TiO_2$ | .20 | .10 | .30 |
| $P_2O_5$ | .30 | .10 | .50 |
| MnO | .10 | .10 | .20 |
| | 99.95 | 100.35 | 99.25 |

[1] Am. Jour. Sci., 4th ser., vol. 7, 1899, pp. 294–295.

[2] Bull. U. S. Geol. Survey No. 168, 1900, p. 190.

### QUARTZ DIORITE PORPHYRY.

The quartz diorite near the contact and the dikes from the parent mass are gray porphyritic rocks composed of quartz, plagioclase, biotite, and hornblende phenocrysts 3 to 4 millimeters in diameter in a quartz-feldspar groundmass with an average grain of about 0.04 millimeter. The quartz occurs as a few rounded and corroded phenocrysts, many of which show embayment, and as an abundant constituent of the groundmass. The stout, sharply defined crystals of plagioclase are fresh, attain a length of 2 millimeters, and are generally tabular after the form 010. They exhibit albite, Carlsbad, and pericline twinning and zonal development. In composition the plagioclase ranges from an interior of basic labradorite to an outermost zone of acidic oligoclase. The biotite occurs in foils up to 0.5 millimeter in diameter, many of them having frayed edges from magmatic resorption. It varies from clear yellow to brownish black in pleochroism and is intimately associated with the hornblende. The hornblende is pale green to colorless and shows but little pleochroism. It occurs in stout prisms up to a millimeter in length. There is considerable apatite, magnetite, and zircon. Chloritic material is abundant and other products of alteration are present in minor quantities. Small dikes of a similar character, generally much altered, were observed in the country rock (diabase). Many of these dikes are very finely granular and, close to the contact with the wall rock, aphanitic, with some traces of fluidal texture.

The talus slopes at the foot of the conspicuous, sharply terminated mountain about 2 miles from the camp of August 18, on Nenana River, are composed of a medium to fine grained porphyritic rock varying in color from gray to brown. Brown is the prevalent color and gives the mountain as seen from a distance a rather striking dark appearance. In the hand specimen of this rock are seen quartz and unaltered feldspars with scattering fine prisms of a black mineral in a fine-grained gray to brown groundmass. The rock contains quartz, plagioclase, hornblende, and pyroxene, with apatite and considerable magnetite as accessories. The phenocrysts are up to 3.5 millimeters in size and the grains of the groundmass range from 0.15 to about 0.03 millimeters. Quartz occurs sparingly as phenocrysts but is abundant as a constituent of the groundmass. It is present in both angular and rounded forms and attains a diameter of 2.5 millimeters. The plagioclase feldspar is the most abundant phenocryst. It contains many inclusions, shows albite, Carlsbad, and pericline twinning and beautiful zonal development, and occurs in equidimensional individuals up to 3.5 by 1.3 millimeters. A study of zones on 010 sections showed a variation in composition from basic labradorite with an extinction of $-25$ to acidic oligoclase with an extinction of $+12$. Generally the interiors were found to be more basic, but in some sections intermediate zones more basic than the central portions were observed. The feldspar of the groundmass is similarly twinned and zoned. It occurs in more or less automorphic prismatic forms flattened parallel to 010, and its composition is such as to give an extinction of $-14$ within and of $+12$ on the outer zone. The hornblende occurs in prisms up to 1 millimeter in length and 0.15 millimeter in width. In pleochroism it varies from nearly colorless to a pale reddish brown. It is largely altered to a yellowish-brown opaque substance. The pyroxene occurs also in irregularly terminated, nearly colorless prisms up to 1.25 millimeters in length and 0.26 millimeter in width. The largest angle of extinction observed was 44°. A cross parting is common and alteration has taken place along the parting planes and fractures, giving rise to a greenish substance which separates the crystal into grains. The end result of the alteration of both hornblende and pyroxene is the production of much yellowish-brown ferruginous substance, probably limonite, which imparts the color to the rock.

The material of this mountain is similar to that of the western slope of the ridge at the western base of Mount McKinley, near the contact of the intrusive with the inclosing rock.

The most general characteristic of the dioritic rocks is the predominance in both the granular and the porphyritic forms of those members which contain a large proportion of quartz in association with soda-lime feldspar.

### DIABASIC AND GABBROIC ROCKS.

One of the common igneous rocks is a diabase varying in color from dark greenish gray to black and in grain from a porphyritic rock containing narrow feldspar prisms up to 2 centimeters long in a medium-grained groundmass to a rock so fine in grain as to appear aphanitic in the hand specimen. This rock occurs abundantly along the northwestern base of the Alaska Range, where it expresses itself in the topography as a series of rough, dark-colored minor peaks and ridges in strong contrast with the sedimentary rocks. It is found also in the eastern foothills of the Alaska Range and in the Rampart region. It includes probably both intrusive and extrusive rocks. Some of them are fresh and some are largely altered. Mineralogically they are divisible into diabase, quartz diabase, and olivine diabase.

A dark-colored hill at the western base of the ridge west of Mount McKinley, about 5 miles south of the camp of August 5, is a type of the diabase. The rock is greenish black in color and of medium to fine grain; in the hand specimen it is apparently composed of a greenish-gray mineral and a black mineral in about equal proportions. Under the microscope it resolves itself into an ophitic fabric of plagioclase and pyroxene, with abundant accessory ilmenite. The plagioclase occurs in forms tabular after the plane 010 with a length of edge up to 2.5 millimeters and a thickness across the twinning of 0.3 millimeter. It is twinned according to the albite and Carlsbad laws and shows zonal development. A study of the twinning combinations and of zones on the face 010 shows a variation in composition from that of a basic labradorite to that of a basic oligoclase. It is partly altered and the white opaque patches of alteration product which form locally in the crystal contrast with the clear feldspar substance about them and produce a mottled appearance. The interspaces are filled with areas of brownish augite up to 2 millimeters in diameter. Some of the augite is twinned and here and there it shows a basal parting. There is some alteration to a serpentinous substance mixed with secondary quartz. The ilmenite occurs in granular masses up to 5 millimeters in diameter and in plates a millimeter in width. It is partly altered to leucoxene and contains pyrite in small grains scattered thickly through it.

The rock at this locality is in close relation with the intrusive quartz diorite already described, and many porphyritic dikes of the diorite penetrate the diabase, becoming very fine grained to aphanitic where they come into contact with it. Both rocks are cut by small dikes of a fine-grained diabase composed of predominant feldspar, pyroxene, interstitial quartz, and ilmenite. The feldspar is twinned and zoned and in composition ranges from basic labradorite to oligoclase. An even more acidic feldspar is also present. One section studied contains considerable interstitial feldspar with a lower index of refraction than the balsam and an extinction angle on a section normal to the positive bisectrix of 10°. In many crystals the basic interior is decomposed, leaving only the outer acidic zone. The quartz is of primary origin and fills the interstices of the feldspar. The pyroxene is a limpid rose-colored augite with greenish border. It occurs in the angles between the feldspar and in places has a somewhat automorphic development. The rock contains considerable green chloritic substance, secondary quartz, and calcite. Some of the ilmenite is altered externally to leucoxene.

The hill about a mile east of the camp of July 30 is composed mostly of successive ridges of diabase with a northeasterly trend separated by sedimentary rocks. The rock varies in grain from coarse to fine and weathers to a reddish color. Under the microscope it is seen to be porphyritic in texture and to be composed mostly of feldspar and a brownish augite, both prismatically developed. The interstices are filled with a fine graphic intergrowth of quartz and feldspar, probably orthoclase. The plagioclase attains a length of 3 millimeters and has a nearly square section of 0.5 millimeter. It is mostly decomposed to a mass of kaolin showing only traces of the albite twinning. The prismatic augite attains a length of 2 millimeters and a diameter of 0.5 millimeter and shows generally automorphic development. A parting is common, parallel to the basal plane. Much of the augite is altered along the axis of the prism to serpentine. There is abundant ilmenite partly altered to leucoxene.

The above descriptions of the augite and quartz diabase apply to the rock occurring at numerous localities along the base of the range. In many places there is much uralite and brownish hornblende of secondary origin; epidote, quartz, and calcite are common alteration products. The feldspars generally yield to alteration before the pyroxene. Sections were found showing masses of comparatively fresh pinkish augite with sharply angular outlines in an opaque mass of alteration products. In some localities biotite occurs in considerable proportion. Ilmenite is generally present as an abundant accessory and here and there is so abundant as to form an important constituent of the rock. Along the contact with the sedimentary rocks the diabase is very fine grained and of a dark-green color. In one place, at a contact with limestone, the diabase includes fragments and slabs of the limestone altered to a mass of calcite and serpentine.

A similar diabase occurs east of the Alaska Range near the camp of June 11. Along the trail there are large outcrops of a grayish-green medium-grained rock composed of a feldspar with development similar to that described above and a composition ranging from that of labradorite to that of oligoclase, a little quartz in the angles of the feldspar, much brownish augite, and accessory ilmenite and apatite. The rock contains a considerable quantity of a chloritic alteration product. Closely associated with this rock is a dark grayish-green fine-grained rock with plagioclase and green hornblende which is in the ophitic relation to the greatly altered feldspars and has probably been derived from the augite.

In the small stream opposite the camp of August 11 were found many bowlders of a hard, tough rock. A specimen collected from one of them proved to be an olivine diabase. It is an even-grained rock of a dark color flecked with green and white and composed of olivine, pyroxene, and plagioclase, with a little biotite and accessory magnetite. The feldspar is a basic labradorite twinned according to the Carlsbad and albite laws and partly altered to a mixture of the usual decomposition products. Here and there it is seen in the ophitic relation with the pyroxene. The proportion of feldspar is small compared with that of the other constituents. A little biotite is present, in many places forming rims around the magnetite grains. The bulk of the rock is composed of a nearly colorless, slightly pleochroic pyroxene and olivine in about equal proportions. The pyroxene has an angle of extinction as high as 40° on 010, locally shows twinning, and varies in pleochroism from a pale green to a reddish tinge like that of hypersthene. It is automorphic in character and fills many of the spaces between the olivine grains. The olivine occurs in somewhat rounded forms up to 3 millimeters in diameter. It is comparatively fresh, showing only dark lines of magnetite grains along the fractures. The rock contains some apatite and magnetite. A greenish substance and a small amount of brownish hornblende are among the alteration products.

The stream gravels indicate that highly altered gabbro occurs locally in connection with the diabase. These rocks are composed of basic feldspar, diallage, and olivine, all in an advanced stage of alteration. Fragments occur also that were originally composed mostly of olivine and are now a mass of serpentine, tremolite, talc, magnetite, and pyrite.

## EXTRUSIVE ROCKS.

### RHYOLITIC ROCKS.

In the foothills along the northwestern base of the Alaska Range, northeast of the camp of August 17, are extensive outcrops of a gray porphyritic rock containing many phenocrysts of feldspar up to 7 millimeters in diameter and fewer of quartz somewhat smaller in size in an aphanitic dark groundmass. The quartz is somewhat fractured and clouded with minute opaque inclusions. The feldspar is mostly kaolinized but includes both orthoclase and plagioclase. A small amount of biotite is scattered irregularly through the section, which shows also considerable magnetite and a little zircon. This rock has apparently a wide distribution in the area.

About 2 miles north of the camp of August 1 volcanic material occurs in the stream gravels. One specimen found contains numerous porphyritic white feldspar phenocrysts 8 millimeters in length and about 4 millimeters in width and smaller quartz phenocrysts embedded in a dark-red aphanitic groundmass. The quartz occurs in forms with both prism and termination and in rounded and corroded grains, many of which show embayment. It is considerably fractured. The feldspar is mostly decomposed. In one section it proved to be orthoclase. The groundmass is in the main aphanitic and contains much finely disseminated iron ore, chiefly limonite.

Three miles east of the camp of August 2, in the talus slopes, occur fragments of a dark-gray aphanitic rock made up of a few small, rounded phenocrysts of quartz and feldspar in a finely granular to aphanitic groundmass. Flow structure is prominently developed, being marked by the arrangement of minute opaque particles along the lines of flow. Branching tufts of crystallites are abundant and a chloritic or micaceous mineral is disseminated in minute particles through the section. Both magnetite and limonite are abundant. Bowlders of the rock containing inclusions of the quartz diorite were observed in the stream gravels. Some specimens contain, besides the phenocrysts of quartz and feldspar, fragments of brown volcanic glass. The groundmass is a yellowish perlitic glass with many microlites.

Rhyolitic rocks occur also in the schists south of Healy Creek, a tributary of Nenana River. They have broken through the schists to the surface, forming conspicuous white towering masses with some associated volcanic glass. Along their margins fragments of the schist are included. Andesitic types are associated with them at this locality.

### METAMORPHOSED RHYOLITIC ROCKS.

Large areas of porphyritic schists of igneous origin, with some cherts, occur in the northern foothills of the Alaska Range, overlying Paleozoic carbonaceous slates and quartzites. They form prominent east-west ridges over an area about 25 miles wide, rising 1,500 to 2,000 feet above the valleys. The color of the rocks ranges from dark gray to white. The prevailing tone is whitish from the weathering of the large amount of feldspar that the rock contains, and much kaolinic material has been contributed by it to the Tertiary deposits which occupy large areas in the intervening valleys. These schists have in most localities steep dips to the north and strike northeast and southwest.

The rock is composed essentially of angular quartz and perthitic orthoclase grains in a finely granular mass of quartz, feldspar, and sericite. It contains a few small grains of plagioclase (albite), apatite, zircon, magnetite, limonite, chloritic material, and some specimens show considerable carbonaceous matter.

There are in general three varieties—a coarse-grained variety with feldspars up to 4 centimeters in diameter, a medium-grained variety (the most common) with feldspars 2 to 5 millimeters or more in diameter, and a fine-grained variety, which is a glistening sericite schist containing only a few isolated grains of quartz and feldspar. At all localities the rock exhibits a greater or less degree of schistosity, but this is due rather to the arrangement of the fine material than to that of the quartz and feldspar phenocrysts, some of which are conspicuously oriented with their longer diameters nearly at right angles to the general structure. The sinuous lines of fine material wind irregularly among the grains in directions governed by their presence. At some localities the coarse feldspars have, through weathering, been released from the groundmass and their crystal forms and edges are well preserved. Under the microscope the same is found to be true of much of the quartz, and both quartz and feldspar exhibit many cases of embayment. In the least altered rocks the phenocrysts are still in the original relation to the groundmass and the structure of the groundmass is preserved; it is microgranitic, granophyric, or flow structure. In the rocks showing flow structure protoclastic phenomena are common.

In the process of metamorphism the quartz and orthoclase have been fractured, and in every specimen observed where this had happened with the two in contact the quartz had yielded to the feldspar. Both quartz and feldspar have in many places been converted into augen by the physical and chemical shifting and deposition of material about their margins.

A striking characteristic of these rocks is the universal presence of quartz-feldspar and feldspathic veins. Some of these are a foot or more thick, but most commonly they are but a few inches thick and of small extent. The minutest gash veins cutting the rock in various directions are of the same character. One such vein in thin section proved to be composed for the greater part of its length of feldspar alone. Toward the termination of the vein, however, the feldspar is limited to the margins of the vein, from which automorphic forms extend toward the middle of the vein, where they become embedded in granular quartz. The feldspar is perfectly fresh, has a lower index of refraction than balsam, and on sections cut at right angles to the positive bisectrix gave angles of 5° to 7° to the basal cleavage. No evidence of twinning was observed, and in composition it is probably a nearly pure potash feldspar. So far as noted there is no indication that these feldspathic veins are connected with intrusion, and their material has apparently been derived from the rocks in which they occur. They are unmetamorphosed. In the lack of detailed observations and studies of these veins any explanation can have but a tentative value, but it would seem that the inciting cause is to be found in the process of metamorphism to which these rocks have been subjected.

So far as the evidence is available, this assemblage of gneisses and feldspathic schists comprises highly metamorphosed rhyolitic rocks, presumably flows, with possibly some associated tuffs and quartz-feldspar sediments.

### ANDESITIC ROCKS.

The andesitic rocks are roughly separable into dacite, hornblende andesite, augite andesite, and hypersthene andesite.

A large area in the mountainous country south of Skwentna River is occupied by volcanic rocks with associated breccias and tuffs. These form a complex, heterogeneous mass of rocks with a wide range of composition and texture. In composition they range from augite andesite to rhyolitic types; in texture from rocks that are holocrystalline to those composed almost entirely of volcanic glass. They show changes in composition within narrow limits and the relations of the different rocks have not been determined. They occur probably as alternating sheets of varied composition.

The most common rock is gray, brown, or black in color and contains abundant plagioclase and scattered quartz phenocrysts in an aphanitic groundmass. There is a little biotite in the rock, apatite and magnetite are the common accessories, and chlorite is the most abundant alteration product. Much of the quartz is automorphic, but some of it is much corroded, and locally it shows embayment. The plagioclase occurs in stout prisms up to 2 millimeters long in places thickly crowded in the glassy groundmass. It is twinned according to the albite, Carlsbad, and pericline laws and ranges in composition from andesine to oligoclase. Many of the crystals are bent and broken by the motion of the groundmass before solidification. The groundmass as a rule exhibits flow structure and contains many microlites.

The holocrystalline variety is porphyritic, containing numerous phenocrysts of plagioclase of the same composition as the other in a spherulitic and granophyric groundmass of feldspar and some quartz. This variety also contains a little biotite and decomposed hornblende. Magnetite and apatite are present as accessories, and chlorite and epidote are the most abundant alteration products.

Interbedded with these rocks are bands composed almost entirely of volcanic glass or of glass containing zones of the plagioclase crystals or other zones containing much quartz.

The most basic andesitic rock observed in this area is an augite andesite containing basic labradorite and augite phenocrysts in a groundmass composed of feldspar microlites, magnetite, and glass. Flow structure is prominently developed, and the rock has rounded cavities filled with chloritic substance.

Associated with these intermediate rocks are volcanic breccias and tuffs of widely varying composition within the limits of the rocks from which they have been derived.

About 3 miles southeast of the camp of August 11 is an isolated knob of hornblende andesite occurring in sandstone and conglomerate. The rock has a splintery fracture, is of a bluish-gray color, and contains numerous brilliant brownish-black hornblende prisms up to 5 millimeters by 1 millimeter in an aphanitic groundmass. A closer examination reveals many glistening cleavage surfaces of small feldspar phenocrysts. The feldspar is an automorphic plagioclase occurring in all sizes from phenocrysts 1 by 0.5 millimeter and tabular after the face 010 to the minute feldspar microlites of the groundmass. It is twinned according to the albite, Carlsbad, and Baveno laws and shows a fine zonal development. In composition it ranges generally from a basic labradorite to an acidic andesine. One section parallel to the face 010 showed an interior of a composition which gave an extinction of $-32°$ and an outer zone with an extinction of $-22°$; another gave an extinction of $-23°$ for the central portion and $-7°$ for the outer zone. The combinations of Carlsbad and albite twins gave nearly symmetrical extinctions of 28° and 29° in one member and an extinction of 40° in the other. This is the most basic feldspar observed among the twinning combinations and its composition approaches that of anorthite. Inclusions of a yellowish substance are numerous and are generally arranged with reference to zones. Here and there decomposition has attacked the interiors and in many places a shell of clear feldspar incloses a porous mass of inclusions and products of decomposition. The hornblende varies in size from the irregularly terminated prisms a few millimeters in length and having sharply defined automorphic cross sections to angular fragments and minute grains. In color it ranges from a pale transparent brown to a dark opaque brown. The borders are generally resorbed. The rock holds numerous prisms square in cross section and attaining a maximum length of nearly a millimeter. These prisms are composed entirely of alteration products, probably from pyroxene, of which calcite is the most abundant. The rock contains also some apatite and considerable magnetite. The groundmass is composed of very minute feldspar crystals embedded in a feldspathic base. The proportion of phenocrysts is variable. In one section they are thickly crowded; in another there is a greater proportion of groundmass.

Hornblende andesites occur also in Jumbo Dome, north of Lignite Creek, a tributary of the Nenana. The rock is predominantly black, being made up of brilliant hornblende phenocrysts up to a centimeter or more in length in a finely granular groundmass flecked with plagioclase phenocrysts. Under the microscope, in addition to these two minerals, a few augite and olivine phenocrysts are observable. The hornblende is brown, with resorbed borders. The plagioclase is zoned, its central portions approximating anorthite in composition and an outermost border being basic oligoclase. The groundmass is predominantly feldspathic and contains also small prismatic augites. The mode of occurrence at this locality is probably that of a neck penetrating the schists.

About 6 miles northeast of the camp of August 7 occurs a dark-red rock composed of medium-grained phenocrysts in an aphanitic base. The phenocrysts are plagioclase, hypersthene, and hornblende. The plagioclase occurs as fresh automorphic individuals up to 4 millimeters in diameter tabular parallel to the face 010. It is twinned according to the albite and Carlsbad laws and shows pronounced zonal structure. In composition it ranges from basic labradorite to oligoclase, the central portions of the individuals giving extinctions to basal cleavage on sections parallel to 010 as high as $-31°$. The pyroxene consists mostly of hypersthene in prisms from 1.3 millimeters in length by 0.4 millimeter in width to small, slender forms in the groundmass. It shows the characteristic emergence of the negative bisectrix on sections parallel to 100 and the pleochroic colors varying from a pale green to a yellowish tint. It commonly shows a cross parting. Here and there are prisms bounded by a narrow zone of augite. A small amount of hornblende is present. It occurs in prisms up to 1 millimeter in length by 2 millimeters in width, which consist mostly of a dense mass of magnetite grains inclosing a small quantity of the original substance. It is strongly pleochroic, varying from a clear yellow to a deep reddish-brown color. The groundmass is composed of plagioclase laths, much iron ore, mostly limonite, and some glass. Many cavities are lined with concentric layers of quartz. This rock is similar in composition to andesites collected by Mendenhall [1] in the Mount Wrangell region.

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, pp. 57-62.

BASALTIC ROCKS.

The rocks near the camps of July 23 and 24 are aphanitic dark-green rocks with phenocrysts of plagioclase in a fine-grained groundmass composed mostly of augite with scattering feldspar laths. The rock is probably part of a basaltic flow. Volcanic rocks and tuffs form a large part of the igneous material in the Rampart region and have been described by Spurr.[1]

Olivine basalt occurs sparingly at several localities in the Nenana Valley and the Rampart region and is probably present as both flows and dikes. The appearance, composition, and texture are for the most part uniform. The rock is dark gray to black, is composed of plagioclase, augite, olivine, magnetite, and apatite, quantitatively present in the order given, and locally a small amount of biotite. Generally the proportion of plagioclase is such that the augite is distributed through the section in small grains occupying angles between the feldspars. With a larger proportion of augite the ophitic texture becomes prominently developed. Glass is present in some of the thin sections and here and there are amygdular cavities filled with limonite, calcite, and concentric layers of granular and chalcedonic quartz.

The feldspar occurs in forms tabular parallel to the face 010 and a millimeter thick. It shows albite, Carlsbad, and pericline twinning and zonal development. In composition it ranges from basic labradorite to oligoclase. The pyroxene is a rose-colored, probably titaniferous augite. It occurs mostly in minute xenomorphic angular fragments filling the spaces between the feldspars but has also less commonly a somewhat automorphic development to a diameter of 1.5 millimeters. Olivine occurs in grains about 1 millimeter in diameter, with irregular outline and a partial alteration to a reddish substance resembling iddingsite. Biotite is present in irregular foils and borders some of the magnetite grains. Granular magnetite is scattered throughout the rock. Apatite is locally present in considerable quantity.

In the stream gravels near the camp of August 20 were found fragments of a very fine grained grayish-black rock composed of orthorhombic and monoclinic pyroxene, plagioclase, olivine, glass, and much fine dust. The olivine occurs sparingly and only as phenocrysts. It reaches a diameter of 3 millimeters and is but slightly altered. The bulk of the rock is fresh orthorhombic pyroxene thickly crowded in prisms up to 1 millimeter in length by 0.1 millimeter in thickness, with a prismatic cleavage and cross partings. It is colorless, shows no pleochroism, and has a parallel extinction and a low birefringence. Most of these prisms have a thin outer zone of monoclinic pyroxene with an extinction as high as 37°, higher relief, and higher interference colors. In some prisms this outside layer is so thick as to leave but a slender axis of the orthorhombic pyroxene. Under crossed nicols the contrast in birefringence between the interior with its low color and the exterior zone of monoclinic pyroxene with its bright-yellow or red color is very striking. A few entire prisms are of the monoclinic variety. The plagioclase is present in moderate quantity and is crowded between the pyroxene in minute forms showing albite twinning and tabular development parallel to the plane 010. There is considerable transparent glass between the feldspars and the pyroxenes. This is crowded with opaque globular bodies which are probably magnetite.

CONTACT ROCKS.

The sedimentary rocks of the Alaska Range and of the Rampart region are largely black highly carbonaceous slates, and these have been altered at many localities by the igneous intrusions to a black, tough, banded hornfels which rings under the hammer and has been sometimes called by the miners "iron rock." The abundance of this material in the stream gravels throughout the region indicates the extent of such alteration. There are many varieties of this rock, and doubtless detailed investigation would reveal the presence of rocks representing the various stages of metamorphism characteristic of typical localities where such contact phenomona have been studied. The two kinds most commonly found are characterized by the development of andalusite and cordierite.

[1] Spurr, J. E., Geology of Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 239–242.

A black heavy rock containing brilliant andalusite crystals resembles a porphyritic igneous rock. The andalusite occurs in crystals up to 6 millimeters long by 2 millimeters wide. It is colorless and exhibits no pleochroism and the exteriors of most of the sharply automorphic crystals are perfectly fresh. The interiors are crowded with alteration products and inclusions, and in some places there are only elliptical spongy areas of the mineral. These are embedded in a mass of quartz grains and biotite flakes thickly strewn with grains of a black substance, much of which is probably carbonaceous matter. Pyrite is locally abundant. Float of this material was found in the gravels of streams near Tyonek, along the western base of the Alaska Range, and in the Rampart region, where it is in close relation with the intrusive granitic and monzonitic rocks.

A similar rock containing cordierite in place of andalusite was found in the Alaska Range among the glacial bowlders derived from the mountains at the head of Caldwell Glacier and again near the camp of August 5, in the gravels of the glacial stream which originates in Peters Glacier. The rock is a fine-grained brownish-black schist flecked with numerous small glistening areas. In the thin sections these resolve themselves into rounded elliptical or hexagonal sections of cordierite formed by the interpenetration of three individuals. These areas contain much magnetite and other inclusions and merge gradually into the surrounding finely granular mass of quartz, biotite, and carbonaceous matter. Pyrite is abundant in the rock derived from Peters Glacier.

## SUMMARY.

The granitic and dioritic rocks range in composition in the one direction through hornblende granite, quartz-hornblende monzonite, and granodiorite to quartz diorite and in another direction from granite through pyroxene monzonite to olivine-pyroxene monzonite. Proportionally the quartz diorite and biotite granite are apparently the most abundant. The presence of the olivine-pyroxene monzonite in the Alaska Range and in the Rampart region bears witness to the fact that the conditions for the formation of this rock were operative over widely separated areas, and its occurrence in other countries in similar association is further proof that this rock is one of the types to be looked for in areas of granitic and dioritic rocks. Through this rock there is a close relation of the granular and dioritic rocks to gabbroid olivine diabase and thus to the diabases and basaltic rocks which are abundant in the Alaska Range and the Rampart region.

The relationship of these rocks to one another is further accentuated by the distribution of the essential minerals. Primary quartz occurs with great persistency not only in the monzonitic rocks, where it is found in a small amount even in some of the olivine-pyroxene monzonite, but also in the dioritic rocks, where it occurs abundantly. Its presence in some of the volcanic rocks forms transitional types between the rhyolites and andesites. A single thin section showing olivine embedded in alkali feldspar is expressive of the wide range of composition throughout the region.

The dioritic and granitic rocks belong, for the most part at least, to the great mass of Mesozoic intrusions, and the dioritic rocks appear to have preceded the granite. It is probable that the granitic and monzonitic rocks of the Rampart region were approximately contemporaneous with those of the Alaska Range, and some of the Rampart rocks cut Upper Cretaceous sandstones.

The fresh basaltic rocks in the Rampart region belong to a later date than the Tertiary rocks with which they are in close association, and similar rocks of the Nenana Valley are perhaps to be correlated with them.

The Cook Inlet region is occupied largely by intrusive rocks belonging to granitic, dioritic, and monzonitic groups. Mount Susitna is composed in part of biotite granite, and in the hills to the west of Mount Susitna is granodiorite. The Shell Hills are composed of quartz monzonite and quartz-pyroxene monzonite and in the surrounding flat country there are isolated rounded hills composed of the same material. Farther west is a zone of volcanic rocks, with some intrusive rocks and sedimentary beds. The volcanic rocks include andesites, rhyolitic dacites, breccias, and tuffs. The whole forms a complex of great variety and is intruded by biotite granite and diabase. Other intrusive rocks present in the area are alaskite and quartz monzonite, but the relations of these to the volcanic rocks were not observed. The volcanic rocks form prominent peaks of alpine character, and the snows of the higher points are frequently darkened by the volcanic dust carried by the wind to these older rocks from the active volcanoes far to the south.

The intrusive rocks of the Alaska Range are predominantly gray in color and contrast strongly with the dark-colored sedimentary rocks. They range from granite to quartz diorite. The olivine-pyroxene monzonite forms a dark intrusive mass near the head of Kichatna River and fragments were found here and there in streams draining the western slopes of the range. The intrusive masses have a more or less linear arrangement extending in a northeast-southwest direction and their culminating points are Mount Foraker and Mount McKinley. The abundance of andalusite and cordierite schists in the gravels indicates a wide distribution of contact phenomena in connection with these rocks. Father west, among the foothills, these intrusive rocks are paralleled by the persistent masses of diabase, which form dark rugged peaks in the black slates. Volcanic and tuffaceous rocks are of common occurrence throughout the Alaska Range and are grouped especially in the area between Mount Foraker and Mount McKinley, where rhyolitic rocks form prominent brilliantly colored hills, and in the region north of Muldrow Glacier, where there are extensive areas of rhyolites and andesites. Areas of olivine basalt, apparently of small extent, were observed in the Nenana Valley.

The igneous rocks of the Rampart region include essentially granitic and monzonitic rocks and uralitized diabase with a small amount of fresh olivine basalt. The prominent group of hills in the vicinity of Rampart is composed of sedimentary beds intruded by igneous rocks. Granitic and monzonitic rocks are present in Lynx and Wolverine mountains, in the divide at the head of the Baker Creek drainage basin, and as small dikes scattered throughout the area. Many of these dikes are rich in biotite and are minette-like in character. They are probably associated with the larger areas of intrusive rocks. Andalusite-bearing contact zones are developed along the margins of the sedimentary rocks. The greenstones are the most characteristic rocks of the region and include altered gabbro, diabase, basalt, and tuffaceous material. They form the bed rock of lower Minook Valley, a large part of the Little Minook Valley, and the hills close to the Yukon below Rampart. Olivine basalt is in close association with Tertiary rocks near the mouth of Minook and Hunter creeks. The Rampart region may be characterized as an area of sedimentary deposits containing old intrusive and extrusive rocks (the greenstones), subjected to a much later intrusion of granitic and monzonitic material which is of more recent date than some of the Cretaceous rocks.

The igneous rocks are in their character, associations, mode of occurrence, and age similar to rocks in the western part of the United States and Canada. They present an illustration of the uniformity of types produced by differentiation in widely separated regions and also of the wide variation possible in individual types within small areas. Most of them are comparatively fresh, but protoclastic phenomena are exhibited by some of the olivine-pyroxene monzonites, where the pyroxenes have been granulated to a greater or less extent before the final consolidation of the rock, and cataclastic phenomena are shown in the minute faulting and partial granulation of the quartz in quartz diorites collected near Mount McKinley. The results of an advanced stage in the metamorphism of an igneous rock are shown in the rhyolitic schists of the northern foothills of the Alaska Range. The wide distribution of the igneous rocks, the great altitudes attained by many of them, and their occurrence at several geologic horizons all bear witness to a great amount of igneous material, to long-continued igneous activity, and to the great structural influence of these rocks.

## MINERAL RESOURCES.

### INTRODUCTION.

Mineral deposits are widely distributed throughout the Mount McKinley province, but nearly all of those which have been developed lie outside of the area surveyed by the party in 1902. In fact, most of the important discoveries and developments, including Willow Creek lodes and the Yentna and Fairbanks placers and lodes, have been made since this survey. Besides the deposits above mentioned, gold placers have been mined on Willow and Valdez creeks and in the Bonnifield, Kantishna, Baker Creek, Rampart, and Gold Mountain districts, and auriferous gravels have been found in many other localities. Large quantities of high-grade bituminous coals occur in the Matanuska field and of lignitic coal in the Nenana field. Smaller areas of lignitic rocks are also widely distributed. These include all the mineral deposits of proved commercial importance, but auriferous lodes have been reported from a number of other localities, notably in the Willow Creek district. Silver, copper, and antimony bearing ores have also been found.

It has been shown that the investigations of the expedition were confined to a narrow zone along the route of travel, much of which traversed a region which had up to that time seldom or never been visited by white men. The hasty field observations on the occurrence of useful minerals could therefore not be supplemented by information gleaned from the work of prospectors and miners. It is for this reason obviously impossible to make any complete statement of the mineral wealth of the province.

A brief summary will be presented of what is known of the occurrence and distribution of the mineral resources throughout the area covered by the geologic map (Pl. IX, in pocket). In so doing use will be made of the results of the surveys by Moffit, Atwood, Paige, Knopf, and Martin in the southern parts of the province and by Prindle in the Yukon-Tanana region. Furthermore, the writer has drawn upon data based on his own investigations in the Fairbanks and Rampart districts during 1905, 1907, 1908, and 1909 and in the Matanuska region in 1910. This account will contain only a general outline of the salient features of the economic geology, which it is hoped may serve a useful purpose, but for detailed statements regarding individual districts reference should be made to the original reports.

### HISTORY OF MINING.

Alaska's great mining industry had its beginnings in Kenai Peninsula, for it was here that the first placer and coal mining was attempted, representing the only effort made by the Russians to exploit the mineral wealth of their American colony. The Russian-American Company, which absolutely controlled Alaska until its transfer to the United States, was organized and administered solely for the fur trade. For the first half of the nineteenth century the profits from a rich harvest of sea otter and other furs poured a continuous stream of wealth into the coffers of the company. Indiscriminate slaughter of the sea otter gradually depleted the hunting grounds, so that the stockholders, seeking for new sources of revenue, finally turned their attention to a search for mineral wealth. Another cause of the decrease in revenues was the fact that the governorship of the colony, at first in the hands of experienced traders, had by royal ukase (in 1831) been transferred to naval officers. Many of these officers, though able administrators, were probably less interested in the success of the commercial ventures than their predecessors had been.

It appears also that the directors of the Russian company were influenced by the California gold discoveries to turn their attention to mining. Be this as it may, in 1849 a government mining engineer named Doroshin was dispatched to Sitka, and during the following two years he made active efforts to find gold in the colony. Doroshin devoted most of his attention to Kenai Peninsula and with a large force of laborers prospected Kaknu River. The labor of two seasons resulted in the extraction of only a few ounces of placer gold, and this meager return discouraged the fur company, though Doroshin's own opinion of the possibilities of mining auriferous deposits in Alaska appears to have been favorable. These operations were the beginning of the placer-mining industry of Alaska, which now (1909) annually yields in gold $15,000,000 or $16,000,000.

The only other mining venture of the Russian company was the exploitation of the coal deposits on Cook Inlet, which had long been known and from which a small amount had been taken for use in the company's shipyard at Sitka. The demand for coal in California and the desirability of having a supply of it for the company's vessels led, in 1854, to the systematic development of coal at Port Graham, on the east side of Cook Inlet. With the aid of American capital[1] a plant was installed and several thousand tons of coal were mined. It was found, however, upon shipment to California that, on account of its low grade, the coal commanded so small a price that the enterprise was continued only to supply the Russian steamers.

One of the earliest mining enterprises in Alaska after the transfer of sovereignty was on Kachemak Bay, where some of the lignitic coal seams were opened in 1888. These operations have continued spasmodically to the present day.[2] There has also been some coal mining on Port Graham, a few miles south of Kachemak Bay.

The first placer mining in the Cook Inlet region after Doroshin's efforts was done about 1890, when some auriferous beach gravels were discovered near Anchor Point, on the east side of Cook Inlet. These deposits appear to be of small extent and not very rich, but yielded some gold to hand methods. In 1890,[3] it is said, three men were engaged in this beach mining and obtained $7 worth of gold each a day. Since that time there has been occasional mining at this locality.

Placer gold was found on Resurrection Creek, a southerly tributary of Turnagain Arm,[4] about the same time. It does not appear, however, that there were any important mining developments until 1894, when placer gold was found on Bear and Palmer creeks; these were followed in the succeeding year by other discoveries. The news of these finds brought in many gold seekers in 1896, and since then mining has been continuous in this placer field, though its annual production has of late been declining.

