Professional Paper No. 41

Series { A, Economic Geology, 48
B, Descriptive Geology, 60

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

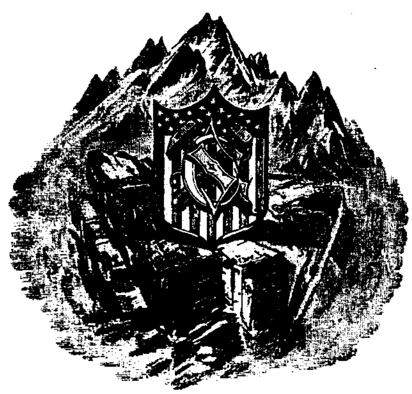
GEOLOGY

OF THE

CENTRAL COPPER RIVER REGION, ALASKA

BY

WALTER C. MENDENHALL



WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., July 13, 1904.

SIR: I transmit herewith the manuscript and illustrations of a report by Mr. Walter C. Mendenhall, entitled "The Geology of the Central Copper River Region, Alaska," and recommend its publication as a professional paper.

The field work on which this paper is based was completed in 1902, and the economic results have already been made public in Professional Paper No. 15, entitled "The Mineral Resources of the Mount Wrangell District, Alaska," by Walter C. Mendenhall and Frank C. Schrader. It has been thought best, for the sake of making this report complete, to republish here that part of the economic matter included in Paper No. 15 that has to do with the Copper River region, with such slight changes as the passage of time requires.

The value of this report is increased by the fact that it becomes the medium of publication of the reconnaissance maps of the Copper River region by T. G. Gerdine and D. C. Witherspoon.

Very respectfully,

ALFRED H. BROOKS,
Geologist in Charge Division Alaskan Mineral Resources.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

GEOLOGY OF THE CENTRAL COPPER RIVER REGION, ALASKA.

By Walter C. Mendenhall.

INTRODUCTION.

It is an interesting evidence of the prompt responsiveness of our governmental organization to popular needs that the year 1898, which saw the first rush of argonauts to Alaska as a result of the discovery of the Klondike in 1896, saw also several well-equipped Federal parties at work in the Territory, mapping its great waterways and mountain ranges, investigating the feasible means of transportation within it, laying out routes for future lines of communication, and studying the mineral resources and the plant and animal life. It is true that before that year, in which the general attention of the world was fixed upon our heretofore lightly regarded northern province, fur traders, adventurous travelers, and hardy prospectors had made little-heralded journeys through the interior, and that one or another of the governmental departments had had representatives on special errands within its borders, but the amount of private and public energy expended there in 1898 probably exceeded that of any ten previous years.

That part of Alaska which lies within the valley of Copper River first attracted the attention of prospectors in 1898, and since then has received a fair share of the expenditures made each year by the Government in its attempt to encourage the development of its Alaskan territory by responding promptly to reasonable calls for the exercise of its legitimate functions.

During 1898 the War Department[a] had a large party in the Copper River district under the direction of Capt. W. R. Abercrombie, and another command operating from Cook Inlet as a base under Capt. E. F. Glenn, which crossed the western edge of the Copper River Plateau and entered the Tanana Valley by way

[a] Reports of Explorations in the Territory of Alaska, War Department, Adjutant-General's Office, vol. 25, 1899.

of Delta River. Since that date the work of the War Department has been continued each season and has resulted in the construction and maintenance of the military trail across the Chugach Mountains, and the completion of the Signal Service telegraph line from Valdez to Eagle, two undertakings of the utmost importance in their influence upon the development of the Copper Valley.

The Coast Survey during the same period has accurately charted many miles of shore line, including the great delta of Copper River and the more important harbors of Prince William Sound; the Revenue-Cutter Service has increased its activities with the growth of trade and the increase of the tonnage engaged in it; and recently the Agricultural Department has established an experimental farm at Copper Center, to test the suitability of soil and climate to the production of the hardier food and forage plants. There is also an urgent demand for land surveys in the interior, to which the Land Office is preparing to respond. Thus the various Government bureaus are keeping well abreast of the needs of the region; indeed in many instances the Federal representatives have been the true pioneers, penetrating, exploring, and investigating in advance even of the prospector, whose hardihood and persistence keep him always in the skirmish line in civilization's attack on the fast-shrinking, unreclaimed wilderness.

The Geological Survey's first representative in the Copper River country was Dr. C. W. Hayes, who in 1891 accompanied Lieut. Frederick Schwatka from Fort Selkirk on the Yukon to the Chitina and Copper valleys by way of White River and Skolai Pass.

In 1898, Mr. F. C. Schrader was assigned to duty in the district as geologist to military expedition No. 2, and in this capacity carried out reconnaissance studies in Prince William Sound, in the southern part of the Copper River basin, and in the mountainous area between. During the same season the writer, as geologist to military expedition No. 3, crossed the western part of Copper River basin, from the head of Matanuska River, which flows into Cook Inlet, to Delta River, a tributary of the Tanana.

In 1899, Mr. Oscar Rohn, a geologist and topographer in the employ of the War Department, whose results were published by the Geological Survey, conducted a reconnaissance through the northern Chitina basin, crossed the Wrangell Mountains to Chisana (Tanana) River, and returned to Valdez by way of the Nabesna and Copper valleys.

In 1900, Messrs. Schrader and Spencer, geologists, and Messrs. Gerdine and Witherspoon, topographers, all of the Geological Survey, made closer studies than had previously been possible of the geologic and geographic features of the southern and southeastern parts of the Copper River basin.

The results secured by all of these various expeditions have been published from time to time, each publication[a] throwing additional light on the practical and scientific problems of a geologic and geographic nature which are presented in the region.

In 1902, two combined geologic and topographic parties entered the field, the object being to carry over the central and northern parts of the Copper River drainage basin and the adjacent parts of the Tanana system reconnaissance studies similar in general character to those carried out in the Chitina basin in 1900. The northern party, whose work was in charge of Mr. F. C. Schrader with Mr. D. C. Witherspoon as topographer, was assigned to the upper Copper, the Nabesna, and the Chisana drainage basins, while the second party, in charge of Mr. T. G. Gerdine, with the writer attached as geologist, mapped the south and west slopes of the Wrangell Mountains and the southern face of the part of the Alaska Range that is drained by the tributaries of the Copper. The north-central portion of the Copper Valley, from the mouth of the Slana nearly to the mouth of the Tonsina, falls within the field of the second party.

The economic results of the work of these two expeditions have already been collected and published,[b] and the prime object of the present paper is to present the more general scientific results for that part of the field studied by the writer, and covered by the accompanying topographic and geologic maps (Pls. IV, XI, XIV, and XIX). It is designated the central Copper River region. Because of the time which has elapsed since the publication of the economic results by Mr. Schrader and the writer in Professional Paper No. 15, and in order to make this report as complete as possible for the region of which it treats, that part of Professional Paper No. 15 in which the mineral resources of the central Copper River region are discussed is reproduced here, with only such slight changes as recent developments require.

ORGANIZATION AND ITINERARY.

The parties whose fields were to be, respectively, the northern and the central portions of the Copper River region were organized by Mr. Schrader in the winter of 1901–2, and the work of placing the supplies and equipment in the field was intrusted to Mr. D. C. Witherspoon, who during March and April sledded the combined outfits of the two parties across the Chugach Mountains and made

[a] Those who are interested in the earlier reports should consult: Reconnaissance in Alaska in 1885, by Lieut. Henry T. Allen. An expedition through the Yukon district, by Charles Willard Hayes: Nat. Geog. Mag., vol. 4, May 15, 1892, pp. 117–162. Explorations in Alaska, Government Printing Office, 1900. A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898, by F. C. Schrader: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7. A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898, by W. C. Mendenhall: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7. A reconnaissance of the Chitina River and Skolai Mountains, Alaska, by Oscar Rohn: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2. The Geology and Mineral Resources of a portion of the Copper River district, Alaska, by F. C. Schrader and A. C. Spencer; a special publication of the U. S. Geol. Survey, 1901.

[b] Mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader: Prof. Paper U. S. Geol. Survey No. 15, 1903.

caches of supplies at Copper Center and at Batzulnetas, on Copper River. Mr. T. G. Gerdine, the responsible head of the southern party, reached Copper Center in April, assumed charge, and began at once the work of establishing and locating a base from which to expand a network of triangles over the area to be mapped by the party under his command. The writer, assigned as geologist to this party, reached Copper Center on May 9, completing the personnel as organized for the summer's work.

At this date, although the greater part of the ice had gone from the rivers and the snow from the valleys, snow still covered the lower hills, and grass had not appeared even at the most favorable points, while back among the foothills of the mountains pasture sufficient for the sustenance of the animals of the pack train was not available until early in June. While waiting for the grass to appear short trips, for which sufficient grain could be carried, were made up the Klutina to Stück Mountain, and to Tonsina Bridge, and investigations were carried out in the immediate neighborhood of Copper Center.

On June 3 the party moved eastward toward Nadina River, and during the remainder of this month the topographic and geologic work was extended across the basins of the Nadina, the Dadina, and the main branch of the Chetaslina to the east fork of the latter stream, where it was connected with the work of 1900. On July 1, it being regarded as desirable that the Kotsina and Elliott Creek copper properties should be visited, the party was divided, three men, including the geologist of the expedition, taking two horses eastward to the Kotsina, while the topographic contingent returned slowly to the cache left at the Nadina, working en route into the heads of the Chetaslina and Dadina valleys. This party, after reaching the Dadina cache, advanced northward from it toward Sanford River, and was overtaken just south of the latter stream by the geologic party, which in the meantime had visited the upper Kotsina and its tributaries and the basin of Elliott Creek.

From this time until the close of the season the topographer and the geologist worked from the same base camps. On August 2 the upper part of Copper River was reached and crossed between Batzulnetas and Slana River. After replenishing the supplies from caches established in the spring at Batzulnetas and Chistochina, the survey was continued northwestward along the valleys of Ahtel and Indian creeks, across the east fork and the middle fork of the Chistochina, to the Chistochina placer district, which was reached late in August, about the time of the first snows of the season. Several days were spent here in map work and in a study of the placer deposits and the complex bed-rock geology. The new snow on the foothills and the freezing each night indicated the rapid approach of the end of the field season, but as it was highly desirable to connect with the work of 1898 at the head of Delta River, the party continued westward across the Gakona as far as the glacier which is a source of Phelan Creek and the Gulkana, and therefore furnishes water to both the Yukon and the Copper River systems.

During the succession of storms which continued from September 6 to 9, inclusive, the party remained in a camp at the foot of this glacier, in the hope that an improvement in the weather would permit work from the hill tops, and enable the desired geographic connections to be more accurately made. The attempt had to be given up, however, because of continuous snow and rainfall, and on September 9 a return was made to Gakona River, and work continued in the lower country east and west of the middle course of this stream.

The party reached Chistochina River, and completed the season's field work on September 14, and on that day began the journey to Valdez by way of the military trail. It arrived in Valdez on September 27, was joined there by the northern party on September 29, and sailed on October 2 for Seattle.

The results of the topographic work accomplished by Mr. Gerdine during the season are presented in the accompanying expressive map (Pl. XIX), a glance at which will convey to the sympathetic student of topographic forms some idea of the inspiring character of the district from the scenic point of view. The map work is a continuation of that done by Mr. Gerdine and Mr. Witherspoon in the southeastern part of the Copper basin in 1900, and was continued to the northeast by Mr. Witherspoon during the summer of 1902 (Pl. XX). Mr. Witherspoon's results will also be published with a geologic report by Mr. Schrader, and the maps then available will be nearly complete for the Copper River basin. No other part of Alaska, except the Seward Peninsula, has been so thoroughly covered by the Survey topographers.

The geologic work whose results will be presented in the pages which follow was done, as is usually the case in such preliminary work, without a topographic base, the geologic and topographic mapping being carried on simultaneously. This condition in connection with the large area covered precluded the possibility of detailed studies, so that the results are essentially those of a rapid reconnaissance. Yet the opportunities were much better than in the more hasty route surveys of the kind heretofore carried out by the writer in his Alaskan work, and the results are presented with more confidence. Perhaps the relative values of the two classes of work are well expressed by the scales of the maps upon which the results are usually published, a scale of 1 : 250,000 being used in the one instance, while 1 : 625,000 suffices to show the data secured in the other.

In the following pages it is designed to present as a foundation as complete a discussion of the rock masses and the land forms studied as is justified by the facts at hand, and to sketch upon the basis of this discussion the principal events in the geologic and geographic development of the region, so that this paper, with one by Messrs. Schrader and Spencer in 1900 and another by Mr. Schrader to follow, shall constitute a preliminary general record of earth history in this part of Alaska, and serve as an adequate basis for future detailed studies of special areas.

The mass of facts available for the territory generally is rapidly growing, and it will soon be possible to outline with fair accuracy the larger events in its geologic history. This work has been attempted in a tentative way for the Copper River basin in the present paper in the chapter on the geologic history of the region. Such a record, together with an understanding of the processes and the principles involved in geologic evolution, is the goal toward which all purely scientific geologic work, as distinguished from that which has a direct economic bearing, will logically trend. When eventually it shall have been written, accurately and with full detail, the first epoch in our study of the territory will have been passed.

In the discussion which follows a brief general geographic outline is first given. It is intended to be only sufficiently full to make the succeeding parts of the paper, on geology, physiography, and economic geology intelligible, since in previous publications the main geographic features have been recognized and discussed, and because, in addition, a full series of maps, more graphic than any description could be, accompanies the text. In the geologic treatment full descriptions have been given of the formations whose character and significance have not been generally recognized heretofore; but in discussions of other rock masses, like the Valdez formation and the Nikolai greenstone, more closely studied by other workers, only a condensed résumé of their conclusions is given, so that there may not be burdensome repetition. In the physiographic portion, likewise, those conceptions which have developed as a direct result of the work of 1902 are fully expressed, while a statement without argument of the accepted conceptions of colleagues whose conclusions are now in print is deemed sufficient. The economic geology, as already stated, is practically a reprint of that part of Professional Paper No. 15 which treats of the central Copper River region.

GEOGRAPHY.

The drainage basin of Copper River has an area of about 23,000 square miles, for the most part ruggedly mountainous, but including sufficient plain to give full effect to the relief of the mountain masses. This area is rudely crescent shaped with Mount Wrangell lying near the middle of the concave side, Mentasta Pass in one horn and the source of the Chitina in the other. The median line

OUTLINE MAP OF ALASKA.

of the crescent is closely defined by the courses of the Copper and its great eastern tributary, the Chitina, the trunk stream below the junction, crossing the Chugach Mountains to the sea in a way which strikingly disregards the general outlines of its basin (Pl. XI).