Long before the Cook Inlet placer fields had reached a productive stage auriferous gravel had been found in the Yukon basin, first (1879) in the bars of Lewis River, on the Canadian side of the boundary, followed in 1887 by the discovery of gold in Fortymile River, on the Alaska side of the boundary. The notable yield of these placers during the succeeding years led to an influx of miners every spring over the Chilkoot Pass, and these men gradually extended the field of prospecting. Gold was found in the Rampart district about 1890 and important auriferous gravels were discovered in the Birch Creek district in 1893, but it was not until 1896 that productive mining began in this field. The discovery of the Klondike started the great rush of 1897–98 into the interior and marked the transition from the pioneer conditions on the Yukon to those of the present epoch.

Although the Klondike excitement took many of the active miners from the older camps on the Alaska side of the boundary, it also attracted so large a population that the field of prospecting was rapidly extended. Gold was first found at Fairbanks on Pedro Creek, in 1902, and though this discovery was of no great importance in itself, it attracted many prospectors and led to the further discoveries in the following two years which established Fairbanks as an important producer. The annual output of gold in this district increased rapidly and in 1909 had a value of $9,650,000.

Between 1903 and 1906 the discoveries of gold placers in the Bonnifield district, which embraces the streams tributary to Nenana and Wood rivers, and the Kantishna district, also tributary to the Tanana, showed that an auriferous belt extended along the foothills of the Alaska Range. The finding of placers on Willow Creek in 1898, in the Yentna basin in 1904, and in the upper Susitna basin (Valdez Creek) in 1906 established the presence of gold-bearing rocks south of the range. In 1907 and 1908 important gold discoveries were also made in the southern part of the Rampart district.

The estimated production of the most important districts is given in the following table. These figures are of necessity largely based on estimates, as up to four years ago no systematic collection of the figures showing the annual production of precious metals in Alaska had been

[1] A subsidiary company was organized whose chief purpose was to supply ice to California from Alaska glaciers.
[2] Stone, R. W., Coal fields of the Kachemak Bay region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 54–55.
[3] Report on population and resources of Alaska: Eleventh Census (1890), 1893, p. 69.
[4] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 8–9.

attempted, and even now the statistics obtained from the producers are far from being complete and have to be supplemented by estimates based on the best information available. To arrive at a total valuation of the gold output of the province, about $250,000 should be added to the figures in the table for the production of the Kantishna, Bonnifield, and Gold Mountain districts.

*Estimated value of gold production of Mount McKinley province.*

| Year. | Fairbanks district. | Rampart district. | Kenai Peninsula and Susitna districts. | Hot Springs district. |
|---|---|---|---|---|
| 1895 | ........ | | $50,000 | ........ |
| 1896 | ........ | | 120,000 | ........ |
| 1897 | ........ | | 175,000 | ........ |
| 1898 | ........ | | 150,000 | ........ |
| 1899 | ........ | $616,000 | 150,000 | ........ |
| 1900 | ........ | | 135,000 | ........ |
| 1901 | ........ | | 80,000 | ........ |
| 1902 | ........ | | 120,000 | $263,000 |
| 1903 | $40,000 | | 100,000 | |
| 1904 | 600,000 | 90,000 | 100,000 | 146,000 |
| 1905 | 6,000,000 | 80,000 | 100,000 | 120,000 |
| 1906 | 9,000,000 | 120,000 | 150,000 | 180,000 |
| 1907 | 8,000,000 | 125,000 | 125,000 | 175,000 |
| 1908 | 9,200,000 | 75,000 | 150,000 | 150,000 |
| 1909 | 9,650,000 | 100,000 | 185,000 | 325,000 |
| | 42,490,000 | 1,206,000 | 1,990,000 | 1,359,000 |

## STRATIGRAPHIC DISTRIBUTION AND LITHOLOGIC ASSOCIATION OF MINERAL DEPOSITS

*Introduction.*—Mineral deposits should be considered with regard to their lithologic and stratigraphic association as well as their areal distribution. This involves a study of the areal and stratigraphic geology, but as these subjects have been treated at length in a preceding section of this report (pp. 64–111), it remains simply to apply the conclusions already presented to the occurrence of the mineral deposits.

The geologic map and sections (Pl. IX, in pocket) graphically illustrate the relations of the known mineral deposits to the various formations. These relations can therefore be interpreted in terms of economic geology. Known occurrences of commercially valuable mineral deposits are marked by symbols on the map, but the marking has been limited for the most part to those deposits which have been mined on a commercial scale. For alluvial gold two symbols are used, one marking placer mines or groups of placer mines and the other simply localities where placer gold is known to have been found. It is believed that the information conveyed by the second symbol, incomplete as it is, may be of value to the prospector. As there has been no coal mining in the area covered by the geologic map, the symbols for coal mark the position of what are believed to be workable coal beds.

*Birch Creek schist.*—It has been shown that the oldest rocks of the province are comprised in the Birch Creek schist, which occupies large areas in the northern part of the province and forms the source of extensive gold placers. The schists of the Willow Creek region of the lower Susitna, also auriferous, are provisionally correlated with this formation. It is made up of highly altered sediments, chiefly quartz and mica schist and quartzite, with some limestone, all of which have been much sheared. In many places the alteration has amounted to a complete recrystallization of the original minerals. In association with these altered sediments are found many phases of igneous rock, in part massive but more commonly sheared and crushed and in many places entirely recrystallized. These altered igneous rocks now occur as greenstones and mica and chloritic schists.

The Birch Creek schist is in many places seamed with quartz veins, and these locally carry metalliferous minerals. This mineralization appears to follow zones of shearing, and recent developments near Fairbanks indicate that in some of these zones the gold values may be sufficiently localized to form commercial ore bodies. In any event it seems probable that the gold placers which occur in the Birch Creek schist have derived their metallic content from these quartz stringers and veins. The most extensive placer deposits of the Yukon region occur in association with rocks of this character and at or near the contact zones of massive intrusive granite or diorite.

*Undifferentiated metamorphic rocks.*—On the map are indicated some considerable areas of slate, phyllite, and graywacke, including some volcanic and intrusive rocks east and south of the Alaska Range, which are classed as undifferentiated metamorphic sediments and are probably in the main of Paleozoic age. These rocks are all closely folded and as a rule both considerably fractured and locally altered. Quartz veining is not uncommon and some metalliferous veins which carry gold values have been found.

The physical character of these beds causes the fracturing to be more localized and persistent than in the Birch Creek schist. For this reason it appears that the metallization is more likely to be concentrated in these rocks than in the schists, where the planes of foliation are the lines of movement and may afford channels for the dissemination of the mineral-bearing solutions. These conditions favor the occurrence of quartz veins. Auriferous veins have been found in the rocks here considered on Prince William Sound, on Kenai Peninsula, and north of Turnagain Arm.

Though some alluvial gold occurs in association with rocks of this type, they do not appear to be the source of so extensive placer deposits as the Birch Creek schist. The information at hand would appear to indicate that the mineralization of the rocks of this class has not been as widespread as in the other schists. They form, however, the country rock of the Sunrise placer district and probably also of some of the placer districts of the Susitna River basin.

*Paleozoic rocks.*—The next higher group of rocks stratigraphically comprises those of Paleozoic age occurring on both sides of the Alaska Range at horizons ranging from Ordovician to Devonian. In the Alaska Range region these rocks are highly folded and faulted and in places considerably altered. Quartz veins are rather common, and it would appear that some of them are mineralized, though definite proof is wanting; but in any event it is known that some of the gravels derived from these rocks are more or less auriferous. For example, the slates of the Yentna placer district probably belong to this group of sediments, as do also extensive areas of rocks in the Rampart region. There is, therefore, a possibility that these rocks may be found to be auriferous in other parts of the field. Spurr noted the presence of metalliferous veins cutting the Paleozoic slates in the upper Kuskokwim basin. (See p. 169.)

In the region lying south of the Tanana the Paleozoic rocks have been divided into three groups. The lowest of these, called the Tatina group, is of Ordovician age and is made up of cherts, slates, and graywackes, with some limestone. These rocks are as a rule closely folded and locally metamorphosed. Quartz veins are not uncommon in them. This group so far has not proved to contain commercially valuable mineral deposits, but some of the streams traversing it carry some alluvial gold.

The second Paleozoic group, here called the Tonzona, is made up of red, green, and black slates, cherts, and graywackes. So far as the evidence in hand goes, this group is not favorable to the occurrence of any metalliferous deposits, though locally it contains quartz veins, some of which carry iron pyrite. In the Nenana basin, south of the Tanana, extensive areas of gneissoid rocks occur in association with the Tonzona sediments. (See Pl. IX, in pocket.) These appear to be altered rhyolites and are locally mineralized.

The third division, of Devonian age, consisting of heavy siliceous blue limestone, appears to be barren of mineral wealth. In other parts of the Yukon region this same limestone is associated with extensive greenstone intrusive rocks that appear to carry some gold.

*Carboniferous rocks.*—A heavy conglomerate and sandstone and slate series, here called the Cantwell formation and assigned to the Carboniferous, stretches along the northern front of the Alaska Range and rests unconformably on the older rocks. This formation is not as intensely folded as the older rocks, nor have any quartz veins or mineralization been found in it. It appears, therefore, to be somewhat definitely established that the formation is not likely to furnish any metalliferous deposits. With it were found a few coal beds, but these are comparatively thin and so far as observed of no commercial value. A more detailed study of the field, however, will be necessary before it can be definitely stated that there are no workable coal beds in this formation.

*Skwentna group.*—A great mass of volcanic rocks, here called the Skwentna group, of Middle or lower Middle Jurassic (?) age, constitutes the next succeeding terrane. It is made up of effusive rocks of many types cut by a large number of intrusive rocks. Though no quartz veining or other mineralization suggesting the occurrence of gold in this group was seen, some alluvial gold was found in the gravels of the streams cutting across it in the Yentna basin. Moreover, Spurr[1] found that some mineralization had taken place along the contact of these volcanics and granitic rocks intruded in them. Paige and Knopf[2] found some mineralization of the volcanic rocks of the Matanuska basin, which are here correlated with the Skwentna group. This they describe as follows:

Though placers have not been found within the areas of older volcanic rocks, mineralization has occurred. West of Hicks Creek a large cropping of gossan about 100 feet wide was found. This red capping is due to the oxidation of finely divided pyrite disseminated through a quartz porphyry. A sample selected for assay showed a trace of gold and no silver.

For several miles the whole southern flank of Sheep Mountain at the head of Matanuska River is colored a strong red from the oxidation of pyrite in the greenstones. At some points the sulphuric acid formed during the oxidation of the pyrite has bleached the greenstones to a pure white color. The rugged range thus tinted in vividly contrasting colors presents a marked scenic effect. Certain streams emerging from the range are so highly charged with iron salts as to color their gravels red with oxide. The pyritization of the greenstones, which are here roughly schistose, has affected a great thickness of rocks but is of a diffused character. An assay of a sample selected as showing the maximum mineralization yielded only a trace of gold and no silver.

It is perhaps significant that the ore body (gold) of the Apollo mine on Unga Island occurs in association with andesitic and dacitic lavas which are not unlike those of the Skwentna group. Becker,[3] to be sure, regarded the volcanic rocks on Unga Island as of Tertiary age, but both Martin[4] and Atwood,[5] who were very familiar with the geology of the adjacent region, have called in question this determination. Atwood described several localities on the Alaska Peninsula where mineralization of volcanic rocks has taken place. Similar phenomena have been observed by both Becker[6] and Collier[7] on Unalaska Island, near Dutch Harbor. Becker described a quartz vein which carried iron and copper pyrite and Collier a vein which carried iron pyrite and a small amount of gold.

It is not possible to prove that the mineral deposits which have been described occur in lavas of the same age. Be this as it may, the facts presented go to show that some of the volcanic rocks, chiefly of andesitic and dacitic types, are more or less mineralized. To this class belong some of the rocks of the Skwentna group, and this terrane is therefore worthy of careful investigation on the part of the prospector.

*Tordrillo formation.*—The next higher formation is the Tordrillo (Middle Jurassic), which is made up of conglomerates, grits, sandstones, slates, and shales. This formation does not appear to be favorable for the occurrence of ore bodies and so far as known contains no coal. Some of the slates included with the rocks are partly altered and there is a little mineralization with some quartz veins. There is no evidence, however, that any of these veins are auriferous, though the occurrence of placer gold in the headwaters of Styx River is reported. If this formation is ore bearing, the deposits probably occur at or near the margin of the granitic intrusives.

*Upper Jurassic rocks.*—The series next younger than the Tordrillo formation, which includes 2,000 feet of shales, arkoses, and tuffs, with some coal beds, is of Upper Jurassic age and occurs in the upper part of the Matanuska basin. The coals are chiefly lignites, but possibly the semianthracites of the Matanuska field belong at this horizon. These coals have not been sufficiently prospected to prove their commercial importance. The formation has been recognized only in the eastern part of the province, but it is known to extend beyond the limit of the area represented on the accompanying map (Pl. IX, in pocket).

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 259.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 65.

[3] Becker, G. F., Reconnaissance of the gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 85.

[4] Martin, G. C., Gold deposits of the Shumagin Islands: Bull. U. S. Geol. Survey No. 259, 1905, pp. 100–101.

[5] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, p. 150.

[6] Becker, G. F., op. cit., p. 85.

[7] Collier, A. J., Gold mine on Unalaska Island: Bull. U. S. Geol. Survey No. 259, 1905, pp. 102–103.

*Granitic intrusive rocks.*—Large masses of intrusive granites and granodiorites cut the Tordrillo formation and older sedimentary rocks of the province. These intrusive rocks are believed to be for the most part of Mesozoic age and were probably injected chiefly during the latter part of Jurassic time. Lithologically and in time of intrusion they correspond to the great batholiths of granite which form the Coast Range of southeastern Alaska and British Columbia. It has been shown by Spencer,[1] the Wrights,[2] and others that in southeastern Alaska there is a close association and a genetic relation of the ore bodies and the granitic intrusive rocks. In that area the zones of mineralization are most commonly found near the contact of the granitic intrusive rocks, and similar relations probably prevail in other parts of Alaska.[3] For example, on tracing the western margin of the Coast Range intrusive belt northward from Lynn Canal it is found to pass near the Porcupine placer field, through the Rainy Hollow copper district, and through the region where gold and copper deposits have been found near Lake Kluane. The Chistochina placer districts, in the Copper River region, appear to be similarly located in reference to a granodiorite intrusion. It seems probable that similar relations may prevail in the Bonnifield, Kantishna, Valdez Creek, and Yentna placer districts, though this supposition can not now be proved.

As the granites of the Alaska Range are similar in character to those of the Coast Range of southeastern Alaska, it is plausible to consider that they also may be agencies of mineralization. In this connection it will be of interest to quote the observations of Spurr [4] in reference to mineralization along the contact of the granite with the volcanic rocks of the Skwentna group, already referred to. It should be noted that the siliceous dikes referred to the Eocene by Spurr are now believed to be of Jurassic age and to belong to the same epoch of intrusion as the granite.

> The rocks of the Skwentna series are frequently altered and slightly mineralized along the contact of the Eocene dike rocks, especially in the district between the second and third canyons. At the camp of June 24 a few small veins interstratified with the bedded rocks contained, in a calcite matrix, iron rust, peacock copper, and copper pyrite. The greatest mineralization, however, was noticed in the third canyon, where the stratified tuffs and basalts are cut by dike rocks in great abundance. The dikes are sometimes well-defined and sometimes irregular bodies, which have in general a trend parallel with the strike of the beds and a mostly vertical dip. Along the contact of these intrusive bodies the rock is mineralized, being impregnated with sulphides of various kinds. Figure 6 shows a sketch of an irregular body of granite which is surrounded by a zone of mineralization. The mineralized rock is weathered, brown, and crumbling and shows fresh sulphides only on broken surfaces where iron pyrite and chalcopyrite appear. An assay made from a sample of this by the Geological Survey showed 0.05 ounce of gold and 0.15 ounce of silver to the ton. Besides the mineralization of the wall rock along the contacts there are also many small quartz veins in the vicinity of the dikes; these, as well as the altered country rock in which they lie, carry sulphides. A sample of these rusty and cavernous veins from the lower end of the canyon was assayed by the Survey and showed 0.1 ounce of gold and 0.25 ounce of silver to the ton. A third manner in which the rock is mineralized is along certain zones not in exact contact with the dikes, although in their neighborhood. These zones are generally conformable to the stratification, following porous strata, for there is very little shearing, and consequently few shear zones.
>
> In this locality the mineralization evidently depends directly upon the intrusive rock and has been brought about by solutions accompanying the intrusion and very likely separated from the intrusive magma at the time of cooling. The gold-bearing and silver-bearing siliceous and ferruginous solutions have naturally affected the rock at the immediate contact with the igneous body most, although where zones favorable for circulation were found they have penetrated along these and deposited their silica and their metals as sulphides.

Spurr [5] states that he found quartz veins carrying iron and copper pyrite and a little galena, with traces of gold, in the region adjacent to the upper Kuskokwim River, and these he thinks are "undoubtedly connected with the dikes which cut the slates." He concludes also that the placer gold found by him on the Yentna and Skwentna is derived from pyritiferous quartz veins cutting the volcanic rocks (Skwentna group).

Jaggar [6] found evidence of mineralization along the margin of a granitic intrusive in volcanic rocks on Unalaska Island, near the east end of the Aleutian chain. These volcanic rocks are of

[1] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906, pp. 21-38.

[2] Wright, C. W., Lode mining in southeastern Alaska: Bull. U. S. Geol. Survey No. 314, 1907, pp. 81-86. Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: Bull. U. S. Geol. Survey No. 347, 1908, pp. 77-93.

[3] Brooks, A. H., Distribution of mineral resources in Alaska: Bull. U. S. Geol. Survey No. 345, 1908, pp. 27-29.

[4] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 259.

[5] Op. cit., p. 259.

[6] The geologic results of Professor Jaggar's expedition have not yet been published in full. A reference to this occurrence, however, is contained in the "Journal of the Technology expedition to the Aleutian Islands in 1907, by T. A. Jaggar," reprinted from Tech. Review, vol. 10, no. 1, pp. 17-19.

unknown age, but Jaggar suggests that they may be Jurassic or Tertiary. It seems possible that they are identical in age with the Skwentna group and that the mineralization noted by Jaggar is of the same type as that described above by Spurr. Although Jaggar does not state that these zones of mineralization carry any precious metals, yet it has been shown that at least one auriferous vein occurs on Unalaska Island and that it is near the contact described by Jaggar.

The great batholithic intrusions forming the Talkeetna Mountains belong to the same period of injection as those of the Alaska and Coast ranges. If, then, this granite has a mineralizing influence, it would be expected that metalliferous deposits might occur along its contact zone. So far as known, however, the only ore deposits which have been discovered in the zone are those of Willow Creek, an easterly tributary of the lower Susitna. Placers have long been known on this stream, and some promising auriferous lodes are said to have been found in 1906–7 in the granite close to the schist contact.

Prindle [1] has shown that the granites of the Yukon-Tanana region were intruded at different times up to the Upper Cretaceous. It seems probable that these intrusive rocks may be, in part at least, of the same age as those of the Alaska Range, which have been correlated with those of southeastern Alaska. As regards the possible mineralizing influence of these granitic intrusive rocks, Prindle says:

> The influence of igneous intrusion is far reaching, especially in areas of such permeable rocks as siliceous schists, and in view of the widespread distribution of igneous rocks in the Yukon-Tanana region, both in space and time, and their relation to the facts at our disposal, it seems justifiable to ascribe to them the widespread mineralization of the region and to refer a part at least of this mineralization to the close of the Mesozoic.

It is significant that most of the localities where metalliferous veins have been found in the Yukon-Tanana region lie in or near the contact zone of a granitic or dioritic intrusive. This is true on Chicken Creek, in the Fortymile region, and in the Birch Creek region, but is better shown by the recent discoveries of auriferous lodes in the Fairbanks district.

All the observations here noted point to the conclusion that at least some of the granitic intrusive rocks have had a mineralizing influence on these contact zones and that these zones have been found to be the loci of metalliferous deposits. It does not follow that mineralization has taken place along all the intrusive contacts, for this is known not to be the case. The conditions which favor the formation of metalliferous deposits along the contacts of the intrusive rocks of this province are not sufficiently well understood to permit their being set forth. It is certain, however, that the occurrence of mineralization is as dependent on the character of the country rocks which have been intruded as on the igneous rock itself. The practical deductions from the evidence is that regions intruded by igneous stocks and dikes are favorable for the occurrence of metalliferous deposits, especially so in the contact zones.

*Cretaceous rocks.*—The Cretaceous period is represented by two groups of rocks—one (Lower Cretaceous) made up chiefly of limestone and occurring in the southeastern part of the area here under discussion, and the other (Upper Cretaceous) made up of sandstones and slates which are cut by granite, limited to small areas in the northwestern part of the field. In neither of these groups, so far as known, are there any commercially important minerals.

*Kenai formation.*—The youngest of the hard-rock terranes is the Kenai formation (Eocene). This is of commercial importance because it includes valuable coals. Kenai rocks are widely distributed in the province and vary greatly in physical character. In the Kenai of the Matanuska basin, where the best coal has been found, the formation is made up of hard conglomerates and slates, with beds of bituminous, semibituminous, and lignitic coal. These rocks are also known to occur between the forks of the Susitna and the Chulitna, in about latitude 62° 30′. Here the coals seem to be chiefly lignitic, the prevailing type of the Kenai beds. Soft conglomerate, sandstones, and shales with lignitic coals, also of Kenai age, occur in the Cook Inlet region and in the Susitna basin.

Some Kenai beds, chiefly slates and sandstones, are infolded with the older rocks along the inland front of the Alaska Range but appear to include very little coal. On Nenana River and in the adjacent region lignitic coal beds are abundant in association with friable white

[1] Prindle, L. M., Occurrence of gold in the Yukon-Tanana region: Bull. U. S. Geol. Survey No. 345, 1908, pp. 184–186.

conglomerate, sandstone, and shale, all of Kenai age. The Kenai beds with some lignite occur in small patches along the Yukon.

*Quaternary deposits.*—The Quaternary deposits of the province include the widely distributed gravels, sands, and silts that constitute the extensive Pleistocene bench gravels and the modern stream deposits. The commercial importance of these deposits depends on their gold content. So far no gold placers have been developed except in the alluvium of the present streams. Gold has been found, however, in the high gravels of the Minook Valley and in the extensive bench gravels of the Bonnifield district, both of which are regarded as of Pleistocene age. It will remain for the future to determine whether the gold in these older gravels is sufficient in quantity to permit extraction.

*Summary.*—The Birch Creek schist, comprising the oldest rocks of the area, is locally mineralized and the alluvium derived from it carries valuable gold placers. Some promising auriferous quartz veins have also been found in these schists. The so-called undifferentiated metamorphic rocks are locally known to be auriferous, and some of them carry auriferous lodes. The Paleozoic rocks which skirt both margins of the Alaska Range are locally mineralized, and those on the Yentna have yielded some commercial placers. Evidences of mineralization have been found in volcanic rocks of the Skwentna group, but up to the present time they have yielded no commercial ore bodies. Mineralization is known to occur in many places along the contacts of the granitic and other igneous rocks with the sediments in which they have been intruded. The contact zone of these intrusive masses would appear to afford the most favorable localities in which to search for mineral deposits. The Tordrillo formation does not appear to be favorable for carrying gold, though in some places evidences of mineralization have been observed near the contact with intrusive rocks. Some coal has been found in the Upper Jurassic sediments, but its commercial value has not been established. The chief coal-bearing formation of the province is the Kenai, which in the Matanuska basin carries high-grade bituminous coal. Throughout most of the area, however, the coals of this formation are chiefly of a lignitic character. Gold placers are widely distributed in the Quaternary gravels, but as the region as a whole has been little prospected the distribution of the auriferous alluvium has not been determined. Some of the Pleistocene bench gravel is also known to be auriferous.

## GEOGRAPHIC DISTRIBUTION OF MINERAL DEPOSITS.

### *METALS.*

It is proposed here to summarize briefly the information regarding the productive districts of the province, but for detailed statements recourse must be had to the special reports from which the information presented was for the most part extracted. The districts will be considered in order from south to north.

#### COOK INLET.

The gold placers of Kenai Peninsula [1] occur for the most part near its northern margin and in the region adjacent to Turnagain Arm, in the so-called Sunrise district. Only the north end of this field is shown on the map (Pl. IX, in pocket). The most important streams of the Sunrise district so far as production is concerned are Resurrection Creek and Sixmile Creek, together with their tributaries, lying south of Turnagain Arm, and Glacier Creek, lying north of Turnagain Arm. Some gold has also been mined on the tributaries of Kaknu River. The bed rock of all these streams belongs to the slate and graywacke series, and there appears to be a marked absence of intrusive rocks.

The alluvial deposits of this district include three general types—the deposits of the present streams, the bench gravels, and glacial deposits which have been more or less worked over by water. Much of the alluvium is characterized by an irregularity of occurrence to be expected in a region where the glacial deposits are so intimately associated with the fluviatile materials.

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 1-52.

Large bowlders are not uncommon and increase the cost of mining operations, as they require special handling. It is said to be largely on account of the bowlders that the attempt to work the Resurrection Creek placers by means of a dredge was abandoned Some of the bench gravels are favorably located for hydraulicking and the water supply is far more abundant than in most of the interior placer camps. In not all localities, however, is the water supply adequate to permit hydraulic mining throughout the open season.

Most of the early mining was confined to the stream beds of the smaller tributaries of the creeks mentioned above. The gold contained in these stream beds is to a certain extent a concentration from the bench gravels, which are also auriferous. It is to be expected that the stream beds are richer in gold than the benches. Later the benches were prospected and some were found to carry values which could be recovered at a profit where water under head was available.

The early history of the district was one of only very primitive methods of gold extraction, but in 1898 a number of hydraulic plants were installed. Unfortunately careful prospecting of claims and determination of water supply did not always precede such installations; consequently there have been many failures. The evidence at hand indicates that there are considerable bodies of gravel which carry from 6 to 40 cents in gold to the cubic yard. It would appear that some of these gravels ought to be profitably mined. It should be remembered, however, that the presence of large glacial bowlders in some of these gravels increases the difficulties of mining and that therefore, in spite of the favorable location of the bench deposits, the cost of extraction of the gold may be considerable. During the last two or three years the gold production of this field has gradually decreased, and unless new deposits are discovered it will probably continue to decline until some of the larger deposits of low-gold tenor are exploited. Several large plants are now being installed.

The occurrence of placer gold in the beach deposits at Anchor Point, already referred to (p. 156), is worthy of note. This gold must have been concentrated by wave action, either from the high gravels which rest upon the Kenai formation close to the beach or from the Kenai formation itself. Auriferous Kenai sediments occur in the Yukon basin. The Kenai at Anchor Point probably derived its material from metamorphic rocks to the east, which are known to be auriferous, and it also may carry gold. It is probable, however, that the gold content is not sufficiently concentrated to have any commercial importance.

The Anchor Point placers have yielded a little gold almost every year since they were discovered. The gold has been taken out with rockers. An attempt made some years ago to install a large plant for working these deposits was a failure. It appears that the deposits are too small to warrant exploitation by machinery.

Except for that at Anchor Point, the only placer gold known in the immediate vicinity of Cook Inlet is that on Beluga River. Fine gold has long been known to occur in the alluvium of this stream. In 1902 an attempt was made to mine it with the aid of a hydraulic plant, but this was soon abandoned. Operations in 1909 consisted in prospecting for dredging ground, but the results are not available for publication. This is one of the fields where large glacial bowlders may be found in the alluvium—a fact which should be taken into account in the choice of a method of mining.

Moffit shows that the gold of the Sunrise placers is probably derived from small quartz veins, which are not uncommon in the metamorphic rocks of Kenai Peninsula. He further notes that some of these quartz veins carry sulphide minerals, usually pyrite with arsenopyrite or chalcopyrite and in places zinc blende and galena. On Bear Creek a vein has been discovered which shows sphalerite, galena, pyrite, and arsenopyrite, together with a little free gold. The gangue is chiefly quartz containing some calcite. It is reported that the best ore at this locality is in a 16-inch vein included in mineralized rock 6 feet thick. On Sawmill Creek there is a gold-bearing quartz vein which has a maximum thickness of 4 feet but is very irregular. It is considerably faulted. The quartz carries values of $2 in gold to the ton, though some shoots are very much richer.

Moffit also notes the presence of small nuggets of native copper with the placer gold on several creeks. On Lynx Creek a copper sulphide bearing ledge has been discovered. Paige and Knopf,[1] who visited this property in 1906, report that the ore body occurs along a zone characterized by intense shearing having a nearly vertical direction. The metallic minerals—chalcopyrite, pyrrhotite, and iron pyrite, with a gangue of quartz—have been deposited along this zone of shearing. The mineralized area is from 6 inches to 2 feet in thickness. Grant and Higgins [2] have described some auriferous lodes in that part of the Kenai Peninsula which is tributary to the town of Seward. The ore deposits are of two types—(1) auriferous quartz veins and (2) mineralized dikes of igneous rocks. Both cut the foliation and bedding of the country rock, which consists of closely folded slates and graywackes. Some quartz veins 1 to 6 feet in width were noted and a mineralized dike over 10 feet wide where exposed. The ores carry native gold, galena, pyrite, and arsenopyrite. A gold telluride is reported to occur in some of these ores. At the time of Grant and Higgins's visit in 1909 the most promising discoveries were those in the so-called Moose Pass district and at False Creek. In 1910 many other gold prospects were reported at various localities in Kenai Peninsula. A discovery was also made at the head of Crow Creek, north of Turnagain Arm. Most of the ores collected by prospectors show free gold and many are very rich. Current reports indicate that sufficient work has been done on some of these prospects to indicate that they will become producing mines, and the outlook for further discoveries is encouraging.

Paige and Knopf also report, on the authority of prospectors, the occurrence of copper in the high mountains between Knik and Matanuska rivers. This ore is said to be chalcopyrite associated with pyrrhotite. It is significant, in considering this deposit, that the copper-bearing rocks of Prince William Sound are very similar in character to some of the bed rock of Kenai Peninsula and of the region between Knik Arm and Matanuska River. This suggests that these occurrences of copper may be similar to those of Prince William Sound, and if this proves to be the case it increases the chances of finding commercial ore bodies. Grant and Higgins [3] have described briefly some occurrences of gold and copper bearing lodes in the vicinity of Seward. The copper deposits resemble the occurrences on Prince William Sound and the gold deposits are not unlike those described above.

The open season for placer mining in the Kenai Peninsula and Cook Inlet region extends from May until October. Deep mining could of course be carried on at all times. The harbors on the east side of the peninsula are open to steamboat navigation throughout the year. Timber is abundant. There are some water powers which could be developed, and in many places water is available at high levels for hydraulic mining. Some of the auriferous gravels attain a thickness and have a position that permit them to be mined at low cost. On the other hand, in parts of the district the gold of the stream gravels is unevenly distributed and that of higher benches has in only a few places been won at a profit. The discoveries of the auriferous lodes indicate that bed-rock mining may yet become an important industry in Kenai Peninsula.

### SUSITNA VALLEY.

The work of Eldridge [4] and the reports of prospectors have shown that placer gold is widely distributed along the main valley of Susitna River, at least from the Yentna to Indian Creek. Eldridge found only fine colors, but his opportunities for examination were limited to the main river. He noted that above the Chulitna the gold is coarser and seems to lie nearer its bed-rock source. These statements are borne out by those of others who have prospected the main river and some of its tributaries. Prospectors report that colors have been nearly everywhere found on the upper river.

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 314, 1907, pp. 124–125.

[2] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of the Kenai Peninsula: Bull. U. S. Geol. Survey No. 442, 1910, pp. 171–173.

[3] Grant, U. S., and Higgins, D. F., Notes on the geology and mineral prospects in the vicinity of Seward, Kenai Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, pp. 98–107.

[4] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 20–21.

According to Eldridge, this gold was derived from quartz stringers which occur in the metamorphic rocks termed the Susitna slate. Many of these quartz stringers carry traces of pyrite and a few that were assayed showed traces of gold and silver. Eldridge states that few of the quartz seams exceed 8 inches in width and that most of them are less than 4 inches. He notes that certain areas where the rocks have been particularly deformed as a result of crushing are probably the most favorable localities for mineralization, and he observed one locality of this kind on the hills southeast of the Susitna, 2 miles below Indian Creek, and another on a tributary of Nenana River. Another was reported by prospectors on the Chunilna, a tributary of the Talkeetna from the north. All this information indicates that the bed rock of the main Susitna Valley is more or less mineralized.

Paige and Knopf have noted that the bars of the main river have been worked to a minor extent for gold and that fairly good prospects were found on the Chunilna. Although this district would appear to be favorable for the occurrence of gold placers, it can not be denied that the results of the prospecting on the main river are not very encouraging. It is probable, therefore, that the gold in the bars is derived from tributary streams. In the basins of some of these, including Willow Creek, Valdez Creek, and the tributaries of the Yentna, workable placers have been found. Of the easterly tributaries of the Susitna, Willow Creek alone has yielded commercial placers.

Gold placers were found on Grubstake Creek, a southerly tributary of Willow Creek, in 1898 and have been worked since about 1900. The pay streak is said to average 200 feet in width and to have a depth of 2½ to 3 feet, and most of the gold occurs on bed rock or in the crevices of the bed rock.[1] The source of this gold appears to be in the quartz stringers which cut the mica schist. It should be noted that this mica schist is a rock of an entirely different type from that found to the north in the Matanuska basin. It is far more crystalline, and reference to the map (Pl. IX, in pocket) will show that it has been provisionally correlated with the Birch Creek schist. A hydraulic plant has been in operation on these deposits since 1904.

In 1907 and 1909 gold-bearing quartz ledges which are said to carry high values were found on Willow Creek. Unfortunately it has been impossible so far for the Survey to investigate these deposits, but the following notes are based on data which are believed to be reliable. The district lies about 30 miles north of Knik, with which it is connected by horse trail. According to Paige and Knopf,[2] Willow Creek follows the contact between a quartz diorite and granite mass on the north and a belt of garnetiferous mica schist and chlorite-albite schist on the south. The placer gold of this district, according to the same authors,[3] is derived from quartz stringers in the schists. Since they made their examination some auriferous quartz veins have been found in this district, and these are reported to occur chiefly in the granite. This occurrence may be due to the fact that the deformation of the region may have opened well-defined fissures in the massive granite, whereas in the schist the stresses may have produced zones of shattered rock. There is not enough evidence in hand to make a definite statement, but it appears that the placer gold has been derived from the schists and that the gold-quartz veins which have been opened occur chiefly in the granite. The quartz veins carry free gold, iron pyrite, arsenopyrite, and possibly chalcopyrite. High gold values but only very low silver values are reported. In one deposit which has been opened free-milling gold quartz was found at the surface and to a depth of 50 feet, where the lode gradually changed into a refractory ore. A 3-stamp mill was installed in this district in 1908 and a small prospecting mill in 1909; preparations were made to erect a third mill in 1910. Both these mills have made a small output and a number of other prospects have been opened.

In 1909 some prospecting was done on Metal Creek, a tributary of Knik River. The results are said to have been encouraging, and plans for further development have been made.

In 1910, after the above was written, F. J. Katz made a brief study of the occurrence of gold in the Willow Creek basin. The following notes are extracted from his report, which is

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Talkeetna and Matanuska basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 65-66.

[2] Idem, p. 10.

[3] Idem, p. 66.

now in course of preparation.[1] The country rock of the southern part of the Willow Creek basin is a highly foliated mica schist, cut by numerous quartz stringers. The schist is bounded on the north by an area of granodiorite, which forms a part of the Talkeetna Mountain massive. A few small basaltic and aplitic dikes cut this diorite. On the south these schists are separated from a belt of Tertiary sediments by a narrow band of granodiorite. The important gold-lode prospects thus far developed all lie north of Willow Creek and within the granodiorite; the placers occur to the south, within the schist area. Most of the ore bodies are quartz fillings in fissures, as a rule with sharply defined walls. The quartz is white and bluish gray, in many places banded and giving evidence of having been broken and recemented. The veins which have been staked range from 16 inches to 4 feet in thickness and appear to follow regular fissures, some of which persist for several hundred feet. There is little visible mineralization in the quartz, but it carries minute specks of pyrite and some of it high free-gold values. All ore mined up to 1910 was taken either from the surface or within 150 feet of the surface.

Auriferous quartz is also said to occur on the head of Granite Creek, tributary to the Matanuska, and on Little Willow Creek, tributary to the Susitna. The information regarding most of these lodes is too incomplete to permit a statement regarding their future importance. It seems, however, to point to the conclusion that the marginal zone of the intrusive granodiorites of the Talkeetna Mountains is a locus of auriferous and possibly cupriferous mineralization. It has already been pointed out that in other parts of Alaska extensive mineralization has been found along the margins of intrusive granodiorites of the same age as those of the Talkeetna Mountains. The theoretical deductions, therefore, are on the whole favorable to the discovery of ore bodies.

In 1908 to 1910 considerable lode prospecting was done on other tributaries of the Susitna. In 1909 Frank Wells discovered a copper-bearing lode on Iron Creek, a tributary of the Susitna. This lode is reported to be 30 feet in width, to be well defined, to strike about north and south, and to occur at a contact between slate and greenstone. The ore consists of chalcopyrite and pyrite and is said to carry copper and gold values.

### YENTNA DISTRICT.

Placer gold was found in the headwater region of the Yentna, a westerly tributary of the Susitna, during 1904–5. Though this district has not been studied by geologists, considerable information about it is available from the reports of prospectors and of R. W. Porter, of the Cook expedition. The accompanying map (Pl. XV, in pocket), made by Mr. Porter, shows the topographic character of the region.

The area within which auriferous gravels are known to occur includes a belt of foothills of the Alaska Range about 20 miles wide, stretching northeastward from Nokochna River through to the Tokichitna Valley, a distance of some 50 miles. This region is characterized by broad alluvium-filled valleys trending northwestward, separated by wide flat-topped ridges that are made up chiefly of gravels. The placers so far developed have all been on the small streams with comparatively narrow valleys which are tributary to those described above.

The hard bed rock seems to be chiefly slate, which is here correlated with that of the Kichatna Valley, assigned to the Paleozoic. Prospectors report some porphyry dikes in this formation. Some lignite-bearing friable conglomerates and sandstones have also been found in this district, and these probably belong to the Kenai formation. They are only slightly indurated and are known to the prospectors as the "cement gravels" or "red gravels." Overlying these are the Pleistocene gravels, which reach a thickness of several hundred feet and which, locally at least, contain many bowlders. The recent stream gravels in which occur the placers that are thus far productive merit no special description.

A little gold has been mined on the upper part of Nokochna River, near the mouth of Kellar Creek, at the west end of the belt. Here the gravels are said to be about 20 feet thick and to rest on a slate bed rock. Considerable bodies of auriferous gravels are reported to have been

[1] Mr. Katz's statement will be published in Mineral resources of Alaska—report on progress of investigations in 1910: Bull. U. S. Geol. Survey No. 480, 1911 (in preparation.)

found on Eagle and Independence creeks, tributaries to the west fork of the Skwentna. The values in these gravels are said to be high enough to warrant the installation of a mining plant. There has also been productive mining on Wagner Creek and some other tributaries of Lake Creek. These placers are said to be shallow and to rest on a slate bed rock. The most important developments have been in the basins of Cache and Peters creeks, both tributary to the Kahiltna. The upper basins of these two streams are deeply incised in a heavy sheet of Pleistocene gravels which forms a high terrace between Kahiltna and Tokichitna rivers. The top of this terrace is nearly flat, with a gentle dip away from the mountains. Cache Creek valley is incised to a depth of 200 to 300 feet below the surface of the terrace. Its walls are broken here and there by benches, marking former stream levels. Near the point where the river debouches on the lowlands of Kahiltna River, Cache Creek flows through a narrow steep-walled canyon, but above this point its valley floor widens to 1,000 or 1,200 feet. The placers of the main Cache Creek valley rest on the "cement bed rock"—that is, the lignite-bearing formation. Here the highest values occur in a red gravel 4 to 6 feet in thickness, above which there is a gray sand. All the gravels, including those of the high terraces, are said to carry some gold. On Nugget, Falls, and other northerly tributaries of Cache Creek considerable mining has been done in gravels which rest on a slate bed rock. Much mining has also been done in the upper basin of Peters Creek, where the conditions of occurrence are probably similar to those on Cache Creek.

The Cache Creek gold is rather coarse, well rounded, and bright in color. Its value is $17.80 an ounce. Very dark iron-stained gold is also said to occur in the district. The data at hand suggest at least that the Cache Creek gold is in part derived by reconcentration from an older placer deposit and not directly from a bed-rock source in the slate. This older placer may have been a high channel in the Pleistocene gravels or may have been in the "cement" or Tertiary gravel. In any event the facts at hand make it appear that auriferous gravels are rather widely distributed and that, locally at least, the values are sufficiently concentrated to warrant exploitation. The successful operation of the hydraulic plant on Cache Creek, installed in 1910, will probably encourage similar enterprises. The water supply available for mining is better than in many of the other Alaskan camps.

The route to Yentna district is by way of Susitna River and its tributaries. River steamers connect at Beluga with vessels on Cook Inlet, and launches running up the Susitna connect with the end of the railway on Turnagain Arm. Steamers can ascend the Yentna as far as the mouth of Lake Creek and launches as far as the West Fork. From the West Fork a trail leads to Eagle and Independence creeks. Another trail leads from the mouth of Lake Creek to the diggings on Cache Creek, a distance of about 50 miles. The Alaska road commission is now building a bridge across the Kahiltna at the trail crossing, which will make Cache Creek readily accessible in summer. Most of the supplies for this region have been hauled in winter from the mouth of Lake Creek or from Susitna station.

### VALDEZ CREEK.[1]

By F. H. Moffit.

Valdez Creek is one of the small headwater tributaries of Susitna River. (See Pl. III, in pocket.) It rises in the foothills of the Alaska Range and flows in a general southwesterly direction for about 12 miles. It is approximately 160 miles north-northwest of Valdez or 120 miles directly south of Fairbanks. It lies in a region difficult of access and consequently not well known.

Although the creek is a tributary of Susitna River, the trails most frequently used for reaching it approach the stream from the Copper River valley. Two trails are in use. One leaves Copper River at the mouth of Gulkana River and follows that stream to the head of its western fork. Crossing the divide to the Susitna drainage basin, it descends McLaren Creek to Susitna River and then turns northward, going up the river to the mouth of Valdez Creek. This trail traverses a broad, flat area, swampy and dotted with lakes, so that traveling is difficult

[1] These notes were obtained from prospectors who came from Valdez Creek in September, 1908. They are extracted from Bull. U. S. Geol. Survey No. 379, 1909, pp. 157-160.

at many places. The second trail follows the southern foothills of the Alaska Range westward to Valdez Creek from Paxton's road house, between Gulkana and Summit lakes, on the Valdez-Fairbanks trail. This trail was used during last summer (1908) and is said to offer many advantages over the more southern one. Food and mining equipment for Valdez Creek have usually been taken in over the southern trail in winter, but in 1908 contracts were made for the delivery of freight by boat at the head of navigation on Susitna River, whence it was to be taken overland to Valdez Creek with horses. The trip from Valdez Creek to the mouth of Indian River in the fall of 1908 was made with horses in eleven days, the distance being approximately 90 miles. Eldridge has stated [1] that Susitna River is probably navigable for light-draft stern-wheel steamers for a distance of 130 miles above its mouth, which would be to a point near the mouth of Indian River. In July, 1898, the little steamer *Duchany*, drawing about 2 feet of water, ascended the Susitna to a point within 12 miles of Indian River. It is believed, however, that this would not be possible later in the summer. A light steamer drawing 2 feet of water could probably reach the Talkeetna, 87 miles from Cook Inlet, at nearly all stages of open water, but it could traverse the remaining 35 miles to Indian River only on high water. When once established, this more direct route will doubtless result in a great saving of both money and time.

The excessive cost of freighting supplies into the region has hindered the development of mining and has prevented prospecting to a great degree. The average cost of supplies under present conditions is not far from 50 cents a pound, and the price paid for labor is $1 an hour without board.

The present importance of Valdez Creek lies in its gold placers, discovered in 1903. It is estimated that these placers have produced between $175,000 and $200,000. Mining is practically restricted to two localities on the creek—Lucky Gulch and the vicinity of Discovery claim, at the mouth of Willow Creek. The productive area is a small one, and although a large number of claims have been staked, only a few have contributed to the estimated output given above.

Valdez Creek has cut its present channel through deep gravels and has intrenched itself in the underlying schist bed rock. On claim "No. 2 above" the bench bordering the creek has a height of 170 feet. The lower 60 feet is rock, leaving a thickness of 110 feet of gravel.

Gold is found in the creek gravels and in the bench gravels. A considerable portion of that in the creek is probably derived from the benches and is therefore a product of secondary concentration. Gold is not distributed in paying quantity throughout the bench gravels, nor uniformly over the bed rock, but occurs in a well-defined pay streak—an old channel occupied by the stream before its present rock-walled channel was cut. The two channels intersect each other on claim "No. 2 above," the old channel being 60 feet above the present one. The portion of the pay streak or old channel on claim "No. 2 above" is exploited directly from the face of the bench, but the values of the Tommy claim are recovered through a tunnel starting from the bench face and crossing low-grade or barren ground of "No. 2 above." The entrances to these workings are of course 60 feet above the creek. Gold is found in paying quantities in the lower 5 feet of gravel and in the upper 2 feet of the schist bench on which the gravel rests. The average width of the pay streak is 40 feet, and it has been exploited for a distance of about 400 feet from the face of the bench.

A hydraulic plant was installed on Valdez Creek below Willow Creek in 1908, but until that time most of the work of washing the gravels had been done by hand methods. This plant includes a pipe line with two giants and an elevator. For the most part Valdez Creek affords good dumping ground for tailings, but unfortunately an elevator is required at the locality where this plant is in operation.

The gravels of Lucky Gulch are shallow, averaging about 4½ feet in depth. There is much coarse gold in the product of this gulch, nuggets ranging from $5 to $50 being frequently

[1] Eldridge, G. H., A reconnaissance in the Sushitna Basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 10.

obtained. The largest yet discovered had a value of $970. Lucky Gulch is reported to yield about $40 a day to the man.

In 1910, after the above was written, F. H. Moffit made a reconnaissance of the Valdez Creek region. The following statement is extracted from his report.[1] The bed rock of Valdez Creek is slate probably of Mesozoic age, locally altered into schist and cut by granitic dikes. South of the slates is a large area of basalt, and to the north an area of granite. The slates are locally cut by quartz veins which are in places auriferous and appear to be the source of the placer gold. The gravels in the creek bed which have been mined are from 3 to 8 feet thick. Placer gold has also been mined in an old channel 60 feet above the present stream bed.

### UPPER KUSKOKWIM BASIN.

Only the upper portion of the Kuskokwim basin is included in the Mount McKinley province, and in this portion no productive mineral deposits have yet been found. There is a possibility that the Birch Creek schist, which has yielded the placer gold in the Kantishna district, has a southwesterly extension paralleling the main range. If this proves to be the case, placer gold is likely to be found in the basin. The Paleozoic rocks in the foothill belt do not seem to be extensively mineralized, though a few colors have been obtained in the associated gravels. A few quartz veins have been discovered which carry metallic minerals. Spurr[2] found a few colors of gold in the gravels of the upper Kuskokwim, near the mouth of Styx River. In 1907–8 a party of prospectors found coarse gold on a tributary of the upper Styx and fine gold on the bars of Hartman River, in the same district. The location of this auriferous alluvium indicates that its bed-rock source was in the Tordrillo formation. It may have been derived from one of the contact zones of the granitic intrusive rocks. A gold-bearing quartz vein is reported to have been found in this vicinity.

### BONNIFIELD AND KANTISHNA DISTRICTS.[3]

By L. M. Prindle.

#### INTRODUCTION.

The northern foothills of the Alaska Range have been widely traversed by prospectors since the establishment of Fairbanks as a permanent supply point. In 1903 gold-placer mining commenced in the Bonnifield country, about 60 miles south of Fairbanks, and during 1906 the Kantishna region, about 150 miles southwest of Fairbanks and 30 miles north of Mount McKinley, was an area of considerable activity. These regions had produced, respectively, about $30,000 and $175,000 in placer gold. The writer and C. S. Blair, field assistant, were detailed to investigate the placers and also the deposits of lignitic coal of Nenana River, which were visited by the Brooks party in 1902.

The sketch map (fig. 28), with the foot traverses of the party in the two regions added to the topographic map made by the Brooks party in 1902, shows the geographic relations. The two most important geographic features of the entire area are the Alaska Range and the Tanana Flats.

The Alaska Range in this part of Alaska trends round from the northeast toward the east and is composed of lofty alpine ridges, surmounted here and there by beautiful peaks. (See Pl. III, in pocket.) Minor ridges flank the main range on the north, and their outer members descend with more or less abruptness to the level of the Tanana Flats. All the drainage flows to the Tanana. The main drainage lines extend northward, transverse to the ridges. Many of the upper valleys are gorged with glaciers and the lower valleys are a succession of narrow canyons interrupted by east-west valleys parallel to the ridges.

[1] Mr. Moffit's preliminary report on this area will be published in Mineral resources of Alaska—report on progress of investigations in 1910. Bull. U. S. Geol. Survey No. 480, 1911 (in preparation).
[2] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 260
[3] Taken mainly from Bull. U. S. Geol. Survey No. 314, 1907, pp. 205–221.

The Tanana Flats extend northward from the base of the foothills to Tanana River. They have a width in the area under consideration of about 30 miles. They widen rapidly toward the west, as the river flows northwest and the mountains recede to the southwest, and form an impressive foreground to the mountains. The flats absorb small streams from the foothills

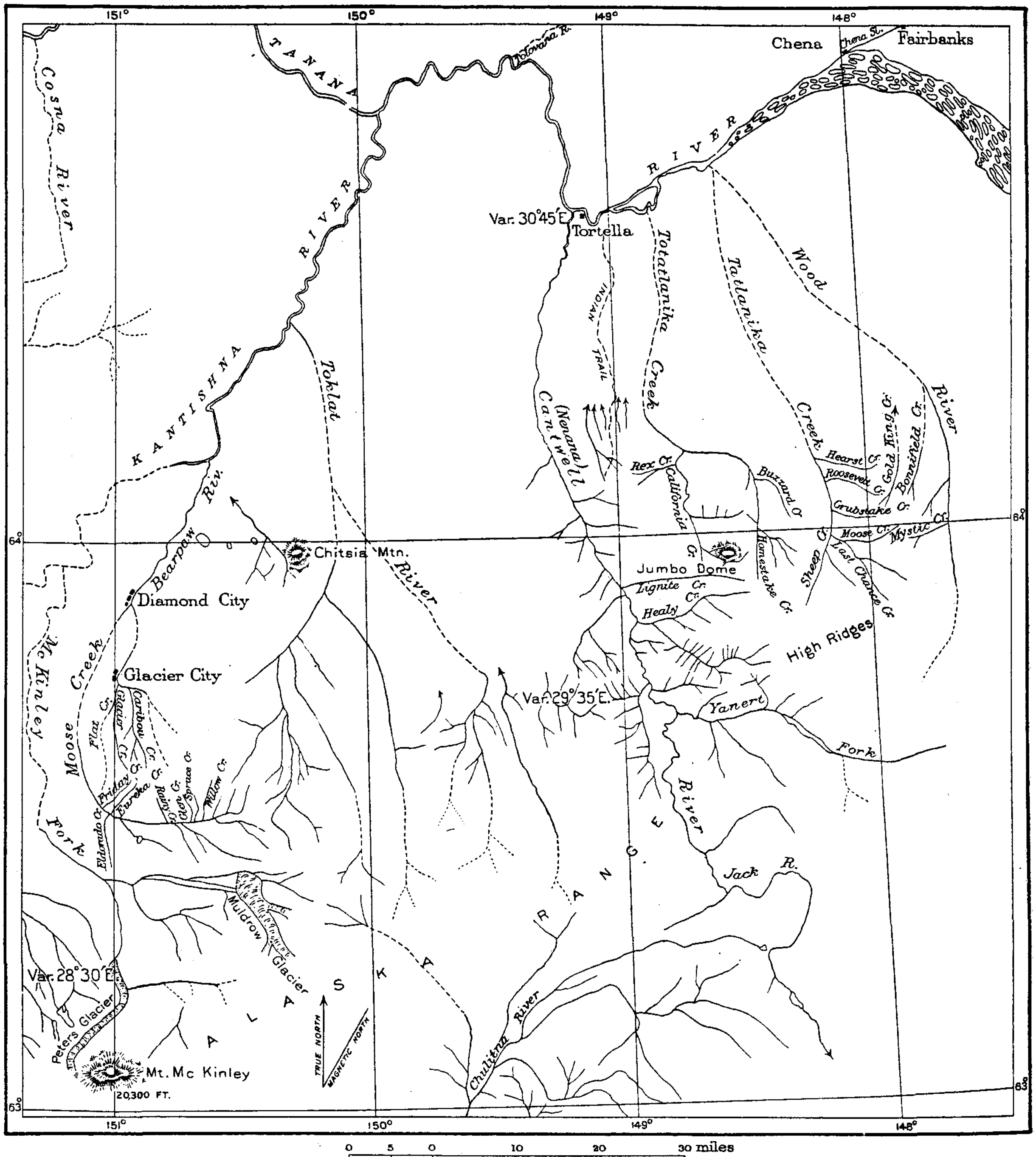
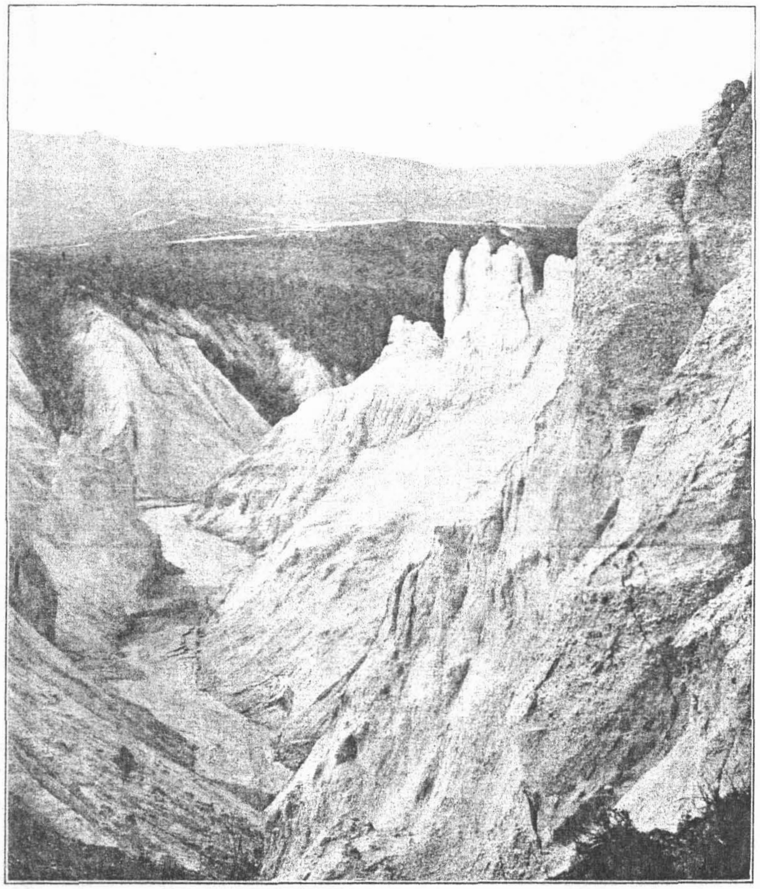


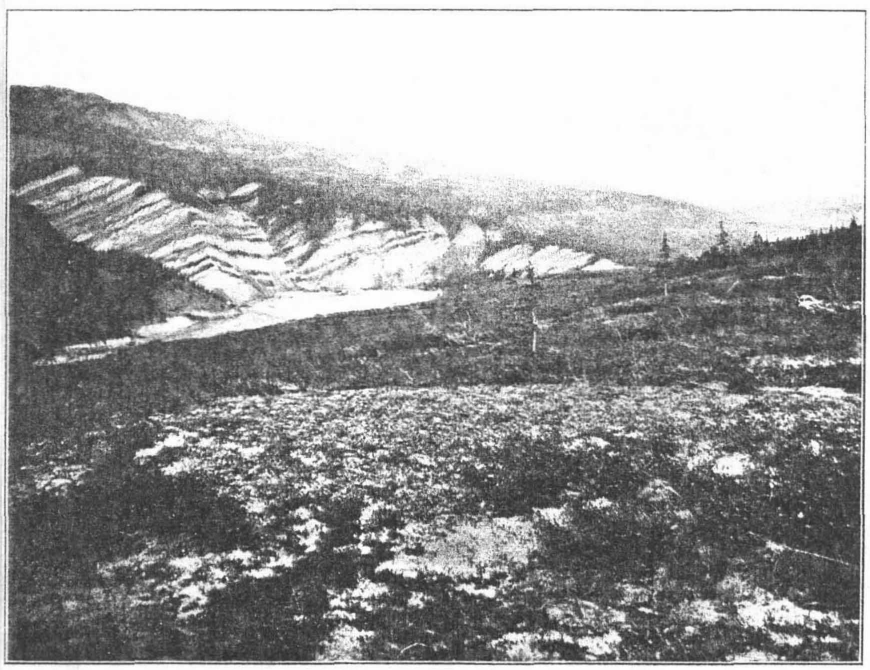

FIGURE 28.—Sketch map of Bonnifield and Kantishna regions.

and the surface is drained by swampy creeks, which cross them irregularly. The larger streams, a few miles after leaving the hills, meander sluggishly in no well-defined valleys and enter the Tanana with sloughlike inconspicuity. The surface is sparsely timbered with small spruce. tamarack, birch, and aspen, with a larger growth near the major streams and along



*A.* KENAI ROCKS ON ADAMS CREEK, A TRIBUTARY OF THE TOTATLANIKA, AT NORTHERN FRONT OF ALASKA RANGE.

Showing typical erosional forms. See page 97.



*B.* LIGNITIC COAL INTERBEDDED WITH WHITE SANDSTONE AND CONGLOMERATE ON HEALY FORK.

See page 189.

the base of the foothills. Swampy areas flecked with lakes are interspersed with patches of birch where the ground is bare and dry and the traveling therefore fairly good. Feed is good along the watercourses, but during the long hot days of summer there is scant relief for the pack animals from the horseflies and mosquitoes, which render an otherwise friendly area a place of almost constant torment.

The bedrock of the Bonnifield and Kantishna regions includes highly metamorphosed ancient rocks and loosely consolidated deposits of comparatively recent origin. (See Pl. IX, in pocket.) The most common distinction made by the miners is that between hard and soft bed rock, and this distinction is warranted by the conditions. The ridges are formed for the most part of metamorphic schists and igneous rocks; the intervening longitudinal valleys, of deposits in the main unconsolidated but older than those of the present streams. The most important fact economically is the distinction between the two groups of hard and soft bed rock. The hard bed rock from south to north includes a belt of highly metamorphosed schists, predominantly quartzitic schists with a small amount of interbedded crystalline limestone, and some carbonaceous schists; a belt of black slates with quartzite and cherty beds; and a belt of metamorphosed porphyritic feldspathic rocks. The belt of quartzite schists forms most of the bed rock in the Kantishna region, crosses Nenana River just south of Healy Creek, and extends northeastward to the south of the Bonnifield region; the slates occur in the high ridges at the head of the Totatlanika and the porphyritic feldspathic schists form the several ridges to the north. These porphyritic schists occupy large areas in the northern foothills of the Alaska Range. They were observed throughout the area between Nenana and Wood rivers. To the south they are interrelated with the black slates containing quartzite beds that succeed the quartzite schists. To the north they form the outermost ridges overlooking the Tanana Flats. Throughout this area are several prominent east-west ridges of these rocks rising 1,500 to 2,000 feet above the valleys that separate them. The color ranges from dark gray to white. The prevailing tone is whitish, from the weathering of the large amount of feldspar that the rock contains, and much kaolinic material has been contributed by this rock to the deposits that occupy large areas in the longitudinal valleys between the ridges. The rock ranges in character from a coarsely porphyritic sericitic variety with feldspars 4 centimeters or more in diameter to a fine, evenly grained white or gray sericite schist with no grains visible to the eye. These rocks are of igneous origin and comprise highly metamorphosed rhyolitic rocks with probably some associated tuffs.

The soft bed rock includes thick beds of slightly consolidated sands, clays, and fine gravels and many beds of lignite, all overlain by thick deposits of gravel. (See Pl. XVI, A.) Some of these deposits, at least, are of Tertiary age.

## BONNIFIELD PLACER REGION.

### GENERAL DESCRIPTION.

The region known as the "Bonnifield country" is named for John E. Bonnifield, who was one of the first men to locate in this part of Alaska. The name referred originally to the region immediately west of Wood River, but as prospectors explored valleys farther west the name came to be used in a broader sense, and for the purposes of this report includes all areas of placer mining between Wood River and the Nenana, 50 miles farther west.

The region is difficult of access in summer. The waterways are not easily navigable, even for small boats, yet supplies are sometimes brought in them about 40 miles upstream to points a dozen miles or more from the hills, whence they are transported overland by man or horse power about 20 miles to the creeks where they are to be used. Pack trains are occasionally taken over the flats along the west side of Wood River, but this method is expensive. Most of the supplies are transported during the winter, when streams afford good traveling for dog or horse sleds and the time consumed from Fairbanks to the creeks where mining is in progress is but a few days.

The region is delimited on the south about 20 miles south of the flats by prominent eastward-trending ridges which overlook it. The area between these ridges and the flats contains several ridges approximately parallel, with altitudes of 4,000 feet, and intervening spaces a few miles in width at a level 2,000 feet below that of the ridges. Isolated prominences like Jumbo Dome form important landmarks and the area is one of diversity.

### THE CREEKS.

The most striking characteristic of the drainage and one that finds explanation in the different conditions that once prevailed is the fact that the streams in general have cut canyons in ridge after ridge in their northward progress toward the flats. These canyons are for the most part narrow, and talus from the overtowering cliffs obstructs the streams. The intervening parts of the valleys are in general open, and gravel plains up to 1,000 feet or more in width have been developed. The gravels include angular bowlders from the hard bed rock, finer material of the same nature, and a large proportion of well-washed gravels, in the main rather fine, which have been derived from the unconsolidated deposits that occupy large areas in the longitudinal valleys.

The creeks on which most work has been done are Totatlanika with its tributary Homestake; Grubstake, Roosevelt, and Hearst creeks, tributaries of the Tatlanika; and Gold King Creek, which flows independently out of the hills into the flats.

*Totatlanika Creek.*—Totatlanika Creek is comparable in size to streams of the Yukon-Tanana country like the Chatanika. It is formed by the union of several tributaries which originate in a high schist ridge to the south. It flows northward toward the flats, cutting canyons in several ridges of the igneous schist, and has developed in the intervening spaces tributaries that drain large areas in which the hard rocks are largely covered with coal-bearing deposits.

Mining was being done at scattered localities on the main creek along a distance of about 6 miles and on Homestake Creek, a small tributary. The conditions on the main creeks at all the localities are similar. The stream flat attains a width in the more open parts of the valley of several hundred feet, and the grade of the valley is approximately 100 feet to the mile. The quantity of water varies greatly. At ordinary stages there are, on a rough estimate, perhaps a dozen sluice heads available, and for the most successful working, by the methods employed, a low stage of water is desirable. The gravel bars at low water are mostly bare, and it is there and in the stream bed that the mining is being done. The bed rock includes hard, blocky porphyritic feldspathic schist with some associated carbonaceous schist and abundant quartz veins. A belt of andesitic rocks crosses above the mouth of Homestake Creek. The gravels are derived from these varieties of bed rock and from the unconsolidated coal-bearing deposits, which supply many vein-quartz and chert pebbles, pieces of lignitic coal, and a few large bowlders of the granite and greenstone that occur in the uppermost beds of these deposits. The thickness of the stream gravels where work is being done ranges from 3 to 6 feet.

The gold is found in most places scattered through the gravels, but in others is confined to the surface of the bed rock, and where this is blocky is generally found to a depth of 3 feet or more within it. The gold is mainly flat and most of the pieces are less than a quarter inch in diameter. Occasionally pieces are found worth 25 cents, and a $2 piece was the largest noted. It is all well worn. Pay has been found over widths of 50 to 100 feet, with values up to 1½ ounces a day to the man, but too little work has been done to give definite information regarding the average dimensions, values, or persistence of the pay streak.

Mining is done by open cuts in combination with wing dams. The ground is for the most part free from frost, and the only trouble from this source has been experienced in constructing bed-rock drains. Wing dams are used to deflect the water from the ground that is being worked, and water for sluicing is carried from the dam a distance of a few hundred feet to the sluice boxes. These are given a grade preferably of 9 inches to the box. There is but little sediment in the gravels and no dump boxes are used.

The timber available for sluice-box lumber in this part of the valley is limited, and lumber is packed 5 to 25 miles from the lower canyon in the winter. About a dozen men were working on the creek during the summer of 1906.

*Homestake Creek.*—Homestake Creek is a small stream, about 4 miles long, which enters Totatlanika Creek in the uppermost canyon. The valley consists of two parts of different character. The upper part is open and flat—hardly more than a depression in an undulating, well-nigh timberless area several miles wide that extends east and west between the ridges. The lower part is a deep canyon with vertical walls of andesite that crowd the stream to a narrow, crooked course and burden it with great fragments. The grade of the upper valley is approximately 100 feet to the mile; that through the canyon is over 200 feet to the mile. The amount of water carried by the stream is, during a dry season, insufficient for mining purposes. The bed rock of the upper valley is composed of unconsolidated clay and sand of the coal-bearing formation; that of the lower valley is the igneous rock of the canyon.

Most of the mining has been done at the upper end of the canyon and in the open part of the valley half a mile farther upstream. The deposits that are worked range from 2 to 6 feet in thickness. Gold has been found in 2 to 3 feet of gravel, and part of it is coarser than that of Totatlanika Creek, one piece worth $15 having been found. All the gold apparently is well worn. The stream heads in gravels and above the canyon has not yet cut down to hard bed rock, and it would seem that the gold has been derived from the gravels.

There are but few trees in the upper valley. Sluice-box lumber and even firewood are packed from the main stream. Some of the ground prospects well, but so little work had been done at the time of visit that the possibilities of the creek were not definitely known. Unlike those on the main stream, successful operations on Homestake Creek are dependent on abundant rainfall.

*Tatlanika basin.*—About 10 miles east of Totatlanika Creek is the Tatlanika, formed by the union of Sheep and Last Chance creeks. This is a somewhat larger stream and has developed for itself in the section of the valley under consideration a gravel plain several hundred feet wide, with a grade of about 90 feet to the mile. A finely preserved bench 40 feet high and half a mile or more wide limits the stream on the west, and 3 miles to the west high gravel hills separate the Tatlanika drainage basin from the headwaters of Buzzard Creek; on the east are blunt terminations of low, broad ridges that separate the small tributaries entering from that side—Grubstake, Roosevelt, and Hearst creeks, on which most of the mining is being done. These enter in the downstream order given, the mouths being separated by distances of 3 miles and 1 mile, respectively. The creeks are similar in size and character, and gold occurs on all of them under about the same conditions and with apparently the same origin. The Tatlanika in this area has not yet cut down to hard bed rock, and these minor streams have cut narrow valleys for themselves in the unconsolidated gravels, clays, and sands of the coal-bearing deposits. Grubstake Creek heads along the contact of the schistose bed rock and the soft deposits and is the only one of the three that has the hard bed rock within its drainage basin.

Mining on Grubstake Creek is confined to a mile of the lower valley. The stream is 200 to 300 feet below the steep inclosing slopes of soft material and the stream flat is 150 to 300 feet wide. The grade is approximately 100 feet to the mile. At the lowest stage the creek carries approximately a sluice head of water. The bed rock is sticky clay, sand, and coal, all three distinct from the stream deposits. The thickness of the gravels that are being mined ranges from a few inches to 6 feet. These gravels include both fine and coarse material, with a small proportion of bowlders. They are made up of schist, vitreous quartzite, compact conglomerate composed largely of chert pebbles, vein quartz, chert, granite, and diabase; the amount of sediment in them is small.

Gold is found scattered through about 2 feet of gravel or confined mostly to the surface of the clay bed rock. The pay streak has a width of 25 to 75 feet, but outside of 25 feet is reported to be patchy. The coarsest piece found was worth $1.43 and the gold is valued at $17.35 an ounce. The common variety is composed of small flat pieces, all well worn. Mining is done by open cuts. In some places a few feet of the top gravel is stripped off, but generally all the material from surface to bed rock is shoveled in, and the character of gravel and bed rock is such that 6 cubic yards a day per man can be handled. The black sticky clay which forms the bed rock, after being cleared of the stream gravels, contains considerable gold which has settled into its surface or been trodden into it in the progress of the work, and experience has shown that the best way of saving this is to strip off a thin layer one-fourth inch or more thick, leave it in the sluice boxes overnight with a small amount of water running over it, and in the morning stir it with a sluice fork. The loosened mass then easily yields up its gold. The boxes are set on a grade of 8 or 9 inches to the box. The lumber for mining purposes is brought from the lower canyon of the Tatlanika, a distance of 14 miles. Some mining was done during 1905 and half a dozen men were at work during 1906.

The lower part of the valley of Roosevelt Creek is rather open and is covered with a light growth of small spruce. The mining area is about 2½ miles above the mouth, where the valley is narrow. The bed rock is sticky clay and yellowish sand that belong to the coal-bearing formation. The stream gravels are similar to those of Grubstake Creek and are derived from the thick bed of gravels that caps the sands and clays. They are shallow, and gold occurs in 1 to 1½ feet of gravel over a width of 20 to 60 feet. The gold is small, flat, and well worn, the coarsest piece found being worth about 45 cents. At the time the creek was visited there was insufficient water for sluicing. The gold has most probably been concentrated together with the stream gravels out of the thick gravel deposits in which the creek originates. A point to be emphasized is that the soft clays and sands which form the bed rock are just as truly bed rock to the stream gravels that overlie them and carry the gold as if they were hard rock. A thickness of several hundred feet of these unconsolidated deposits may overlie the hard bed rock, and any attempt to sink through them to the solid formation would be not only a most difficult task, but, inasmuch as the only run of gold known overlies them, would be in all probability useless.

The conditions on Hearst Creek are similar to those on the other two streams. In the lower part of the valley the creek meanders deeply in a narrow canyon, exposing sections 100 feet thick of the unconsolidated light-colored cross-bedded sands and fine gravels of the coal-bearing formation. These deposits in places have been benched and capped with stream gravels. The upper part of the valley is more open and the stream heads in the thick gravel beds that overlie the sands and clays. The only work that has been done is at a point about 2 miles above the mouth, where in 1905 a few thousand dollars' worth of gold was reported to have been mined. In 1906 this locality was being prospected.

*Gold King Creek.*—Gold King Creek is about 8 miles east of the Tatlanika. The stream heads in hard bed rock and flows through a V-shaped valley sunk to a depth of 1,200 feet below the inclosing gravel ridges. Long, flat, tonguelike spurs extend from these ridges into the narrow stream flat. The grade is about 100 feet to the mile, and the quantity of water at the lowest stage is approximately three sluice heads. The bed rock at points where mining is in progress is clay. The gravels include the same varieties as are found on the other creeks, and the proportion of bowlders 3 feet or more in diameter is large. They lie scattered through the gravel and have acted as efficient riffles in retaining the gold. The thickness of the gravels that are being mined ranges from 4 to 8 feet. In some places gold is found in 4 to 5 feet of gravel; in others it is mostly near the clay bed rock. Generally about 2 feet of overburden is ground sluiced off, and from 1½ to 4 feet shoveled into the boxes. The gold is flat; there are many pieces over one-fourth inch in diameter, and the coarsest piece was worth $1.25. This gold is said to assay $17.82 to the ounce. Some of the ground is reported to yield about 1½ ounces to the shovel. All the mining is done by open cuts, and the presence of so many bowlders retards the work. Shoveling in can begin in some seasons about the 1st of June. In 1906, however, on account of the extent of glaciers in the creek, work did not begin until June 20. The gold, like that of the other creeks, probably originates in the high gravels, and these are reported to carry prospects in many places far above the creek and even on the surface of the high, flat ridges. About a dozen men were working on the creek in 1906, and wages were $6 and board per day.

### SUMMARY.

The creeks of the Bonnifield region may be divided into two classes—those that have, in a part of their valleys at least, cut into hard bed rock, and those that are still cutting their valleys entirely in unconsolidated deposits, including gravels, sands, clays, and coal beds. The greatest part of the gold has in all probability been derived from the thick gravels. The form of its occurrence in these thick deposits is unknown. It may be regularly distributed through them, it may be confined to some particular stratum in which it is spread broadly, or it may occur as a more or less clearly defined pay streak. The material of the gravels is all found in the ranges to the south. The gravels were deposited under conditions much different from those of the present time and are probably mixed in their upper part with some glacial material.

The only general test of the values that these gravels may contain thus far available is that afforded by the gold found in the gravels of the present streams. Although fair pay has been found in places on some of the creeks, it would seem that if the high gravels carried noteworthy values the placers derived from them would be much richer than they have yet proved. All the work has been accomplished on a small scale under adverse conditions. Most of the mining is being done above the timber line. The work is hampered and in some places brought to a standstill by lack of water. The soft nature of the bed rock in some of the creeks means a prodigious amount of material that clogs the work and complicates the situation caused by lack of water. In general it may be said that the quantity of gold is not so great as to overshadow the economic factors of water supply, character of bed rock, presence or absence of bowlders in the gravels, timber resources, and transportation, but that these are everywhere the determining factors in the situation.