Defined in terms of geographic position, the drainage basin of the Copper lies near the southeast corner of the main mass of Alaska, between the meridians of 141° and 148° west longitude, almost touching both of these extremes, and between the parallels of 60° and 63° 10′ north latitude. It includes points which range from sea level to more than 16,000 feet above tide. The geographic diversity represented within it will be recognized from the fact that it embraces portions of three great mountain ranges, wholly distinct in topographic character, and that these rise from a broad interior plain 80 miles or more in width.

CHUGACH MOUNTAINS.

The Chugach Mountains form a range 60 to 80 miles wide, which extends westward from Mount St. Elias, curving about Prince William Sound, and continuing southwestward through the Kenai Peninsula as the Kenai Mountains (Pl. XI). Directly east and west of the valley which lower Copper River has cut across these mountains, their crests when viewed from a sufficient elevation fall into a plane about 6,000 or 7,000 feet above the sea, and the series of sharp ridges which actually make up the range blend into a remarkably even sky line. Eastward toward Mount St. Elias superior heights appear above this plane until its even-crested character disappears, and westward between the head of Port Wells and the valley of the Matanuska other heights rise 2,000 or 3,000 feet above the general level.

In crossing the range by any one of the few feasible routes it is found to be exceedingly rugged in detail; deep canyon-like valleys occupied, near their heads at least, by glaciers and separated by precipitous ridges succeed one another in a confusing labyrinth, and the general effect of a plain, produced by the harmony in the elevations of the summits when seen from a distance, is wholly lost.

WRANGELL MOUNTAINS.

The next range to the north, the Wrangell Mountains, separated from the Chugach Mountains by the Chitina Valley, is wholly different in character as in origin. This group, which may be regarded as beginning at Skolai Pass near the one hundred and forty-second meridian west longitude and extending northwestward 100 miles to the base of Mount Drum or Mount Sanford, consists of a series of dissociated peaks and lofty ridges, with a dozen points over 12,000 feet in height (Pls. II and XI). The most conspicuous summits are: Mount Sanford, 16,200 feet; Mount Blackburn, 16,140 feet; Mount Wrangell, 14,000 feet; Mount Regal, 13,400 feet; Mount Jarvis, 12,300 feet; and Mount Drum, 12,000 feet.

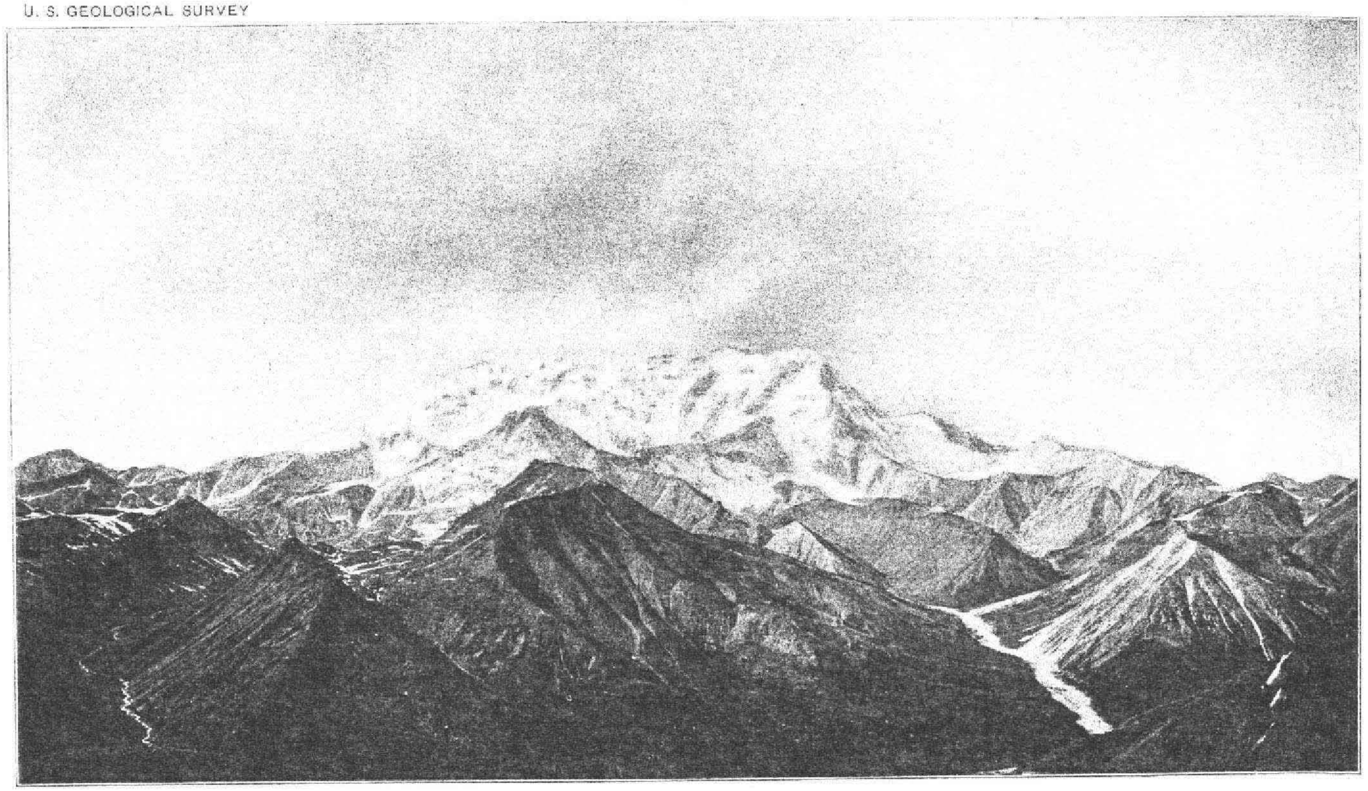
Mount Wrangell, the central peak and the active volcano of the group, is a rounded, snow-covered dome, the diameter of whose base is ten times its height. Its slopes therefore are gentle, and its mass is much greater than that of any of its associated peaks. The vent from which columns of smoke and vapor rise intermittently seems to be just east of the summit proper (Pl. VIII). It has never been visited by white men and probably not by natives, although the ascent of the mountain would be a comparatively easy task. Mount Wrangell and the northern slopes of the ridge which extends east from it form what is probably the largest snow field in Alaska outside of the coastal mountains. Copper, Nabesna, Chisana, and Kennicott glaciers are the principal ice streams which drain this extensive névé.

Mount Sanford is the northwestern peak and the highest of the group. Its southwestern face, drained by Sanford Glacier, is extremely precipitous (Pl. III, *B*). For this slope of 10,000 or 12,000 feet averages probably 60°, but when viewed from the north or northwest the mountain presents the smooth, rounded outlines of the conventional sugar loaf, broadly conical with a rounded top. A great snow-covered saddle 10,000 feet high connects this peak with Mount Wrangell.

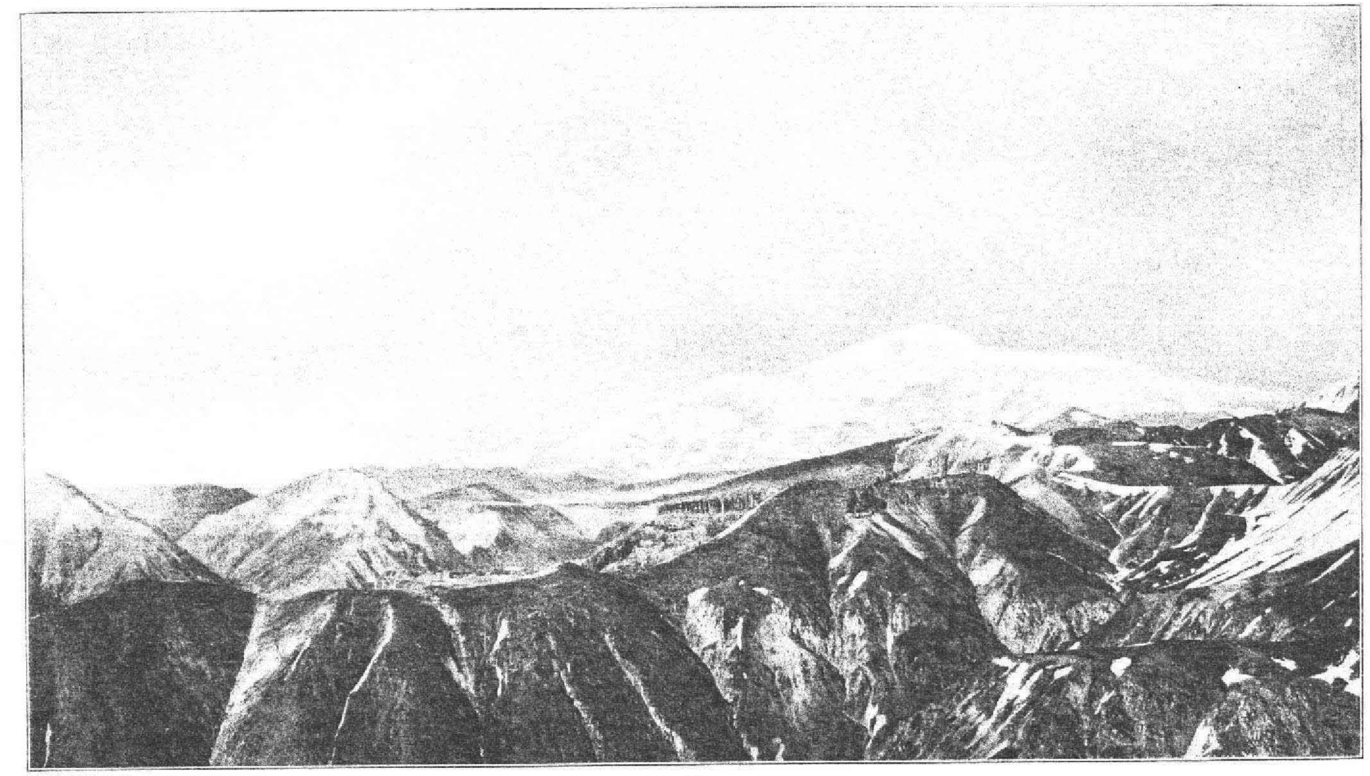
The second peak in height, Mount Blackburn, 16,140 feet, is 28 miles southeast of Mount Wrangell, at the head of the Kennicott and Kuskulana drainages. In the snow fields of its northern slope rise the eastern tributaries of the Nabesna Glacier. The upper reaches of the mountain are gentle, probably original constructional forms, but glacial erosion has attacked it on all sides, so that the intermediate slopes are very precipitous and present sufficient difficulties to invite the most hardy mountain climber.

Mount Drum, although but 12,000 feet high, is especially conspicuous because of its position and isolation (Pls. VII, XII, *A*). It is the westernmost and perhaps the most picturesque of the great peaks and stands well out in the plain of the Copper River Valley, which surrounds it on three sides. On the east it is separated from Mount Wrangell and Mount Sanford by a pass about 5,000 feet high connecting the valleys of Sanford and Dadina rivers. The work of ice and water together has completely obliterated the original constructional form of the peak and has given it the bold and rugged outlines characteristic of mature erosional mountains.

Mount Jarvis, east of Mount Wrangell, and Mount Regal, east of Mount Blackburn, are the highest among a number of points rising from the broad irregular ridge which serves as the backbone of the group.

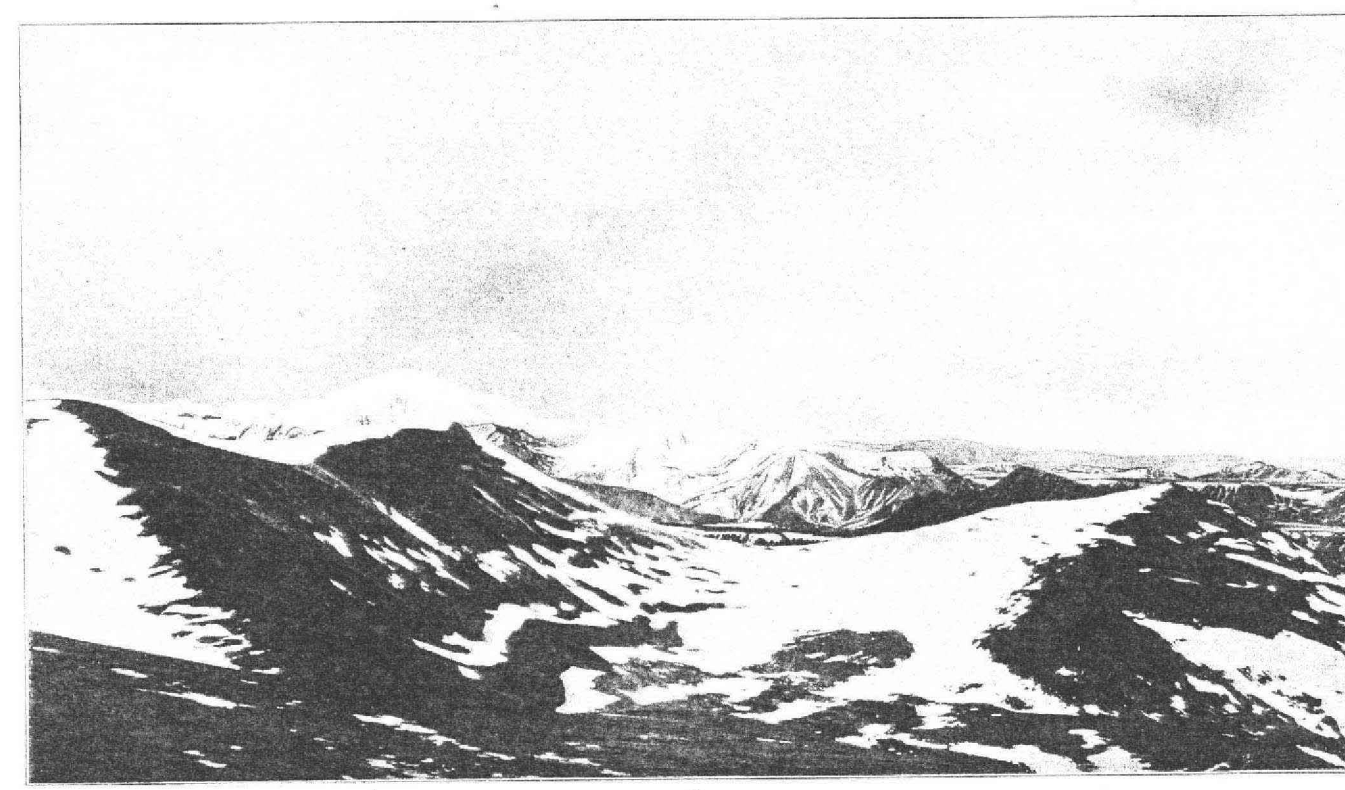


A



B

C



D

PANORAMA OF THE WRANGELL MOUNTAINS.

ALASKA RANGE.

North of the Copper River basin is the eastern end of the great Alaska Range which swings westward and southward around the Sushitna Valley, culminating near the middle of its extent in Mount McKinley.

This range probably differs in the details of its history, as it does in character, from both the Chugach and the Wrangell mountains. It is everywhere very rugged and very irregular in height, and the numerous passes through it separate it into a number of distinct masses, which together constitute the range. Directly north of the Copper basin lie what the prospectors frequently call the Chistochina Mountains, extending from Delta River eastward to Gillett Pass, near the source of the Slana, and culminating in Mount Kimball, about 10,000 feet high. East of these are the Mentasta Mountains, extending to Nabesna River, and west of them is a group which continues to Cantwell River and has as its highest point Mount Hayes, 14,000 feet high.

The northern face of this range has not been closely studied nor accurately mapped as yet, but its southern slope within the drainage basin of Copper River is flanked by groups of foothills, usually separated from the central dominant chain and frequently from each other by well-marked valleys. These are narrow and occupy relatively small areas near the base of the main range, where the foothills are high, but are broad and occupy relatively large areas farther from the range, where the foothills are low. This foothill belt presents no regular aspect, but includes, south and west of the Slana, a high rough mass of granitic mountains penetrated by flat-bottomed valleys and abundant passes. Northwest of these hills the outer heights are low rounded rock islands rising from the timbered levels of the Copper River Plateau. Still farther west they increase in height, and becoming more closely set are known as the Bald Hills of the Sushitna, the winter feeding grounds of the caribou.

INTERIOR VALLEY.

The Copper River basin is a wide, rudely crescent-shaped expanse of swampy plain which encircles the Wrangell Mountains and expands indefinitely west of these toward the valley of Sushitna River. One greatly lengthened horn of the crescent extends up Chitina River and terminates in an irregular expanse which includes the mouth of the Nizina. The northern horn swings east around Cornwall ridge and includes the valleys of upper Copper River and Batzulnetas Creek. Copper River flows through this plain from north to south, somewhat east of the median line, and the plain declines in elevation from both its borders toward the channel of the river, the eastern slope being steeper than the western and decreasing rapidly in grade from the base of the Wrangell

The Gulkana is but imperfectly known. Its eastern fork rises west of the source of the Gakona, in a glacier which also feeds Phelan Creek, a tributary of Delta River. Within sight of its source this fork flows through a lake 4 or 5 miles long and half as broad, and a few miles below enters another narrow lake, 10 miles in length. A sluggish, tortuous western tributary whose source is unexplored joins the main stream about 25 miles above its mouth.

Gakona River drains by far the largest glacier yet reported on the south side of the Alaska Mountains. Larger ice streams drain eastward from the Mount McKinley group, and others of greater mass may be found between the head of the Delta and the head of the Cantwell, but they have not yet been reported. From the foot of the glacier the Gakona flows directly southward about 75 miles to the Copper without receiving any important tributaries, Excelsior Creek, the largest, being a comparatively small stream.

The Chistochina, in marked contrast to the Gakona, has three important branches—Middle Fork, East Fork, and West Fork—in addition to the trunk stream, and an important tributary, the Chisna. All of these, except the Chisna, have glacial sources in the Alaska Range. At its mouth the Chistochina has a wide gravel delta and enters the Copper by several channels. Its volume was considered by Lieutenant Allen in 1885 to be as great as that of the Copper itself.

Slana River heads opposite the Middle Fork of the Chistochina in a lateral valley, whose western extension is occupied by Chistochina Glacier, and whose eastern continuation leads by way of Gillett Pass to the Tok drainage. From its source the Slana flows east and south into an open valley leading to the East Fork of the Chistochina, then turns eastward into the mountains again, flowing past Mentasta Lake to join the Copper about 45 miles below Copper Glacier.

Above the Slana, Batzulnetas Creek, a rather important clear-water stream, drains Tanada Lake. The most feasible routes from the Copper to the Nabesna lie along its valley.

RELATIONS OF GEOGRAPHY TO SETTLEMENT.

The great influence exerted by geographic conditions upon the movements of man is particularly well illustrated in the Copper River and adjacent regions, both in the distribution of the native tribes and in the later development and settlement by the white races.

The native settlement of Alaska seems to have been accomplished by two distinct movements, the one of Indians northward along the coast or through the great interior valleys from the more favorable region in the United States and Canada, the other of Eskimos southward from the Arctic. The Prince William Sound natives, closely allied to those of the Aleutian Islands and the Alaska

Peninsula, have strong Eskimo affinities, while the Copper River tribes, separated from those of the coast by the barrier of the Chugach Range, are much more closely allied to the Indians of the Yukon Valley. The series of passes through the Alaska Range, of which the Mentasta is the best known, are so favorable to free movement between the Copper and the tributaries of the Yukon that migration back and forth across this range takes place freely now, as it probably has since the first native settlements here. From the upper Copper Valley, movement has been unrestricted across the Copper River plain to the northern base of the Chugach Range and, indeed, has reached Cook Inlet by way of the Matanuska and Sushitna River valleys, the natives here being of the interior type.

But while the Alaska Range with its open passes has thus favored free communication, the Chugach Range, much more difficult to cross, has served as an effectual barrier both to the Aleuts south of it and to the Indians north, so that it separates the two great families to the present day.

The influence exerted by the local geography upon the movements of the white traders, prospectors, and settlers has been quite as marked as that exercised upon the natives, but its results have been different as the character of the movements of the races has differed.

During the century of exploration, colonization, and trade by the Russians previous to the American purchase, only two or three disastrous attempts were made to penetrate to the Copper Valley, although some of the most flourishing of the Russian settlements existed at near-by coastal points, as in Cook Inlet and Resurrection Bay. But neither the Copper, the Matanuska, nor the upper course of Sushitna River leading to the Copper Valley are navigable, and the Russians do not seem to have known of either of the passes across the Chugach Range. Always following in their trading and exploring expeditions the lines of easy communication, usually the great navigable streams, they established trading posts on the Yukon, the Kuskokwim, and the lower Sushitna, but were turned aside from the Copper Valley by the difficulties involved in crossing the Chugach Mountains, the same barrier which so effectually debarred the native tribes of the interior from the coast. The Russian occupation of the interior of Alaska was never complete enough to lead them into the Copper Valley from the north, although they seem to have known of the communication between the Copper Valley and the Yukon tributaries, it being one of the objects of Serebrenikof's expedition of 1848 to trace the relations of the Copper drainage to that of the Kwikpak, as the lower Yukon was called.

After the purchase in 1867, the few American prospectors and traders who entered the territory followed the highway of the Yukon, which became comparatively well known long before any definite knowledge was had concerning the upper valley of the Copper. Indeed, previous to 1898, the only successful expeditions within the latter valley were those definitely organized for its exploration, usually under Government auspices. The difficulties to be overcome in penetrating it, due wholly to its geographic environment, were too great for private enterprise in the early stages of the era of prospecting and trading.

But the human flood of 1898 swept over all barriers. Its greatest force was spent in the Yukon Valley, but some 4,000 people, inspired by vague rumors of great mineral wealth along Copper River, landed at Valdez. A few ascended the Copper in small boats in spite of the difficulties involved, but by far the greater number reached the interior by the shorter but equally hazardous route across the Valdez Glacier. Before the close of the season, one or two of the most adventurous came out by way of Thomson Pass, and the Tasnuna route was explored and mapped by Schrader. Thus, at last and at great cost, two feasible ways had been found through the barrier which nature had set up against man.

Since 1899 the military trail has been built into the valley by way of Thomson Pass, and the Government telegraph has been constructed from Valdez to Eagle, so that communication is now comparatively easy. But even under these improved conditions the handicap which the character of the Chugach Range and the swift waters of the Copper place upon development will be realized from the facts that supplies and wages are at present as high in the Chistochina gold field as in the remote Koyukuk region, 250 miles farther north, and that provisions and machinery, the latter strictly limited in weight, can not be delivered in the Chitina copper district, 150 miles from Valdez, for less than 25 cents per pound.

Not until a railroad shall have been built across the Chugach Mountains will this interesting region find itself economically on equal terms with the Yukon Valley. Man by its building will have finally overcome the physical obstacles to free movement imposed by lofty mountain ranges and unnavigable streams.

GEOLOGY.

GEOLOGIC SUMMARY.

The earliest rocks recognized in the central Copper River region are the Tanana and Dadina schists, which include both sedimentary and igneous members, and are regarded tentatively as pre-Silurian. The Silurian system may be represented in the conglomerates, arkoses, shales, and schists of the Valdez formation. These rocks constitute the chief part of the Chugach Range.

Sediments and volcanics, which are supposed to be Carboniferous or Devonian, are found in the northern edge of the Copper basin. They are somewhat altered, but the alteration is not comparable in intensity with that affecting the older rocks, although greater than that observed in those of later age.

The upper Carboniferous is probably represented in the geologic column by the Nikolai greenstone, a series of flows of basic lavas. These seem to close a period of Paleozoic land or shoal-water conditions, which gave way in the Permian to widespread marine influences that continued well into the Triassic. This marine deposition was closed by a period of folding and general erosion, followed in Jura-Cretaceous time by the deposition of coarse materials. Another period of folding and erosion ensued, and when, in the upper Eocene, sedimentation was resumed it was of the fresh-water type, probably in isolated or nearly isolated water bodies of limited extent.

The principal post-Eocene events have been the uplift of the mountain ranges, the outpouring of the Wrangell lavas, and the accumulation of the Pleistocene silts, sands, and gravels.

Provisional correlation table.

	Schrader and Spencer: Copper River district, 1900.[a]	Mendenhall: Resurrection Bay to the Tanana River, 1898.[b]	Brooks: Pyramid Harbor to Fortymile River, 1899.[c]	Eldridge: Sushitna Valley, Alaska Range, and Cantwell River, 1898.[d]	Spurr: Southwestern Alaska, 1898.[e]	Brooks: White River and Tanana district, 1898.[f]	Mendenhall: Central Copper River region, 1902.	Schrader: Headwater region of Copper and Tanana rivers, 1902.[g]
Pleistocene	Silts, gravels, and bowlder clays.	Sands and gravels.	Silts, sands, and gravels; effusive rocks in part.	Sands, gravels, and bowlder clays.	Silts, sands, and gravels.	Silts and gravels.	Silts, sands, gravels, and tills.	Silts, clays, sands, gravels, and tills.
Neocene			Tok sandstone and effusive rocks in part (?).		Tyonek beds, Hayes River beds, Nushagak beds.	Tok sandstone.	Wrangell lavas.	Wrangell lavas, andesites, basalts, diabases, dacites.
Eocene or Oligocene.				Kenai series.	Yentna beds.		Gakona formation.	
Cretaceous	Kennicott formation, Orca series (?).	Matanuska series.		Cantwell conglomerate (?).	Tordrillo series, Holiknuk series, Kolmakof series, Oklune series.		Kennicott formation.	Diorite, Skolai volcanics, Mesozoic. Undifferentiated sediments.
Jurassic					Naknek series, Skwentna series.			
Triassic	Triassic shales and limestones.						Triassic shales and limestones.	
Carboniferous	Chitistone limestone.						Mankomen formation (Permian), Nikolai greenstone.	Nabesna formation.
Carboniferous and Devonian.	Nikolai greenstone (?).	Sunrise series (?).	Nutzotin series.	Cantwell conglomerate (?).	Tachatna series.	Wellesley series, Nilkoka beds (?).	Tetelna volcanics, Chisna formation.	Suslota formation.
Silurian	Valdes series (?).	Greenstones (?).	Greenstone schists (?), Kotlo series.			Greenstone schists (?).	Valdez formation.	Jacksina formation, Monte Cristo diorite.
Pre-Silurian sediments.	Klutena series (?).	Tanana schists.		Sushitna schists.		Tanana schists, Nasina series.	Tanana schists, Dadina schists.	Mentasta schist.
Archean			Gneissic series.	Basal granite and gneissic series.		Gneissic series.		

[a] See, also, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska, by Oscar Rohn: Twenty-first Ann. Rept., pt. 2.

[b] A reconnaissance from Resurrection Bay to the Tanana River, Alaska: Twentieth Ann. Rept., pt. 7.

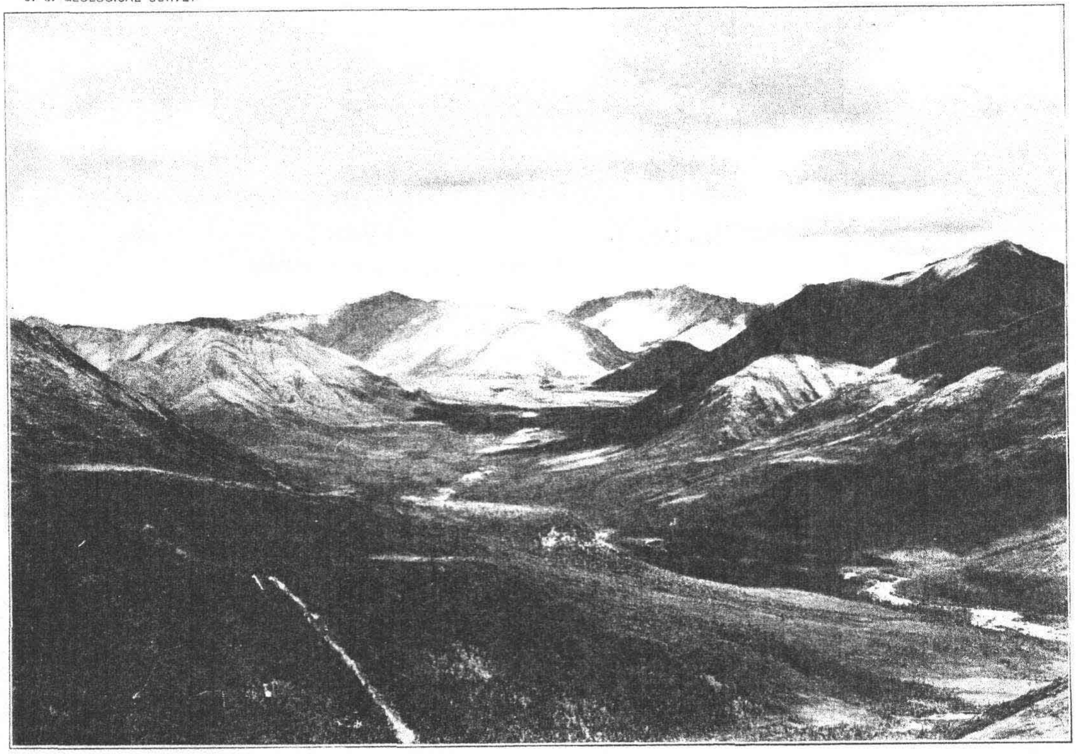
[c] A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: Twenty-first Ann. Rept., pt. 2.