## KANTISHNA PLACER REGION.

### GENERAL DESCRIPTION.

The rich shallow diggings discovered in the Kantishna region in 1905 were found to be of smaller extent than was at first supposed, and the results of 1906 were unequal to expectation. During the fall of 1905 there was much travel by steamer from Fairbanks. Passengers and freight were carried at $40 apiece and $50 a ton, respectively, and landed at Roosevelt, on McKinley River, or at Diamond, 60 miles above the mouth of the Bearpaw. The town of Glacier also was established 12 miles from Diamond, at the mouth of Glacier Creek, about midway between the steamer landing at Diamond and the placers of Glacier Creek. During the winter of 1905–6 there was much travel between all these places and the creeks, and the winter trail from Fairbanks up Nenana River to the road house at the crossing and thence overland was also used extensively. The month of February found many already on the back trail. During the summer of 1906 the town of Roosevelt, situated remote from the creeks across an 18-mile stretch of swampy tundra, became practically deserted, and in the fall the many empty cabins of Glacier and Diamond testified with depressing emphasis to the decadence from the activities of the previous year.

The Kantishna placers, about 30 miles directly north of Mount McKinley, are in an outlying ridge somewhat apart from the main range and separated from it by high bare hills, which form the foreground to this portion of the range. This ridge trends northeast and southwest, and its most prominent summits have altitudes of 4,000 to 4,700 feet. To the southwest it abuts against the foothills; to the northwest it descends abruptly to the level of long, flat slopes that extend for miles from the base of the hills into the extensive flats of the Kantishna Valley.

The slopes are deeply furrowed by narrow V-shaped valleys. The drainage on the south runs into Moose Creek, a stream that heads far back in the foreground of the mountains, flows close along the southern base of the ridge in a finely benched open valley, and finally cuts a canyon through the ridge to flow northward to the Bearpaw. The streams that drain the northern slopes have long lower valleys limited on either side by the edges of low tonguelike spurs.

The material of the ridge is for the most part a highly metamorphosed and closely folded quartzitic schist, with garnetiferous quartz-mica schist, carbonaceous schist, a small amount of interbedded crystalline limestone, and much greenstone, part of which at least is intrusive. This formation is like that at the canyon of Nenana River, south of Healy Creek, and is the same in character as that of the Fairbanks region. The occurrence of gold also and the associated minerals is the same for the most part as in the Fairbanks region. The formation has in general a northeasterly strike. The foreground of the mountains to the east is formed of hornblende granite and granite porphyry and some dikes of granite porphyry cut the schists. Small areas of the coal-bearing rock occur in the region and coal from a fork of Moose Creek is utilized to some extent for blacksmithing purposes. The extension of the schist area to the southwest has not been determined. Topographically it terminates apparently at McKinley River; to the northeast it is probably continuous with the schists of the Nenana Canyon. The rocks of the Alaska Range to the east are in general black slates partly altered by contact metamorphism, greenstones, intrusive granitic rocks, and volcanic rocks.

### THE CREEKS.

The creeks head in open V-shaped areas formed by the convergence of two or more small tributaries. The lower parts of the valleys are narrow canyons. Where these join the main valleys benching is prominent, and their deposits merge into the immense body of gravels that has been spread far and wide from the Alaska Range. This material is for the most part easily distinguishable from the schistose gravels of the creeks.

The creeks where mining has been done are located on both sides of the ridge. Named from east to west on the south side of the ridge, round the west end, and eastward along the northern slope, they are as follows: Spruce, Glen, Eureka, Friday, Glacier, and Caribou.

*Spruce Creek.*—Spruce Creek flows its last mile in the valley of Moose Creek. Above this part of its course for about 1½ miles the valley is narrowly V-shaped, but near the head it is more open. The grade in the narrow part is about 350 feet to the mile and the amount of water carried at ordinary stages is about 2 sluice heads. The lower valley has a considerable growth of spruce in a narrow belt near the stream. The bed rock observed is predominantly quartzitic schist, with some carbonaceous and green schists. The only point where mining was being done is about 2½ miles upstream, above timber line and about 700 feet above the level of Moose Creek. The gravels at this point are about 3 feet thick and comprise quartzitic schists with a small proportion of green schist, carbonaceous schist, crystalline limestone, and vein quartz. Pay is found over a width of about 12 feet. The gold occurs mostly on bed rock and to a depth of 2 feet within it. Much of the gold is coarse, and the largest piece found was valued at $6.40. Some of it is rough and has quartz attached, and there is no reason to doubt its local origin. Three men were working at this locality. Their sluice boxes were made of lumber packed from Glen Creek and were set on a 10-inch grade.

*Glen Creek.*—Glen Creek is somewhat larger than Spruce Creek and is more deeply cut below the spurs that rise nearly 1,000 feet above it on either side. From the forks to the mouth, a distance of 3 miles, there is a grade of about 500 feet. The gravels are similar to those of Spruce Creek, being predominantly quartzitic schist, and where work is being done they range from a few inches to about 3 feet in thickness. In some places gold is found through 2 feet of gravel and at others it is all on or within bed rock. The width over which pay is found ranges from 30 to 150 feet, and values have been reported of $20 to $100 to the box length, or approximately a maximum value of 65 cents to the square foot of bed rock, but their distribution is irregular. Much of the gold is coarse; several $8 to $10 nuggets have been found, and the largest piece discovered weighed over 3 ounces. A few garnets are found associated with the gold. At the time of visit most of the miners had left for the season and it was reported that only about 7 men would winter on the creek.

*Eureka Creek.*—Eureka Creek proved to be the best producer of the region. It is a small creek, only about 5 miles long, flows southwestward in a deeply cut valley, and enters Moose Creek just below the point where that stream has turned northward through the ridge. The valley of Moose Creek at this point is a flat several hundred feet wide, and the creek itself, a powerful stream, swings round to the east and is cutting laterally into the bed rock just at the point where Eureka Creek enters. The valley of Eureka Creek has a grade of about 235 feet to the mile, and the smallest quantity of water flowing during the season of 1906 was reported to be 2 sluice heads. The bed rock is principally quartzitic schist, with some associated carbonaceous schist and greenstones. Small basaltic dikes were observed in a few places cutting the schists. Throughout most of the valley the stream gravels are composed of material derived from the bed rock, but in the lower part of the creek these rather fine subangular schist gravels become mixed with material derived from the heavy Moose Creek wash that rests on a bench over 150 feet vertically above Eureka Creek. In the process of downward cutting through which the drainage system has passed these bench gravels, comprising bowlders of granodiorite, greenstone, hard conglomerate containing chert pebbles, and metamorphic slates, all of these being materials mostly unlike those characteristic of the Eureka Valley but entirely similar to those of the Alaska Range, have become intimately mingled with the local deposits.

Mining has been confined for the most part to 2 miles of the valley immediately above the mouth. The thickness of the deposits that are being worked ranges from 1 to 5 feet and the width is in most places that of the stream gravels, which is rarely more than 100 feet and in some places less than 20 feet. The gold is mostly on bed rock or within it to depths of 1 to 3 feet, but all the gravel from surface to bed rock is generally shoveled into the boxes. The richest ground was in the first half mile above the mouth, where many nuggets were found, the largest two of which were worth $186 and $678. Nuggets are not confined to this part of the creek, however, and some worth as high as $40 have been found 2 miles above the mouth. The nuggety gold is generally of a lighter color than the finer grade. The gold found in the upper part of the valley is mostly rough and gritty. Average assay values were reported ranging from $15 to $16 an ounce. The proportion of black sand accompanying the gold is small. Here and there pieces of stibnite occur in the gravels, and these have been derived, probably like similar occurrences on Caribou Creek, from veins in the schists. The association in this respect is similar to that of the Fairbanks region.

The reason for the richness of the gravels near the mouth has often been a subject of inquiry, and it might be supposed that a part of the gold at least was derived from the heavy Moose Creek bench gravels through which Eureka Creek has cut. So far as could be learned, however, these bench gravels are not known to carry profitable values, and the explanation is rather to be found in the riffle efficiency of large bowlders in retaining gold that would otherwise be carried out from the smaller valley along with the finer wash. A decrease of grade of the smaller stream near the mouth may also be a factor.

All the gravels are worked by the open-cut method. Boxes are given grades ranging from 7 to 9 inches to the box. There is but little sediment in the gravels and no dump boxes were employed. The flats of Moose Creek opposite the mouth of Eureka Creek are covered with a light growth of small spruce and a few small spruce dot the steep slopes of the lower Eureka Valley, but lumber for mining purposes has to be brought from points 6 miles down the Moose Creek valley.

Gold was discovered on Eureka Creek in July, 1905. The richness of the gravels justified to a great degree the stampede that followed. The richest ground that has been discovered was mostly exhausted during July and August, 1906, when there were 50 or more miners on the creek. Wages during the busiest time of the season, when shifts were working night and day, were $1.25 an hour, paid in gold dust valued at $16 an ounce. There was a settlement of considerable size at that time on the flat of Moose Creek just above the mouth of Eureka Creek. A restaurant was in operation, with rates for board alone of $4.50 a day, and there were small stores where supplies of various kinds were obtainable. About a dozen men were working in August, 1906. Various estimates of the output were reported, ranging from $150,000 to $160,000.

A small amount of work was done during the summer of 1906 in the canyon of Moose Creek, about 5 miles below Eureka Creek, and some pay was reported.

*Friday Creek.*—Friday Creek is 2½ miles long and carries at the lowest stage about half a sluice head of water. The valley is cut to a depth of 1,500 feet below the inclosing ridges. The upper part, where small streams unite, is somewhat openly V-shaped; the lower part is very narrow and has a grade of over 400 feet to the mile.

Mining is confined to about a mile of the creek above the point where it emerges into the valley of Moose Creek. The bed rock includes quartzite schist, carbonaceous schist, greenstone, crystalline limestone, and dikes of granite porphyry. The gravels are formed mostly of these materials and are from 3 to 6 feet thick. Gold is found in 1½ to 2 feet of gravel and about the same thickness of bed rock. The gravels are in some places limited to the narrow space of 12 feet between the bed-rock walls; in others they reach 100 feet in width. Both nuggets and fine gold are found. The nuggets range in value up to $29. Many of them contain much quartz and are very rough and some are rudely crystallized. Scattered pieces of galena several inches in diameter are found in the stream gravels, and one of these was assayed for the Survey and found to carry 184.76 ounces of silver and 0.20 ounce of gold to the ton. Only 6 men were working on the creek in 1906.

*Glacier Creek.*—It is about 8 miles around the base of the hills from Friday Creek to Glacier Creek. The latter is a larger stream than the other creeks that have been described, heads against them, and after emerging from its deep V-shaped canyon flows for several miles between broad, level-topped ridges before it joins the Bearpaw. Cabins were built at intervals along the entire length of the creek during the winter of 1905–6, but the area that proved most productive is a section of the valley about a mile long where the creek emerges from the hills into the area of long gravel-covered ridges. Near the end of the season of 1906 it was reported that pay was being found also on Yellow Creek, a small tributary near the head.

Glacier Creek, although considerably smaller than Moose Creek, is a powerful stream, and there has been no lack of water for mining purposes. The grade of the valley in the part that is being worked is approximately 130 feet to the mile. The bed rock observed comprised quartzite schists, greenstone schists, and garnetiferous mica schists, with abundant quartz seams and lenses. The gravels are coarse and the proportion of bowlders is large. The thickness of the deposits in the working area ranges from 2 to 5 feet and the width in places is 250 feet. The gold is mostly on bed rock. The creek meanders sharply at its point of emergence from the hills, and the best pay is reported to have been found just above the points of the meanders. Values have been found ranging from $75 to $200 to the box length, and the gold is reported to be worth $16.40 an ounce. Many nuggets have been found, and the largest was valued at $365.

At the point where the stream leaves the hills there is a bench about 75 feet above the creek, capped by 3 to 5 feet of gravel underlying 6 to 8 feet of muck. Gold occurs in about 18 inches of the gravel and is yellower and flatter than the creek gold. Several areas of the bench gravels were reported to prospect, but insufficient work had been done to determine their values definitely. All the work was done by open cuts, and some of the lumber for sluice boxes was packed distances of 12 to 14 miles from Moose Creek. In the fall of 1906 there were approximately 20 men on the creek.

*Caribou Creek.*—Caribou Creek is somewhat larger than Glacier Creek, but in other respects the conditions on it are similar. There is the same variety of bed rock and deposits, but up to the present time (1907) no well-developed pay streak has been found. In the early part of the season of 1906 considerable work was done on Crevice Creek, a small tributary near the head. The gold was found to be rough and coarse, the largest piece being valued at $90. At the time Caribou Creek was visited by the Survey party but few men were working.

Stibnite (antimony sulphide) occurs in the wash of Caribou Creek, and a ledge containing this mineral has been located a short distance above the point where the creek emerges from the hills into the benched area of the lower valley. The creek forks at this locality, and on the southern fork, which has been named Last Chance, the ledge is exposed. The vein is about 4 feet thick, and the vein matter includes essentially quartz and stibnite. The quartz is partly massive and partly in the form of small crystals up to an inch in length. The antimony sulphide is in part a crystalline mass embedded in the spaces between the quartz crystals and in part a bluish-black, very fine-grained massive variety. The ledge strikes northeastward and dips 75° N. The country rock is hornblende schist, to the structure of which the vein conforms. A short distance upstream the hornblende schist is structurally conformable to the quartzitic schist. A small amount of work was being done here in the hope that the ledge material would be found to carry values. Of three specimens from this locality assayed for the Survey two contained silver at the rate of 4 and 2.76 ounces to the ton and the latter carried in addition 0.12 ounce of gold to the ton; the third specimen contained 0.12 ounces of gold but no silver. Too little work had been done to give definite information regarding the proportion of the antimony sulphide in the vein, but pieces of nearly solid ore up to a foot in diameter were obtainable.

### SUMMARY.

The Kantishna placers are in an area of crystalline schists. The gold-producing creeks head near each other. The bed rock of all the creeks comprises practically the same kinds of rock and the gravels are shallow. The bulk of the gold has in all probability been derived from the valleys in which it is found. The occurrence is not confined to any particular section of the valleys, but is such as to suggest a derivation from different points along them. The manner of its occurrence in the bed rock is indicated by the many pieces found in most intimate association with quartz, by a small, flat nugget one-tenth of an inch thick attached to garnetiferous mica schist, and by the occurrence of silver and gold bearing galena and stibnite in the gravels of several creeks. Pieces of these sulphide ores a foot or more in diameter were observed in the gravels, and the fact that in one place high values in silver with some associated gold were carried by this material lends not only a qualitative interest to this occurrence but a quantitative one as well. The vein of stibnite on Caribou Creek, although carrying in the material tested no high values in silver or gold, illustrates the form of occurrence, and its interest is enhanced from the fact that the metal antimony, which forms about 70 per cent of the mineral stibnite, is at present (1907) in considerable demand. Regarding the question whether there is sufficient high-grade silver ore or stibnite to pay for working, nothing definite can be said. It is probable that both the lead and antimony sulphides and the small amount of iron pyrites associated with them occur as small veins scattered through the schists. Although both stibnite and galena resemble each other to some extent, the former has often been determined by miners through its character of fusing readily in the candle flame. The coarser varieties can also be distinguished from galena by their lighter color and somewhat fibrous texture. The coarser varieties of galena break into little cubes.

There is a great resemblance between the Kantishna and Fairbanks regions. The geologic environment and mineral associations are practically the same. The essential difference is apparently one of physiographic development. The Kantishna region is in a youthful stage. The valleys are narrow and have steep grades, and their deposits are consequently shallow and have undergone less shifting with the accompanying gravitative differentiation of the heavy constituents to the vicinity of bed rock.

The bulk of the production has come from Eureka Creek and most of the remainder from Glacier Creek. The conditions on Eureka Creek probably find an explanation in the fact that the heavy foreign wash derived from the bench near the mouth, working in combination with a decrease in grade, checked to a greater or less extent the removal of the gold that was being brought down the valley of Eureka Creek while the canyon was being cut, and thus brought about an enrichment at this particular point. There is the possibility, too, that the bench gravels contributed a part of the gold. It is noteworthy in this connection that the richest ground on Glacier Creek is at the point where the valley emerges from the hills into the benched area that surrounds their base.

There was no lack of water during the summer of 1906, but in a dry season the small creeks shrank below the economic limit. The timber resources in the vicinity of the hills are scanty. There is some fair timber along parts of the valley of Moose Creek and this increases in quantity toward the mouth, but in general the localities where mining is done are above the limits of good timber, and lumber has to be packed for several miles. The town sites of Glacier and Diamond are well timbered, and the valleys of the Bearpaw and Kantishna contain many small areas of fine spruce.

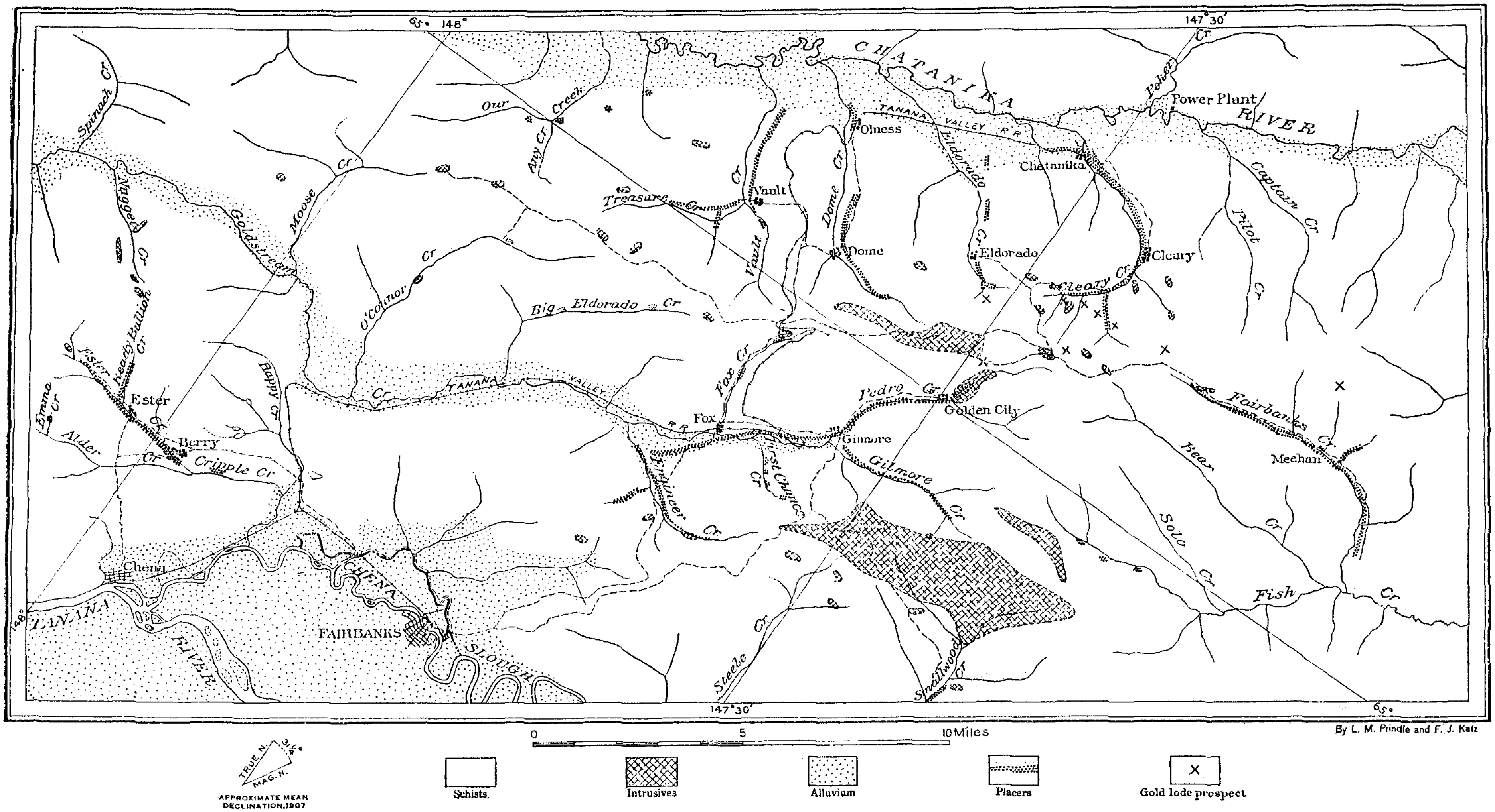
Steamer transportation during the summer of 1906 was very irregular, and the accessibility of the placers to the points where it is possible to land supplies from steamers is rendered difficult on account of swampy areas that in places well-nigh block the approaches to the hills. Up to the present time but little attempt has been made to construct summer trails, as most of the transportation between the creeks and the local supply points has been done in winter.

The auriferous gravels thus far discovered are adapted only for summer work, when sluicing can be done from about the 1st of June to the early part of September, and the rich ground first discovered has been largely worked out. There is ground still remaining that is said to contain some pay, and about 50 men intended to remain during the winter of 1906–7 to prospect.

NOTE.—Since the above account was written there has been no material change in the Kantishna district. Some engineers have examined the Bonnifield district with the view to determine the economic possibility of exploiting some of the heavy gravel deposits. In 1909 a hydraulic plant was installed on a tributary of Wood River. In 1909 also much interest was excited among mining men by the discovery of auriferous lodes near the northern base of the Alaska Range and in the Bonnifield placer district. These lodes lie about 40 miles south of Fairbanks and can be reached by a direct trail during the winter. In summer they are accessible only by long horse trails via either Little Delta or Nenana River. In 1910 this region was examined by S. R. Capps,[1] who reports that there have been no new discoveries of placers since Prindle's investigations, except on Moose Creek, an easterly tributary of the Nenana, about 40 miles from the Tanana. In 1909 and 1910 some gold was produced on this creek. The largest enterprise in this district in 1910 was a hydraulic plant installed on Gold King Creek. In all about 12 miles of ditch have been constructed to supply this plant. It is proposed to hydraulic the heavy bench gravels with this equipment. The future of this phase of mining in this district is dependent on the gold content of the gravels, which so far does not appear to have received very close attention.

Capps reports that the gold of the district seems to have been derived from schists which form the prevailing bed rock and suggests that its source is in the contact zones of granitic intrusives. On Chute Creek there is a complex series of schists cut by intrusive rocks. Some zones in the schists are heavily charged with pyrite and are reported to carry gold values. One zone of mineralization, so far as can be determined, has a width of about a hundred feet. The owners of this property report it to carry about $9 in gold to the ton, about half being free. If the assays made represent average samples, the value of the ore body seems to be assured. This ore body has been penetrated by a 30-foot tunnel, throughout the length of which the schist showed the same character. Capps also reports that a little work has been done on a mineralized zone on Kansas Creek, a tributary of Wood River.—A. H. B.

[1] A preliminary report on Capps's investigations will be published in Mineral resources of Alaska—report on progress of investigations in 1910: Bull. U. S. Geol. Survey No. 480, 1911 (in preparation).




GEOLOGIC MAP OF FAIRBANKS DISTRICT.

See page 181.

## FAIRBANKS DISTRICT.

By ALFRED H. BROOKS and L. M. PRINDLE.

It is not intended to present here a detailed account of the Fairbanks district, for which the reader is referred to the published reports.[1] As, however, the greater part of this district is covered by the accompanying maps (Pls. III and IX, in pocket) and as it forms the most important commercial center of the province, it seems desirable to present a brief summary account of its gold deposits.

As defined by the gold discoveries up to 1908, the auriferous zones of the Fairbanks district lie in an area including 350 to 400 square miles, which stretches from the Cripple Creek basin on the southwest to the Fish Creek basin on the northeast, a distance of about 30 miles. This area has a width varying from 10 to 15 miles. As the same general geologic conditions are believed to prevail both to the northeast and to the southwest of this area, it is possible that further prospecting may show the presence of other mineral-bearing zones.

On the northwest the district as defined is bounded by the broad alluvium-floored valley of Chatanika River and on the south by the lowlands of the Tanana. (See Pl. XVII.) The western half is interrupted by the broad depression occupied by the valley of Goldstream Creek. The topography is characterized by long, flat-topped ridges broken by higher domes. The ridges are from 1,000 to 2,400 feet in elevation; the domes stand a few hundred feet higher. The streams throughout the district have broad, flat valleys with very low gradients. This fact makes the disposal of tailings a difficult problem. Small tributaries of the larger creeks, however, have steeper gradients with narrow valleys, and in places these valleys are cut to bed rock. All the larger streams flow on alluvial floors.

The country rock throughout the district is chiefly quartzite, quartzite schist, and mica schist. (See Pl. XVII.) All these belong to the group which has been termed the Birch Creek schist (p. 56). Interbedded with these schists are lenses of crystalline limestone and some schistose greenstones. The limestone is in some places represented by metamorphic rocks made up entirely of secondary minerals. Granitic and dioritic intrusive rocks occur as dikes and large stocks, many of the latter being expressed in the topography by domes. In addition to these there are some small dikes made up of a more basic rock.

The region as a whole is almost lacking in bed-rock outcrops except along the crest lines of the ridges, where the rock is deeply weathered. Studies of the bed-rock geology therefore have been exceedingly difficult. In fact, in many areas the character of the bed rock was not ascertained until it was revealed by the operations of the placer miner.

The alluvial deposits include gravel, sands, clay, and muck. The muck contains a large amount of vegetable matter, with a considerable percentage of clay and sand. The depth of the muck varies greatly on different creeks and also on the same creek, the minimum thickness being from 2 to 3 feet and the maximum 100 to 160 feet. The gravels rest on bed rock underneath the muck and vary in thickness from 3 feet up to 135 feet. Most of the gravels are well rounded, but in places the lowest layer next to bed rock is subangular. The pebbles are all from rocks outcropping within the stream basins.

In addition to the alluvial material described above, there is a widely distributed deposit of fine silt, locally several hundred feet in thickness, which occurs as a terrace along the larger streams.

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[1] Brooks, A. H., Reconnaissance in the White and Tanana River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 431–494; Placer-gold mining in Alaska in 1902: Bull. U. S. Geol. Survey No. 213, 1903, p. 47; Placer mining in Alaska in 1904: Bull. U. S. Geol. Survey No. 259, 1905, pp. 25–28: The mining industry in 1906: Bull. U. S. Geol. Survey No. 314, 1907, pp. 33–37; The mining industry in 1907: Bull. U. S. Geol. Survey No. 345, 1908, pp. 38–43.

Prindle, L. M., Gold placers of the Fairbanks district, Alaska: Bull. U. S. Geol. Survey No. 225, 1904, pp. 64–73; The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 251, 1905, pp. 66–84; The Yukon placer fields: Bull. U. S. Geol. Survey No. 284, 1906, pp. 110–123; The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. U. S. Geol. Survey No. 337, 1908, pp. 1–63.

Prindle, L. M., and Katz, F. J., The Fairbanks gold-placer region: Bull. U. S. Geol. Survey No. 379, 1909, pp. 181–200.

In addition to the maps contained in the above-named reports, there have also been published the Fairbanks special map, scale 1 mile to the inch, with 25-foot contours, and the map of the Fairbanks quadrangle, scale 4 miles to the inch, with 200-foot contours.

The bed rock of the valleys, on which the gravels rest, in most places has a gentle slope parallel to that of the present alluvial floors. Here and there, however, a sharp drop in the bed-rock floor has been noted. Much of the bed rock is covered by a layer of clay, evidently of residual origin.

As the gold placers of the Fairbanks district rest on bed rock, they are from 10 to 300 feet below the present stream levels and are therefore mined chiefly by underground methods. The pay streak ranges from a few inches up to 12 feet or more in thickness and everywhere includes a considerable portion of the underlying bed rock. As a rule it occupies only a part of the stream valley and ranges from 30 feet to 800 feet in width. As at present mined, the gravels carrying values average probably 200 feet in width. The pay streaks usually wind from one side of the valley floor to the other, except where the valley is narrow. Many of the streams have a steep wall on the west or north side and a gentle slope on the other. Such creeks usually follow the steep walls of the valleys.

The total length of pay streak, including that which has been mined out, developed by the mining operations up to 1908 measures roughly about 50 miles. The values in the pay streaks vary greatly. In the early days of the camp it was probably impossible to recover at a profit values of less than $10 to the cubic yard, but with improvement of methods the average is about $5 to the cubic yard. This does not mean that there may not be some pay streaks as rich as those already mined, but rather that, the cost of mining having been reduced, it is possible to work the lower-grade deposits, and this reduces the average gold content of the material mined. The cost of mining being estimated at $3.50 to $4.50 a cubic yard (1908), it is evident that there must be much ground of a lower grade which can not now be exploited. As much of the richest gravel has been mined, the future of the camp depends on a decrease in the cost of operating. This can be brought about only by better transportation facilities and an improvement in the methods of extracting the gold-bearing gravels. In 1908 the placers of Cleary, Fairbanks. Dome, Vault, Ester, and Goldstream creeks and their tributaries were the chief producers of the district.

Auriferous quartz veins have been found at many localities in the Fairbanks district, the richest of them in valleys that have proved large producers of placer gold. These veins are located in the schist, in some places in proximity to intrusive granitic rocks. They range from small stringers to veins 12 to 15 feet thick. They crosscut the schist, run parallel with the main structure of the schist, or have been deposited along joint planes and shear zones. In places they have been faulted, shattered, and even brecciated. Quartz has been reintroduced, and the present quartz veins embody the result of a sequence of events, one of the last of which for some of the veins has been the introduction of gold and sulphides.

The metallic minerals that have been found in the quartz veins are iron pyrites and its alteration products, stibnite, arsenopyrite, galena, sphalerite, and gold; those found in the gravels are cassiterite, wolframite, and bismuth. Much of the gold of the quartz veins is free and visible, occurring as small flakes and grains in the quartz or embedded in limonitized crystals of iron pyrites. Its most common associates in the richest veins are stibnite and arsenopyrite. Veins composed of the sulphides alone, however, have been found to carry but little gold. Values found in the rock showing free gold are naturally high and help raise the average values over a width of several feet, in some places to about $50 a ton.

The introduction of gold in the quartz veins has been an event closely related to that of the sulphides. No auriferous quartz veins have been recognized in the granitic rocks, but there are several localities where the granite is abundantly pyritized, and some placer gold has been found which was derived evidently from such pyritized granite. The facts at present available indicate a genetic relation between the gold with its associated sulphides and the granitic intrusions. The transportation of the auriferous after-products of intrusion from deep-lying sources to a zone of accessibility is believed to have been greatly facilitated by the extensive shattering which the rocks of the Fairbanks district have undergone.

Only the superficial portions of the ore had been exposed and insufficient work had been done in 1909 to determine with definiteness changes in the character or value of ore with increase in depth. In a few places a decrease in the values of free gold at greater depth had been noted. It has been demonstrated that there are some auriferous veins of such dimensions and values as to be possible producers. In 1910 considerable progress was made on some of the quartz mines near Fairbanks. Several of the mines were put on a productive basis, but the total lode-gold output of the camp had a value of less than $50,000.

### RAMPART REGION.

The Rampart district includes the tributaries of Minook Creek, which flows into the Yukon, and those streams[1] lying to the south which flow into Baker Creek, tributary to the Tanana. The geology and mineral resources of this district were investigated by Prindle and Hess[2] in 1904, and to their reports the reader is referred for details of the placer deposits.

The northern part of the Rampart region is one of strong relief, the ridges and domes rising to altitudes of 4,000 to 5,000 feet and many of the valleys being sharply cut. (See Pl. III, in pocket.) In strong contrast to this topography is that of the southern part of the region, where the broad depression occupied by Baker Creek and its tributaries slopes gently to ridges rising not over 1,000 to 2,000 feet above the sea. The north side of the Baker Creek valley rises gradually to a sloping gravel-floored bench which forms one of the important sources of the placer gold of the district. A gravel-floored bench skirts the east side of the Minook Creek valley about 600 feet above the floor. This bench falls off by a precipitous slope to the gravel floor of Minook Creek. It is in strong contrast to the bench north of Baker Creek, which slopes gently to the main stream.

The developed placers are of two types—those of the present stream bed and the bench deposits. Although the high bench along Minook Creek is known to carry gold, its placers have not been developed because of the difficulty of working them. The benches on the north side of the Baker Creek valley have been very productive. The first mining in this valley was on the streams that cut across these benches and have reconcentrated the gold, but during the last two years the bench gravels themselves have been worked on a considerable scale. Throughout the district the gravels are usually shallow, 5 or 6 feet being probably the average, though 10 to 20 feet of gravel is not uncommon, and in a few places thicknesses of 100 feet have been found.

The productive creeks of the district up to 1907 included Minook Creek and its tributaries, chiefly those that enter it from the east and cut across the high bench gravel, but workable placers have also been found on Quail Creek, a tributary of Troublesome Creek, which flows into Hess Creek. Gold-bearing gravels, though not known to carry commercial values, also occur in other parts of the Minook Creek basin. A number of streams tributary to Baker Creek carry values. The chief of these are the streams tributary to Pioneer, Rhode Island, Omega, and Thanksgiving creeks, all of which cut the bench deposit which has been described. In 1907 gold was discovered on Patterson Creek, which lies to the south of Baker Creek and flows directly into the Tanana. Since then some valuable placers have been opened in this part of the field. The gold-bearing region, as roughly outlined by the mining operations, includes about 200 square miles in the Baker and Patterson creek basins and about 100 square miles drained by Minook and Hess creeks. It is not intended to imply that these entire areas are gold bearing, for the placers have been found only in certain creeks.

The geology of the Rampart district is varied. (See Pl. IX.) The region includes a small area of highly altered schists, here correlated with the Birch Creek schist, and succeeding formations made up of chert, slates, graywackes, and some limestones provisionally assigned to the Silurian, together with some smaller areas of blue siliceous limestones assigned to the Devonian (p. 81). In addition to these rocks, intrusive masses of granite are not uncommon. It is a significant fact that a large part of the Rampart placers derive their gold from rocks which are

[1] Now included in the Hot Springs district.

[2] Prindle, L. M., and Hess, F. L., The Rampart gold-placer region, Alaska: Bull. U. S. Geol. Survey No. 280, 1906. Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska, with a section on the Rampart placers by F. L. Hess and a paper on the water supply of the Fairbanks region by C. C. Covert: Bull. U. S. Geol. Survey No. 337, 1908. Besides the maps included in these reports, the Survey has also issued the map of the Rampart quadrangle.

younger than the Birch Creek schist. This mode of occurrence of placer gold is exceptional in the Yukon-Tanana province but is known at other localities in Alaska. No lode deposits have been found in the Rampart district, though many of the quartz stringers occurring in the various rocks associated with the placers are mineralized. The statements in regard to the source of the gold which have been made about the Fairbanks district (p. 182) probably apply to the Rampart district also.

#### GOLD HILL DISTRICT.

Placer gold has been found on several creeks tributary to the Yukon between Rampart and a point 20 miles below the Tanana, but at only two places in this area has any gold been extracted. One of these is near the mouth of Homestake Creek, a confluent of Morelock Creek. About this occurrence little is known.

The placers near Gold Hill have been briefly described by Maddren[1] on the basis of a hasty examination made in 1908, and from his report the following notes are extracted. The bed rock of the district is the Birch Creek schist, characterized by considerable quartz veining. The quartz stringers are in many places iron stained and some of them are known to carry gold.

Placer gold has been found on Grant, Illinois, and Mason creeks, tributaries of the Yukon, as well as on a number of tributaries flowing northward into the Melozitna. The gravels are shallow and in part unfrozen. Though many claims have been staked in this district, there has been relatively little prospecting and the production has been small.

The first attempt to open a lode mine on the Yukon was at Gold Hill, where an adit was driven on a quartz vein for about 100 feet in 1890. A surface cropping of iron-stained quartz 2 to 3 feet in thickness was the incentive for this attempt at mining. Though the quartz carried some gold and silver, the operations were not a success and were long ago abandoned.

## *COAL.*

#### INTRODUCTION.

It has been shown (pp. 159, 161) that there are two coal-bearing formations in this field—the Kenai (Eocene),[2] which includes all the coals of proved value, and the Middle Jurassic, which also carries coal but whose commercial importance has not been established. All the mapped areas of the Kenai (Pl. IX, in pocket) carry some coal except those on the inland front of the Alaska Range. Except in the Matanuska Valley, all the Kenai coal is of a lignitic character. So far as known, the Jurassic coals are limited to the upper part of the Matanuska Valley and are probably for the most part lignitic. The Matanuska field includes a large quantity of high-grade bituminous coal, much of which will coke, and this field shares with the Bering River field preeminence in the Alaska fuel reserves.

Estimates of areas of coal fields which are based only on reconnaissance surveys have no lasting importance, for detailed examinations are necessary to determine the presence or absence of workable coal beds. Such estimates may, however, serve as approximate measures of the importance of the fuel resources.