[d] A reconnaissance in the Sushitna basin and adjacent territory, Alaska, 1898: Twentieth Ann. Rept., pt. 7.

[e] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept., pt. 7.

[f] A reconnaissance in the White and Tanana river basins, Alaska: Twentieth Ann. Rept., pt. 7.

[g] Geologic reconnaissance of the headwater region of Copper and Tanana rivers, Alaska: Prof. Paper. (In preparation.)



A. GENERAL VIEW OF THE UPPER VALLEY OF AHTEL CREEK.

B. SOUTH FACE OF MOUNT SANFORD FROM DADINA VALLEY.

DESCRIPTION OF FORMATIONS.

In various portions of the Copper River basin, as in other parts of Alaska, areas of schistose rocks have been encountered at different times and described by different writers. Of these, the Valdez formation and the Tanana schists exhibit certain definite characters which make it possible to recognize them with a considerable degree of probability when found in new areas. Other detached occurrences are known, usually in small masses, which exhibit variations from these types, and since any fossil evidence which may have existed in the sedimentary phases of the beds has been destroyed by the metamorphism which they have undergone, their assignment to a definite place in the stratigraphic column is usually not possible.

DADINA SCHISTS.

OCCURRENCE AND CHARACTER.

Such a detached area or succession of areas appears along the flanks of an old ridge running northwest from upper Cheshnina River to near the base of Snider Peak (Pl. IV). This ridge represents what must have been a prominent topographic feature previous to the outpouring of the Wrangell lavas, but which was engulfed entirely by the products of this late volcanism and has since been only partly uncovered in the erosion of the modern valleys of Dadina and Chetaslina rivers.

The northernmost exposure of these rocks is along the south side of a tributary of the Dadina that drains from the flanks of Snider Peak. The exposures here, to an estimated height of 1,500 feet above stream level, show, where examined, a coarse quartz-biotite schist, the quartz grains frequently cloudy with dust-like inclusions. In addition to the quartz and biotite, smaller quantities of green amphibole and of magnetite are present.

Across the Dadina from this locality, in the base of the ridge which separates the Chetaslina and Dadina valleys, is another extensive exposure, which is repeated east of the ridge, where the schistose rocks reappear from beneath their covering of a few hundred feet of recent lava. The variety and complexity of the rock types here displayed are confusing. Near the base of the section on the Dadina is a succession of dark, bedded rocks which prove to be crushed and somewhat altered lavas of an andesitic type. Higher than these, but not necessarily overlying them, are amphibolite-schists, mica-schists, and small bodies of gray marmorized limestones. These older rocks, in part sedimentary, in part igneous, are all intruded by dikes of quartz-diorite, which are unaltered and frequently coarse grained.

In the gorge of Chichokna Creek, the westernmost branch of the Chetaslina, and on the hillside above the gorge, several varieties of schist outcrop, conspicuous among them being a pale-greenish quartz-calcite variety, probably an altered sediment, and a metamorphic biotite-schist which may be igneous. The walls at the upper end of this gorge are made of a somewhat sheared gabbro, whose augite is peripherally much altered to green hornblende. This basic intrusive is evidently much later than the great mass of the schists, but earlier than the diorite bodies that cut them. In the geologic map of this area (Pl. IV) the altered gabbro, whose limits were not made out in the field, has been included in the area assigned to the schists.

At the southern point of the long ridge between Chichokna Creek and the Chetaslina are some outcrops of amphibolite-schists, intricately intruded by diorite dikes, which are supposed to represent apophyses from the main diorite mass to the north. Similar schistose rocks, probably sheared eruptives, appear across the Chetaslina east of this point.

Along the valley of the East Fork of the Chetaslina, 2 or 3 miles below the foot of the glacier, there again appear restricted outcrops of schistose rocks. A soft, green, knotted chloritic-schist and an amphibolite-schist with hazy areas suggestive of original feldspar phenocrysts, are among the varieties noted.

DIORITE INTRUSIVES.

Dikes of diorite, not exceeding a few feet in width, were observed in the Dadina area, and much more extensive intrusions of the same rock may be found farther north along this stream, for it was not possible to make a close examination except at one point. On the Chetaslina and the Chichokna a large body of the diorite occurs. Although the recent andesites and tuffs overlie it on the north and east and conceal its relations in these directions with the rocks older than the lavas, it is altogether probable that the schists and their earlier dikes, including the gabbro masses, have been the host into which it was everywhere intruded. This is evidently the relation in the case of the occurrence on the East Fork of the Chetaslina.

The diorite is a gray, medium-grained, granular rock, rather uniform in megascopic and microscopic character, its most conspicuous feature in the hand specimen being the number of hornblende crystals, 5 to 6 mm. or less in length, which are present. The feldspars are white or yellowish and sphene is frequently conspicuous.

Under the microscope the twinned feldspars, which make up from 50 to 75 per cent of the slide, prove in most instances to be labradorite. Occasionally they are found surrounded by orthoclase, and in such cases they are completely automorphic. Quartz is generally present in much less amount than the orthoclase, both being very subordinate to the labradorite. The green hornblende is the principal dark constituent, but occasionally a little augite is present. Sphene, apatite, magnetite, and zircon are the accessories.

The diorite is rather irregularly jointed, and in a few cases quartz veins follow the joint systems. In an interesting case observed on the East Fork of the Chetaslina (fig. 1) a basic segregation in the diorite is displaced slightly along a joint which has been filled, producing a narrow quartz vein about 1 inch wide. A later system of joints has offset this veinlet a few inches at each observed intersection of the joints with the vein, both systems of joints proving thus to be accompanied by slight movement. These were the only instances observed which prove definitely that the rock masses of the region have been subjected to stresses subsequent to the intrusion of the diorite.

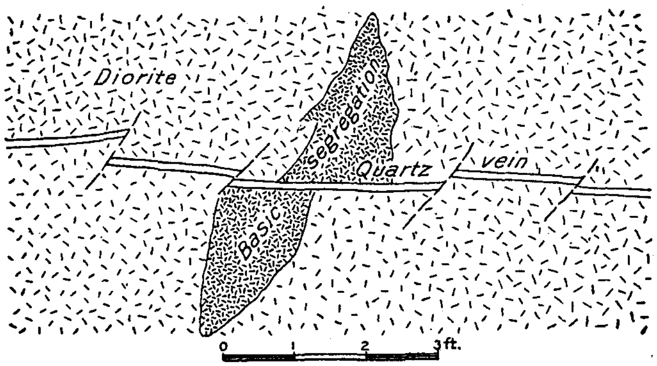


FIG. 1.—Movement along joint planes in diorite.

CORRELATION AND AGE OF THE SCHISTS.

In 1898 Schrader[a] described under the name "Klutena series" a body of schists and crystalline limestones which occur near the foot of Lake Klutina. The resemblance between the Klutena rocks and Spurr's Fortymile series in the Yukon district was pointed out at the same time.

In 1900, Messrs. Schrader and Spencer[b] encountered near the junction of Chitina and Tana rivers a limited area of similar rocks, which were tentatively assigned to the same series. In each case the more intense metamorphism exhibited leads to the conclusion that these rocks are of greater age than the Valdez series with which they are closely associated.

Those phases of the schists on Dadina and Chetaslina rivers which are not demonstrably of igneous origin are very similar to rocks from the Chitina and from the Lake Klutina localities. In addition, the Chitina rocks are intricately intruded by diorities which closely resemble those of the Chetaslina. It seems probable then that we find on the Chetaslina another fragment of the same ancient sedimentary record exhibited at Lake Klutina, and between the lower Tana and the Chitina.

[a] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1898, p. 410.
[b] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901.

Unfortunately, existing evidence is insufficient to fix the age of this period of sedimentation. The schists are certainly older than the Nikolai greenstone, whose nearest known outcrop, less than 3 miles east of the Chetaslina locality, shows practically no metamorphic action. The best available evidence indicates that the greenstone is Carboniferous, probably upper Carboniferous, so that the schists may with certainty be assigned to a period previous to the upper Carboniferous. The attempt to fix it more definitely than this involves the age of the Valdez rocks and the relations of the schists to them. Schrader and Spencer,[a] after reviewing the data bearing upon the age of the Valdez formation, assign it with doubt to the Silurian. If the belief that the Klutena rocks are older than the Valdez schists and graywackes is correct, then they are probably pre-Silurian in age.

AGE OF THE DIORITE INTRUSIVES.

The quartz-diorites which are intrusive in the Dadina and Tana representatives of the Klutena beds are very much later than their host. Similar granular rocks are known to cut the Valdez schists about the northern foot of the Valdez Glacier, where, as in the occurrences on the Chetaslina, the intrusives themselves are unmetamorphosed. Gabbroic intrusives in the Dadina schists, which are older than the diorites, are not greatly altered, so that the diorites themselves are later than the Valdez rocks and are probably later than the major part of the metamorphism in both these and the Klutena beds, for the change in both cases is so general, and bears so little relation to the diorite occurrences, that it must be regarded as due to regional metamorphism and can not be attributed to their intrusion.

The general freedom of the unaltered sediments of the Chitina Valley from massive intrusives of this type indicates that the diorites are older than the sediments—i. e., that they are pre-Permian. Accepting the Silurian age of the Valdez formation and allowing sufficient time for metamorphism, the period for the intrusions becomes narrowed with a fair degree of probability to the upper Paleozoic.

TANANA SCHISTS.

OCCURRENCE AND CHARACTER.

The Alaska Range north of the Chistochina drainage basin, so far as its constitution could be determined from the moraines of the glaciers which flow down from it, from a study of its forms at a distance, and from actual examination of rocks in place at one or two points, seems to be made up entirely of highly schis-

[a] Schrader, F. C., and Spencer, A. C., 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.

tose rocks whose original form and mineralogic composition have been almost completely changed.

An outlier of these schists is found on the divide between the Slana and the Middle Fork of the Chistochina along the south side of the lateral valley that separates the main range from the foothills south of it (Pl. IV). The schists in this exposure are dark, fine-grained, feldspathic beds, really schistose graywackes, cut in all directions by an intricate network of quartz veinlets. Across the valley to the north graphitic varieties occur, and the glaciers draining southward from the crest of the range discharge a mass of schistose débris, which includes silvery-white mica-schists, green chloritic or epidotic varieties, and black, highly carbonaceous phases. All are foliated and almost all contain numerous quartz stringers and veinlets. A few basic intrusives that are not schistose were noted.

The eastern part of Chistochina Glacier carries, in addition to fragments of shales from a near-by source, an abundance of lustrous white mica-schist, which is probably brought down by a tributary that drains the northwestern slopes of Mount Kimball. The eastern side of West Fork Glacier carries material of the same sort, but west of its medial moraine fragments of a coarse dioritic intrusive occur to the exclusion of almost all other rock types. The wash from Gakona Glacier, like that from the others described, is composed almost entirely of schistose material.

In 1898, in reporting upon a reconnaissance from Resurrection Bay to Tanana River, the writer[a] described a belt of schistose rocks exposed in the valley cut by Delta River through the Alaska Range. Along this section the schists were found to extend from the foot of Cantwell Glacier north to the Tanana Valley, constituting the axis and all the northern face of the Alaska Range. The varieties exposed in this section may all be duplicated in the occurrences examined in 1902 about the headwaters of the northern tributaries of the Copper, and it can not be doubted that the same formation extends eastward from the Delta to Gillett Pass and beyond. Mr. Schrader has described personally to the writer similar rocks about Mentasta Pass. He reports that a short distance east of this point the schists are replaced by younger rocks and that at the same time the range loses much of its prominence and ruggedness.

But little can be said about structures in the schists. Original bedding is usually not to be distinguished. The planes of schistosity in the Delta River section exhibit a great variety of dips but strike about parallel with the axis of the range. North of the Chistochina the dip, where it was possible to recognize it, is to the north at a low angle.

---

[a] 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. 313.

AGE AND NOMENCLATURE.

The name Tanana schists was first used in 1898 for members of this series recognized by Brooks[a] at a number of localities along Tanana River and by the writer[b] in the Delta River section. The rocks here described are a northeastward continuation of those exposed in the Delta River Valley.

In the Chistochina region the oldest unaltered rocks whose age has been definitely determined are Permian. Beneath the Permian lie little-altered rocks which are believed to be Devonian or Carboniferous. On Nabesna River Schrader finds limestones of upper Carboniferous age. The schists are much older than any of these. In the Snag River Valley in 1898 Brooks found some fossils associated with a conglomerate later in age than the general metamorphism. Schuchert referred these to upper Paleozoic, probably Devonian or Carboniferous time. Along the Yukon, Spurr and Collier report Devonian strata which are but little altered, and in the discussion of the age of the Klutena series Schrader and Spencer have been quoted as to the Silurian age of the much less altered Valdez rocks. The relations and unaltered condition of adjacent upper Paleozoic strata prove very definitely that the Tanana schists are older than upper Paleozoic. More general considerations, such as the fact that they are much the most thoroughly metamorphosed rocks which occur in the central Copper River region, surpassing in this respect the rocks of the Valdez and Klutena beds, lead to the belief that they are very old, probably early Paleozoic or pre-Paleozoic.

VALDEZ FORMATION.

Rocks of this formation, which make up the greater part of the Chugach Mountains where sections have been studied across them in the vicinity of Valdez Glacier, the military trail, and Copper River, occur along the southern border of the central Copper River region, where the northern face of the Chugach Mountains is included in this area. No special study was made of them during 1902, and no new light was thrown on their genesis, structure, or distribution. Schrader and Spencer[c] describe the rocks as a complex of more or less schistose quartzites and arkoses, with interbedded thin bands of dark-blue or black slate, mica-schist, graphite-schist, and stretched conglomerate, and occasional bodies of rather impure limestone.

---

[a] Brooks, A. H., A reconnaissance in the Tanana and White River basins, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 468.

[b] Mendenhall, W. C., A reconnaisance from Resurrection Bay to the Tanana River, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 313.

[c] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska: a special publication of the U. S. Geol. Survey, 1901, p. 34.

The alteration which they have undergone has not proceeded so far but that their original sedimentary character is easily recognized, and stratification in them is rarely obscured by the later schistosity.

No determinable organic remains have as yet been found in these beds, although in many instances their alteration has not gone so far but that plants or shells, had they ever existed, should be preserved. Until fossil evidence is discovered, the determination of age must rest on none too definite structural grounds.

Schrader and Spencer,[a] after considering the evidence available in the Chitina Valley and the Prince William Sound region, decided that the Valdez rocks must be much older than the Carboniferous Nikolai greenstone, and were probably older than the slates, shales, and sandstones of the "Orca series" which are doubtfully assigned to the Mesozoic. The conclusion was reached tentatively that they belong to the lower Paleozoic, perhaps to the Silurian.

CHISNA FORMATION.

OCCURRENCE AND CHARACTER.

At the very head of Chisna River, just west of the pass leading to the Middle Fork of the Chistochina, a bed of quartzitic conglomerate 75 feet thick is found, striking east and west and dipping 30° south, toward the irregular hills which separate the Chisna and the Middle Fork. Climbing southward from this exposure, pyritiferous tuffs are found to succeed the conglomerate, and these are cut by porphyritic intrusives and covered by their effusive representatives. The hills east of the Chisna were found, wherever examined, to consist of similar tuffs, quartzites, and conglomerates, or of associated igneous rocks. The isolated hill north of Powell Gulch shows outcrops of the same character, but with the tufaceous beds are some slightly calcareous members, which carry very fragmental and unidentifiable but unmistakable organic remains.

West of the Chisna in the beds of the tributaries which join it from the east are outcrops of very rusty white quartzite, but the greater part of this mountain mass is made up of diabasic or dioritic intrusives. Two and one-half miles southeast of Chisna post-office, near the southern end of the ridge which separates the Chistochina from its Middle Fork, a green quartzite carrying an abundance of pyrite outcrops.

The south end of the ridge between the Chistochina and its West Fork appears to be made up of quartzites and arkoses, with later intrusives, and is,

[a] Schrader, F. C., and Spencer, A. C., 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.

therefore, assigned to the same formation. In 1898 the writer[a] encountered and described certain rusty tufaceous beds west of Phelan Creek and the upper Delta, which are probably members of the same formation. It therefore seems to form an interrupted belt along the southern base of the higher Alaska Range from the Chisna west to the upper Delta.

The reference to this formation of a group of rocks which appear in scattered outcrops along the ridge extending eastward from a point about 5 miles south of Gakona Glacier is rather doubtful. Somewhat schistose limestone, which in one observed locality carries crinoid buttons, and dense quartzites form the mass of the ridge. These sediments are interrupted by gabbroic and diabasic intrusives and the quartzites at least are rusty from the oxidation of pyrite which they carry, but the granular and acidic intrusives which are so abundant in the rocks about the head of the Chisna were not observed.

The rocks of the Chisna formation, everywhere except at the last locality described, form hills which are especially conspicuous because of their red color. Scarcely a specimen was taken which was not heavily mineralized, cubes and irregular masses of pyrite or occasionally of chalcopyrite being scattered all through it. There seems to have been but little mechanical deformation, the rocks, except in the doubtful locality along the Gakona and the head of Excelsior Creek, being generally free from marked evidence of strain. Rarely narrow quartz stringers are to be seen. The freedom from crushing and metamorphism is rather surprising in view of the very extensive penetration of the rocks by massive intrusives.

AGE AND RELATIONS.

The character of the Chisna formation is such that fossils are scarcely to be expected in it. The few fragments found near Powell Gulch are not identifiable, but it is certain that they are organic. The crinoid buttons in the schistose limestone on the Gakona were not collected.

Northeast of the locality where the Chisna rocks are best exposed is an extensive development of Permian beds to be described further on in this report. The contact between the rocks of the two series is a fault of unknown throw, but structural and lithologic considerations leave little room for doubt that the Chisna beds are older than the Permian. The latter are relatively unmineralized and, although intruded abundantly by diabasic material, are free or nearly free from the dioritic dikes and greater masses to whose intrusion the mineralization of the tuffs is presumably due. Were the tuffs younger than the shales and limestones of the Permian we should expect the latter to have suffered from

[a] 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. 313.

similar intrusions. They are certainly to be regarded then as pre-Permian. Schrader describes the upper Carboniferous east of the Chistochina in the Nabesna region as a calcareous formation and the terrane immediately underlying the Chitina Permian is the Nikolai greenstone of altered basalts, much more basic rocks than those from which the Chisna tuffs were derived. It is probable that the tuffs are older than either of these, i. e., that they are older than upper Carboniferous. They are, therefore, until more definite evidence is forthcoming, assigned to the lower Carboniferous or Devonian. The fragmentary evidences of organic life observed, especially the abundance of crinoids at one locality, are in harmony with this decision and make it probable that they represent about the same time interval as certain slates and conglomerates, described by Brooks[a] from the upper Tanana and White River valleys in 1898, as the Wellesley formation.

INTRUSIVES AND EFFUSIVES.

The collections of igneous rocks made from the Chisna formation are not complete, nor are the specimens fresh enough in many instances to permit accurate determination, but the notes which are appended will indicate approximately the types that were observed.

The highest point in the Chisna area is a ridge south of Powell Gulch and at the head of Gold Creek. The backbone of this ridge is made up of a massive granitic intrusive similar to one which forms the west wall of the Chistochina Valley just below Slate Creek. As seen in the hand specimen, this rock is medium grained, and has a brownish-red tone, given by the color of the feldspars. Under the microscope the quartz, which is prominent in the hand specimen, is seen to constitute at least 25 per cent of the rock mass. The feldspars are all very much clouded and are not suited to optical tests, but appear to include orthoclase as well as acid plagioclase. Magnetite is the only accessory detected, but small quantities of a metasilicate may perhaps be represented by chloritic areas. The rock is probably a quartz-diorite or monzonite.

The canyon of Chisna River, 1½ miles above its mouth, is cut through a low ridge of quartz-diorite with a large percentage of oligoclase and little or no orthoclase. A small amount of hornblende originally present is now largely represented by areas of calcite, chlorite, and magnetite. A green mica is also present in notable amount.

Near the source of Chisna River a greenish-gray porphyritic intrusive with phenocrysts of quartz and of plagioclase, which is in part at least oligoclase, and somewhat exceeds the quartz in amount, is found as a dike in the tuff. The

[a] Brooks, A. H., A reconnaissance in the Tanana and White River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, p. 470.

phenocrysts do not exceed 5 mm. in diameter and the groundmass is not a glass, but a microcryptocrystalline aggregate in which are embedded small but well-individualized grains that probably represent both minerals of the phenocrysts.

Capping the hilltop south of this dacitic dike is a comparatively recent flow of dark-greenish lava that exhibits conspicuous and beautifully developed columnar structure. The flow is finely and rather sparingly porphyritic, the phenocryts being a very acidic oligoclase close to albite, and an occasional quartz crystal in a microcryptocrystalline groundmass through which are scattered microscopic cubes of magnetite. Larger magnetites are also present in the slide, and chloritic areas probably represent an altered amphibole. This dacitic effusive is regarded as the surface form of the more coarsely porphyritic phase described above.

Among the hills east of Chisna are quartzitic sediments containing a variety of intrusives, which include dacites similar to those occurring near the head of Chisna River, and members of the diorite family that are semiporphyritic with labradorite and hornblende phenocrysts from 1 to 5 mm. in diameter. The phenocrysts are embedded in a holocrystalline groundmass of the same minerals in finer grain. Diabases occur at many places in the Chisna rocks, usually as late intrusives, later than the mineralization which seems to have been induced by the great quartz-diorite masses.

TETELNA VOLCANICS.

OCCURRENCE AND CHARACTER.

With few exceptions the rocks exposed along the valley of Indian Creek and its tributaries are igneous. This field lies just along the western edge of the great mass of intrusive diorite that appears to occupy the greater part of the area immediately south and west of Slana River, and, as the diorite is younger than many of the igneous rocks exposed in the valley of Indian Creek, these are often greatly altered, the alteration presumably dating from the intrusion of the diorite. The hills in which the exposures occur are often low and rounded. They are usually timbered along their lower slopes and frequently covered from top to bottom by a mantle of glacial wash, so that outcrops are confined to chance exposures in post-Glacial ravines or along the bare tops of the hills. These conditions prevail particularly within the southern and western parts of the Indian Creek basin. In its eastern portion relief is greater, exposures are better, and more definite evidence can be secured, but the condition of the rocks, the character of the exposures, and the necessities of reconnaissance geology have together resulted in a lack of sufficient evidence to more than indicate a few of the obscure problems of volcanism, intrusion, and metamorphism, which await solution in this section. Some of the rock types seen will be briefly described and the general relations which are inferred will be touched upon.

Between the upper course of Ahtell Creek and certain western tributaries of Indian Creek, in a region whose high hills are made up largely of resistant igneous masses, are some scattered exposures of fine-grained, siliceous, banded rocks which appear to be altered sediments. Northeast of the northernmost of the numerous passes leading from the upper course of Indian Creek to the Chistochina drainage is a porous greenish quartzite. These beds are quite like the finer sedimentary members of the Chisna formation.

But the host for the later intrusives seems generally to have been an effusive of the less basic andesitic type. Such a rock, much altered, is exposed in the canyon of the West Fork of Indian Creek, 2 miles above its junction with the East Fork. Five miles northeast of this exposure, forming the upper slopes of a hill east of Indian Creek along whose lower slopes are exposures of intrusive diorite, is a sparingly porphyritic andesitic lava, with phenocrysts of labradorite, often much crushed and broken, and a smaller amount of biotite.

About 2 miles below the source of the West Fork of Indian Creek, near the margin of the diorite mass, a dark, altered lava, carrying an abundance of magnetite, is intruded by porphyritic and granular phases of the diorite. In places the host carries quartz veins and is crushed and slickensided until it looks more like a slate than an effusive. It is probably andesitic. The first high knob south of Mankomen Valley and east of the Chistochina drainage basin is capped by a similar lava, much weathered but with little mechanical alteration. The ferromagnesian constituents are represented by chlorite and magnetite, and the plagioclases are not determinable.

Another knob, northeast of the one last described and south of the eastern end of Mankomen Valley, gives a typical exposure of these old andesites. In this case the feldspar of the phenocrysts is in part at least andesine, and a little porphyritic quartz also occurs. The groundmass is holocrystalline. Another much fresher andesite in this same locality may be an effusive representative of the quartz-diorite. Often these older rocks, both the sediments and the lavas, are pyritized.

Basic dikes, generally diabases, are abundant. They are later than the old andesitic lavas, and are in some instances later than the diorites which intrude them. In some localities, notably over the hills east and west of the lower course of Indian Creek, all of the rock outcrops examined were of the fine-grained basic type.

CORRELATION AND AGE.

The two or three small areas of quartzitic sediments along Indian Creek closely resemble the similar sediments in the Chisna area, and the old lavas on Indian Creek might well be represented by the tuffs of the Chisna rocks. This very general parallelism in type is suggestive of equivalence in age and history, and the suggestion finds support in the approximately equal degrees of alteration suffered in the two cases. In neither case are the rocks schistose, if we except the area at the head of Excelsior Creek, which contains some slightly schistose limestones doubtfully assigned to the Chisna period. In both cases pyritization occurs, but it is much more extensive on the Chisna. Both the Chisna rocks and the Tetelna rocks have served as hosts for great dioritic intrusions, and both are cut by later more basic and more acidic dikes. Because of these resemblances in general character and history, the two areas are assigned to the same period, although the rocks in one are chiefly pyroclastics and in the other chiefly effusives, i. e., the evidence available now points to an upper Paleozoic age for both series.

AHTELL DIORITE.

Although the basin of Ahtell Creek has not been fully explored by the geologist, the hills drained by its western tributaries and those to the north and east of it, where examined, are found to be carved in the massive diorite which has been mentioned frequently in the preceding discussions (Pl. III, *A*). As the topography in the unexplored part of the Ahtell basin exhibits the characters displayed by the diorite hills in the explored portions, there is little doubt that the rock covers an extensive area around and including the valley of this stream.

Where examined at several localities about the periphery of the mass, the rock is granular or porphyritic and often pink or pale brownish red in general color tone. Under the microscope the plagioclases, which are the predominant minerals in the rock, forming the phenocrysts in the porphyritic varieties, and usually a large part of the granular groundmass, prove in the majority of the examples tested to be oligoclase. In the groundmass both quartz and orthoclase are associated with the oligoclase, but in subordinate amounts. Micropegmatite is not unusual. Either hornblende or biotite is generally present, with one or more of the accessories, magnetite, axinite, zircon, and tourmaline.

The rock is well exposed in its massive form in either wall of the pass which leads north from the West Fork of Indian Creek to a southern tributary of the Slana. In the apophyses and dikes around the periphery of the main mass variations from the ordinary quartz-diorite phase occur, but these have not been sufficiently closely studied for adequate description.

Other similar quartz-diorites have been found on the upper Chistochina, and a somewhat more basic rock has been described from the Dadina and Chetaslina

River region, and in earlier reports at various localities in the Chitina Valley and in the Chugach Mountains. The Ahtell diorites are thought to be of the same age as the similar rocks on the Chetaslina and are regarded as having been intruded at about the same general period as the Chitina occurrences.

The extensive belt of Permian sediments to be described later is unaltered and is generally unaffected by intrusives of this type, although near the base of the Permian section just west of the upper Slana one sill or sheet strongly resembling the Ahtell diorites, but too much altered for a critical comparison, is found in the tufaceous sediments, as though the intrusive activity represented by the diorites was just dying out with the beginning of Permian sedimentation. The rocks which are most extensively affected by the intrusions have been assigned on incomplete evidence to the upper Paleozoic, i. e., to the lower Carboniferous or Devonian; hence the intrusion itself is regarded as having occurred mainly in upper Carboniferous time and as extending perhaps into the Permian.

NIKOLAI GREENSTONE.