In the following table the areal data bearing on each of the three grades of coal are grouped under three headings. In the first are placed the known coal lands. These comprise the areas about which sufficient is known to warrant the conclusion that they are underlain by beds of coal at such depth and of such quality and thickness as to make it certain that if they can find a market they can be profitably exploited. There has been no mining in these fields and but little prospecting; hence these estimates are based solely on the information gleaned from the surface outcrops. In the second column are given the total known areas of the coal-bearing formations, parts of which undoubtedly include commercial coal beds. These areas were determined by measurements on the map of the known outcrops of the coal-bearing rocks. In

[1] Maddren, A. G., Placers of the Gold Hill district: Bull. U. S. Geol. Survey No. 379, 1909, pp. 234–237; Bull. U. S. Geol. Survey No. 410, 1910, pp. 80–85.

[2] It should be noted that it has not been definitely determined that all the Tertiary coals belong to the Kenai formation. The rocks mapped as Kenai in the Matanuska Valley may include some that are older, and the Tertiary of the Nenana Valley may include some that are younger.

the third column are conservative estimates of the possible total areas of coal-bearing rocks. In this are included (1) areas of known coal-bearing rocks, as in the second column; (2) areas of supposed coal-bearing rocks covered by younger formations of no great thickness, and (3) an estimate of the area of coal-bearing rocks in regions which have not been actually surveyed. This third column can be regarded as a rough estimate of the possible extent of the coal fields here under consideration.

*Areas of coal fields of Mount McKinley region.*[1]

[In square miles.]

| Character of coal. | Known coal lands. | Known areas of coal-bearing rocks. | Estimated possible total areas of coal-bearing rocks. |
|---|---|---|---|
| Anthracite and semianthracite | 4.5 | ........ | ........ |
| Bituminous and semibituminous | 42.0 | 260 | 900 |
| Lignite | 90.0 | 1,086 | 1,660 |

[1] See geologic reconnaissance map, Pl. IX.

As considerable weight may be given to quantitative estimates of mineral wealth published in official reports, it should be the aim of such reports to err, if anything, on the conservative side. This aim is expressed in the foregoing table, and for this reason the extent of the possible coal fields may be many times what is here estimated, especially that of the lignite-bearing formations. The lower Susitna basin is so heavily mantled by Quaternary gravels that there is little clue to the underlying bed rocks. Kenai rocks have, however, been found along both margins of the basin, and it is not impossible that they may underlie the entire lowland at no great depths. The Tanana Valley also contains heavy gravel deposits which may cover extensive areas of Kenai formation. All this makes it possible that there may be many thousand square miles of lignitic formations within the Mount McKinley province.

There are few data on which to base tonnage estimates for these coal fields. However, some rough computations of certain parts of the Matanuska field indicate that the recoverable coal ranges from 10,000 to 60,000 tons to the acre. A few sections measured in the Nenana field show a coal content of 5,000 to 50,000 tons to the acre.

Most of the coal of the province is of a lignitic character, with 30 to 35 per cent of fixed carbon. The coal classed as bituminous includes both subbituminous coal, with about 50 per cent of fixed carbon, and semibituminous, with 65 per cent of fixed carbon. It appears probable that in the Matanuska field the higher grade of bituminous coal dominates, but more detailed work will have to be done to determine this point. There is also some anthracite coal in the region, but up to the present time (1908) it has been found only in one small area. A sample of this coal yielded 84 per cent of fixed carbon.

If the extent and accessibility of the fields and the quality of the coal are taken into account, the bituminous areas are by far of the greatest commercial importance. These, so far as known, are all confined to the basin of Matanuska River. Lignites are very widely distributed, and some of these will in time have local value. This is especially true of the lignites north of the Alaska Range, which can be utilized for the placer districts, where the advancement of the mining industry and the rapid consumption of the more accessible timber will cause a growing demand for fuel.

## MATANUSKA COAL FIELD.

The writer has visited only a part of the Matanuska coal field, and the following summary is based almost entirely on the work of Martin [1] and of Paige and Knopf,[2] to whose reports the reader is referred for detailed information.

[1] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906; also unpublished data derived from surveys of 1910.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907.

This field lies in the basin of Matanuska River, a tributary to Knik Arm and a swift-flowing muddy stream, with a fall of probably 20 to 25 feet to the mile. Its valley is bounded on the south by the rugged Chugach Mountains, some 6,000 to 8,000 feet in height, and on the north by the Talkeetna Mountains, of even greater ruggedness and about the same altitude.

Two coal-bearing terranes have been recognized. The upper includes the Tertiary shales, sandstones, and conglomerates assigned to the Kenai formation, which contains valuable bituminous coal beds and has a thickness of about 3,000 feet.[1] A series of shales, sandstones, tuffs, conglomerates, and arkose, with some lignitic beds (Upper Jurassic), forms the lower of the two coal-bearing terranes and has a thickness probably of 2,000 feet. The Tertiary coal measures occur in several detached areas in the lower part of the Matanuska Valley and on Chickaloon Creek, a northerly tributary of the Matanuska. The Upper Jurassic lignite-bearing rocks lie to the east of the Tertiary basin and are known to extend beyond the area shown on the geologic map (Pl. IX, in pocket). Toward the west end of the field the bituminous coals of the Tertiary grade into lignite.

The known area of coal-bearing rocks of Tertiary age is about 260 square miles,[2] but there may be a much greater area underneath the Quaternary gravels. Of this area about 42 square miles is known to be underlain by coal beds which vary from 5 to 30 feet in thickness. These Tertiary beds are thrown up into broad, open folds which are considerably faulted and cut by stocks and dikes of igneous rocks. Up to 1908 anthracite had been found at only one locality—along Anthracite Ridge, which is east of the area here considered, between Boulder and Hicks creeks. The extent of this deposit is unknown; but it is estimated that at least 4 square miles is underlain by coal. The age of this anthracite is not definitely determined, but Paige and Knopf are inclined to the opinion that it may belong to Tertiary beds infolded with the Mesozoic.

The coal-bearing rocks of Upper Jurassic age underlie an area of 268 miles within the limits of the area shown on Plate IX, and probably the coal field as mapped might be regarded as at least 300 square miles, while it is known to extend east of the mapped area. These coals appear to be mostly lignitic and are therefore of much less value than those of the Tertiary horizon. They do not exceed 3 or 4 feet in thickness.

The Matanuska coal field was first known to prospectors about 1898, but it was several years before its importance was recognized. Since 1903 there has been considerable prospecting of these coals. Many claims have been located and surveys made for patent. In the aggregate not more than a few hundred feet of rock work has been done. The quality of the coal of this field is indicated by the subjoined analyses:

*Proximate analyses of Matanuska coal.*

| Kind of coal. | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. |
|---|---|---|---|---|---|
| Anthracite, 1 analysis | 2.55 | 7.08 | 84.32 | 6.05 | 0.57 |
| Semibituminous coking, average of 16 analyses | 2.71 | 20.23 | 65.39 | 11.60 | .57 |
| Subbituminous, average of 4 analyses | 6.56 | 31.14 | 49.44 | 8.57 | .37 |

## COOK INLET AND SUSITNA BASIN COAL FIELDS.

All the coals of the fields adjacent to Cook Inlet, as well as those of the Susitna basin, are of lignitic character and occur in soft sandstone interbedded with conglomerate and shales of the Kenai formation, which are as a rule but little disturbed. The known Tertiary rocks of this region underlie only 130 square miles; but it is estimated that the total area of Tertiary rocks may be 500 square miles. Of the known 130 square miles only about 32 square miles are known to be underlain by coal beds.

[1] Martin's surveys of 1910 indicate a thickness of over 5,000 feet.
[2] Martin's survey shows that a part of the rocks mapped as Tertiary are Mesozoic.

These lignitic coals have been mined at only two localities—Tyonek, on the west shore of Cook Inlet, and Point Campbell, on the southeast side of Knik Arm. In both places operations were confined to the surface croppings with the purpose of obtaining coal for local use.

The largest areas of coal occur in three separate localities. One of these covers the northwest end of Kenai Peninsula and lies along the eastern margin of Cook Inlet. Here the coal-bearing rocks are mantled, for the most part, by a gravel sheet, outcropping only in a low bluff near the sea; but no workable coal beds are known to have been found.

A second area of coal is exposed for several miles along the beach near Tyonek (fig. 29), and what appears to be an extension of the same coal belt is traversed by Chuit and Beluga rivers. This field, examined by Eldridge in 1898 and by the writer in 1902, was studied in far greater detail by Atwood[1] in 1907, and from his report most of the data here given are taken. Though the coal exposures in the Tyonek field are confined practically to the sea cliffs along Cook Inlet, it is probable that coal beds underlie the extensive gravel sheets to the northeast. The total surveyed area of coal-bearing rocks is 85 square miles, of which only 10 square miles are known to be underlain by coal.

The section south of Tyonek shows a thickness of 500 to 600 feet of friable sandstone and a little fine conglomerate, shales, and lignite, which are upturned, dipping to the north at angles varying from 15° to 60°. (See fig. 19, p. 95.) The edges of these coal-bearing rocks have been planed off and are covered by 50 to 60 feet of Quaternary gravels. About twenty seams of lignite are exposed varying in thickness from a few inches up to 20 feet, the average being 4 to 6 feet. No coal bed more than 5 or 6 feet in thickness, however, was found which was not interrupted by bone partings or sandy layers. Atwood estimates the total thickness of workable coal at about 50 feet. Much of the Tyonek coal is fibrous, having a well-marked woody texture. It is brown to black in color and much of it seemingly of low grade. It has, however, been successfully used on local steamers on the inlet.

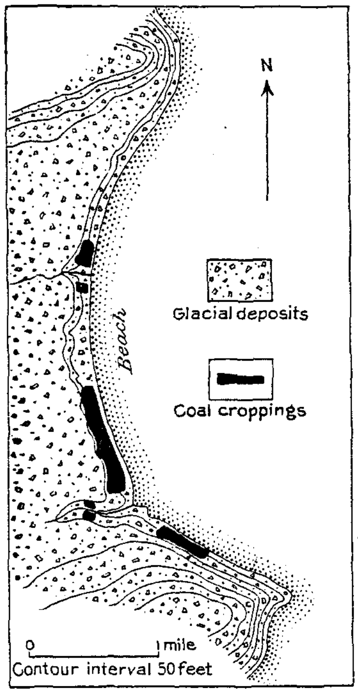


FIGURE 29.—Sketch map showing distribution of coal along beach near Tyonek, Cook Inlet. By W. W. Atwood.

The average of five analyses of coals from this field is as follows:

*Average analysis of coal from Tyonek field.*

| | |
|---|---|
| Moisture | 21. 50 |
| Volatile matter | 37. 28 |
| Fixed carbon | 30. 60 |
| Ash | 10. 63 |
| Sulphur | . 57 |

Of the inland extension of the Tyonek coal field Atwood[2] says:

Northwest of Tyonek, in the area where Beluga River crosses the coal field, the beds in general continue to dip to the northeast, and in following the valley upstream the entire section may be examined. From these exposures it is evident that the lignite seams in the upper portion of the section are of much poorer grade than those near the base. The strike varies from N. 17° E. to N. 22° W., and the average dip is about 55°. The sediments are of the same character as those exposed along the beach south of Tyonek, consisting of loose sands, sandstones, clays, shales, conglomerates, and seams of lignite. Near the base of the section there are two seams of lignite 10 and 12 feet thick, which are more brittle and harder and appear to be of much better grade than any exposed elsewhere in the field. They outcrop 10 miles above the mouth of the Beluga, measured along the stream, and about 2 miles above a belt of dangerous rapids.

A small area of the Kenai formation at Point Campbell, near the entrance to Knik Arm, is described by Martin[3] as follows:

There is an area of lignite at or near Point Campbell, at the juncture of Knik and Turnagain arms, which has been used to a limited extent as local domestic fuel. The coal seen by the writer had been picked up at the outcrop and

[1] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 117-121.
[2] Op. cit., p. 120.
[3] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, p. 25.

was a lignite of rather poor quality. It may be that the coal from this bed would be better were it not so badly weathered, or that there are more valuable seams in the vicinity.

A belt of lignitic coal-bearing rocks is reported to stretch northward from the Matanuska along the eastern margin of the Susitna Valley. These rocks probably belong to the same horizon as the Tertiary coals of the Matanuska Valley, but the connection of the two areas has not been traced and the field is known only through the reports of prospectors. If this belt extends northward, it may be coextensive with some Kenai coal-bearing rocks which occur near the junction of the Susitna and Chulitna and of which Eldridge[1] says:

The third coal field along the main river, 4 to 10 miles above the Chulitna, appears in outcrop for a distance of 6 or 7 miles and is perhaps the exposed portion of an extensive area. The strata form bluffs 100 to 300 feet high and consist of clays and sandstones, the former predominating, with coal seams from 6 inches to 6 feet thick. There are perhaps ten or fifteen coal beds exposed in the entire length of the outcrop. Their general dip is 5° to 10° SSE., with undulations. The thickness of the series exposed is perhaps 500 feet.

Lignitic coal-bearing rocks of a similar character were found by Spurr[2] in the Skwentna Valley at the mouth of Hayes River. (See Pl. IX, in pocket.) Some of the coals seemed to be a lignite of fairly good grade. Similar rocks occurring in the Kichatna Valley include some thin fibrous brown lignitic beds. Considerable lignitic coal has been found by prospectors in the Yentna placer districts northeast of the Kichatna Valley. Beds 10 and 15 feet in thickness are reported. Coal-bearing rocks are said to occur also in considerable areas near the head of the Chulitna, 5 to 15 miles east of Broad Pass.

It has been pointed out that the coal-bearing Kenai formation has been found along both margins of the Cook Inlet and Susitna lowland. This suggests that the entire lowland may be underlain by these beds. If this is the case, these coal fields may include an area of 10,000 square miles. However, as there is no measure of the thickness of the Quaternary beds which form the surface terrane of this lowland, there is no evidence at what depth the coal would be found. In any event the fragmentary evidence above given indicates that the Tertiary rocks underlie considerable areas in the region along the margins of Cook Inlet and the Susitna basin and that, locally at least, they carry beds of lignitic coal. The rocks are as a rule comparatively little disturbed, and some of the coal beds, where accessible, are thick enough for exploitation. Owing to the proximity of the high-grade coal of the Matanuska basin, however, and to the fact that the same lignitic coals occur on a good harbor at Kachemak Bay, in the southern part of Kenai Peninsula, it is not likely that these fields have any immediate prospective value except for a very local market.

### KUSKOKWIM BASIN.

So far as known, no coal of commercial value occurs in that part of the Kuskokwim basin which was explored by the writer. Beds of lignitic coal have, however, been found by W. E. Priestly[3] in the region lying immediately southwest of the junction of the two forks of the Kuskokwim. In the valley of Big River, Mr. Priestly reports, there is considerable coal, some of which is in thick beds. A specimen of this coal indicates that it is a lignite of good grade.

### NENANA COAL FIELD.[4]

By Alfred H. Brooks and L. M. Prindle.

The Nenana coal basin embraces a roughly quadrangular area drained by Nenana, Tatlanika, and Wood rivers, all tributary to the Tanana from the south (Pl. III, in pocket; fig. 28, p. 170). These rivers rise in the Alaska Range, which they leave through narrow valleys cut into metamorphic rocks. Between this belt of metamorphic rocks and the alluvial flooring of

[1] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 22.

[2] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 262.

[3] Mr. Priestly made a winter trip from the Innoko to Seward in 1909, and kindly furnished the writer with some notes on the region traversed by him. In the course of this journey he explored the lower part of the Big River basin, where he found the coal.

[4] Brooks, A. H., Cantwell River, in The coal resources of the Yukon, Alaska, by A. J. Collier: Bull. U. S. Geol. Survey No. 218, 1903, pp. 44-46. Prindle, L. M., The Bonnifield and Kantishna regions: Bull. U. S. Geol. Survey No. 314, 1907, pp. 223-226.

the Tanana Valley is a foothill belt, much of which is underlain by Tertiary deposits broken by islands of the older rocks and in part buried by a heavy mantle of Quaternary gravel. The gravel sheet forms a plateau in which the streams have incised sharp channels, along whose valleys the coal beds outcrop. The coals are associated with friable sandstone of almost snow-white color, with some intercalated conglomerate and shale strata (Pl. XVI, *B*, p. 170). A heavy conglomerate forms the basal bed. The rocks are for the most part but slightly consolidated and have been thrown up into open folds with dips of 30° to 35° and in places 90°. Faulting is not uncommon in these beds. (See fig. 20.) The coal-bearing strata comprise a thickness of 500 to 1,500 feet, and these are succeeded by about 800 to 2,000 feet of yellowish and reddish gravel. The upper gravels contain a good many bowlders of the various types of metamorphic and igneous rocks found in the Alaska Range.

Fossil leaves have been found in association with the coal-bearing rocks, and on the basis of this evidence they have been referred to the Kenai (Eocene) and therefore represent the formation that is so widely distributed both in the Yukon basin and on the south side of the Alaska Range (p. 94). It is of interest to note that the gravels associated with these deposits are in places auriferous and appear to be the immediate source of the gold found in some of the placers of the Bonnifield region. (See p. 171.) It has not been determined whether this gold came from the upper heavy gravel or from the lower part of the series in which the coal is found. Kenai beds have been found to be auriferous in other parts of the Yukon basin. The total area of the coal-bearing strata exposed is about 600 square miles, of which 66 square miles is known to be underlain by coal. The total area of the coal field, however, including that covered by the later gravels, is probably much more than 600 square miles. (See Pl. IX, in pocket.) Moreover, the coal field is known to extend into the unmapped area on the east.[1]

The coal beds, which measure from a few inches up to 20 feet in thickness, are very numerous at some places, as will be shown in the following sections. The formation is well exposed along Healy Creek, an easterly tributary of the Nenana. Here the beds strike about east and west and dip from 10° to 20° N., resting unconformably on the older metamorphic rocks. The following section was measured on the north side of the valley about 2 miles above the mouth of Healy Creek, a mile above the camp of August 21. (See Pl. IX.)

*Section of coal-bearing rocks on north side of Healy Creek, about 2 miles above the mouth.*

| | Feet. |
|---|---|
| Reddish gravel, with some sandy layers | 2,000± |
| White gravel and sand | 100 |
| Clay shale | 10 |
| Gravel and sandy layers | 100± |
| Blue clay shale, in part indurated | 40 |
| White sand and gravel | 100 |
| Carbonaceous shale | 2 |
| Clay shale | 6 |
| Carbonaceous shale | 3 |
| Clay shale | 10 |
| Sand, with some layers of gravel | 100 |
| Shaly lignitic coal | 4 |
| Sand, gravel, and clay, with some small layers of lignitic coal | 30 |
| Impure shaly lignitic coal | 4 |
| Sandy clay shale, carbonaceous | 30 |
| Impure lignitic coal | 1 |
| Sandy clay | 10 |
| Impure shaly lignitic coal | 2 |
| Sandy clay shale, with some carbonaceous layers | 10 |
| Carbonaceous and clay shale | 3 |
| Shaly lignitic coal | 2 |
| Sandy clay | 15 |

[1] Investigations made by S. R. Capps in 1910 indicate that the coal-bearing formations may underlie the heavy gravels as far east as Delta River.

| | Feet. |
|---|---|
| Shaly lignite | 2 |
| Clay and sandy shale | 20 |
| Sand, with gravel layers | 40 |
| Lignitic coal, in part shaly | 15 |
| Sandy clay shale | 6 |
| Friable fine sandstone | 40 |
| Shaly lignitic coal | 4 |
| Sandy clay shale | 4 |
| Lignitic coal | 3 |
| Sandy clay shale | 5 |
| Shaly lignitic coal | 6 |
| Sandy clay shale | 10 |
| Friable fine sandstone | 60 |
| Lignitic coal | 1 |
| Sandy shale | 5 |
| Lignitic coal | 2 |
| Sandy and carbonaceous black shales | 6 |
| Fine friable sandstone | 30 |
| Lignitic coal | 4 |
| Sandy clay shale | 6 |
| Shaly lignitic coal | 20 |
| Sandy clay shale | 20 |
| White sand | 10 |
| Lignitic coal | 15 |
| Sandy clay shale | 10 |
| Friable fine sandstone and gravel | 40 |
| Shaly lignite | 15 |
| Clay shale | 2 |
| Friable fine sandstone | 10 |
| Lignitic coal | 20 |
| Friable sandstone | 50 |
| Lignitic coal | 5 |
| Friable sandstone | 3 |
| Lignitic coal | 20 |
| Friable sandstone and conglomerate, loosely cemented | 220± |
| Conglomerate resting on metamorphic rocks. | |
| | 3,311 |

The coal of the entire section aggregated about 125 feet in thickness, contained in about fifteen beds. Of this coal probably 60 feet was a lignite of fairly good grade. The heaviest bed is 20 feet thick, but includes some bone and shale. In character the coal varies from a fibrous impure lignite, probably entirely worthless, to a better grade of lignite that has commercial value. The better-grade lignite of this section appears to be near the bottom of the series and has a lustrous black color and conchoidal fracture.

As there has been no mining, the coal beds were accessible only along the outcrop, where they are made up of noncoherent lignite. A sample taken almost at random from one of the larger beds was analyzed by E. T. Allen in the Geological Survey laboratory, with the results given below. The sample was not sealed and was analyzed several months after being collected.

*Analysis of coal from Healy Creek.*

| | |
|---|---|
| Moisture | 13.02 |
| Volatile matter | 48.81 |
| Fixed carbon | 32.40 |
| Ash | 5.77 |
| | 100.00 |
| Sulphur | .16 |

In considering this analysis it should be borne in mind that owing to the short time given to the examination of the locality it is quite possible that coal beds of better grade were overlooked. In any event it would require considerable excavation below the zone of surface weathering to determine the quality of the coal.

Coal beds were also found on Lignite Creek, a few miles north of Healy Creek, but, so far as determined, they are of no better quality than the Healy Creek coals. North of Lignite Creek and apparently higher in the series seams of fibrous and impure lignite, with carbonaceous shales, are not uncommonly found interbedded in sandstone. It does not seem likely that any of these beds have any prospective commercial value. In the opinion of the writers, the best coals are near the base of the sandstone series.

In the valley of Lignite Creek, where the space between the hard-rock ridges is wider than in the Healy Creek valley, the coal deposits extend from the schist ridge that limits the valley on the south to the base of Jumbo Dome, a distance of about 3 miles, and on the east extend to the schist ridge at the head of the creek. The series has here been incised to a depth of 1,000 feet or more by the many tributaries of Lignite Creek, which have steep grades and form, where they cross the resistant coal beds, waterfalls about 30 feet in height. These narrow cuts are clogged with masses of detrital sandy beds that break away in great blocks from the steep bluffs above to form sand heaps at the bottom and contain blocks of coal 20 feet or more in diameter. The following two sections were measured in this part of the field:

*Section on Lignite Creek, 6 miles above the mouth.*

| | Feet. |
|---|---|
| Gravel, thickness undetermined. | |
| Thin beds of coal alternating with sands and clays | 250 |
| Lignitic coal | 18 |
| Sands | 10 |
| Lignitic coal | 1 |
| Argillaceous sand | 10 |
| Cross-bedded sands | 100 |
| Lignitic coal | 16 |
| Sands | 100 |
| Lignitic coal | 8 |
| Sand | 75 |
| Lignitic coal | 32 |
| Sandy clay | 40 |
| Lignitic coal | 10 |
| Sand | 12 |
| Lignitic coal | 20 |
| Coal, thickness undetermined. | |

The total coal in this section is 129 feet in beds from 1 to 20 feet in thickness.

*Section near head of Lignite Creek.*

| | Feet. |
|---|---|
| Gravel, thickness undetermined. | |
| Shaly lignitic coal | 8 |
| Sandy clays | 50 |
| Lignitic coal | 6 |
| Clay | 10 |
| Lignitic coal | 12 |
| Sand, thickness undetermined. | |
| Lignitic coal | 1 |
| Gray sand and gravel, with some argillaceous matter | 40 |
| Lignitic coal | 1½ |
| Friable clays | 10 |
| Clean sand | 20 |
| Lignitic coal | 1 |
| Sandy clays | 2 |
| Cross-bedded gray sands and fine gravel | 50 |
| Soft sandstone | 2 |
| Lignitic coal | 6 |
| Thin-bedded sands | 100 |
| Lignitic coal | 10 |
| Plastic clay | 25 |

The total coal in this section aggregates 45 feet and the valleys in this part of the field appear to contain a large amount of coal.

In the area east of that described the coal-bearing beds are exposed wherever the gravel deposits have been eroded. Coals have been found on Coal Creek, a small tributary of Totatlanika Creek, where they have a small local use among the miners, on the Tatlanika, and on Mystic Creek about 2 miles from Wood River, where two beds 20 feet and 12 feet thick are exposed in a section 80 feet high. They are also reported to occur east of Wood River as far as Delta River. It seems probable that the coal-bearing series is continued west of Nenana River, and there may be considerable coal between the Nenana and the Toklat, but this coal has not been included in estimating the size of the Nenana coal field, for the region is unmapped. Lignitic coal also occurs farther southwest in small basins in some of the streams tributary to the Kantishna. Of significance is the reported discovery of lignitic coal on the north side of the Tanana Flats near Salchaket River. This suggests that much of the Tanana lowland may be underlain by Kenai formation. It is doubtful, however, whether lignitic coals occurring below the surface-water level and underneath an undetermined thickness of gravels have any value that can now be foreseen.

The Nenana field is the largest known coal-bearing area of the Yukon basin. Its coal beds appear to be somewhat thicker than those in other parts of inland Alaska. The coals, so far as known, are of poorer quality than those of the lower Yukon, some of which are subbituminous. The Nenana coals, however, are geographically so located that for use of the placer fields they would not come into competition with any other fuels of a higher grade.

The possible market for these coals is in the gold fields of the Yukon-Tanana region. It is estimated that in 1907 the Fairbanks district alone consumed about 35,000 cords of wood. This consumption is making a serious drain on the accessible timber, which is far from abundant. In addition to the legitimate use of the forests for cordwood and lumber, large areas are annually destroyed by fire. Unless these inroads are stopped, the accessible forests will probably be destroyed before the placers are mined out. Even under favorable conditions the price of cordwood will undoubtedly increase. Therefore it seems possible that the Nenana coal field may become an important element in the industrial advancement of the Fairbanks and adjacent districts.

There appear to be two ways in which this coal can be utilized. One is by the construction of a railway from Fairbanks, a distance of about 65 miles. In this connection it should be noted that the proposed route of the Alaska Northern Railway to Fairbanks passes through the Nenana coal field. Another plan is to install a plant in the coal field and transmit electric power to the mining districts. A transmission line of 50 or 60 miles would reach all the developed parts of the Fairbanks district and a 100-mile line would reach the Baker Creek fields. It must be left to engineers to decide whether such a plan would be economically feasible. A factor of importance to the scheme is the insufficiency of water supply under head in the placer camps to carry on mining operations. There are large bodies of gravel which can not be exploited under the present expensive system of mining but which might be worked if cheap power were available. Such power might be used for pumping water, for mechanical elevators, or for dredges. In planning the utilization of this coal in a central plant the possibilities of competition with water power should be carefully considered.

### YUKON COAL FIELDS.

It is not worth while here to consider the various coals which occur on the Yukon, as only a small part of these fall within the Mount McKinley province, and they have been fully described by Collier.[1] A white friable sandstone carrying a few lignitic seams and closely resembling the beds of the Nenana field occurs near Rampart, above the mouth of Minook Creek. Some attempt has been made to mine these seams, but work on them has been abandoned. Kenai beds also occur on the north bank of the Yukon just above the mouth of the Tanana, but, so far as known, do not carry any considerable seams of lignite.

[1] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903.

### SUMMARY.

It has been shown that placer-gold mining is by far the most important present industry of the province. The very wide distribution of auriferous gravels makes it certain that alluvial mining will continue long after the bonanzas now being exploited have been exhausted. Much of the Susitna basin and the Yukon-Tanana region is still almost virgin ground to the gravel prospector, and there is therefore no reason to believe that new deposits will not be found which can be profitably mined by simple methods. However this may be, the most promising field for placer mining is in the exploitation of the extensive bodies of auriferous gravels whose gold tenor is too low to permit economic recovery by hand methods. Much of this kind of mining will have to be deferred until railways and wagon roads render this region more accessible. The future discovery of rich placer deposits can not be definitely expected, but the extensive bodies of auriferous gravels carrying low values in the Yentna, Valdez Creek, Bonnifield, Fairbanks, and Rampart districts form a visible asset which needs only the capitalist and engineer to assure long continuation of the placer-mining industry.

Less definite statements can as yet be made of auriferous lode mining. The discoveries of gold-bearing quartz in many parts of the province and the beginnings of lode mining that have been made on Willow Creek and at Fairbanks encourage the belief that this industry may yet become important.

The extensive coal deposits of the province are untouched, yet these form one of the most valuable of its known mineral resources. The high-grade steaming and coking coals of the Matanuska Valley have, so far as known, no equal in the Pacific States except in the Bering River field. This Matanuska coal will of course be at some disadvantage in comparison with the Bering River coal because of the longer haul to tidewater. As the demand for these high-grade fuels will constantly increase, however, there is no reason to doubt that the Matanuska coal will in time also find a market.[1]

The Nenana coal field is the most extensive of those lying on the inland side of the coastal barrier. Its future utility depends on the advance of the gold-mining industry of the Yukon-Tanana region, by which a market for fuel and power will be created. Take it all in all, the Mount McKinley province as here defined is one of the richest parts of Alaska. It only needs better means of communication and more capital for large enterprises to continue the prosperity which it has had in the past. Such advancement will attract a population which in turn will make a local market for the farmer and assure a development of the agricultural resources, which are of no mean proportions.

## CLIMATE.

### GENERAL FEATURES.

There is a dearth of meteorologic data about most of the Mount McKinley region. Some records have been kept at several stations on Cook Inlet and on the Yukon, but few of these cover a period of more than two or three years and they can at best furnish only a general guide to climatic conditions. The only records available for the region between Cook Inlet and the Tanana are notes of exploration parties, and these, being taken at many different localities, have little value. The data contained in the accompanying tables are mostly derived originally from records of the United States Weather Bureau and based on the work of volunteer observers. As here given, however, they are in the main assembled from previous compilations published in several reports.

Climatically the Mount McKinley region as here defined is divisible into two general provinces, separated by the Alaska Range. On the inland side of the range the climate is characterized by short, comparatively warm summers and long, cold winters, with a low precipitation. The area draining into the Pacific enjoys more equable conditions, the summers being longer and cooler and the winters warmer than in the interior, while the precipitation is very

[1] The writer has recently discussed the market for these coals in an article entitled "Alaska coal and its utilization" (Bull. U. S. Geol. Survey No. 442, 1910, pp. 47-100).

much greater. Within these two general provinces there is infinite local variation, especially in the coastal province. For example, such records as exist show marked difference in the meteorologic conditions on the two sides of Cook Inlet. These in turn contrast strongly with those prevailing on Turnagain Arm. Farther from the coast there are probably still greater variations due to the irregular topography and the influence of mountain barriers, such as the Talkeetna Mountains. Elevation, too, is everywhere a modifying factor, as is also distance from the sea.

It seems probable that local variation is not so marked in the inland province, though here again the records are inadequate for any generalization. In the Yukon basin as a whole there is a notable increase in precipitation westward and southwestward from the international boundary toward Bering Sea, and there appears to be a corresponding increase in mean annual temperature. The mean annual temperature of the coastal province is probably between 30° and 40° F. and the precipitation ranges locally from 16 to 40 inches. In three summer months the average temperature is 50° to 55° F. and in the three winter months 10° to 20°. In the inland province the mean annual temperature is probably between 18° and 22°; the mean of the three summer months is about 55° and that of the three winter months −10° to −15° F. The annual precipitation is 12 to 14 inches.

## PACIFIC SLOPE.

At four stations—Kenai, Tyonek, Sunrise, and Kodiak—meteorologic observations have been taken for some years. These observations are summarized in the accompanying table, which affords a fair example of the great local variations which characterize the climate of the southern province. The mean annual temperature at Kenai is about 31°; at Tyonek, just across the bay, it is probably 7° or 8° higher. The precipitation at Tyonek is about 24 inches, while at Kenai it is only 18 inches. At Sunrise the mean annual temperature is 33° and the precipitation is about 37 inches.

*Extreme and mean temperatures (°F.) in the Cook Inlet region.*

| | | Sunrise. | Tyonek. | Kenai. | Kodiak. |
|---|---|---|---|---|---|
| January | Maximum | 44 | 38 | 49 | 51 |
| | Minimum | −29 | −27 | −36 | − 1 |
| | Daily mean | 8 | 11 | 10 | 30 |
| February | Maximum | 51 | 49 | 45 | 52 |
| | Minimum | −24 | −21 | −46 | −10 |
| | Daily mean | 18 | 21 | 18 | 28 |
| March | Maximum | 58 | 58 | 52 | 64 |
| | Minimum | −11 | − 9 | −34 | 11 |
| | Daily mean | 25 | 25 | 20 | 33 |
| April | Maximum | 57 | 59 | 59 | 61 |
| | Minimum | 6 | − 1 | −17 | 20 |
| | Daily mean | 35 | 34 | 32 | 36 |
| May | Maximum | 76 | 68 | 64 | 62 |
| | Minimum | 25 | 22 | 21 | 20 |
| | Daily mean | 47 | 38 | 45 | 43 |
| June | Maximum | 76 | 91 | 87 | 76 |
| | Minimum | 31 | 33 | 29 | 34 |
| | Daily mean | 51 | 47 | 51 | 49 |
| July | Maximum | 75 | 83 | 80 | 82 |
| | Minimum | 34 | 38 | 30 | 40 |
| | Daily mean | 53 | 57 | 53 | 55 |
| August | Maximum | 76 | 76 | 75 | 75 |
| | Minimum | 31 | 31 | 29 | 41 |
| | Daily mean | 52 | 54 | 53 | 55 |
| September | Maximum | 70 | 70 | 65 | 68 |
| | Minimum | 20 | 29 | 16 | 36 |
| | Daily mean | 44 | 49 | 46 | 50 |
| October | Maximum | 54 | 61 | 60 | 59 |
| | Minimum | 8 | 10 | −10 | 30 |
| | Daily mean | 36 | 34 | 32 | 42 |
| November | Maximum | 50 | 44 | 42 | 53 |
| | Minimum | −11 | −13 | −27 | 15 |
| | Daily mean | 23 | 20 | 18 | 34 |
| December | Maximum | 48 | 49 | 45 | 50 |
| | Minimum | −14 | −21 | −43 | − 6 |
| | Daily mean | 19 | 17 | 16 | 30 |
| Length of record (years) | | 4 | 5 | 4 | 8 |

*Mean precipitation in inches, including melted snow, and mean number of rainy and snowy days in the Cook Inlet region.*

| | | Sunrise. | Tyonek. | Kenai. | Kodiak. |
|---|---|---|---|---|---|
| January | Days | 9 | 6.9 | 5.7 | 16 |
| | Precipitation | 2.01 | 2.02 | .65 | 4.82 |
| February | Days | 7.5 | 5.8 | 5.4 | 14 |
| | Precipitation | 1.07 | 1.1 | .26 | 4.44 |
| March | Days | 9.6 | 4.1 | 5.6 | 11 |
| | Precipitation | 1.85 | .92 | .78 | 4.17 |
| April | Days | 15.2 | 4 | 4.9 | 14 |
| | Precipitation | 2.77 | .78 | .58 | 2.92 |
| May | Days | 13.5 | 3.4 | 6 | 14 |
| | Precipitation | 1.38 | .49 | .88 | 4.97 |
| June | Days | 14.2 | 6.2 | 7.6 | 9 |
| | Precipitation | 1.31 | 1.15 | .99 | 2.11 |
| July | Days | 18.3 | 9.8 | 11.9 | 7 |
| | Precipitation | 2.23 | 3.04 | 2.44 | .80 |
| August | Days | 21.8 | 14.6 | 14.7 | 10 |
| | Precipitation | 3.87 | 4.31 | 3.72 | 2.37 |
| September | Days | 13 | 11.4 | 11 | 12 |
| | Precipitation | 2.04 | 3.87 | 3.12 | 1.95 |
| October | Days | 19.04 | 11.6 | 11.8 | 18 |
| | Precipitation | 6.6 | 3.55 | 1.91 | 6.31 |
| November | Days | 14.6 | 6.6 | 2.8 | 18 |
| | Precipitation | 5.76 | 1.23 | 1.04 | 6.52 |
| December | Days | 14 | 6.5 | 7 | 18 |
| | Precipitation | 6.47 | 1.18 | .87 | 5.72 |
| Mean annual | Days | 170.1 | 89.9 | 99.4 | 161 |
| | Precipitation | 37.29 | 23.59 | 17.74 | 45 |
| Length of record (years) | | 4 | 8 | 9 | 1 |

In 1904 Moffit spent 140 days on Kenai Peninsula, chiefly on the Cook Inlet side of the divide, and on 79 of these days it rained, but this number is nearly twice as great as was recorded by R. E. Oldham on Crow Creek during the same period of the previous year. Moffit also reports that during the winter of 1903–4 a temperature of −2° was reached only once at Seward, on the east side of Kenai Peninsula, and the same was true of Seldovia, on the west side. As a rule, however, the climate of the west and north sides of the peninsula is colder and drier than that of the Pacific seaboard. Moffit noted a great variation in temperature throughout the northern half of the peninsula, Sunrise, for instance, being as much as 10° warmer than some of the neighboring creeks. The snowfall at Kenai is 4 or 5 feet, and in the high ranges it is somewhat greater. At Kenai the months of July, August, and September show the largest number of rainy days and the greatest precipitation. The highest recorded temperature in this locality is 80° and the lowest −43°.