In the southeastern part of the central Copper River area, as represented on Pl. IV, the western limit of a series of old basalt flows, described in the Chitina Valley by Rohn[a] and by Schrader and Spencer[b] as the Nikolai greenstone, appears. These rocks outcrop as the lowest member exposed in the Elliott Creek anticline. They appear in a narrow belt beyond the dividing ridge to the north of Elliott Creek in the upper tributaries of Copper Creek. They form a prominent expanse east of Long Glacier in the valleys of Clear and Kluvesna creeks, and were recognized at one point west of the Kotsina Valley in the upper drainage basin of the Cheshnina. As described by Schrader and Spencer, the Nikolai greenstone is a series of old volcanics, whose pseudobedding, parallel to the stratification in the overlying limestone, is due to the superimposition of successive sheets of basic lava one upon the other. The evidence for this origin of the formation consists in the pseudobedding already mentioned, which in some localities is very clearly shown; in the great textural variations displayed by the formation within narrow vertical limits, and in the total absence of intrusive phenomena such as dikes or apophyses in the overlying limestone. The rocks have the mineralogic composition and the texture of typical basalts. After their outflow they served as a basement upon which the Chitistone limestone and the overlying Triassic shales were deposited and later suffered the same deformation which has affected these younger beds. They have been assigned to the period just preceding the Permian, but it is possible that they belong to a later period. This question will be more fully discussed in the consideration of the age of the Chitistone limestone.

[a] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 246.

[b] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901, p. 40.

MANKOMEN FORMATION.

OCCURRENCE AND CHARACTER.

The mountain block lying north of the Mankomen Valley and between the Middle Fork of the Chistochina and the upper course of the Slana is conspicuous from those points to the south of it from which it is visible, because of the contrast which it presents to all the surrounding mountains whose topographic forms are carved from intrusive or metamorphic rocks. This area is made up of a sedimentary series of sandstones, shales, and limestones, with intrusive sheets whose total thickness, as determined from rough barometric measurements, is between 6,000 and 7,000 feet (fig. 2). The lowest rocks recognized in the field as belonging to the terrane are exposed at the southeastern corner of the area at the base of the spur between the Mankomen Valley and Slana River. Some thin limestones and red calcareous shales and sandstones here overlie diabase, which is intrusive in them, but at a point 100 feet farther down the slope is an altered red porphyry resembling a rock which a few miles south of this point underlies similar calcareous beds that have been deposited upon it. It is therefore quite possible that the basement upon which the series was originally laid down is exposed here.

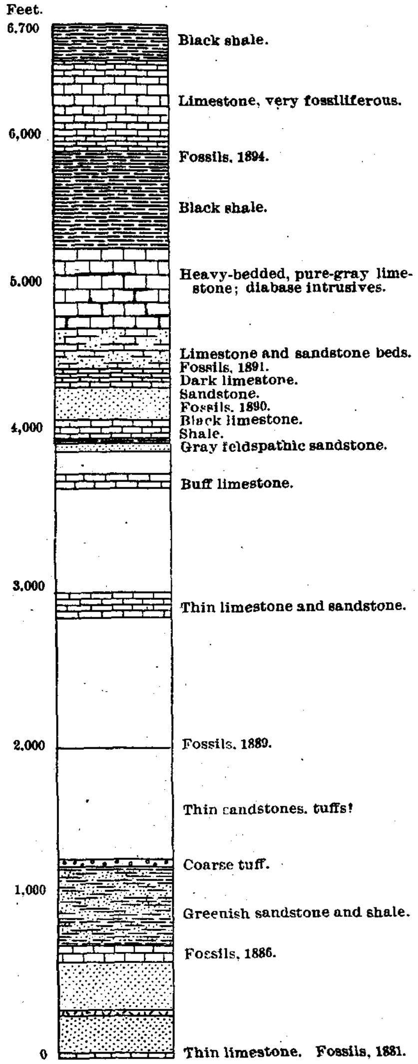
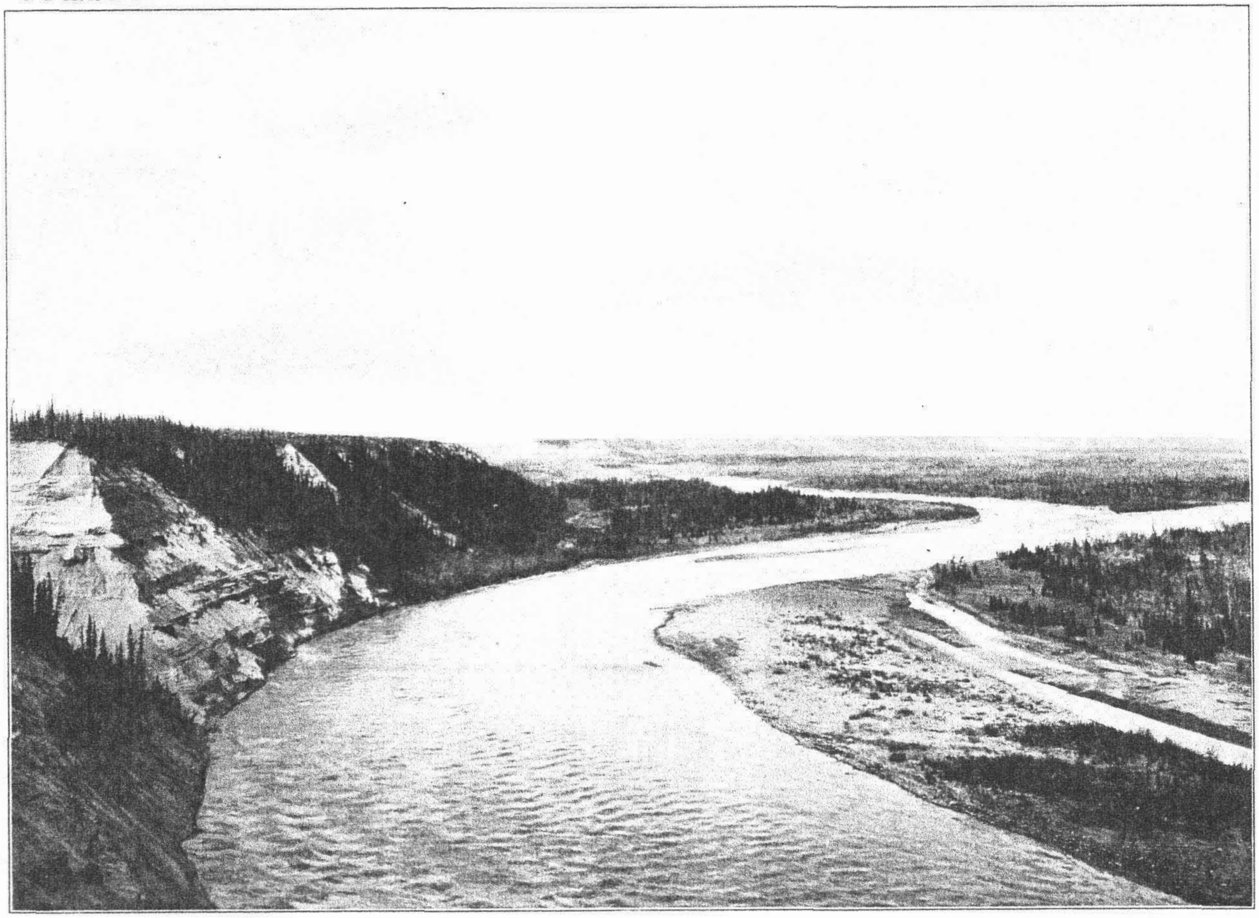
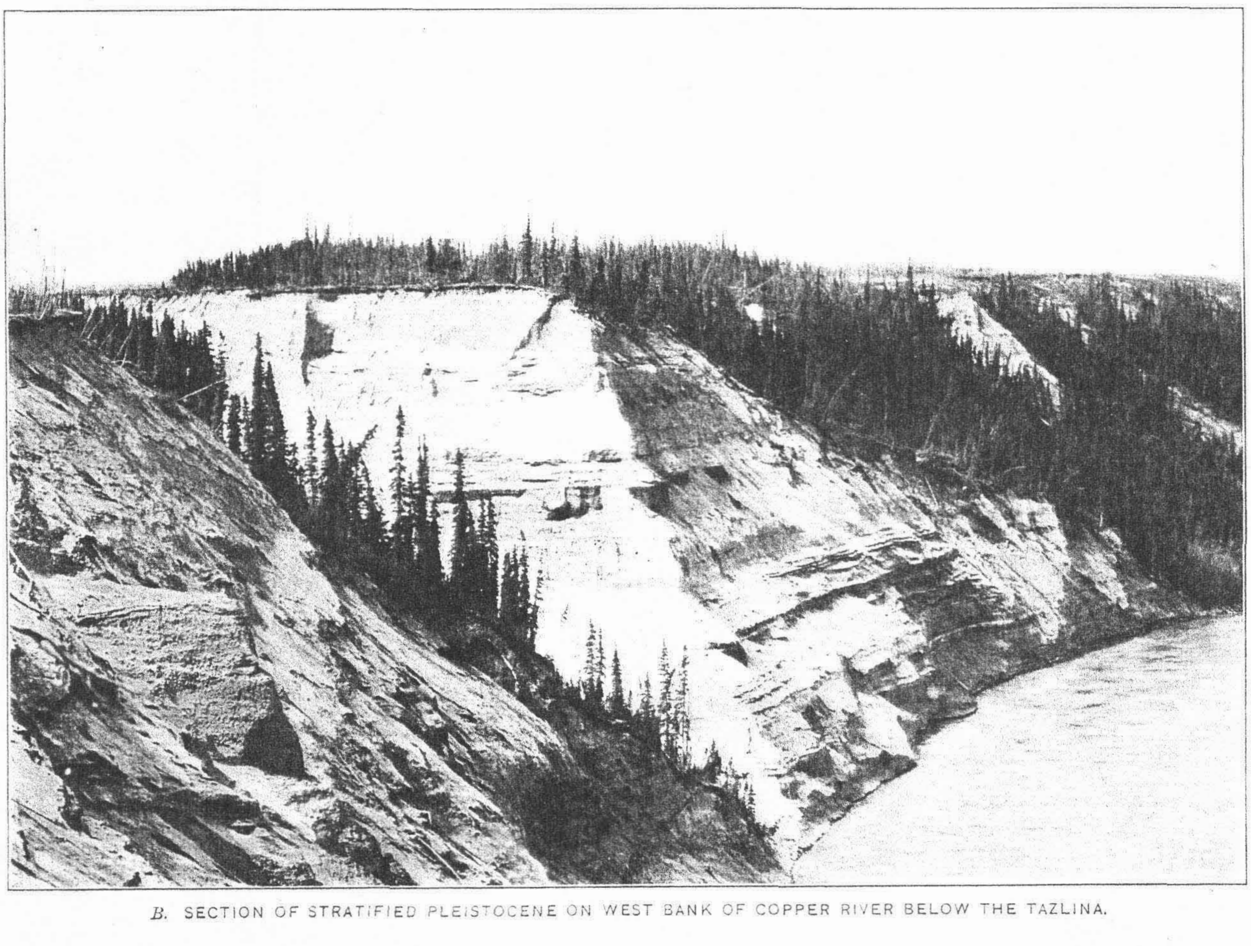


FIG. 2.—Section of Permian sediments north of Mankomen Valley.

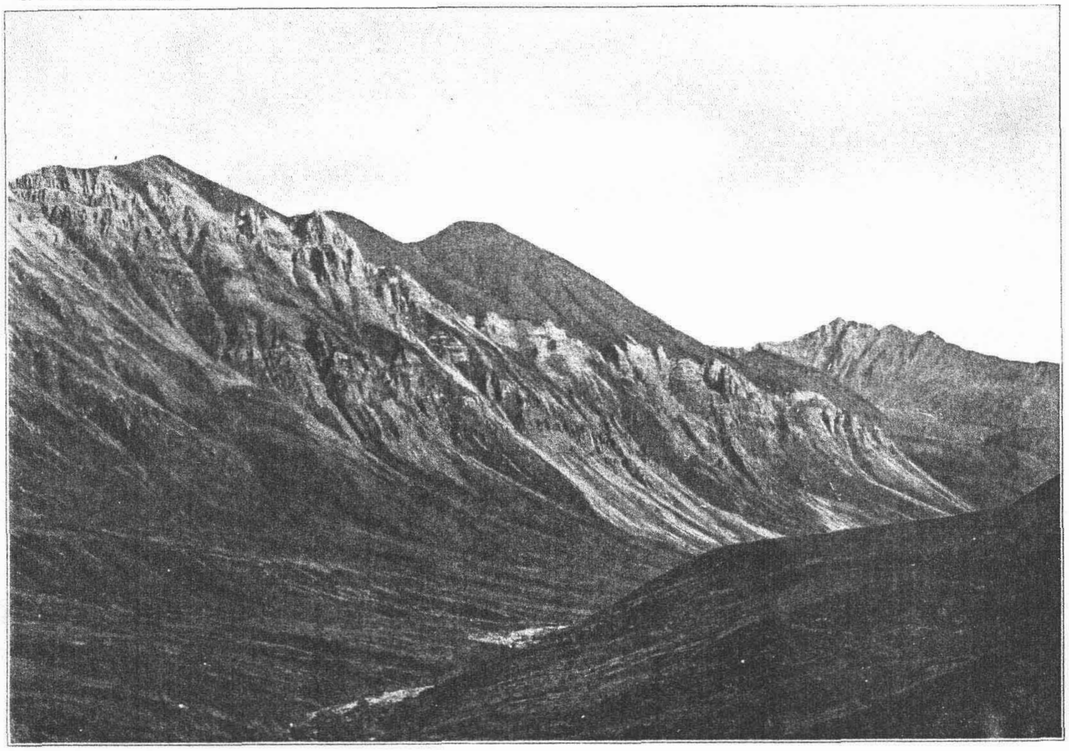
About 2,000 feet of sediments, interbedded flows, and intrusives are shown in this spur. The sediments are for the most part variegated feldspathic sandstones, often exhibiting decidedly tufaceous phases. One prominent gray limestone, 75 feet thick, which assumes a yellowish tinge when weathered, occurs about 700 feet above the bottom of the section. Throughout the upper 1,000 feet of the spur the pyroclastic beds are coarser and more numerous than below. Associated with them are one or two sheets of andesitic lava and an altered fine-grained sheet or sill which resembles some of the marginal aspects of the Ahtell diorite.



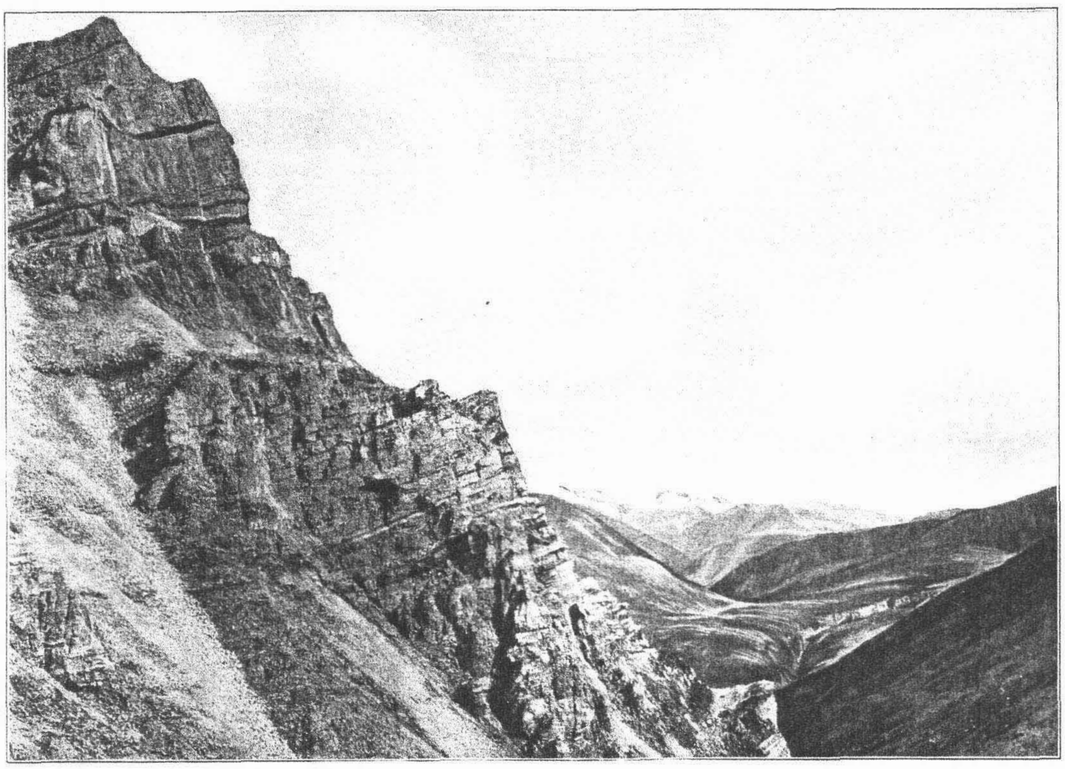
A. JUNCTION OF COPPER AND TAZLINA RIVERS.



B. SECTION OF STRATIFIED PLEISTOCENE ON WEST BANK OF COPPER RIVER BELOW THE TAZLINA.



A. GENERAL VIEW OF THE UPPER PORTION OF MANKOMEN PERMIAN BEDS ON EAGLE CREEK.



B. HEAVY WHITE PERMIAN LIMESTONE ON EAGLE CREEK.

Northward along the ridge west of the Slana, the exposures are poor for some distance and the northerly dip of 25° or 30° carries probably 2,000 or 3,000 feet of strata below the surface before the individual beds which make up the formation can be again recognized. Some thin-bedded limestones and sandstones which are fossiliferous occur in this interval, their presence being indicated by the surface fragments.

South of the gap that leads from the head of Eagle Creek to the Slana, the great bed of white limestone, whose cliffs are so prominent a feature near the southern border of the Mankomen area, is exposed, and with it several hundred feet of the subjacent strata, which include dark, thin-bedded limestones, sandy limestones, quartzites, sandstones, and some thin beds of black shale (Pl. VI, *A* and *B*.) In all, about 1,000 feet of heavy, bedded strata, with the 500-foot limestone member at the top, are exposed on this ridge.

Along the west side of Eagle Creek, above the forks, the upper part of this section, including the white limestone, is repeated, and above it are several hundred feet of black shales succeeded by about 600 feet of very fossiliferous thin limestone. Over these again are more black shales of undetermined thickness.

This section of approximately 6,500 feet falls naturally into two divisions, an upper prevailingly calcareous division, which includes somewhat more than half the total thickness, and a lower prevailingly arenaceous and tufaceous division over 2,000 feet thick.

Northwest of the main body of the Mankomen sediments a narrow belt of shales and limestones, regarded as representing the upper beds of the group, extends from the head of the Middle Fork of the Chistochina to West Fork Glacier. This belt is only about 3 miles wide, although nearly 12 miles long. A heavy limestone, believed to be the upper part of the Eagle Creek bed, is partly exposed north of the upper Chisna, but generally the sediments of this extension are shales. They are somewhat metamorphosed in the vicinity of Slate Creek, where they are regarded as the source of the gold of the Chistochina district.

Between the east and west forks of upper Indian Creek, surrounded on all sides by igneous rocks of various types belonging generally to the Tetelna volcanics, is a bed of crystalline limestone about 100 feet thick, which forms a low northward-facing scarp about the crest of the hill on which it occurs. It is generally red in color, but has a few gray bands at the top, and is made up in great part of crinoid fragments. A few fossils (lots 1863 and 1864) were collected from the top and bottom of this bed, which was regarded in the field as approximately equivalent to the basal member of the formation exposed north of the Mankomen Valley. These fossils, while too few in number to fix the position of the bed in the greater section to the north, indicate that it belongs to the same formation.

"From the Copper River basin 33 species are listed, and 9 of these are also found in upper Yukon River, and 2 on Kuiu. This shows that the two first named regions have considerable faunal relationship. On the other hand, the 6 faunulæ collected by Mendenhall (his loc. 1894, 1891, 1890, 1889, 1886, and 1881) from as many ascertained stratigraphic zones distributed through apparently more than 6,000 feet of rocks, do not indicate any evolutional series nor duplication of horizons. The meaning of these somewhat sharply differentiated faunulæ is probably best explained by noting that they are widely separated stratigraphically in a sequence of great thickness. This occurrence probably indicates that there is in the Copper River basin an extensive Permian fauna of which we have secured but a meager representation."

General faunal comparisons.—"In looking over the collection listed in the large table not submitted in this report, the first impression made is its strangeness when compared with other American late Paleozoic faunas, excepting that of northern California as yet unpublished. Nearly every species is new, certainly new for North America so far as the published record goes. The developmental aspect is clearly late Paleozoic, and yet there is not present a single diagnostic upper Carboniferous or Permian species of the Mississippi Valley. Further, we miss of the brachiopods of the last-named basin the ever-present *Rhipidomella*, *Enteletes*, *Derbya*, *Meekella*, *Seminula*, and *Hustedia*. On the other hand, this arctic fauna predominates in *Productus* and *Spirifer*. Of the former genus the species are nearly all strangers to American paleontologists, since the bilobed or deeply sinused and the abundantly spinose forms are the common ones. The *Spirifers* also are strange in that hardly any have the plications strongly bundled as in *S. cameratus*, while such little known groups as that represented by *S. arcticus* and *S. supramosquensis* (also recalling *S. neglectus* of the Lower Carboniferous) predominate.

"Ten or more species of Bryozoa are present, of *Fenestella*, *Pinnatopora*, *Goniocladia*, and *Rhombopora*. None, however, can be specifically identified and those of the genus *Rhombopora* are of a type—stout branches from $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter—unknown in the Mississippi basin. This is also true of *Goniocladia*. Pelecypoda are all small and rare (5 species), and the Gasteropoda (3 species, 4 specimens) almost absent. Not a trace of a cephalopod is present, and this is all the more strange since the Indian Permian has 14 forms of nautiloids and 7 of ammonoids. Nor is there a trace of a trilobite, while the corals are represented by one or two species of cyathophylloids.

"The work of the United States Geological Survey in California and Alaska is establishing two facts of great value in general geology, namely, that on the west coast of North America there is (1) a great thickness and grand sequence of Carboniferous and Permian strata; (2) that these have faunæ of the Pacific type and not of that of the Mississippian basin."

Table of Permian species collected by Mendenhall in the Copper River basin, Alaska.[a]

Species with a (°) also occur in northern California.	1894.	1891.	1890.	1889.	1886.	1881.	1864.	1863.
Goniocladia sp		×				×		
Orthotichia sp								×
Orthothetes sp						×		×
Chonetes cfr. uralica Moeller	×							
Chonetes cfr. granulifer Owen						×		
Productus sp. 4 (group of P. multistriatus)		(?)				×		
° Productus semireticulatus var	×	×	×		×	×		
Productus sp. 7 (group of P. semireticulatus)						×		
Productus sp. 9 (group of P. cora)						×		×
Productus sp. 11 (group of P. cora)	×							
Productus sp. 15 (group of P. undatus)	×							
Productus sp. 17	×							
Productus sp. 18 (group of P. humboldti)				×				
Productus sp. 20 (group of P. humboldti)		×						
Marginifera sp. 1	×							
° Marginifera longispinus (Sowerby)					×	×		
Camarophoria, near C. pinguis Waagen		×						
Camarophoria sp. 2	×							
Rhynchopora, near R. nikitini Tsch	×	×						
Reticularia cfr. lineata (Martin)	×							
Martinia sp. 1						×		
Martinia sp. 2				×				
Spirifer sp. 1 (group of S. striatus)	×					×	×	×
Spirifer sp. 6 (group of S. striatus)			×					
° Spirifer sp. 3 (group of S. arcticus)		×					×	
Spirifer sp. 3a (group of S. arcticus)							×	
Spirifer sp. 4 (group of S. supramosquensis)		×			×			
Spirifer sp. 5 (group of S. supramosquensis)						×		
Spirifer sp. 7 (group of S. supramosquensis)		×						
Spirifer sp. 7a (group of S. supramosquensis)	×							
Spirifer sp. 8 (group of S. alatus)	×							
Spiriferina sp. 1		×	×					
Straparollus sp. undetermined				×				
Total of species at each locality	12	9	3	3	3	11	3	4

[a] Localities of collections:
1863–1864, 100-foot limestone bed on upper Indian Creek.
1881, near base of spur, between Mankomen and Slana valleys.
1886, top of buff limestone, 700 feet above 1881.
1889, thin, dark limestone, near top of spur, between Mankomen and Slana valleys.
1890, upper part of ridge, between Eagle Creek and Slana Valley.
1891, top of ridge, between Eagle Creek and Slana Valley.
1894, base of upper limestone, west of Eagle Creek.

Schuchert's work on these and other Alaskan collections clearly establishes the interesting fact that an extensive series of Permian beds, allied not with the eastern North American Permian but with the Asiatic Indian beds, exists in western North America. He finds further that the different collections are rather sharply differentiated, and infers the existence of an extensive fauna, but meagerly represented in the collections thus far made. This inference is abundantly sustained by the field conditions observed. Near the base of the section several calcareous bands occur which carry abundant molluscan remains. For one or two thousand feet above the base the coarse sediments, often tufaceous, represent conditions unfavorable to life, and unfavorable for the preservation of fossils. Calcareous beds will no doubt be found even here, however, which will yield an additional fauna. In the upper half of the section the thin limestones and calcareous shales and sandstones are full of shells. The three collections, 1890, 1891, and 1894, represent this abundant life very meagerly indeed. There is probably not 100 feet in the entire upper 1,500 feet of the section above the top of the heavy white limestone from which fossils may not be secured, and at many horizons they are very abundant. The heavy limestone itself seems barren, but below it for at least 1,000 feet shell-bearing strata are numerous.

The disposition of the beds, and the gentle structures near the southern part of the area, will make it possible to determine very exactly the stratigraphic relations of the various collections. Much more detailed work than was possible in 1902, with more abundant collections, will be awaited with great interest. It is anticipated that material exists here for one of the most complete Permian sections on the continent.

STRUCTURE.

The largest area of the Permian beds lying east of the upper Middle Fork has the structure of a rather simple tilted block. The general strike of the beds, although abundant local folds introduce variations, is N. 60° or 70° W., parallel to the axis of the adjacent parts of the Alaska Range, to the structural valleys of the region and to the longer axes of the different rock belts. The dips are north, northeast, or northwest, are generally low near the southern margin of the block, and increase considerably toward its northern border. The recorded variations are between 5° and 55°, but these probably do not represent maxima or minima. Toward the north the formation is limited by a profound fault, which throws the upper Permian beds against the schists of the Alaska Range. The faulting has crumpled the soft Permian shales, and the confusion has been increased by the introduction of a great number of dikes in the neighborhood of the fracture, hence there is a zone along the northern edge of the formation in which structures are too complex for solution by reconnaissance work. The impression gained, however, was that the northerly dips simply increase in steepness toward the fault line. The expected synclinal repetition of beds just south of the major fault was not recognized, but minor branch faults are suspected.

The extension of the Permian area from the Middle Fork northwestward, beyond the head of the Chisna toward West Fork Glacier, is an extension of the northern confused zone adjacent to the fault, in which only the upper members of the Permian are represented. The tufaceous and sandy layers of the lower part of the section do not appear, the lowest member in the Chisna area being a heavy white limestone, probably the bed which is so prominent on Eagle Creek. The Chisna belt of Permian is therefore limited on the south as well as on the north by a fault which cuts off 4,000 feet or more of the basal beds.

This fault is expressed topographically in the east-west lateral valley of the upper Chisna and Slate Creek, and its westward continuation is inferred in a low gap which crosses the ridge between Chistochina Glacier and West Fork Glacier and separates black shales and slates to the north from Chisna beds and intrusives to the south. Within this narrow band of Permian, with faults north and south of it, structures are complex and the crushing has induced a certain amount of metamorphism, so that the shales have become slaty and carry narrow stringers of quartz. This metamorphosed area is regarded as the source of the Chistochina gold.

In the extreme southeastern part of the central Copper River region (Pl. IV) a heavy-bedded white limestone forms prominent outcrops on Elliott Creek, Copper Creek, and just north of the Kotsina, in the valleys of Clear Creek and Kluvesna Creek. This massive stratum is about 200 feet thick on Elliott Creek, where its upper beds appear to have been removed by the erosion immediately preceding the deposition of the Kennicott conglomerate. It is somewhat thicker on Clear Creek and Kluvesna Creek, where it is overlain by interbedded limestones and shales of Triassic age. Eastward beyond the area examined by the writer it has a wide distribution north of the Chitina, where it has been studied by Rohn and by Schrader and Spencer, who have called it the Chitistone limestone. Correlating it with a fossiliferous bed on Kletsan Creek just north of Skolai Pass, from which Brooks made collections in 1899, these authors regard it as of Carboniferous age, but on the basis of the more complete collections made in 1902, Schuchert now assigns the Kletsan Creek limestone to the Permian. Since Schrader and Spencer's studies of this formation have been much more extensive than the writer's, he accepts their determination, and the bed is accordingly mapped as Permian, although there are some reasons, set forth under the heading "Correlation," for believing that it may be younger. If it is really of Permian age, it is probably the equivalent of the heavy limestone near the top of the section exposed north of the Mankomen Valley. Lithologically the two limestones are much alike, the doubt as to their equivalence arising principally from the fact that Permian fossils have been found just above the Mankomen bed, while the only collections made from the shales overlying the true Chitistone are Triassic.