The upper part of Cook Inlet is usually closed by ice from early November till about the middle of April. Resurrection Bay is free from ice throughout the year. Sluicing operations in the Sunrise placer district begin between the first and middle of May and are continued till the first or middle of October.

If any complete records of the region farther inland were available, they would undoubtedly show still greater variations in local climatic conditions. The observations of the Survey parties indicate that the Susitna basin has a lower precipitation than Cook Inlet, though this probably does not hold true of that part of the basin lying immediately adjacent to the high ranges. Eldridge's observations in 1898 show 32 rainy days for the months of May to September, inclusive, while the average for Tyonek for the same period is about 50 rainy days. The observations of our own expedition in 1902 indicated that the months of May and June were clear and dry on the south side of the range. Martin, in 1904, reported that the Matanuska Valley is colder and has less rain than Cook Inlet. On the other hand, Paige and Knopf, in 1906, encountered almost continuous rainy weather during the months of July, August, and September in the Matanuska and Talkeetna basins.[1] Fragmentary records show that the ice on the Susitna breaks between May 15 and June 1, and the river probably remains open until about October. The ice is not strong enough for sleighing until about a month later.

In the absence of complete records for the region adjacent to and north of Cook Inlet it has seemed worth while to publish the following table of observations made at Chickaloon.

[1] Systematic meteorologic records were begun at Chickaloon, Matanuska Valley, in March, 1910, by Harry Hicks, volunteer observer for the Weather Bureau. Mr. Hicks informed the writer that from March to August, inclusive, the total precipitation recorded by him was only about 3 inches.

which is about 40 miles northeast of the head of Knik Arm. This record has been kindly furnished by Mr. Frank Watson.

*Meteorologic observations at Chickaloon.*

| | Temperature (°F.). | | Remarks. |
|---|---|---|---|
| | 6 a. m. | Noon. | |
| 1907. | | | |
| October 25 | 28 | 37 | Cloudy. |
| 26 | 32 | 36 | Do. |
| 27 | 22 | 42 | Fine a. m., cloudy p. m. |
| 28 | 36 | 40 | Cloudy. |
| 29 | 28 | 30 | Snow a. m., 1½ inches. |
| 30 | 32 | 22 | Snow, 2 inches; temperature at 6 p. m., 16°. |
| 31 | 10 | 17 | Snow, 1¼ inches; high east wind; temperature at 6 p. m., 13°. |
| November 1 | 8 | 18 | Fair, with brisk easterly wind; temperature at 6 p. m., 14°. |
| 2 | 10 | 21 | Light northeasterly wind; temperature at 6 p. m., 13°. |
| 3 | 6 | 14 | Fair, with easterly wind. |
| 4 | 10 | 18 | Snow a. m., clear p. m.; temperature at 5 p. m., 8°. |
| 5 | 4 | 14 | Clear, easterly wind; temperature at 5 p. m., 5°. |
| 6 | 2 | 10 | Cloudy. |
| 7 | 14 | 20 | Clear, with wind. |
| 8 | 6 | 18 | Clear; snow last night. |
| 9 | 28 | 34 | Snow and rain. |
| 10 | 30 | 38 | Snow and rain; earthquake shock last night. |
| 11 | 14 | 32 | Clear. |
| 12 | 28 | 32 | Cloudy. |
| 13 | 28 | 35 | Do. |
| 14 | 30 | 36 | Clear. |
| 15 | 34 | 40 | Cloudy. |
| 16 | 25 | 28 | Clear. |
| 17 | 17 | 30 | Cloudy. |
| 18 | 28 | 32 | Clear. |
| 19 | 28 | 30 | Cloudy. |
| 20 | 18 | 28 | Clear. |
| 21 | 6 | 3 | Clear; temperature at 8 p. m., 10°. |
| 22 | −1 | 17 | Clear. |
| 23 | −2 | 8 | Do. |
| 24 | −3 | 10 | Do. |
| 25 | 5 | 14 | Cloudy. |
| 26 | 10 | 10 | Cloudy and wind. |
| 27 | 18 | 22 | Cloudy; snow in night. |
| 28 | 20 | 25 | Cloudy. |
| 29 | 13 | 18 | Do. |
| 30 | 16 | 18 | Clear. |
| December 1 | 16 | 22 | Do. |
| 2 | 22 | 26 | Clear and windy. |
| 3 | 6 | 6 | Clear. |
| 4 | 4 | 13 | Do. |
| 5 | 13 | 5 | Clear; temperature at 8 p. m., 6°. |
| 6 | −5 | 8 | Clear. |
| 7 | 5 | 18 | Do. |
| 8 | 22 | 24 | Cloudy. |
| 9 | 22 | 24 | Cloudy and windy. |
| 10 | 24 | 24 | Clear. |
| 11 | 26 | 28 | Cloudy; snow a. m. |
| 12 | 12 | 10 | Clear; temperature at 4 p. m., 4°. |
| 13 | 9 | 7 | Cloudy. |
| 14 | 16 | 12 | Do. |
| 15 | 22 | 28 | Do. |
| 16 | 26 | 31 | Do. |
| 17 | 25 | 22 | Clear. |
| 18 | 32 | 30 | Cloudy. |
| 19 | 36 | 32 | Do. |
| 20 | 14 | 20 | Clear. |
| 21 | 11 | 10 | Do. |
| 22 | 14 | 20 | Spitting snow. |
| 23 | 14 | −1 | Clear; temperature at 6 p. m., 8°; at 8 p. m., −10°. |
| 24 | 2 | 4 | |
| 25 | −10 | −13 | Clear; temperature at 9 p. m., −8°. |
| 26 | −20 | −2 | Clear; temperature at 9 p. m., −20°. |
| 27 | −4 | −12 | Light snow. |
| 28 | −30 | −28 | Clear. |
| 29 | −24 | −26 | Do. |
| 30 | −26 | −25 | Do. |
| 31 | −11 | −6 | Do. |
| 1908. | | | |
| January 1 | −16 | −15 | Do. |
| 2 | −6 | 0 | Clear and windy. |
| 3 | 10 | 14 | Clear. |
| 4 | 14 | 17 | Cloudy. |
| 5 | 4 | 10 | Do. |
| 6 | 24 | 26 | Snow, 4 inches. |
| 7 | 4 | 16 | Cloudy. |
| 8 | 10 | 16 | Do. |
| 9 | 20 | 24 | Snowing and wind. |
| 10 | 10 | 12 | Clear; temperature at 6 p. m., −4°. |
| 11 | −17 | −12 | Clear. |
| 12 | 12 | 18 | Cloudy. |
| 13 | 4 | 12 | Clear. |
| 14 | 12 | 18 | Cloudy; snowing. |
| 15 | 17 | 24 | Cloudy. |
| 16 | 30 | 30 | Snow a. m., cloudy p. m. |
| 17 | 22 | 26 | Cloudy, with light snow. |
| 18 | 2 | 12 | Cloudy. |
| 19 | −12 | 10 | Light snow. |

*Meteorologic observations at Chickaloon*—Continued.

| | Temperature (°F.). | | Remarks. |
|---|---|---|---|
| | 6 a. m. | Noon. | |
| 1908. | | | |
| January 20 | −26 | − 4 | Clear. |
| 21 | −10 | 3 | Clear, light easterly wind. |
| 22 | −20 | −12 | Snow. |
| 23 | 16 | 24 | Cloudy. |
| 24 | 24 | 30 | Cloudy; snowing p. m. |
| 25 | 29 | 26 | Cloudy. |
| 26 | 22 | 25 | |
| 27 | 18 | 15 | Clear. |
| 28 | 18 | 24 | Cloudy. |
| 29 | 18 | 28 | Clear. |
| 30 | 13 | 26 | Do. |
| 31 | 0 | 16 | Do. |
| February 1 | 0 | 20 | Cloudy. |
| 2 | 3 | 22 | Clear; first sunshine in south window of cook house. |
| 3 | 1 | 24 | Clear. |
| 4 | 5 | 22 | Do. |
| 5 | −16 | 1 | Do. |
| 6 | −20 | − 1 | Do. |
| 7 | −21 | − 6 | Do. |
| 8 | − 4 | 17 | Cloudy. |
| 9 | 18 | 26 | Do. |
| 10 | 15 | 26 | Clear and sunshine. |
| 11 | 4 | 26 | Clear. |
| 12 | 16 | 30 | Cloudy. |
| 13 | 24 | 26 | Clear. |
| 14 | 8 | 29 | Do. |
| 15 | 18 | 24 | Snowing. |
| 16 | 24 | 28 | Cloudy. |
| 17 | 26 | 36 | Clear. |
| 18 | 14 | 30 | Snowing. |
| 19 | 26 | 36 | Do. |
| 20 | 32 | 36 | Snow and rain. |
| 21 | 32 | 40 | Cloudy, with snow. |
| 22 | 32 | 46 | Cloudy. |
| 23 | 5 | 30 | Partly cloudy. |
| 24 | 20 | 36 | Clear a. m., cloudy p. m. |
| 25 | 20 | 30 | Snowing. |
| 26 | 8 | 30 | Clear. |
| 27 | − 6 | 27 | Clear a. m., cloudy p. m. |
| 28 | −10 | 26 | Clear. |
| 29 | 4 | 24 | Do. |
| March 1 | 0 | 30 | Do. |
| 2 | 7 | 28 | Do. |
| 3 | 20 | 34 | Cloudy. |
| 4 | 23 | 38 | Do. |
| 5 | 30 | 42 | Snow. |
| 6 | 10 | 40 | Snow; clear a. m., cloudy p. m. |
| 7 | 26 | 36 | Snow. |
| 8 | 28 | 40 | Do. |
| 9 | 28 | 30 | Snowing a. m., blowing p. m. |
| 10 | 14 | 36 | Clear; east wind. |
| 11 | 12 | 30 | Do. |
| 12 | 12 | 25 | Clear: strong east wind. |
| 13 | 2 | 10 | Do. |
| 14 | − 3 | 10 | Clear; east wind. |
| 15 | 4 | 24 | Do. |
| 16 | 6 | 22 | Clear; light east wind. |
| 17 | 16 | 34 | Do. |
| 18 | 14 | 29 | Cloudy. |
| 19 | 28 | 30 | Snowing; west wind. |
| 20 | 18 | 35 | Cloudy. |
| 21 | 28 | 39 | Snowing. |
| 22 | 10 | 25 | Snowing a. m., clear p. m. |
| 23 | − 2 | 35 | Clear. |
| 24 | 4 | 33 | Cloudy a. m., wind p. m. |
| 25 | 0 | 42 | Clear. |
| 26 | 2 | 40 | Do. |
| 27 | 18 | 40 | Cloudy. |
| 28 | 22 | 43 | Clear. |
| 29 | 8 | 38 | Do. |
| 30 | 22 | 32 | Cloudy. |
| 31 | 23 | 32 | Do. |
| April 1 | 30 | 45 | Do. |
| 2 | 32 | 36 | Snowing. |
| 3 | 28 | 42 | Partly cloudy. |
| 4 | 8 | 41 | Clear. |
| 5 | 22 | 40 | Do. |
| 6 | 24 | 40 | Cloudy. |
| 7 | 26 | 36 | Snowing. |
| 8 | 8 | 40 | Clear. |
| 9 | 24 | 38 | Clear a. m., windy and cloudy p. m. |
| 10 | 30 | 44 | Clear. |
| 11 | 24 | 46 | Do. |
| 12 | 26 | 45 | Do. |
| 13 | 22 | 44 | Do. |
| 14 | 28 | 44 | Do. |
| 15 | 26 | 42 | Do. |
| 16 | 30 | 44 | Do. |
| 17 | 28 | 44 | Do. |
| 18 | 27 | 46 | Do. |
| 19 | 36 | 44 | Cloudy. |
| 20 | 38 | 50 | Clear a. m., cloudy p. m.; snow, ½ inch. |
| 21 | 36 | 43 | Clear. |
| 22 | 36 | 48 | Do. |
| 23 | 26 | 42 | Do. |

*Meteorologic observations at Chickaloon*—Continued.

| | Temperature (°F.). | | Remarks. |
|---|---|---|---|
| | 6 a. m. | Noon. | |
| 1908. | | | |
| April 24 | 28 | 48 | Clear a. m., cloudy with light snow p. m. |
| 25 | 30 | 43 | Clear. |
| 26 | 36 | 46 | Do. |
| 27 | 36 | 52 | Do. |
| 28 | 34 | 49 | Cloudy. |
| 29 | 42 | 52 | Clear. |
| 30 | 34 | 52 | Do. |
| May 1 | 40 | 50 | Do. |
| 2 | 36 | 52 | Cloudy. |
| 3 | 32 | 56 | Clear. |
| 4 | 36 | 48 | Do. |
| 5 | 40 | 48 | Cloudy. |
| 6 | 39 | 51 | Do. |
| 7 | 45 | 51 | Clear. |
| 8 | 38 | 56 | Clear a. m., cloudy p. m. |
| 9 | 44 | 52 | Clear. |
| 10 | 44 | 53 | Cloudy. |
| 11 | 42 | 52 | Clear. |
| 12 | 40 | 46 | Cloudy with light rain p. m. |
| 13 | 42 | 48 | Cloudy p. m. |
| 14 | 40 | 60 | Do. |
| 15 | 44 | 58 | Clear, light east wind. |
| 16 | 40 | 60 | Clear. |
| 17 | 44 | 60 | Do. |
| 18 | 40 | 64 | Do. |
| 19 | 44 | 60 | Do. |
| 20 | 40 | 56 | Clear a. m., cloudy with light rain p. m. |
| 21 | 44 | 56 | Cloudy; light rain. |
| 22 | 38 | 56 | Clear. |
| 23 | 46 | 54 | Cloudy. |
| 24 | 44 | 54 | Do. |
| 25 | 44 | 54 | Partly cloudy. |
| 26 | 44 | 56 | Cloudy. |
| 27 | 42 | 52 | Do. |
| 28 | 42 | 54 | Clear. |
| 29 | 48 | 60 | Do. |
| 30 | 44 | 56 | Cloudy. |
| 31 | 50 | 60 | Clear. |
| June 1 | 56 | 66 | Clear a. m., cloudy p. m. |
| 2 | 54 | 58 | Cloudy. |
| 3 | 48 | 60 | Do. |
| 4 | 48 | 50 | Do. |
| 5 | 44 | 50 | Do. |
| 6 | 46 | 50 | Do. |
| 7 | 44 | 55 | Clear. |
| 8 | 47 | 60 | |
| 9 | 57 | 62 | Cloudy and clear by spells. |
| 10 | 52 | 60 | Clear a. m., cloudy p. m. |
| 11 | 51 | 58 | Do. |
| 12 | 56 | 56 | Clear. |
| 13 | 48 | 58 | Do. |
| 14 | 46 | 60 | Do. |
| 15 | 56 | 66 | Do. |
| 16 | 52 | 62 | Do. |
| 17 | 50 | 58 | Cloudy. |
| 18 | 50 | 68 | Clear and cloudy by spells. |
| 19 | 53 | 65 | Clear. |
| 20 | 50 | 66 | Do. |
| 21 | 56 | 66 | Clear a. m., cloudy p. m. |
| 22 | 58 | 68 | Clear. |
| 23 | 58 | 70 | Do. |
| 24 | 62 | ........ | Do. |
| 25 | 58 | 78 | Do. |

*Monthly snowfall at Chickaloon.*

| | Inches. |
|---|---|
| October, 1907 | 9¾ |
| November, 1907 | 13¾ |
| December, 1907 | 9½ |
| January, 1908 | 23¾ |
| February, 1908 | 8¾ |
| March, 1908 | 30 |
| April, 1908 | 4¼ |
| | 99¾ |

March 23, 1908, 3 feet 4 inches of snow on the level; April 14, 1908, 2 feet 6 inches of snow on the level.

## INLAND PROVINCE.

In discussing the climate on the inland side of the range one can only abide by such generalizations as are applicable to the Yukon basin as a whole, for the records of stations within this area are as yet too meager to carry any weight. This inland province, separated as it is by high mountain barriers from the humid winds of the Pacific, is continental in character—semiarid, with great extremes of heat and cold. While the coastal belt of Bering Sea is relatively humid, the air becomes drier toward the upper Yukon. The mouth of the Tanana has a rainfall between 12 and 14 inches, as compared with about 10 inches at the international boundary. The rainfall data of the Yukon-Tanana region are summarized in the following table:

*Mean precipitation at stations in Yukon-Tanana region.*

[Compiled from records of United States Weather Bureau by F. F. Henshaw.]

| Station. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. | Length of record. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | *Yrs.* | *mos.* |
| Central | 0.80 | 0.24 | 1.31 | 0.70 | 0.73 | 3.56 | 3.11 | 1.85 | 0.52 | 0.70 | 0.80 | 0.35 | 14.67 | 1 | 7 |
| Circle | 1.05 | .29 | .52 | .67 | .83 | .54 | 1.77 | 2.33 | 1.69 | 1.15 | .30 | .51 | 11.65 | 1 | 22 |
| Fairbanks | 1.99 | .58 | .93 | .11 | .36 | 1.26 | 2.16 | 1.98 | 1.56 | 1.37 | .92 | .88 | 14.10 | 1 | 18 |
| Fort Egbart | 1.01 | .39 | 1.37 | .18 | .66 | 1.23 | 1.98 | 1.73 | 1.95 | 1.93 | .72 | .38 | 13.53 | | 37 |
| Fort Gibbon | .54 | .49 | .46 | .10 | .50 | .74 | 2.80 | 3.04 | 1.05 | .85 | .52 | .50 | 11.59 | 1 | 33 |
| Kechumstuk | .46 | .11 | .12 | .22 | 1.24 | 1.51 | 1.87 | 1.77 | 1.20 | .62 | .22 | .21 | 9.55 | 2 | 18 |
| North Fork | .70 | .39 | .18 | .40 | 1.66 | 2.33 | 2.13 | 2.04 | 1.52 | .42 | .52 | .29 | 12.58 | 1 | 13 |
| Rampart | .90 | .26 | .67 | .03 | .42 | 1.04 | 2.04 | 2.66 | 1.60 | .82 | 1.19 | .33 | 11.96 | 1 | 17 |
| Dawson | 1.01 | .67 | .46 | .54 | .97 | .86 | 1.85 | 1.77 | 1.82 | 1.60 | 1.12 | 1.10 | 13.77 | 5 | 18 |

NOTE.—Values for the different months are averages of all observations for that month. In the column headed "Annual" is given the total of these averages. Amounts given for the winter months, October to March, represent melted snow, and as a rule are taken as one-tenth of the snowfall. The number of years given under "Length of record" indicates the time covered by continuous observations.

The average winter temperature in this province is −5° to −10°, with a minimum of −65° to −76°; for the summer months of June, July, and August the mean is 50° to 60° and the recorded maximum 90°. Snowfall records indicate depths varying from 3 to 5 feet. As many of the snowstorms are accompanied by wind, however, accurate measurements are almost impossible, and the estimate probably exceeds the actual snowfall. In this general field the summer is usually dry from the 1st of May till about the 20th of July, when the rains begin. August and September always have some clear weather but are frequently characterized by steady, though light rains. Spurr reports similar conditions on the Kuskokwim during the expedition of 1898. The estimated rainfall during these drizzles is not great. Incomplete records show an average of 80 to 90 days annually on which there is some precipitation. Fragmentary records indicate that the lower Tanana is warmer than other parts of the Yukon basin, but this is by no means established. The aridity of the climate makes the winter cold easy to bear. Traveling by dog team or horse sled in winter is always possible, even under extreme cold, unless the wind is blowing. The journey from Chitina or Valdez to Fairbanks by stage is now made at all times during the winter by men and often by women and children.

Ice usually begins to run on the Yukon between the first and middle of October, but the delta closes to navigation one or two weeks earlier. In the spring the ice breaks at the mouth of the Tanana about May 10 to 15. So far as the records show, the Tanana breaks a little sooner in the spring and closes a little later in the fall than the Yukon. A few records on the Kuskokwim indicate that the river is open to navigation from the early part of May to the first or middle of October. It is probable, however, that the ice does not go out of the delta of the Kuskokwim until sometime in June and forms again by the end of September. The sluicing season in the Fairbanks district usually extends from about May 10 to the middle or end of September. There are records of creeks opening as early as the middle of April, and in 1907 most of the waterways remained open until the end of October. In the Rampart region the conditions are about the same.

## METEOROLOGIC NOTES OF 1902 EXPEDITION.

The following table by Mr. Prindle is of interest as indicating the climatic conditions along the route of travel in 1902. The temperatures were taken with a Green self-registering maximum and minimum Fahrenheit thermometer. Under the conditions of constant travel it was possible to obtain but few records of maximum temperature. For location of points of observation see Plate III (in pocket).

*Meteorologic record of expedition of 1902.*

| Date. | Minimum temperature above zero (° F.). | Approximate altitude of camps where minimum temperature was taken (feet). | Notes. |
|---|---|---|---|
| June 1 | 35 | 0 | Clear; light clouds near horizon; light breeze from southwest; local thunder showers; maximum temperature 72°. |
| 2 | ........... | 0 | Sun about two hours high at 5 a. m.; clear and warm; northwest breeze. |
| 3 | 43 | 0 | Cloudless sky; light breeze, north to northwest. |
| 4 | 41 | 0 | Slightly cloudy early in day, clearing later. |
| 5 | 35 | 0 | Day very warm; slightly cloudy toward night; light southeast wind. |
| 6 | 39 | 0 | Rather cloudy; wind southeast; light breeze early in day; strong at 4 p. m.; maximum temperature about 78°. |
| 7 | 38 | 0 | Clear morning; cloudy afternoon; light breeze from southeast; maximum temperature 71°. |
| 8 | 38 | 200 | Light cumulus clouds from the north. |
| 9 | 42 | 1,000 | Rained in early morning; clear afternoon; thunder storm over Mount Susitna. |
| 10 | 42 | 1,000 | Rained intermittently preceding night; cloudy morning; clouds from the south; sunshine in afternoon; maximum temperature 66°. |
| 11 | 43 | 1,000 | Cloudy all day; at times during morning rather cold southerly wind; warmer in afternoon. |
| 12 | 42 | 1,000 | Cloudy, foggy; rain in afternoon; clear toward sunset; maximum temperature 65°. |
| 13 | 34 | 1,200 | Clear sky; fresh breeze from southeast. |
| 14 | 39 | 1,200 | Clear and warm; light breeze from north. |
| 15 | 36 | 1,200 | Morning clear and warm; rain in afternoon; cool and cloudy at sunset; fresh breeze from the north. |
| 16 | 42 | 900 | Clear; north wind. |
| 17 | 42 | 800 | Clear; fresh breeze from north. |
| 18 | ........... | 200 | Clear and warm. |
| 19 | 46 | 200 | Rained a little during the night; morning cloudy; afternoon sun and clouds, thunder. |
| 20 | 41 | 200 | Morning cloudy; afternoon clear and warm. |
| 21 | 34 | 200 | Clear and warm. |
| 22 | 40 | 200 | Morning clear; short thunder shower; afternoon cloudy. |
| 23 | 49 | 200 | Morning clear; night of 23d warm and showery. |
| 24 | ........... | 150 | Morning clear; thunder storm during evening. |
| 25 | 43 | 150 | Morning clear; thunder showers during afternoon. |
| 26 | 53 | 150 | Rained during night; morning clear; light rain in afternoon; beautiful sunset. |
| 27 | 52 | 150 | Rainy morning; cleared before sunset. |
| 28 | 42 | 150 | Morning beautiful, clear; afternoon cloudy; wind southeast. |
| 29 | 55 | 150 | Cloudy all day; rain during morning. |
| 30 | ........... | 150 | Clear afternoon and evening. |
| July 1 | 42 | 200 | Morning clear; afternoon cloudy; southeast breeze. |
| 2 | 43 | 1,000 | Cloud and sunshine; pleasant. |
| 3 | ........... | 800 | Morning clear; cloudy toward evening; sun hot at noon. |
| 4 | 47 | 600 | Rain most of the day. |
| 5 | 41 | 800 | Cloudy all day. |
| 6 | 37 | 800 | Cloudy morning; clear at noon. |
| 7 | 45 | 1,000 | Rained during night and part of morning. |
| 8 | 33 | 1,000 | Clear day. |
| 9 | 46 | 1,200 | Morning clear; afternoon cloudy. |
| 10 | 49 | 1,000 | Morning clear; afternoon and evening cloudy. |
| 11 | 50 | 2,200 | Cloudy; west wind; afternoon rainy. |
| 12 | ........... | 2,000 | Rained during night and morning; afternoon clear; northwest breeze. |
| 13 | 44 | 2,000 | Clear early; later somewhat cloudy; northwest breeze. |
| 14 | 41 | 2,400 | Increasing cloudiness all day; evening rain; northwest breeze. |
| 15 | 46 | 2,100 | Rainy most of the day, clearing toward evening. |
| 16 | 47 | 1,800 | Cloudy; sunshine at intervals. |
| 17 | 51 | 1,400 | Cloudy most of day; sunshine at intervals. |
| 18 | 50 | 1,200 | Cloudy most of the day. |
| 19 | 50 | 1,000 | Cloudy early morning; most of day clear and warm. |
| 20 | 34 | 1,000 | Clear morning; afternoon cloudy; light rain between 5 and 6 p. m. |
| 21 | 49 | 1,200 | Cloudy; thunder storm at 3 p. m. |
| 22 | 49 | 1,500 | Fine rain all day; mist hanging over hills. |
| 23 | 45 | 2,800 | Cloudy most of day. |
| 24 | 41 | 3,200 | Sunshine and clouds; thunder shower 6 p. m.; rain during evening; cool, variable wind. |
| 25 | 37 | 3,000 | Morning cloudy; bright sunshine at noon; afternoon showery; clear sunset. |
| 26 | 40 | 3,000 | Morning cloudy; afternoon rainy; mist hanging about the hills. |
| 27 | ........... | 3,000 | Morning clear; afternoon cloudy; northwest wind. |
| 28 | 38 | 2,000 | Clear most of the day. |
| 29 | 44 | 2,600 | Cloudy; strong southerly wind. |
| 30 | 42 | 2,500 | Cloudy; east wind during afternoon. |
| 31 | ........... | 2,800 | Clear day. |
| Aug. 1 | 41 | 2,800 | Morning clear; rained in afternoon about an hour; beautiful sunset. |
| 2 | 41 | 2,600 | Clear morning; cloudy afternoon with thunder shower about 3 p. m. |
| 3 | 44 | 2,600 | Rain, clearing during afternoon. |
| 4 | 38 | 2,600 | |
| 5 | 35 | 2,400 | Cloudy all day. |
| 6 | 40 | 2,000 | Cloudy; rain and thunder about noon. |
| 7 | 34 | 2,600 | Morning cloudy. |
| 8 | 31 | 3,800 | Clear till noon, clouds working up from the south; wind from south. |
| 9 | 33 | 3,000 | Cloudy; rained about three hours in evening. |
| 10 | 37 | 3,000 | Cloudy early; very clear most of day; southerly wind. |
| 11 | 36 | 2,800 | Cloudy early; wind from south; afternoon clear. |
| 12 | ........... | 2,800 | Morning cloudy; wind from southeast. |
| 13 | 32 | 3,000 | Clouds and sunshine alternating; day warm; rain during night. |
| 14 | 43 | 3,000 | Rain. |
| 15 | 34 | 2,400 | Clear morning; cloudy afternoon. |
| 16 | 42 | 1,700 | Cloudy most of the day. |
| 17 | 43 | 1,800 | Rained during preceding night. |
| 18 | 35 | 2,100 | Early morning and evening clear; middle of day cloudy; slight rain. |
| 19 | 36 | 2,800 | Rained intermittently during day, steadily during evening. |
| 20 | 39 | 2,000 | Cloudy; afternoon rainy; cold wind. |
| 21 | 36 | 1,800 | Morning cloudy; evening clear. |
| 22 | 26 | 1,200 | Frost; clear; light breeze from northwest. |
| 23 | 29 | 1,200 | Slightly cloudy; east wind, strong during forenoon. |
| 24 | 35 | 1,400 | Clear; evening and night rainy. |
| 25 | ........... | 1,400 | Cloudy; rainy about half the day. |
| 26 | ........... | 2,000 | Cloudy early, clearing later; clear sunset. |
| 27 | 34 | 600 | Clear morning; strong southeast breeze. |
| 28 | 41 | 400 | Dry morning; no dew; cloudy most of day. |
| 29 | 35 | 400 | Cloudy morning; afternoon sunshine; warm. |

*Meteorologic record of expedition of 1902*—Continued.

| Date. | Minimum temperature above zero (°F.). | Approximate altitude of camps where minimum temperature was taken (feet). | Notes |
|---|---|---|---|
| Aug. 30 | 44 | 500 | Rained at intervals during night; alternately clear and cloudy; warm. |
| 31 | 33 | 400 | |
| Sept. 1 | ........ | 400 | |
| 2 | 37 | 400 | Morning clear; sprinkle during afternoon; breeze from north, changing to northeast. |
| 3 | 41 | 400 | Clear. |
| 4 | 33 | 400 | Clear. |
| 5 | 41 | 400 | Morning clear; thunder shower during afternoon. |
| 6 | 40 | 400 | |
| 7 | ........ | 600 | Clear. |
| 8 | 29 | 600 | Somewhat cloudy; rain during evening. |
| 9 | 40 | 1,200 | Drizzly, rainy day, clearing at sunset. |
| 10 | 24 | 1,400 | Frosty morning; dull, gray sky. |
| 11 | 38 | 1,000 | Rain; southeast wind changing to northwest; clear evening; frost during night. |
| 12 | 24 | 1,200 | Clear, frosty morning. |
| 13 | 30 | 1,000 | |
| 14 | ........ | ........ | |
| 15 | ........ | ........ | |
| 16 | 31 | 400 | |

## VEGETATION AND ANIMAL LIFE.

### INTRODUCTION.

As there was no trained naturalist in the party, biologic study was necessarily confined to random observations on some of the more striking features of the animal and vegetable life of the region. The notes of a layman on an unexplored region are, however, probably of sufficient interest to the naturalist and traveler to justify their publication. In any event they may serve to supplement the biologic investigations made by Osgood[1] and others in adjacent regions having similar faunas and floras.

Though a botanist would probably find great contrasts in the floras of the different provinces traversed by the expedition, yet to the layman, except for variations due to altitude, the vegetation of the coastal and interior belts appears very similar. White and black spruces, poplars, white birches, and a number of varieties of willow are widely distributed throughout the province. Sitka spruce and hemlock are found, however, only in the coastal region. Alder grows in profusion on the Pacific side of the divide above timber line and along the watercourses in the inland province. In the mountainous region "bunch grasses" are abundant, and other varieties of grasses grow at lower altitudes. Blueberries and dwarf birches grow at and above timber line on both sides of the Alaska Range. Among other wild fruits of this region are cranberries, salmon berries, and currants. Wild flowers are abundant in the open glades of the timbered areas and in the region lying above timber. Among these many of the familiar flowers of the States appear to be recognizable, though they differ specifically. Something of the areal distribution and varieties of these flowering plants is established through the small collection made during the expedition. This collection was kindly determined by Mr. F. V. Coville, of the Department of Agriculture. (See pp. 208–211.)

The notes on the animal life of the region were mostly devoted to the game. Moose and large brown bear were encountered on the Cook Inlet side of the divide, white sheep along the northern foothills of the Alaska Range, and moose and caribou in the inland plateau region as well as in some of the tributary valleys. But one black bear was seen—in the Kuskokwim Valley—but these animals are known to exist in the Cook Inlet region. No large game was seen north of the Tanana, though there was evidence of the presence of moose, and migratory caribou are known to be abundant in this region in some years.

[1] Osgood, W. H., Results of a biological reconnaissance of the Yukon River region, with annotated lists of birds by Louis G. Bishop: North Am. Fauna No. 19, U. S. Dept. Agr.; Natural history of the Cook Inlet region, Alaska: Idem, No. 21, 1901; A biological reconnaissance of the base of the Alaska Peninsula: Idem, No. 24, 1904.

Dall, W. H., Alaska and its resources, Boston, 1870.

Sudworth, G. B., *Forest trees of the Pacific slope*, Forest Service, U. S. Dept. Agr., 1908.

See also reports of Harriman Alaska Expedition, vols. 1, 2.

No wolves were seen by the party, though the tracks of the timber wolf were found on both sides of the range. The wolverine is known to be present on both sides of the Alaska Range and is one of the fur-bearing animals hunted by the natives. Beaver appear to be scarce, as but few fresh cuttings were observed by the party. They are, however, known on both sides of the range. Both the Cook Inlet region and the Kuskokwim and Tanana region have been important sources of mink and marten skins to the fur trader. Red foxes are observed throughout the province and other varieties are caught by the natives. The large snowshoe rabbit or hare was seen on the Cook Inlet side of the divide and also in the Tanana Valley. The small whistling marmot was found widely distributed in the areas lying above the timber line throughout the province.

Of the game birds, species of grouse were found in the Cook Inlet region and also north of the Tanana Valley. In the flats northwest of Beluga River there is an abundance of sand-hill cranes and ducks, and geese and swan are known to inhabit the larger rivers close at hand. Ducks and geese are also abundant on the Tanana and some of its tributaries. The ptarmigan, the typical Alaska game bird, was found to be very plentiful above timber line throughout the province.

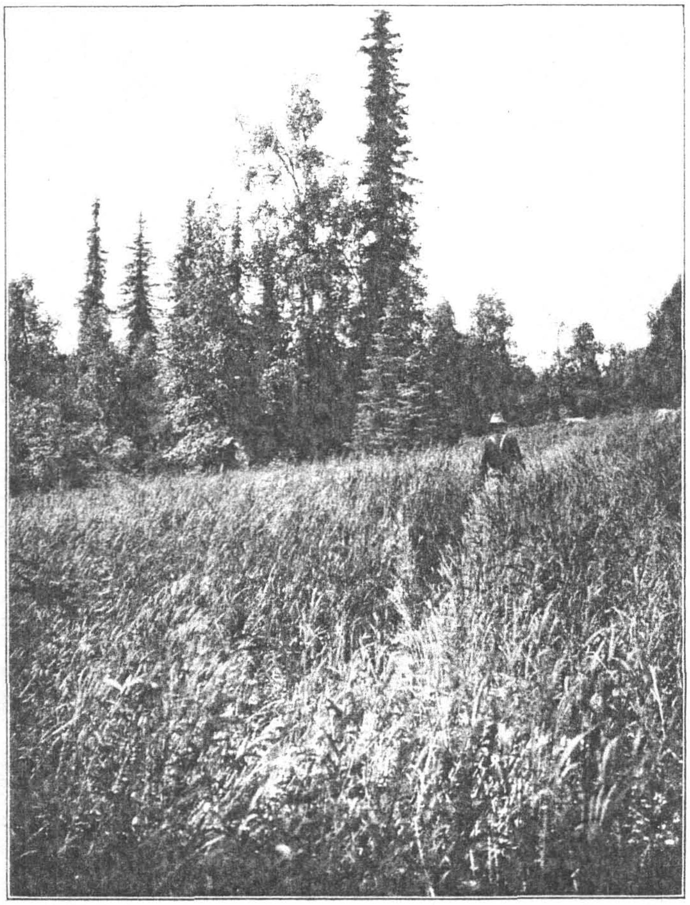
The salmon fisheries of Cook Inlet are important locally, though there are no canneries in this part of Alaska. A number of species of salmon occur in that district. In the spring the candlefish is very abundant. The sea otter, which was formerly hunted by the Russians in the Cook Inlet region, has long since disappeared. Of the fresh-water fish, Alaska grayling was noted in most of the clear-water streams throughout the region. Whitefish and a species of pickerel also occur in the Tanana waters. Rainbow trout were found by Sidney Paige in the small streams tributary to Knik Arm but were not seen along the route of the expedition.

## NOTES ALONG ROUTE OF TRAVEL.

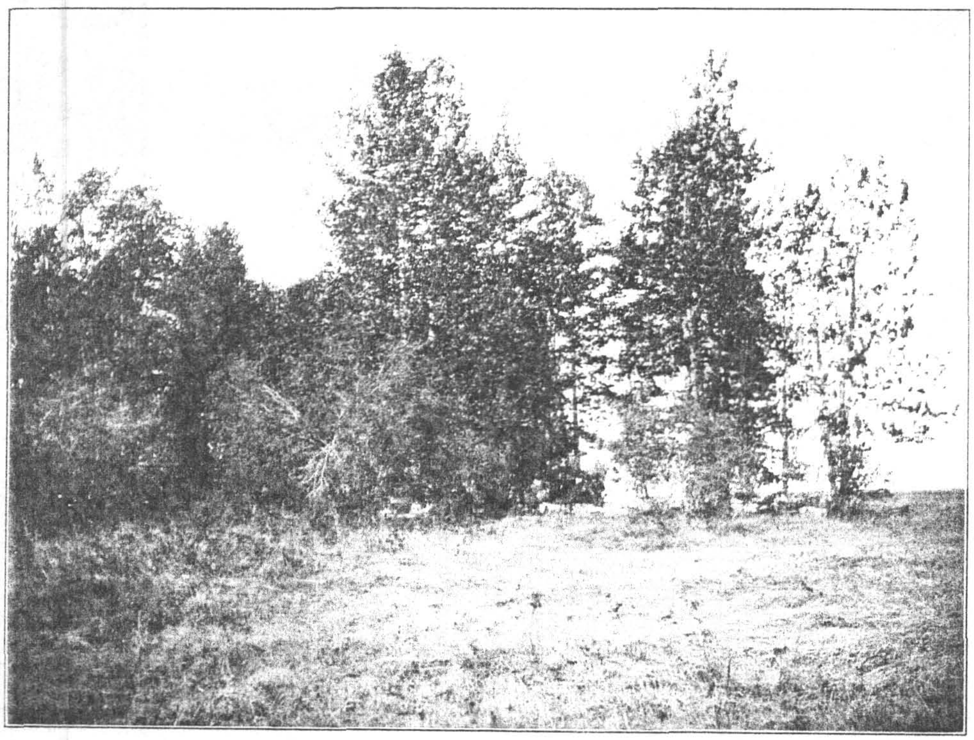
On May 29, when the party landed at Tyonek, the natives and some white fishermen already had their traps and seines out for the king salmon, for which the salteries were paying 15 cents apiece. They were also catching a few red salmon. The only other salt-water fish which came under the observation of the party was candlefish, which on June 4 were running up Beluga River in great schools. The name Beluga is derived from the Russian bieluga, white whale, which is common in the upper part of Cook Inlet. According to the traders, the chief furs of the Cook Inlet district are the marten, mink, beaver, red fox, bear, lynx, and wolverine. The catch for the winter of 1901–2 also included a few silver-gray foxes.

The gravel plateau stretching inland from Tyonek is covered with an open growth of forest in which birch appears to predominate, but there is also much poplar and some spruce, together with alder, along the watercourses (Pl. IV, *A*, p. 44). Here some "devil's club" was observed, and this shrub was also seen on the lower slope of Mount Susitna but not elsewhere in the region. Osgood reports the occurrence of hemlock on Turnagain Arm, but this tree was not observed on the west side of Cook Inlet. Osgood also recognized three varieties of spruce in this general region—the white, the black, and the Sitka—together with the aspen and the balsam poplar. The largest trees noted near Cook Inlet (chiefly white birches) have a diameter of 12 to 24 inches (Pl. XVIII, *B*). In these forests some spruce hen or grouse were observed, which were nesting about the first of June. On June 5 three brown bear were seen near Beluga River, 5 miles from the coast.

The lower eastern slope of Mount Susitna is clothed with an open forest, composed chiefly of deciduous trees, broken by glades of grass. This type of vegetation continues up to about 1,000 feet above the sea, where it gradually merges into a zone covered with grass interrupted by dense willow and alder thickets. A few birches are found up to an altitude of 1,500 feet, which is practically the limit of vegetation except for mosses and flowers. The south slope of Mount Susitna is covered chiefly with deciduous trees, but coniferous trees predominate on the northern slope. The alluvial floor of the valley of the Susitna, as seen from the mountain of the same name, is well timbered.



*A.* GRASS AND TIMBER ON NIN RIDGE, KICHATNA VALLEY.
Near camp of July 2. See page 212.



*B.* COTTONWOOD TIMBER ON BELUGA RIVER.
Near camp of June 6. See page 202.

The gravel plateau crossed between tidewater and the mountains is covered with an open forest of spruce (Pl. IV, *A*, p. 44), with some birch and poplar, and includes some large swamps. Many ducks and sand-hill cranes and some geese were seen on the small lakes of this region, also many old beaver dams, at one of which fresh beaver cuttings were observed. On the high ridge east of the camp of June 9 (see Pl. III, in pocket) spruce, birch, and poplar forests reach an altitude of about 1,600 feet and alder extends up to about 2,000 feet. Toward the foothills of the range the timber becomes gradually more scattering and disappears at altitudes of 1,600 to 1,800 feet, but thick groves of alder and willow were found above these altitudes along the watercourses. Some currant bushes were noted in this part of the province. Grass was fairly abundant in the open and drier parts of this area, but better feed for the stock was found above timber line. Here ptarmigan were abundant and a number of large brown bear were seen. These, like others later encountered in the upper Kichatna Valley, are probably of the so-called peninsula brown-bear type, closely related to and as large as the Kodiak brown bear, though regarded as a distinct species. These brown bears and the three seen near the Beluga were all found above timber line. The experience of the party indicates that these bears are not vicious and probably will not attack a man unless they are wounded. Twice members of the party encountered she bears with cubs at close quarters, and though the mothers turned on them, when the intruders retreated they seemed to be quite satisfied and made off with their offspring.

After traversing the foothill belt the party descended the slopes of the Skwentna Valley through dense alder thickets. The floor of the valley is clothed with a heavy growth of timber. Poplars and birches predominate, and there is also some spruce. The largest trees measure 2 to 2½ feet in diameter. It was noted that measuring worms were destroying the foliage of many of the alders. In the flat between the Skwentna and the Kichatna there is only a light stand of timber but much alder. Near the Kichatna, however, the timber is more abundant, and here the poplars are of especially large size.

In the lower Kichatna the party passed through a beautiful parklike region where the ground in many places is covered with a dense growth of grass higher than the packs of the horses (Pl. XVIII, *A*). Some patches of wild timothy were noted in this district. The timber consists of large birches and poplars (some measuring 2 to 2½ feet) and smaller spruces. Along the Kichatna the timber line is in the neighborhood of 2,400 feet, above which is found only alder and here and there a stunted spruce. An abundant supply of redtop grass was found, except in the very highest valleys traversed, where the grass seemed almost entirely absent.

Though some moose tracks were noted in the early part of the journey, the first moose seen by the party was killed near the camp of July 13, at an altitude of 2,200 feet, near timber line. During the season of the greatest prevalence of insect pests the moose go to timber line or the bars of the largest rivers, in order to avoid, in part at least, the flies and mosquitoes. The writer saw a fresh caribou track at an altitude of about 3,000 feet, near the point where the moose was killed. A newly dropped caribou horn was also found near the camp of July 15, at an altitude of about 2,200 feet, on the Kuskokwim side of the divide. These facts are noted because it seems to be unusual for the caribou to penetrate the high range.

The first of the white Alaska sheep seen by the party were found between the camps of July 15 and 16, below timber line, at an altitude of about 2,200 feet. A young sheep weighing about 70 pounds was killed. The only black bear seen was encountered in the valley of the Kuskokwim, near the camp of July 9, at an altitude of about 3,000 feet, about 500 feet above timber line.

Beyond Rainy Pass the route led through a heavily wooded valley tributary to Dillinger River. Here the timber line is at about 2,800 to 2,900 feet, or 300 or 400 feet higher than on the coast side of the divide. The timber in this valley is chiefly spruce, but includes some poplar. Toward the Kuskokwim the timber gradually becomes larger, the spruce being 12 to 18 inches and the poplar 10 to 12 inches in diameter. The Kuskokwim Valley is well timbered with spruces and contains some scattering poplars. A few white birches were noted on the higher slopes of the valley.

Moose are fairly abundant in this timbered area, which appears to be a favorite hunting ground of the Kuskokwim natives. Near the camp of July 22 (see Pl. III, in pocket) was seen a brush fence constructed by the natives for turning moose along a trail where they could be easily killed. With the introduction of modern firearms these game fences, which formerly were an important aid in procuring food supply, are falling into disuse.

After leaving the Kuskokwim Valley the route of travel for some 200 miles lay for the most part across the gravel-floored piedmont plateau, but in places traversed the foothills. The plateau is covered with a great variety of moss, but has little other vegetation. Among the various species of mosses was noted the white reindeer moss, which furnishes in part the food for the large number of caribou found in this region. The valley floors cut below the plateau surface are in most places covered with a dense growth of grass, and a few scattered spruces were observed near the route of travel. Here the upper limit of the spruce timber is between 2,000 and 2,400 feet, varying considerably from place to place. Above this altitude willows are found along the watercourses as high as 3,000 feet or more. Huckleberry bushes are very abundant along the valley slopes and on the plateau surface, as is also a variety of dwarf birch. The appended list (p. 208) shows that there is a considerable variety of flowering plants in this part of the province, some species being found close to snow line in the high range. North of the route of travel, at altitudes probably of 1,000 feet, lies the densely wooded lowland (fig. 30), drained on one side into the East Fork of the Kuskokwim and on the other into the Toklat, a tributary of the Tanana.

While traversing spurs of the main range between July 22 and 27 the party saw a number of bands of white mountain sheep at altitudes varying from 3,000 to 4,000 feet. The largest of these bands included 36 sheep, old and young. Noteworthy was the finding of moose tracks far above timber line and close to a glacier in this district.

On July 26 the first caribou were seen, and the records show that from that date until the 8th of August 77 caribou were actually counted by members of the party. This number was noted in the journal of the expedition, but as no very careful records of numbers were made it is probable that over a hundred were seen. Most of these caribou were in bands of three to eight. One caribou was found on the moraines of a glacier far up in the heart of the range. All the caribou seen appeared to be of the large woodland variety and of the same species as those observed by the writer above timber line in the White River basin in 1898.

The route of travel continued across the moss-covered plateau region, interspersed with grass-floored valleys, as far as McKinley Fork of the Toklat (camp of August 6), and then entered the mountains. Here the timber line is at 2,700 to 2,800 feet.

It seems probable that the white sheep frequent the foothills and high ranges all along the route of travel, but the rapidity of the journey did not permit many excursions into the higher parts of the range. A small band of sheep was seen about 5 miles east of the camp of July 26. Between the camps of August 10 and 13 a good sheep country was traversed. On August 11 the writer saw within three hours four different bands of sheep which must have aggregated 100 animals. These snow-white sheep form a very conspicuous feature of the landscape. As they wander far below the snow line, their coloring seems to be in no way protective.

The only bear seen by the party on the north side of the range was a big brown one wounded near the camp of August 5, not far from the base of Mount McKinley. This locality is far above timber line, and the animal had probably come to it in search of berries, which were plentiful. A moose was killed near the camp of August 11, in a region where these animals seemed not very plentiful.

From the Yanert Fork of the Nenana the party crossed a high divide to the north and here found the timber line between 2,600 and 2,700 feet. In this area the piedmont plateau is only about 2,200 to 2,400 feet high and is covered with spruce. Where crossed by the party this plateau had been ravaged by forest fires many years before and was covered with a luxuriant growth of grass. From the upper margin of this plateau a good view was obtained across the

Tanana Valley, which was found to be fairly well timbered though it is broken by meadows and swamps, together with some lakes and abandoned sloughs of drainage courses. On traversing this lowland it was found to be made up in part of spruce swamps, in part of dry land covered with an open growth of poplars, white birch, and some spruce. Much of the lowland had previously been burnt over and was then covered with a second growth of timber 25 to 30 feet in height, interspersed with a fine growth of grass. The largest trees noted in the Tanana Valley were the white birches, some of which exceeded 2½ feet in diameter. Spruce trees 18 inches to 2 feet in diameter are also not uncommon but are confined chiefly to the immediate banks of the larger streams. Here are also found extensive areas of tamarack or larch, the largest of which do not exceed 18 inches in diameter. This tree appears to be confined to the lower Tanana Valley, its tributaries, and the upper Kuskokwim. It is also sparingly found on the Yukon, near the mouth of the Tanana, and is reported by A. G. Maddren to occur on Innoko River.

Between the camps of August 18 and 22 one moose and two caribou were seen, these being the last large game encountered during the season. At certain times caribou are abundant in some parts of the Yukon-Tanana region, but for the most of the time while traversing this area the party was in the river bottoms and out of the caribou range. In the river bottom of the Nenana the large snowshoe rabbit was found in great abundance. In August this animal was already changing its color toward the lighter winter coat. No game was seen in the Tanana Valley, probably because the party there followed an Indian trail long used by the natives in their hunting expeditions to the mountains, and because the village of Tortella, on the Tanana (Pl. VII, *A*, p. 48), was only 20 miles distant. As the average Indian shoots at all the game he sees as long as he has ammunition, the placing of modern weapons in his hands soon results in driving the game far away from his settlements.

When the party crossed the Tanana, about September 1, the Indians were catching their winter supply of fish, which appeared to be chiefly humpbacked salmon. Salmon have been seen by the writer as far up the Tanana as Bates Rapids, but they do not appear to ascend farther, though there is no barrier at that point. The natives of the upper river appear to cure only the small white fish which are abundant in some of the clear-water streams.

The timber in the flat drained by the Tolovana is similar in grade and variety to that of the Tanana Valley. On the better-drained portions the deciduous trees—poplar and white birch—predominate; in the wetter portions spruce is usually the most common tree. The courses of the many streams which traverse this lowland are outlined by growths of heavy timber along the banks. The trees are spruce, white birch, and some poplar, and many of them attain diameters of 18 inches to 2 feet; here and there one reaches 2½ feet. Tamarack is also rather abundant on the flats. There is a thick growth of grass on the wet margins of some of the lakes, but it does not appear to be nutritious and the horses did not care for it. In the drier part of the lowland, however, there is a fine growth of grass, which the stock greedily devoured.

The Tolovana lowlands where traversed by the party showed no large game, though some old moose tracks were seen. This region being so accessible by river from the Tanana, the Indians have driven away the moose. Many grouse were found in the spruce woods and ducks, geese, and sand-hill cranes in the small lakes and ponds. The only ducks recognized by the party were mallards, but some small brown wood ducks and black ducks of species unknown to the members of the party were also seen.

Beyond the Tolovana flats the route lay across a portion of the Yukon-Tanana upland and for the most part was below timber line, which is here at about 3,000 to 3,200 feet. As in other parts of the district, the chief trees are spruce, poplar, and white birches, the first two predominating. No game of any kind was encountered in this part of the journey.

In considering the above account of the game, it must be remembered that no time was spent in hunting. There was absolutely no effort made to find the game, and all that was seen was encountered along the route of travel. The record, then, of more than 100 caribou, 15 moose or more, 200 or 300 sheep, and about a dozen bear, together with a large number of wild fowl—ptarmigan, grouse, etc.—indicates that the region traversed is an excellent game country. It is a noteworthy fact that the wild animals appeared to have no fear of the party. The caribou exhibited great curiosity about the pack train and horses. Small bands would hover around the party for hours, sometimes approaching within a hundred yards of the animals. One moose which, paying no heed to the noise made by the horse bells, strolled within a hundred yards of the camp, was shot. Sheep could be approached almost within pistol shot, and the bear paid but little attention to the members of the party.

The presence of fur-bearing animals was noted from their tracks, but only a few were actually seen. Foxes were observed in different parts of the region, a muskrat here and there in the low country, and fresh beaver cuttings at several places. On August 13 the writer saw a wolverine, which watched him with some curiosity at about 75 yards but promptly made off when fired at. The tracks of timber wolves were seen, particularly on the Cook Inlet side of the divide and along river bottoms.

### DISTRIBUTION OF TIMBER.

In the foregoing notes some details on the occurrence of timber in the areas traversed by the party are presented, and the accompanying map (fig. 30) shows the general distribution of timber throughout the province. As regards the adjacent region it appears that the basins of the Susitna, Matanuska, and other rivers tributary to Cook Inlet are fairly well timbered up to an altitude of 1,500 to 1,800 feet, and there is a sparse growth of stunted trees up to an altitude of 2,000 to 2,200 feet. In these districts the spruce, which furnishes the best timber, is usually less than a foot in diameter, though an occasional tree is found 15 to 18 inches in diameter.

There is some large hemlock and spruce timber in the bottoms of the large valleys tributary to Turnagain Arm. In general, however, the timber in this part of the field is little better than that of the Susitna and Matanuska valleys.

In Kenai Peninsula the timber line is at altitudes of 1,500 to 2,000 feet. Most of this timber is small, but in the valley floors spruce trees that will square 4 and 6 inches are not uncommon. Timber of about the same quality but of rather heavier stand covers the plateau which forms the northwestern part of Kenai Peninsula. The best timber of this part of the province is that occurring in the flats at the upper end of Resurrection Bay, where there is a heavy stand of hemlock and spruce, including some trees up to 4 feet in diameter. So far as could be determined from the route of travel, the flats of the upper Kuskokwim have about the same stand of timber as those of the Tanana Valley already described.

In the inland part of the province the supply of timber at best is rather scanty but would probably be sufficient for local use were it not subjected to ravages by forest fires nearly every year. Such fires occur on both sides of the Alaska Range, but especially in the Yukon basin, where the semiarid conditions often allow the forest fire to sweep over miles of territory until it is stopped by a watercourse too wide to be crossed. It is no exaggeration to state that hundreds of square miles of timber have been burned off the Yukon basin during the last decade. This burning of timber is in part done purposely by both whites and natives in order to get rid of insect pests or to improve the growth of grass near their habitations, and is in part due to carelessness. The writer has traced at least one forest fire to a native camp. But the amount of timber annually destroyed by the natives is small compared with that for which the whites are responsible. Many a white man has deliberately started a forest fire which swept over miles of country, solely that he might obtain a few acres of dry wood for winter use. If this willful waste does not stop, the time is not far distant when there will be a scarcity of timber, even for local use. Timber grows very slowly in this northern field, and once destroyed it probably can not be replaced for several generations. It appears to the writer that at the present rate of consumption and destruction by forest fires the timber of the Yukon-Tanana region will not be sufficient for the placer-mining industry, let alone any possible development when this stage has been passed.

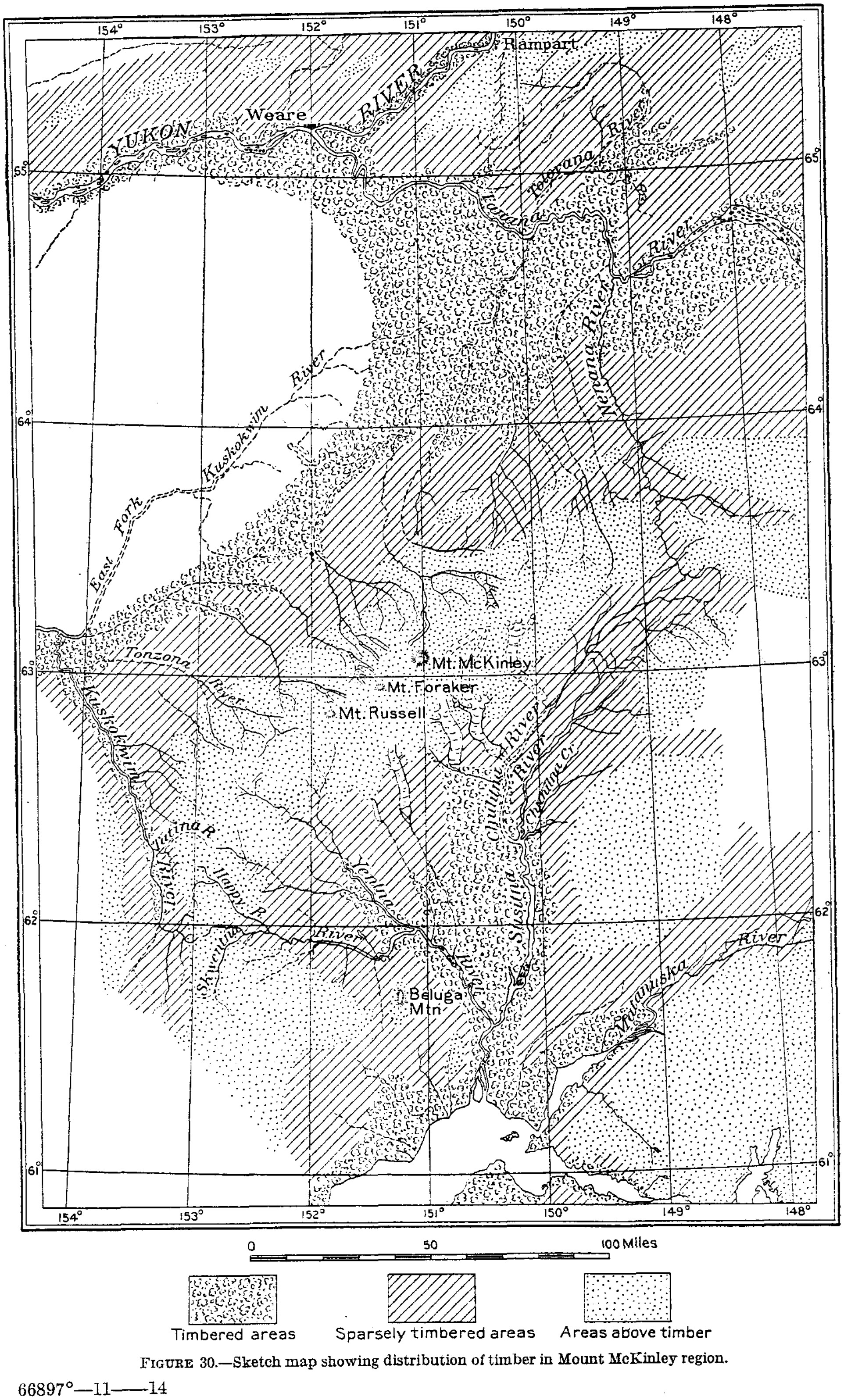



FIGURE 30.—Sketch map showing distribution of timber in Mount McKinley region.

## FLORA OF THE REGION.

The following plants were collected by L. M. Prindle and determined by F. V. Coville:

### Polypodiaceæ—fern family.

*Dryopteris fragrans* (L.) Schott. Kichatna Valley, among rocks, July 5.
*Dryopteris spinulosa dilatata* (Hoffm.) Underw. (*a*) At camp No. 7, Beluga River valley, June 10; grows 2 feet high or more. (*b*) West side of Alaska Range, above timber line, July 29.
*Phegopteris dryopteris* (L.) Fée. Kichatna Valley, among cottonwood, July 5.

### Equisetaceæ—horsetail family.

*Esquisetum arvense* L. (*a*) June 1 (no definite locality given). (*b*) Tanana River, August 29.
*Equisetum sylvaticum* L. Tyonek, June 1.
*Equisetum variegatum* Schleich. Bank of tributary of Happy River, leading to the pass, July 13.

### Lycopodiaceæ—club-moss family.

*Lycopodium annotinum* L. September 8 (no definite locality given).
*Lycopodium complanatum* L. September 8 (no definite locality given).

### Pinaceæ—pine family.

*Larix laricina* (Du Roi) Koch. (*a*) Tanana Valley, east of Nenana River, August 27. (*b*) September 8 (no definite locality given).
*Juniperus nana* Wind. Ridge north of Torbona River, September 8.

### Poaceæ—grass family.

*Phleum alpinum* L. Kichatna Valley, July 4; not abundant.
*Alopecurus geniculatus* L. Torbona Valley, north of the Tanana, September 4.
*Agrostis rubra* L. South side of Tanana Valley, east of Nenana River, August 27.
*Calamagrostis aleutica* Bong. South of Yukon, near the divide between Tanana and Yukon, September 10.
*Calamagrostis canadensis* (Mx.) Beauv. (*a*) South side of Tanana Valley, east of Nenana River, August 27. (*b*) Tanana Flats, east of Nenana River, August 28. (*c*) North of Tanana River, August 31.
*Calamagrostis langsdorfii* Trin. No definite locality given.
*Calamagrostis purpurascens* R. Br. Above timber line, west side of Alaska Range, July 29.
*Beckmannia erucæformis* (L.) Host. (*a*) Tanana River, near Tortella, August 29. (*b*) Lake country, north of Tanana, September 3.
*Panicularia pauciflora* (Prest.) Retz. Lake country, north of Tanana River, September 3.
*Hordeum jubatum* L. Nenana Valley.
*Elymus mollis* Trin. Tanana River, near Tortella, August 29.

### Cyperaceæ—sedge family.

*Scirpus cæspitosus* L. On marshy tundra at camp No. 7, June 10. (Between Tyonek, on Cook Inlet, and Rampart, on Yukon River.)
*Carex aquatilis* Wahl. Tanana River, August 29.
*Carex compacta* R. Br. Near water on bank of slough in Kuskokwim Valley, July 19.
*Carex* sp. near *C. macrochæta* Mey. (too young). Above timber line, east side of Simpson Pass, altitude 2,500 feet, July 10.
*Carex* sp. (too young). On marshy tundra, June 10.
*Carex* sp. (too young). At camp No. 7, altitude 1,300 feet, June 10.

### Liliaceæ—lily family.

*Tofieldia palustris* Huds. On gravel flood plain of the Kuskokwim, overgrown with cottonwood, July 19.
*Zygadenus elegans* Pursh. Kuskokwim Valley, on gravel bar, overgrown with light growth of cottonwoods, July 19.
*Veratrum eschscholtzii* (Roem. and Schult.) Gray. Upper Kichatna Valley, abundant in meadows, July 7.
*Streptopus amplexifolius* (L.) DC. Beluga River valley, on hillsides, June 10.

### Orchidaceæ—orchid family.

*Cypripedium passerinum* Richards. On bank of Kuskokwim River, July 17.
*Limnorchis stricta* (Lindl.) Rydb. South side of Simpson Pass, July 12.
*Gyrostachys romanzoffiana* (Cham.) MacM. Northeast side of Kuskokwim Valley, near base of mountains, in moss, July 21.

### Salicaceæ—willow family.

*Populus balsamifera* L. Between Tyonek and Rampart, June 1.
*Salix arctica* Pallas. Beluga Valley, 6 miles east of camp No. 7, altitude 2,700 feet, June 10.

*Salix bebbiana* Sargent. Tyonek, June 1.
*Salix fuscescens* Anders. Beluga Valley.
*Salix glauca* L. Altitude about 3,500 feet, dwarf willow, July 8.
*Salix polaris* Wahl. On mountain 3,000 feet above valley of Happy River, July 13.
*Salix pulchra* Cham. Camp No. 7, altitude about 1,300 feet, June 10.
*Salix reticulata* L. Northeast side of Kuskokwim Valley, growing in moss, altitude about 1,000 feet, July 21.

#### Betulaceæ—birch family.

*Betula.* (*a*) On marshy tundra at camp No. 7, low spreading, 1 to 2 feet high, higher at base of hill, 30 feet, June 10. (*b*) Between Tyonek and Rampart, July 21.
*Betula.* Retarded birch blossoms, tree nearly broken off, birches generally through blossoming, June 1.
*Betula.* West side of Alaska Range, above timber line, July 29.
*Betula.* Between Tyonek and Rampart, July 29.
*Alnus alnobetula* (Ehrh.) Koch. Tanana Flats, about 10 miles south of river, August 29.
*Alnus.* Between Tyonek and Rampart, June 1.

#### Polygonaceæ—buckwheat family.

*Oxyria digyna* (L.) Campdera. Upper Kichatna Valley, July 9.

#### Portulacaceæ—purslane family

*Claytonia sarmentosa* C. A. Meyer. Upper Kichatna Valley, July 9.

#### Alsinaceæ—pink family.

*Silene acaulis* L. Kuskokwim, growing among rocks, July 18.
*Alsine longipes* (Goldie) Coville. On hillsides in upper Kichatna Valley, altitude about 1,500 feet, July 9.
*Arenaria macrocarpa* Pursh. Above timber line, east side of Simpson Pass, altitude 2,500 feet, July 10.

#### Ranunculaceæ—buttercup family.

*Delphinium brownii* Rydt. Upper Kichatna Valley, July 7.
*Aconitum delphinifolium* DC. Kichatna Valley, plant 3 feet high, July 3.
*Anemone richardsoni* Hook. In moist soil, Beluga River valley, June 10.

#### Papaveraceæ—poppy family.

*Papaver nudicaule* L. (*a*) Kuskokwim, growing among rocks, July 18. (*b*) South side of Simpson Pass, July 12. (*c*) East side of Rainy Pass, altitude about 4,500 feet, July 14. (*d*) About 30 miles north of Kuskokwim, above timber line, July 23.

#### Brassicaceæ—mustard family.

*Cardamine bellidifolia* L. Upper Kichatna Valley, July 9.
*Arabis lyrata intermedia* (DC.) Wight. Tyonek, June 1.
*Parrya nudicaulis* (L.) Regel. Simpson Pass, altitude 2,900 feet, July 11.

#### Droseraceæ—sundew family.

*Drosera longifolia* L. On marshy tundra, June 10.

#### Saxifragaceæ—saxifrage family.

*Therofon richardsonii* (Hook.) Wheelock. Attains height of 2 feet, on west side of pass, July 15.
*Saxifraga hirculus* L. Northeast side of Kuskokwim Valley, near base of mountains, in moss, July 21.
*Saxifraga nelsoniana* D. Don. On hillside in upper Kichatna Valley, altitude about 1,500 feet, July 9.
*Saxifraga serpyllifolia* Pursh. On mountain 3,000 feet above valley of Happy River, July 13.
*Saxifraga tricuspidata* Retz. Kichatna Valley, in rocky soil, July 5.
*Parnassia palustris* L. On a gravel bar of Kuskokwim, overgrown with cottonwood, July 19.

#### Ribaceæ—gooseberry family

*Ribes rubrum* L. Tyonek, June 1.

#### Rosaceæ—rose family.

*Spiræa betulifolia* L. At camp No. 7, Beluga River valley, June 10.
*Rubus arcticus* L. Tyonek, June 1.
*Rubus chamæmorus* L. At camp No. 7, Beluga River valley, June 10.
*Potentilla fruticosa* L. (*a*) Bush 2 feet high, on marshy tundra, Beluga River valley, June 10. (*b*) On gravel flood plain of the Kuskokwim, overgrown with cottonwood, July 19.
*Sieversia rossii* R. Br. West side of Alaska Range, about 30 miles north of Kuskokwim, above timber line, July 23.
*Dryas drummondii* Richards. On gravel bar of Tatina River, July 16.

*Dryas octopetata* L. About timber line, east side of Simpson Pass, altitude 2,500 feet, July 10.
*Sanguisorba latifolia* (Hook.) Coville. Upper Kichatna Valley, July 7.
*Rosa acicularis* Lindl. Simpson Pass, altitude 2,900 feet, July 11.

**Viciaceæ—vetch family.**

*Phaca littoralis* (Hook.) Rydb. Simpson Pass, altitude 2,900 feet, July 11.
*Aragallus gracilis* A. Nelson. (*a*) On gravel flood plain of the Kuskokwim, July 29. (*b*) July 29 (no locality given).
*Hedysarum americanum* (Michx.) Britt. July 21 (no location given).

**Geraniaceæ—geranium family.**

*Geranium erianthum* DC. Upper Kichatna Valley, July 7.

**Violaceæ—violet family.**

*Viola langsdorfii* Fisch. About timber line, east side of Simpson Pass, altitude 2,500 feet, July 10.
*Viola palustris* L. Tyonek, June 1.

**Elæagnaceæ—oleaster family.**

*Lepargyræa canadensis* (L.) Greene. On gravel flood plain of the Kuskokwim, July 19.

**Onagraceæ—evening primrose family.**

*Chamænirion angustifolium* (L.) Scop. (*a*) Kichatna Valley, in woods, July 5. (*b*) On gravel flood plain of Kuskokwim, overgrown with cottonwood, July 19. (*c*) Tanana Flats, east of Nenana River, August 28.
*Chamænirion latifolium* (L.) Sweet. (*a*) Kichatna Valley, July 5. (*b*) On mountain east of Kuskokwim Valley, July 18.

**Haloragidaceæ—water milfoil family.**

*Hippuris vulgaris* L. Lake country, north of Tanana, September 3.

**Cornaceæ—dogwood family.**

*Cornus canadensis* L. Above timber line, toward Simpson Pass, east side, July 10.
*Cornus suecica* L. On hillside at camp No. 7, Beluga River valley, June 10.

**Pyrolaceæ—wintergreen family.**

*Pyrola rotundifolia* L. Growing in moss in the pass, altitude about 2,600 feet, July 14.
*Pyrola secunda* L. Kichatna Valley, in woods, July 5.

**Ericaceæ—heath family.**

*Ledum decumbens* (Ait.) Lodd. In open marshy country, spreading, 1 foot or more in height, altitude 1,300 feet, June 10.
*Menziesia ferruginea* Smith. On grassy slopes under birch and spruce, near camp No. 7, Beluga River valley, June 10.
*Andromeda polifolia* L. On marshy tundra, June 10.
*Arctostaphylos uva-ursi* (L.) Spreng. Tanana Flats, east of Nenana River, August 28.
*Arctous alpinus* (L.) Niedenzu. September 8 (no locality given).
*Vaccinium uliginosum* L. On open marshy tundra, altitude 1,300 feet, June 10.

**Primulaceæ—primrose family.**

*Trientalis europæa arctica* (Fisch.) Ledeb. (*a*) Tyonek, June 1. (*b*) Mount Susitna, June 6. (*c*) At camp No. 7, under birch and spruce, Beluga River valley, June 10.
*Dodecatheon frigidum* Cham. and Schlecht. On west side of the pass, among moss, altitude about 2,600 feet, July 15.

**Gentianaceæ—gentian family.**

*Gentiana frigida* Haenke. On western slope of mountains, near camp No. 51, altitude 2,600 feet, July 29.
*Gentiana glauca* Pall. Nin Ridge, north of camp, July 2.
*Gentiana propinqua* Richards. Gravel flood plain of Kuskokwim, overgrown with cottonwood, July 19.

**Menyanthaceæ—buckbean family.**

*Menyanthes trifoliata* L. Edge of small pond at camp No. 7, Beluga River valley, June 10.

**Polemoniaceæ—phlox family.**

*Polemonium cæruleum* L. (*a*) Upper Kichatna Valley, July 7. (*b*) On marshy tundra at camp No. 7, Beluga River valley, June 10.
*Polemonium humile* Willd. West side of Alaska Range, July.

#### Boraginaceæ—borage family.

*Eritrichum arctioides* DC. Common on mountain slopes on western stretch of range, July 20.
*Myosotis alpestris* Schmidt. (*a*) Upper Kichatna, altitude about 3,500 feet, July 8. (*b*) Simpson Pass, altitude 2,900 feet, July 11. (*c*) North of Kuskokwim, July 23.
*Mertensia paniculata* (Ait.) Don. Tyonek, June 1.

#### Scrophulariaceæ—figwort family.

*Castilleia pallida* Kunth. On gravel flood plain of the Kuskokwim, July 19.
*Pedicularis lanata* Willd. July 21 (no locality given).
*Pedicularis verticillata* L. (*a*) Above timber line, east side of Simpson Pass, altitude 2,500 feet, July 10. (*b*) Near spruce timber, on bank of Kuskokwim River, July 17.

#### Pinguiculaceæ—bladderwort family.

*Pinguicula vulgaris* L. In moss, among gravel, in wet springy place, July 19.

#### Rubiaceæ—madder family.

*Galium boreale* L. North of Kuskokwim, July 23.

#### Viburnaceæ.

*Sambucus racemosa* L. On hillside at camp No. 7, Beluga River valley, June 10.
*Linnæa borealis* L. On hillside in upper Kichatna Valley, altitude about 1,500 feet, July 9.

#### Valerianaceæ—valerian family.

*Valeriana capitata* Pall. On marshy tundra at camp No. 7, Beluga Valley, June 10.

#### Campanulaceæ—bluebell family.

*Campanula lasiocarpa* Cham. Above timber line, on east side of Simpson Pass, altitude about 2,500 feet, July 10.

#### Carduaceæ—thistle family.

*Solidago multiradiata* Ait. (*a*) Simpson Pass, July 11. (*b*) On west side of pass, July 15.
*Aster sibiricus* L. (*a*) East of Kuskokwim, altitude 3,000 feet (no date given). (*b*) South side of Simpson Pass, July 12.
*Achillea borealis* Bong. South side of Simpson Pass, July 12.
*Artemisia chamissoniana* Bess. Simpson Pass, altitude 2,900 feet, July 11.
*Artemisia frigida* Willd. Nenana Valley.
*Arnica lessingii* (Torr. and Gray) Greene. Simpson Pass, July 11.
*Senecio discoideus* (Hook.) Britton. On gravel flood plain of the Kuskokwim, July 19.
*Senecio frigidus* Less. On the west side of the pass, among moss, altitude about 2,600 feet, July 15.
*Senecio palustris* (L.) Hook. September 4 (no definite locality given).
*Saussurea alpina* (L.) DC. July 21 (no definite locality given).
*Saussurea monticola* Richards. July 29 (no definite locality given).

## AGRICULTURE.

Though it is not within the purpose of this report to discuss the agricultural problems of the Mount McKinley region, yet a brief reference to this subject seems pertinent. The agricultural possibilities of Alaska have constituted a field of research by C. C. Georgeson,[1] who has during the last decade published many reports on this subject. The purpose of this section will be only to draw attention to the similarity of the various parts of the field here under discussion to other districts whose agricultural features have been studied by Georgeson.

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and during most seasons wheat and oats and in some years barley have been brought to maturity. Of this work at Kenai in 1903 Georgeson[1] says:

Heretofore the earlier varieties of grain have matured, but this year was an exception in this respect. The spring was late and the summer averaged colder than in previous years. There was less sunshine than usual, with a great deal of misty, overcast weather. The number of clear days was as follows, by months: May, 9; June, 6; July, 12; August, 10. But whatever the cause, the fact remains that grain failed to mature. Of the five years during which we have been at work on this station this is the only total failure to mature grain. From the data now at hand it is evident that grain growing from the seed is uncertain along the coast on the Kenai Peninsula. But there is reason to believe that grain can be matured some 10 or more miles from the coast, where the influence of the winds and mists from the inlet is less sinister.

It has been shown (p. 194) that there are marked climatic differences between the eastern and western shores of Cook Inlet, the mean annual temperature being some 7° warmer and the precipitation about 30 per cent greater at Tyonek than at Kenai. It seems, therefore, quite possible, as Georgeson points out, that there are marked variations in the agricultural possibilities of the Cook Inlet region as a whole.

The later work of the Kenai station was devoted chiefly to experiments in raising cattle on native hay, and these appeared to be eminently successful. Recently the Kenai station has been abandoned and the cattle transferred to Kodiak Island. The huckleberry, currant, raspberry, cranberry, and salmon berry are found in abundance in the Cook Inlet region and are suggestive of future possible phases of agriculture. So far as the data at hand permit a statement, the last frost occurs in the latter part of May or the first week in June and the earliest frost is likely to come the first week in September.

Of the possibilities for agriculture in the Susitna basin little can be definitely stated. This valley, however, must contain an area of 4,000 to 6,000 square miles lying less than 1,500 to 2,000 feet above sea level, and much of this area is characterized by a luxuriant growth of native grasses, many of which are known to be very nutritious. (See Pl. XVIII, *A*, p. 202.) There is an abundance of berries, including cranberries, salmon berries, huckleberries, currants, and raspberries. Much of the soil of the valley is probably a loam, with decayed vegetable matter. Some of the marshes can probably be drained, and the higher timbered areas are dry. Much of this region escapes the dampness of the early summer characteristic of Cook Inlet, and the growing season is probably equal in length to that of the coast. On the other hand, the rainfall is less and the aridity of the climate may be a serious drawback. Of the possibility of gardening and of curing the native grasses there can be no doubt. The feasibility of growing grain on a commercial scale will have to be determined by experiment, but on the whole the outlook seems favorable. This province includes more arable land than any other part of the Pacific slope of Alaska. The region adjacent to the upper part of Knik Arm appears to be specially favorable to agriculture and here some twenty homesteads have been taken up.

Of the interior regions the Tanana Valley appears to afford the best conditions for agriculture. It has considerably more rainfall than the upper Yukon basin and is noted for its fine growth of native grasses. The soil appears to be fairly rich and many farms and gardens near Fairbanks have shown what can be done in the way of agriculture. Of special interest as showing the productiveness of the soil is the farm at Hot Springs, on the lower Tanana, where an area of 20 or 30 acres is warmed by the hot waters and proves to be capable of raising a great variety of vegetables and fruits. There are also a number of ranches near Fairbanks where vegetable and forage crops have been raised on a commercial scale. These facts attest the favorableness of the soil and its possibilities for certain forms of agriculture, and also appear to prove the feasibility of maturing grain during the short summer. The climatic record indicates a growing season varying from 60 to 120 days in the Yukon basin. The Tanana Valley is probably most favorably located with regard to the length of the growing season. Grain has been matured as far north as Fort Yukon, which lies at the Arctic Circle, but what may be accomplished with certainty each year remains to be determined by experiments now being carried on by Professor Georgeson at Fairbanks and Rampart. It appears

[1] Georgeson, C. C., Annual report of Alaska agricultural experiment stations for 1903: Office Exper. Sta., U. S. Dept. Agr. (reprint from Ann. Rept. Office Exper. Sta. 1903), p. 353.

to be settled that this district can produce vegetables as well as forage crops. There is no information on the agricultural possibilities of the upper Kuskokwim Valley, where conditions are probably similar to those in the Tanana region.

Along the inland front of the Alaska Range there is a moss-covered area, probably at least 4,000 or 5,000 square miles in extent, that would furnish an excellent feeding ground for reindeer. Though there are no facts at hand as to the depth of the winter snow, it probably would be too great to permit the reindeer to find food during the winter months. If the inland region attracts a larger population with the development of the mining industry, as the present conditions promise, reindeer might furnish an important food supply. The abundance of the wild reindeer in this field appears to indicate that this is a practical range for the domesticated animal.

The whole matter of agriculture in this part of Alaska hinges on the finding of a market. If railroad transportation to Fairbanks through the Susitna Valley were available, no doubt an agricultural population would spring up along the route of travel. With an increase of population in the Yukon-Tanana region there would be a growing demand for food supplies for both man and beast.

### GENERAL DISTRIBUTION OF GAME AND OPPORTUNITIES FOR HUNTING.

The distribution of game along the route of exploration has been discussed (p. 202). As central Alaska is attracting more and more sportsmen each year, however, it seems desirable to say something of the game in adjacent areas and to discuss the opportunities for hunting.

Kenai Peninsula is visited every year by a few sportsmen in search of big game. Moose are abundant in certain localities and are said to be on the increase because of the killing of the wolves and the enforcement of the game laws. There are but few caribou on the peninsula, and the killing of these is prohibited by law until 1912. The white sheep are abundant in the higher ranges, and both brown and black bear are common.

Parts of the Susitna and Matanuska valleys also abound in big game, but are less accessible than the Kenai Peninsula. Eldridge refers in his report to the abundance of moose, caribou, and large brown bear. Sheep are plentiful in some of the high mountains adjacent to the Matanuska Valley, where they have been but little hunted. The natives each year kill some caribou in the upper basin of the Matanuska, but they are said not to be abundant. Both brown and black bear are to be found in the Matanuska Valley, where good trout fishing is also to be had in the clear-water streams.

Spurr's account of the scarcity of game in the Yentna basin and on the Kuskokwim side of the divide is not borne out by the observations already presented (p. 204). His journey was along the larger watercourses in canoes during the months of June and July, when most of the large game was probably up near timber line. In the same country where he saw very little or no large game at timber line the party of 1902 encountered bear, moose, sheep, and caribou. Moreover, the numerous hunting camps noted by Spurr and also seen by the writer give evidence that at certain times of the year the natives visit this region as a hunting ground.

Little need be added to what has already been said in regard to game on the Tanana. Although the many Indian settlements and comparatively large white population of the lower Tanana have driven away the larger game animals from the main arteries of travel, yet in the many tributary streams moose are still to be found, and at certain seasons of the year the Yukon-Tanana upland is liable to be traversed by large bands of caribou, sometimes, according to the statements of reliable observers, numbering many thousands.

To the sportsman who is seeking large game the slopes of the Alaska Range will furnish an attractive field. Nowhere else in Alaska, so far as known to the writer, are the four largest game animals—the bear, the sheep, the moose, and the caribou—found in such numbers and in such close proximity as in the region traversed by the party. But the very reason of this abundance lies in the inaccessibility of the field, which must deter most sportsmen. The fact that it can not be reached without the organization of an expedition prepared for a campaign of at least two to three months makes it beyond the purse and time of the average hunter.

There are two possible routes of approach to the Alaska Range at present. One is from Beluga by the route followed by the expedition here described or by steamer up the Susitna. To accomplish this journey successfully the party should reach Tyonek [1] not later than the 1st of June, so as to traverse the lowland area between tidewater and the mountains before the swamps are entirely thawed out. Brown bear can probably be found in not over a week's trip from the coast, and as the journey is continued toward one of the passes at the head of the Skwentna drainage moose will be met. Sheep would be found in the high range, beyond which lies the caribou country, under the most favorable conditions at least a month's journey from Beluga.

The second route of approach is from some point on the Tanana, which can be reached by steamer either from the mouth of the Yukon by the middle of July or by way of the White Pass Railway and steamer down the Yukon by about June 20 to July 1. Landing can probably best be made at or near the mouth of the Tanana. The mountains are reached in a four or five days' journey along the Indian trail from Tortella. (See Pl. III, in pocket.) Another route would be by steamer up the Toklat to the head of navigation, but this would probably require the chartering of a special boat, and hence would be far more expensive. If the route up the Tanana is chosen, pack horses might be procured at Fairbanks, but this is by no means certain. Pack horses taken in by rail and boat will probably cost at least $200 apiece delivered on the banks of the Tanana. The cost of a horse landed at Beluga is $100 to $150.

A hunting trip could be made into the Susitna region by taking a steamer up Susitna River to the limit of navigation and then proceeding with small boats up the watercourses or, better still, overland with horses. The expense and duration of the trip are likely to be comparable with those into the Alaska Range described above. A good horse trail leads from Knik, which may be conveniently reached by railway and launch from Seward, to the hunting fields of the Matanuska Valley. A few weeks' trip in this region would probably suffice for some good sheep and bear hunting as well as excellent trout fishing. It is often possible to procure horses at Knik, though this can not be counted on unless arrangements are made in advance.

The northern part of Kenai Peninsula is, to the nonresident hunters, one of the most accessible of the big-game regions of Alaska. Here a licensed guide is required, who can be hired at Seward. Hunting camps for sheep, moose, and bear can be pitched within striking distance of the Alaska Northern Railway, and thus communication can be kept up with mail and telegraph.

Seward, which is connected by cable with Seattle, furnishes a good and convenient outfitting point for the big-game hunter in the Mount McKinley region. Supplies and equipment can there be purchased, and the several provinces can be reached by railway and boat. If horses are needed for the proposed trip, an arrangement in advance is advisable. Except at Seward, there are usually no regular guides to lead hunting parties into the districts here described. It is often possible to find reliable men who have hunted or prospected over parts of the region, but as this is uncertain a party must be prepared to find its own way through the country. Local wages vary from $5 to $6 a day, but for the longer journey reliable men can sometimes be hired at $100 to $125 a month.

The recent revision of Alaska game laws will make this field more attractive to the hunter of big game. The open season for large game, according to the regulations issued in 1909, is as follows:

North of latitude 62°, brown bear throughout the year and moose, caribou, and sheep from August 1 to September 10. South of latitude 62°, moose, caribou, and sheep from August 20 to December 31; brown bear from October 1 to July 1; deer and goats from April 1 to February 1; grouse, ptarmigan, and water fowl, September 1 to March 1. Licenses are required for nonresident hunters, and there are limitations as to the number of animals which may be killed and as to the export of trophies. Licenses and copies of the regulations, which are subject to change, may be obtained by addressing the governor at Juneau, Alaska, or the game warden at Seward.

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[1] Beluga is now the transfer point for local steamers.

## POPULATION.

### INTRODUCTION.

It has been shown that the region traversed by the party was for the most part entirely uninhabited and much of it unknown to whites. There were few signs of the presence of natives except the hunting camps. A few natives were seen at Tyonek, on the Susitna, but no others were encountered until we met a small band of hunters in the upper basin of the Tanana. While traversing the front of the Alaska Range we saw the smoke of native settlements near Lake Minchumina, but otherwise throughout the journey from the Susitna to the Tanana there was no evidence of any permanent native settlements. This does not mean, however, that the region is unknown to the natives, because nearly everywhere except in the high ranges there was evidence of visits of native hunters.

The whites seen were no more numerous than the natives, comprising a few at Tyonek, one man met in the upper Tanana Valley, and those encountered in the Rampart placer district and at the town of Rampart. In the seven years, however, that have elapsed since the close of the work some settlements of considerable size have sprung up in the area under consideration, and these will be briefly referred to in the following notes:

### WHITES.

The town of Seward, on the east side of Kenai Peninsula, has a beautiful location on Resurrection Bay, an excellent harbor. This is the coastal terminal of the Alaska Northern Railway, now being constructed inland, and the largest white settlement in the neighborhood of Cook Inlet. At Tyonek, at the time of our visit, there were probably twenty white men; in 1909 these moved to Beluga and the old station is practically abandoned. There are probably a few hundred placer miners in the Sunrise and Yentna districts (1910). The work done a few years ago in the Matanuska field attracted a small population, but as no patents to coal lands have been granted the entire district now (1910) contains only a few white men. There are no permanent white settlements in the Susitna basin except at the trading post of Susitna and in the Yentna and Valdez Creek districts.

At the time of our journey there was said to be a trading post near the forks of the Kuskokwim, and since then several river boats have ascended the Kuskokwim, so that there is probably a white population in this valley. The Kantishna placer district, as is shown elsewhere (p. 175), also attracted a white population, but this district has been almost deserted since 1907. The Bonnifield placer district and the adjacent coal fields also contain some prospectors and miners, but in 1909 probably not exceeding 200 men.

The town of Fairbanks, lying about 50 miles east of our route of travel, is now the center of the mining industry of the Yukon basin. The permanent population is variously estimated at 3,000 to 4,000; this number is augmented every year by several thousand who spend the winter in the States. The town of Chena is said to have a population of about 500 and several smaller settlements are scattered along the river and on the various placer-producing creeks. The summer population of the Tanana Valley in 1909 was probably 5,000 to 8,000.

In the Rampart district the most important settlement is the town of Rampart, which at the time of our visit probably had a population of 300. Since that time a settlement has been formed at Hot Springs, on the Tanana, and in addition there are probably several hundred prospectors distributed through the placer-bearing areas.

The town of Tanana, at the mouth of the river of the same name, has become of importance since the discovery of the Fairbanks gold placers, as it is the transshipping point of freight and passengers to and from Fairbanks. It probably contains a permanent white population of about 100, and a one-company army post is located there.

## NATIVES.

The reason that the region explored contains no permanent native inhabitants lies in the fact that the streams are for the most part swift and difficult to navigate and are also above the point of migration of the salmon. Alaska natives, as a rule, locate their permanent habitations on navigable waters, which can be traversed by their canoes and rafts and whose smooth surfaces afford good highways for sled travel during the winter. The larger waterways are also usually well timbered, furnishing fuel supply, building material, and shelter from the cold winter winds. Moreover, an abundant supply of fish is one of the essentials to permanent native habitation. In the lower reaches of the large rivers the fish supply is furnished by the salmon and other salt-water fish which migrate inland during the summer months. The heads of the larger streams and lakes farther inland furnish a supply of grayling and whitefish, which are also dried for winter use. From these permanent habitations along the larger streams or along the coast the natives make their annual hunting trips inland and toward the headwaters of the drainage systems. The hunting ground of each tribe is usually well defined, and it is seldom that a native will venture into the region belonging to another tribe. The high divides and the drainage basins determine the tribal subdivisions.

With these facts in mind, the natives of the region under consideration can be divided into three groups—(1) those of the upper end of Cook Inlet and the tributary streams; (2) the Kuskokwim natives—that is, those of the upper river; and (3) the Tanana natives. A fourth group would comprise the natives living along the ramparts of the Yukon, but these are now comparatively few. All three of these native groups belong to the so-called Athabascan or North American Indian stock. Physically as well as in customs they are much alike, and there is also considerable similarity of language. It appears to be generally true, however, that the salmon-eating tribes of the larger rivers and coastal region are now physically less robust than those that depend more on the large game and live farther inland. This may be due, however, to the presence of the whites, for the salmon-eating Indian has been much longer in contact with the white man than those farther in the interior.

The native population of the upper Cook Inlet region and the adjacent tributary basins is given in the Eleventh Census as 551, including those of mixed blood. The Twelfth Census, unfortunately, does not go into detail regarding the distribution of the natives, and it would appear that in 1902 there were probably not more than 300 or 400 natives in this region. The population of the upper Kuskokwim was estimated by Spurr in 1898 as not exceeding 200 or 300 people. This is probably an overestimate, as Herron's careful enumeration along his route of travel in the basin of the East Fork of the Kuskokwim, showed only 53 natives.[1] The writer's estimate of the native population of the lower Tanana, based on several trips made in this region since 1898, indicates a native population not exceeding 300.

The Cook Inlet natives have been in contact with the whites for more than a century, as the Russians sent their first fur-trading expeditions into this field as early as 1787 and soon established a permanent station on the eastern shore of the inlet. Since that time there has been much intermarrying between the Russians and the natives, and as a consequence a very large part of the so-called native population is of mixed Russian and Indian blood. The Russian language has also in part superseded the native language, and the common speech is now a mixture of the two.

The Kuskokwim natives were one of the last of the Alaskan tribes to come into contact with the whites. Though the Russians had a trading post at Kolmakof, far up the Kuskokwim, it was not continued for many years, and after the transfer of the territory the natives of the upper Kuskokwim appear to have lost all contact with the whites except as an occasional party of prospectors invaded their domain or as they made trading expeditions to the mouth of the Tanana to procure a few necessary supplies, chiefly ammunition. Since 1901, however, there has been a trading post on the upper Kuskokwim, and in the later years many whites have traversed this region. Like those of other parts of Alaska, the natives of this region also have become dependent on the white man for both food and clothing. It is possible that this influence may account for the fact that the hunting grounds around the headwaters of these

[1] Herron, J. S., Explorations in Alaska, 1899: War Dept., Adjt. Gen.'s Office, No. 31, 1901, pp. 66–67

streams at the time of our journey did not appear to have been visited by the natives for at least two years. When the native becomes dependent on the whites he is less inclined to make long hunting trips. Most of the camps that we saw appeared to be old ones, but their extent and wide distribution suggested that at one time this region was visited annually by the natives of the lower rivers.

The lower Tanana natives first met the white men at the mouth of the Tanana in the middle of the nineteenth century. The trading post at the mouth of the river was the scene of an annual meeting between the natives and either the Russian traders of the lower river or the Hudson Bay traders of Fort Yukon. As early as 1881 a man named Bean attempted to establish a trading post at Harpers Bend, about 20 miles from the mouth of the Tanana. His wife, who was with him, was murdered by the Indians, and, abandoning his post, he fled to the Yukon. From that time until the discovery of the Fairbanks district there were no permanent white habitations on the lower Tanana, but the natives were abundantly supplied with white man's goods by means of the annual trading trips to the mouth of the river. At the present time, with a dozen steamers running on the Tanana, these natives have altogether lost their isolation. The village of Tortella, which in 1902 contained probably 40 or 50 natives, with no white man, now includes a government school, a mission, and a trading post. Other white settlements are situated on the river below.

Previous to the coming of the white man the natives seldom ventured to go beyond the limit of the hunting grounds of the tribe. The Tanana natives, though they had easy communication with the Susitna and thus with Cook Inlet by way of Broad Pass, seldom visited the coast. Ivan Petroff [1] makes special note of the arrival of two Tanana Indians on Cook Inlet in 1866 and states that the oldest man of the coast Indians remembered only two previous visits by the interior Indians to the inlet. On visiting Tortella, near the mouth of the Nenana, the writer was surprised to find that the natives appeared to have so little knowledge of the region lying beyond the Alaska Range. With the aid of a map he described his route from Cook Inlet. Only a few of the older men appeared to be familiar with the Susitna drainage basin, though they had all been over into the Kuskokwim waters. Herron's experience showed also how afraid the natives are of visiting the regions beyond their tribal hunting grounds. His two native guides from the Susitna deserted him on reaching the divide of the Alaska Range, apparently being fearful of intruding into the domain of another people. It appears that there is an intertribal law among the Yukon natives by which the tribe is responsible for the life of any visitor from other tribes. If a visitor loses his life, the tribe in whose territory the event took place is required to make a payment to the tribe of the deceased. A case of this kind occurred in the early days on Fortymile, when a Tanana native lost his life while visiting the Fortymile region and tribute was immediately demanded by the Tanana natives, though the Fortymile natives were in no way responsible for his death, which was purely accidental. This custom appears to indicate the sharp line drawn between the territorial rights of the different tribes. It is suggested that in the old days visits from neighboring tribes were made either as warlike inroads or as embassies.

The Cook Inlet natives are of special interest from an ethnologic point of view, as they represent the only branch of the Athabascan stock which reaches the shore line. Everywhere else the Alaskan Athabascan is cut off from the coast by the tribes which belong to the Eskimo, the Haida, or the Tlingit stock. It appears that these three coastal stocks were far more warlike than the interior natives and therefore held them in check.

The outlook for the future of these natives, as of those of other parts of Alaska, is not very hopeful. Although many individual members of the various tribes adapt themselves to the ways of the white man and seek regular employment, yet for the most part they still show the careless improvidence and indolent characteristics of the savage. Their trapping fields are being rapidly depleted, partly through the introduction of steel traps by themselves and partly through the inroads of the whites. Modern firearms are driving away the game, and in some waters the stock of fish is being depleted by the introduction of the white man's superior methods

[1] First Ann. Rept. Bur. Am. Ethnology, 1879-80, p. 482.

of capture. The half-breeds of Cook Inlet have shown some activity in the planting of small gardens, where they raise potatoes and other vegetables. This would seem to be a hopeful field in which to educate them. Ordinary schooling seems to help the natives very little, as in his attendance on the schools he is in danger of coming into contact with some of the lower white element and of learning the vices rather than the virtues of the invading race. His natural field for development is probably in agriculture and the mechanical arts. Many of the interior natives have considerable mechanical ability, and if in this were systematically trained they might, in the course of a generation, become mechanics of a high degree of skill who could always find work in the mining camps. In the last few years the Bureau of Education has accomplished much in the industrial education of the Alaska native.

## TRANSPORTATION AND MEANS OF COMMUNICATION.

### PRESENT CONDITIONS.

In the province under discussion, as elsewhere in Alaska, the last decade has witnessed a remarkable development of transportation facilities. Well-equipped steamers running on more or less regular schedules have supplanted the occasional service of small vessels. The steamboat system on the Yukon and its tributaries has been reorganized and affords probably as good service as local conditions permit. Local steamers ply on Cook Inlet and on the Susitna. Above all, trails, wagon roads, and some railways have been built. Yet with all this progress the present transportation system still comes far from serving the needs of the province.

Seward, on the eastern coast of Kenai Peninsula, can now be reached by steamer in four to six days from Seattle. Small coasting boats and some large vessels also enter Cook Inlet during the open season (from May to November). These carry freight and passengers to the several settlements on the inlet, including Knik Arm, the distributing point for the Matanuska coal field. Better facilities are promised by the Alaska Northern Railway,[1] now under construction, which is built out from Seward for about 72 miles to Kern Creek, on Turnagain Arm (pp. 220–222). A number of wagon roads and trails built in Kenai Peninsula have been of great assistance to the miner and prospector.

The discovery of the Yentna gold field has resulted in the establishment of a transportation system on the lower Susitna by means of a steamboat and some small launches which run up within 20 or 30 miles of the placer district. From this point, however, supplies have to be either taken overland, by pack train in summer and sleds in winter, or transported upstream in poling boats. Both methods are expensive and have much increased the cost of mining in this region.

Recent mining progress in the Valdez Creek district led to an attempt to establish a route to this camp via Susitna River. This route, though it has not been much used by the Valdez Creek miners, has benefited the western part of the province by giving steamboat service up the Susitna. River steamers ascend the Susitna to the mouth of the Talkeetna, above which the main river is navigable for steamers only with difficulty and some danger.

There are but few established trails in the district. One leads from Knik through the Matanuska coal field, and there are several in the Yentna district. During the winter of 1907–8 the Alaska road commission sent an expedition across Rainy Pass with the object of finding a shorter mail route to the lower Yukon and Nome. This route would also have the advantage of passing through the upper Kuskokwim Valley and close to the newly discovered placer camps of the Innoko. Should this trail be established, it would help much in developing the Susitna region, especially when the railway to the Matanuska is completed. The overland route from the mouth of Indian Creek to the Valdez Creek district, a distance of about 100 miles, has hardly been sufficiently used to make it a well-established trail. Supplies for this district are usually sledded over the Fairbanks trail from the coast to Gulkana River and then up that stream to Valdez Creek. The summer route to this district is from Paxson and covers a distance of about 65 to 70 miles.

[1] Formerly called the Alaska Central Railway.

It is reported that steamboats have been taken up the Kuskokwim to the forks, and they can probably continue up the East Fork for some distance. Beyond this the transportation up the Kuskokwim is as primitive as it was at the first visit of the white man. The prospector or trapper has to rely solely on the dog team in winter and his poling boat in summer, and under these circumstances no important industrial advancement can be expected unless very rich placer diggings are found. The Kuskokwim can also be reached by an overland trail from the headwaters of the Toklat, and the latter stream has been ascended for about a hundred miles by small river steamers. A horse trail connects the head of steamboat navigation on the Bearpaw with the placer diggings on the Kantishna. Most of the supplies for the Bonnifield and Kantishna camps are brought overland by sledding during the winter. A horse trail from Tortella village, near the mouth of the Nenana, affords a means of approach to the northern front of the Alaska Range, as does also another from the mouth of Little Delta River.

It is said that a steamboat was taken up the Tanana for 30 or 40 miles in 1894, but the first boat to go up any considerable distance was one met by the writer during his exploration of that river in 1898. This steamer, the *Tanana Chief*, eventually reached Chena Slough, and the party wintered there. Since the discovery of the rich placers at Fairbanks many steamers have been used on the lower Tanana, which is easily navigable as far as Chena, at the mouth of Chena Slough. The trip from the mouth of the Tanana takes about two days. One steamer has ascended the Tanana as far as the mouth of the Nabesna, above the Tanana crossing. The difficulties of navigation above the Delta are, however, considerable, and it is not likely that a regular service could be maintained. It is not always possible for a steamer to reach even the mouth of Delta River at low water.

Passengers and freight bound for Fairbanks now go either to St. Michael and up the Yukon by steamer or by rail from Skagway to White Horse and then down the Yukon to the mouth of the Tanana. The journey from Seattle to Fairbanks via St. Michael takes from three to four weeks; via Skagway, from ten to fifteen days. The cost of transportation by these circuitous routes is excessive and it is possible only during the open season, extending from about June 20 to September 25. Moreover, low water may entirely interrupt steamboat navigation for a week or two at a time. In winter Fairbanks is far more accessible, for then the route lies by sled road from Valdez,[1] on the coast, over Thomson Pass, across the divide at the head of the Delta, and down that river to the Tanana, a distance of about 380 miles. This route by a straight course in winter takes eight or ten days and is very comfortably made between December 1 and the middle of April. Some perishable provisions are also sent in this way during the winter, but the long sled haul is too expensive to make it possible to bring heavy freight. This trail has been much improved by the work of the Alaska road commission. Streams have been bridged and stretches of road constructed, so that the trail is rapidly being changed to a wagon road.

The placer district immediately tributary to Fairbanks is now rendered easily accessible by the Tanana Valley Railway, which from Chena and Fairbanks runs to the mouth of Cleary Creek. In addition to this, many good wagon roads have been built, so that practically all the creeks are readily accessible—a condition which has contributed largely to the advancement of the mining industry.

Most of the placer-bearing areas of the Rampart district are readily accessible by road and trail from the town of Rampart, on the Yukon. The Baker Creek district is reached by good wagon road from the Tanana at Hot Springs.

The military telegraph lines have done much to improve facilities of communication. Seward and Valdez, on the coast, are connected by cable with other places in Alaska, as well as with Seattle. An overland telegraph follows the Valdez-Fairbanks trail and extends down the Tanana and the Yukon to St. Michael. Eagle and Rampart are also connected with this telegraph system, and wireless stations are maintained at Cordova, Fairbanks, Tanana, Circle, Eagle, Nome, and St. Michael. An extensive telephone system at Fairbanks connects all the important mining camps.

[1] Another route is from Cordova, on the coast, over the Copper River and Northwestern Railway to Chitina and thence by the military road to Fairbanks.

## NEEDS OF THE FUTURE.

The foregoing statement indicates that the present means of communication are inadequate to the needs of the country. Unless there is a decrease in the time and cost of transporting supplies to or bringing the raw material from the various mining districts, no great advancement can be expected in the mining industry. The coal fields on the Matanuska and the Nenana can be developed only when they are rendered accessible by railways, and the agricultural resources of the Susitna Valley will also lie dormant until that time. Only the richest ground of the Yukon-Tanana region can be profitably exploited under the present high cost, which can not be materially reduced except by more direct and cheaper lines of communication with tidewater. In most districts metalliferous lodes, unless very rich, can not be developed until they are rendered accessible by railway. The first step in the evolution of a new land has taken place, for the last decade has witnessed the change from pioneer to frontier conditions. A second step, perhaps not so great but far more important, is the bringing about of settled industrial conditions, and this can be achieved only by building a railway to tidewater and supplementing it by other means of transportation.

Much has been written on the question of railway routes in Alaska, and bitter controversies have been carried on between the advocates of the several suggested routes. It is not proposed to go into this matter here, for the writer has elsewhere [1] summarized the available facts on routes of approach for a railway which shall tie the Yukon to the Pacific. Whatever railways may be constructed [2] along the Copper River valley, such lines would in no way help to develop the gold deposits of the Turnagain Arm region and the Susitna or the Matanuska coal field. It is equally certain that for a route to Fairbanks the one via Broad Pass, at the head of the Susitna, and down the Nenana has some advantages in grade over any of those proposed via the Copper River valley. There can be no doubt, therefore, that a railway will be built from tidewater into the Susitna and Matanuska basins, and it is only natural to suppose that when constructed so far it will be continued through the Alaska Range into the Yukon basin.

Previous to the beginning of work on the Alaska Northern Railway there were several alternative propositions to reach Susitna River. These can be divided into three general routes—(1) from the east side of Kenai Peninsula, on Resurrection Bay, via Kenai Lake and around Turnagain Arm to the Susitna; (2) from Kachemak Bay along the western margin of the peninsula, also encircling Turnagain Arm; (3) from some harbor on the west side of Cook Inlet and thence paralleling the inlet and extending up the Susitna Valley. Of these three the Resurrection Bay route undoubtedly has the advantage in every way, because, first, it opens up Kenai Peninsula, which has developed placers and some lode mines; second, it is the shortest route to the Matanuska coal field; third, its terminal, besides affording a good harbor, is nearer Puget Sound than either of the proposed coastal terminals. In view of this and the fact that about 72 miles of a standard-gage railway along this route have already been completed (1910) and construction is now going on, the other two need not be further considered.

This route from Resurrection Bay to the Tanana can be briefly outlined as follows: It leaves the Pacific seaboard at Seward, about 1,350 nautical miles from Seattle, on Resurrection Bay, and, traversing a broad, heavily timbered valley, climbs by easy grade to 700 feet at mile 12. It then descends to Kenai Lake, about 500 feet in altitude. Another easy grade brings it at mile 45 to a second pass, 1,060 feet in altitude. Both these summits are reached with a maximum grade of 2 per cent. From this second summit it descends by a series of loops, trestles, and tunnels with a maximum grade of 2.2 per cent to the valley of Placer River. It is stated by the company that by changing the location of the line to the west wall of the Placer River valley this descent can be made with a maximum grade of only 1.5 per cent. Placer River, which has a glacial source, is crossed on pilings, and the line then follows the east side of the valley. Swinging around the head of Turnagain Arm on a broad grass-covered and timbered

[1] Brooks, A. H., Railway routes: Bull. U. S. Geol. Survey No. 284, 1906, pp. 10-17; Railway routes in Alaska: Nat. Geog. Mag., vol. 18, 1907, pp. 165-190; The mining industry in 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 20-46.

[2] The Copper River and Northwestern Railway has now (1910) been completed from Cordova to the town of Chitina, a distance of about 130 miles.

flat, the railway crosses two more small glacial rivers. It then follows the north side of Turnagain Arm with a series of rock cuts and fills. The line, which is standard gage, is completed and in operation to Kern Creek, 72 miles from Seward (1910). Beyond this point location surveys have been made and in all about 2 miles of grading completed.

From Kern Creek the surveyed line follows the north side of Turnagain Arm to Point Campbell, at the entrance to Knik Arm. Here there are no serious difficulties except in the last 10 miles, where there will be a good deal of heavy rock work. The line follows the east shore of Knik Arm from Point Campbell to the mouth of the Matanuska, which is about 140 miles from Seward. It appears that in this part of the line very little rock work will be required. After crossing the Matanuska it is planned to extend the main line westward to the Susitna and a branch line about 40 miles long up the Matanuska Valley to the coal field. Much of the branch line will require no heavy construction.

The coal field appears to be the immediate objective point of this railway, but the manager reports that plans and preliminary surveys have been made for extending the line up the Susitna to the junction of the Chulitna [1] and up that stream to Broad Pass, about 2,000 feet in altitude and about 340 miles from Seward. So far as known, an easy grade can be maintained to this point, and there are no serious engineering difficulties. From Broad Pass the route follows down Nenana River to the Tanana Flats, and here again, it is believed, an easy grade can be established. From this point any locality on Tanana River can be easily reached. If the route is extended north of the Tanana, that river could best be bridged at the big bend near Tortella (Pl. VII, A, p. 48). Details in regard to this route are presented in the following table, in which the distances and altitudes given are, however, only approximate:

*Approximate elevations and distances along railway route from Seward, on Resurrection Bay, to Fairbanks, by way of Susitna River.*

| | Elevation. | Local distance. | Distance from Seward. |
|---|---|---|---|
| | *Feet.* | *Miles.* | *Miles.* |
| Seward, Resurrection Bay | 0 | 0 | 0 |
| First Summit | 700 | 12 | 12 |
| Kenai Lake | 500 | 8 | 20 |
| Second Summit | 1,060 | 25 | 45 |
| Head of Turnagain Arm | 0 | 15 | 60 |
| Kern Creek (railway completed to this point, 1910) | 0 | 11 | 71 |
| Mouth of Matanuska River (coal fields branch line 40 miles long) | 0 | 75 | 146 |
| Mouth of Talkeetna River | 200 | 90 | 236 |
| Broad Pass | 2,000 | 105 | 341 |
| Tanana River at mouth of Nenana River | 400 | 110 | 451 |
| Fairbanks | 560 | 49 | 500 |

The company reports that plans for a branch line to the Kuskokwim, Innoko, and lower Yukon have also been made, but it is not known that this route has yet been surveyed. Such a line would cross Susitna River and ascend the Skwentna Valley to Rainy Pass, about 2,950 feet above tide level and about 150 miles from the Matanuska junction described above. From Rainy Pass to the Kuskokwim at the mouth of Tatina River, where the elevation is about 1,000 feet above the sea, the distance is about 15 miles. The route would then be down the Kuskokwim and across a divide not over 1,000 feet high to the Innoko, the distance being about 150 miles. The distance from Seward to the Innoko or Haiditarod is about 500 miles.

The actual developed tonnage along these proposed railway routes is as yet very small. There are some promising auriferous lodes in the northern part of Kenai Peninsula, some of which is well timbered, and the valley floors include some arable land. Beyond the first divide the railway skirts the eastern margin of the Sunrise placer district. About 150 miles inland the main line will approach within 30 or 40 miles of the Matanuska coal field and close to the Willow Creek lode district. If built up the Susitna Valley, a branch line or wagon road could

[1] It should be noted that the route might lie up the main Susitna and Indian Creek or might be extended up to Chulitna River, as here described.

be constructed to the Yentna placer district, a distance of 30 or 40 miles. Copper and gold lodes have also been reported in the Susitna Valley, but little is known about them. The route as described also traverses the Nenana coal field, which, as has been shown, must eventually prove an important source of fuel for the Yukon-Tanana placer districts. It has been noted elsewhere that the Knik Arm region is believed to contain considerable farming land and that much grazing land which could be utilized if other industries attracted the population to make a local market. The same is true of the Tanana Valley.

The Susitna route has an advantage in reaching navigable waters on the Tanana by the best grade possible. It strikes near the heart of what has been the most productive placer district of the Yukon-Tanana region and the only part of this field where any lode mining has been done. Spurs could be extended up the Tanana Valley and down the Tanana to the Yukon. All in all, the proposed railway up the Susitna Valley will apparently open a large region which has considerable prospective commercial importance. It is at a disadvantage compared with the Copper River route, inasmuch as the latter taps a copper-bearing district of considerable developed tonnage. Auriferous lodes have indeed been found along this proposed route, but the assured tonnage from lode mining is as yet small.

The location of railways has been discussed in some detail because on them depends the commercial future of the province. Without railways the coals will remain unused, the farming lands will not be taken up, and only the richest placers and lodes will be developed. Without railways only the richest and most accessible gold deposits will be worked, and when these are exhausted the land will relapse into the primitive conditions of a decade or two ago.

The railway route described above would not be in itself sufficient to develop all the resources of the region. Branch lines such as have been suggested for the Matanuska field and the Yentna placer district will have to be built in other localities. These in turn will have to be supplemented by good wagon roads, such as have already been constructed in the Fairbanks district. When a transportation system, as above outlined, has been established to supplement the present water transportation, then, and then only, can a large industrial advancement be expected in this province.

# INDEX.





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D.

H.



I.



J.

S.

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