INTRUSIVES.

It has been stated that in the neighborhood of the great fault, at the head of the Chistochina, intrusives are abundant in the Permian. These are usually diabase dikes or sills, the latter more common in the heavierb-edded limestone members of the series. In the lower beds, outcropping along the spur between the Mankomen Valley and Slana River, are some andesitic sheets and one igneous body, probably a sill, which very closely resembles a form of the Ahtell diorites found in apophyses about the periphery of the main body.

Along the line of the great fault, near the pass between the Slana and the Middle Fork of the Chistochina, is a body of diorite, quite unlike that found elsewhere in the Copper Valley. The rock is a pepper-and-salt aggregate, consisting essentially of granular feldspar and green hornblende, with accessory biotite, magnetite, and axinite. The principal feldspar seems to be in the andesine and oligoclase series, while a subordinate amount of orthoclase is present.

A porphyritic rock of the diorite family forms a prominent dike in upper Miller Gulch, where it is called "bird's-eye porphyry." It has a compact green groundmass rich in hornblende, and white tabular feldspar phenocrysts which are much altered and not determinable.

CORRELATION AND PHYSICAL CONDITIONS.

In his report upon the fauna collected from the Mankomen beds, Schuchert has indicated their general correspondence with the following other Alaskan localities (fig. 3):

Kuiu Island, Alexander Archipelago.
Kletsan Creek, White River basin.
Yukon River, near mouth of Tahkandit River.
Jack Creek, Nabesna River basin.

In each of these regions, except the first, the fossils are found associated with a heavy limestone, and a series of dark shale or slate beds, indicating similar marine conditions throughout a large area in east-central Alaska. The Kuiu Island material is from a marine sandstone, in which the shells are abundant, but as the lower part of the Chistochina section carries similar beds, and the other localities may prove upon further investigation to be represented in their lower divisions by arenaceous strata, we can not infer peculiar conditions for the Kuiu Island terrane.

The Chitistone limestone, which is so important a horizon in the Chitina basin, has been correlated with the limestone in Kletsan Creek, just north of Skolai Pass, and as this limestone is now assigned to the Permian by Schuchert, the Chitistone bed is to be regarded as of the same age, and in accordance with this conclusion it is shown in the Permian color on the geologic map (Pl. IV) accompanying this report. Its age, however, can not be regarded as finally settled. It is the basal bed of a series consisting of a heavy limestone, overlain by thin-bedded limestones and shales, which in turn are succeeded by black shales free from limestones. In these latter beds fossils of Triassic age have been found by Hayes, by Rohn, and by Schrader and Spencer, and the series

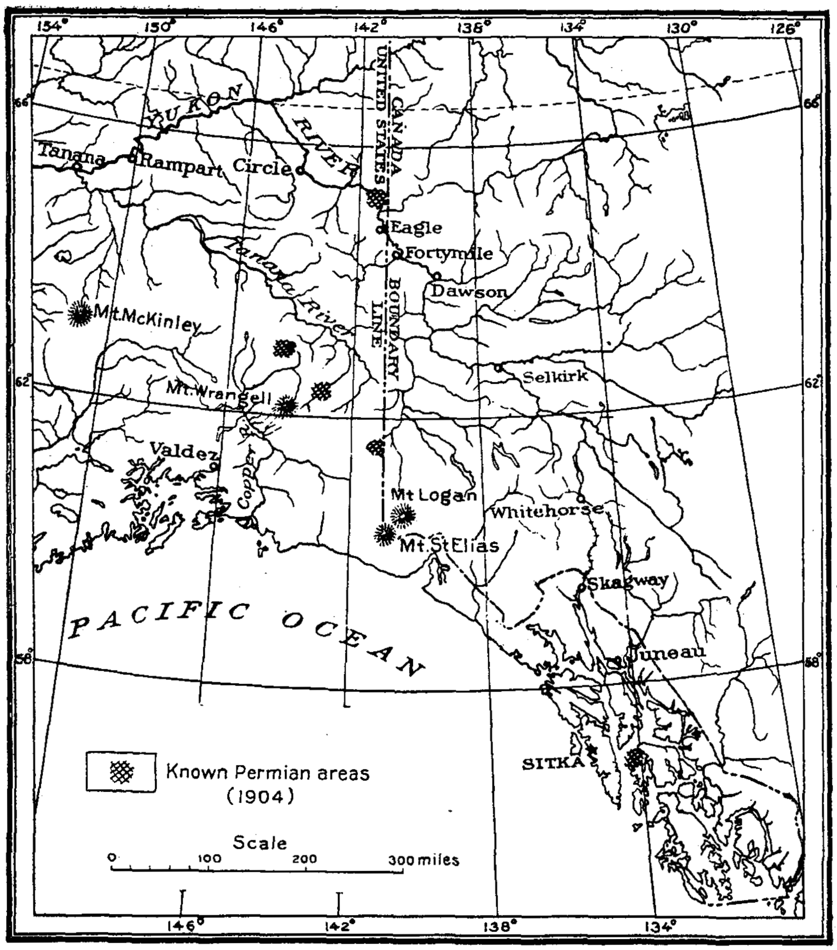


FIG. 3.—Known Permian areas in Alaska.

from the basal limestone to the fossil-bearing shales seems to represent continuous sedimentation. Fossils have not been secured from the limestone itself south of Skolai Pass. Just north of the pass, however, the unquestioned Permian limestone is abundantly fossiliferous, as it is in the Nabesna, the Chistochina, and the Yukon regions. Schrader reports that among the Mesozoic strata of the Nutzotin Mountains, which apparently unconformably overlie the

Nabesna Permian and Carboniferous, are Triassic beds, consisting of black shales and dark limestones closely resembling the thin-bedded dark limestones that are above the Chitistone limestones in the Chitina Valley. A thickening of the basal members of this series from the Nutzotin Mountains southward might readily produce a limestone having the characteristics of the Chitistone bed. That conditions existed for such a thickening of the Chitistone deposit when it was laid down is proved by an increase from 200 or 300 feet on Elliott Creek to about 2,000 feet, the thickness reported by Schrader and Spencer, on the Nizina. It is not conceived, of course, that this change represents a corresponding increase in the amount of material deposited toward the southeast, the direction of thickening, but merely that the proportion of the calcareous element in the beds in the lower part of the section increased in this direction. As the Chitistone thins markedly westward and northward from the region in the Nizina Valley where it has its present known maximum development, it is entirely reasonable to suppose that much farther to the north, in the Nutzotin Mountains, there may be no heavy bed at its horizon. That is, under the conditions which have been pointed out, the absence of a heavy limestone in the Nutzotin Triassic is not good ground for assigning the Chitistone limestone, which is conformably overlain by Triassic beds, to an older period. The correlation, on the ground of lithologic similarity, of the heavy limestone south of Skolai Pass with the heavy limestone north, although complex structures intervene, is of course natural, but the logic of this position is much weakened when it is remembered that everywhere, except in the Chitina Valley, the Permian has proved highly fossiliferous, and that north of the range at least two heavy limestones exist, one of Permian, the other of Carboniferous, age, either of which might equally well be correlated with the Chitistone on lithologic grounds alone. Further, the assumption that the Chitistone is Permian requires the condition of continuous sedimentation from the Permian to the Triassic, as in the Chitina Valley, a condition which is not found north of the Wrangell Mountains, where rocks of the later period appear to be unconformably deposited upon those of the earlier.

Considerations of another sort, which involve the age of the Nikolai greenstone, throw further doubt upon the propriety of assigning the Chitistone to the Permian. The proved Permian beds in the Chistochina basin and, according to Schrader's personal report to the writer, on Jack Creek in the Nabesna basin, are cut by an abundance of diabase and basaltic intrusives. In some areas the intrusives occupy a greater volume than their host. The same condition is exhibited by the fossiliferous limestone on the Nabesna, which is regarded with less certainty as Permian, and by the beds on Skolai Creek from which collections of fossils have been made. The Chitistone limestone, however, and the overlying Triassic beds, are nearly free from diabasic intrusives, although cut by porphyries of a dioritic nature, and the Triassic of the Nutzotin Mountains, so far as known, is likewise free from basic dikes, except at a doubtful locality in Cooper Pass, where it overlies the Permian.

The succession of events which this evidence suggests is as follows: After the deposition and consolidation of the Permian, an epoch of igneous activity with accompanying folding and perhaps faulting began. During this epoch the Permian was intruded extensively by basic dikes, whose effusive products are represented in the great basaltic lavas of the Nikolai greenstone. Following this revolution came a quiescent period in which the Triassic marine beds were deposited, generally as shales or as alternating thin shales and limestones, but with a heavy basal limestone member, which reached its greatest development in the southeastern part of the present known Triassic area, i. e., in the drainage basin of Nizina River.

It is fully recognized that the distribution of igneous masses, whether effusives or intrusives, in the geologic column does not furnish a safe basis for taxonomic conclusions, but, where stronger evidence does not conflict, that hypothesis which permits the correlation of a network of basic dikes with a great accumulation of magmatically similar effusives in an adjacent area, deserves to be given somewhat greater weight than the alternate hypothesis which assigns these two similar igneous masses to different periods.

If this interpretation of events is correct, the Chitistone limestone is Triassic and the Nikolai greenstone is early Triassic or late Permian. The arguments for and against the Permian age of the Chitistone may be tabulated thus:

For Permian age:

1. The Chitistone is geographically very near and lithologically very similar to the Permian north of Skolai Pass.
2. It lies beneath known Triassic.
3. There is no similar heavy limestone in the known Triassic.

Against Permian age:

1. The Chitistone heavy limestone and the thinner beds above it are nonfossiliferous, while the Permian in other localities is very fossiliferous.
2. The Chitistone seems to lie conformably below known Triassic, while the known Permian lies unconformably below Triassic when the relations are shown.
3. The Chitistone is free or nearly free from basic intrusives and overlies basic effusives, while the known Permian, near by, is extensively intruded by basic masses.

The greater weight is probably to be given to the evidence for the Permian age and in support of the conclusions reached by Schrader and Spencer in 1900. The geologic map has been prepared upon this basis, but it is believed that sufficient doubt exists to justify the rather full discussion which precedes.

TRIASSIC SHALES AND LIMESTONES.

Overlying the Chitistone limestone in the basin of Kotsina River and eastward is a succession of interbedded black shales and thin-bedded dark limestones, which Schrader and Spencer report to be about 1,000 feet thick. Above these is a greater thickness of black shales, from which fossils of Triassic age have been collected. The entire series from the base of the Chitistone to the top of the black shales seems to be conformable, although intricate crumpling in the softer upper beds makes this point one which it is difficult to determine absolutely.

These beds have a limited distribution in the area visited in 1902, being confined to a small district in the basin of the Kotsina and its tributaries, where they usually form the hilltops or the higher slopes.

KENNICOTT FORMATION.

Capping the ridge which separates Elliott Creek from Copper Creek is a series of massive conglomerates with interbedded shales, the total aggregate thickness here being about 1,600 feet. The pebbles of the conglomerate are of various types, but there is a preponderance of limestone, greenstone, and shale, the immediately underlying rocks. They are usually an inch or less in diameter, but occasionally exceed 6 inches and evidently record a period of rapid erosion and deposition. The structures in these upper beds do not accord with those in the limestone and greenstone below, the latter being thrown into open folds with dips of 50° or 60° in various directions, while the conglomerates have a gentle inclination of 10° or 20° to the north.

Similar beds appear north of Kotsina River. A single outlier was recognized north of the Cheshnina, and small areas, usually of finer sediments but bearing similar relations to the underlying beds, are reported farther east by Schrader and Spencer and by Rohn. Collections of fossils made by the former authors place the beds in the doubtful series lying at the base of the Cretaceous or the top of the Jurassic.

GAKONA FORMATION.

OCCURRENCE AND CHARACTER IN TYPE LOCALITY.

Between Gakona Glacier and upper West Fork of Chistochina River is a fresh-water sedimentary series, whose outcrop covers 20 or 25 square miles. What appears to be the basal member is a heavy bed of coarse conglomerate, not less than 500 feet thick, which is well exposed along the east side of Gakona Glacier about 5 miles above its foot. A bed which apparently belongs to the same formation forms the base of the spur between the east and west branches of the glacier.

This conglomerate, where examined east of the glacier, caps a high ridge whose base is made up of igneous rocks. It dips eastward and is believed to pass beneath the soft, fissile or massive, gray or buff-colored shales which, with interbedded gravel, sand, and lignite beds, make up the greater part of the terrane that extends through to the head of the West Fork.

The degree of consolidation of these beds shows considerable variation. The basal conglomerate is thoroughly indurated. The shales on the upper Gakona, nearest the base of the series, are likewise compact and fissile. The higher beds near West Fork are slightly indurated clays or sands, and the highest recognized member, an iron-stained pebble bed, is not sufficiently well consolidated to be termed a conglomerate—it is rather a cemented gravel. These soft upper beds, which appear in that part of the section farthest from the mountains, make definite outcrops only under the most favorable conditions. Usually they are buried under the general mantle of glacial gravel, so that their extent is problematical.

It is estimated that there can not be less than 2,000 feet of these beds, and it is probable that their total thickness is much greater than this.

Vegetable remains are abundant in the Gakona beds, but well-preserved fossils are rare. Single tree trunks, now altered to lignite, are scattered through the upper horizons, and an occasional leaf is found in the indurated clays. Lower down a small collection of plants was made from a calcareous bed in which they were well preserved. These were submitted to Dr. F. H. Knowlton, who reports as follows on them:

"This collection consists of eighteen pieces of matrix on which I find the following species of fossil plants preserved:

Sequoia sp. A broken fragment of a cone.
Taxodium tinajorum Heer. Several fine branchlets.
Taxodium distichum miocenum (Brgt.) Heer. A large number of finely preserved branchlets.
Corylus MacQuarrii (Forbes) Heer. The most abundant dicotyledon in the collection.
Juglans nigella Heer. Represented by portions of two leaflets.
Tilia alaskana? Heer. A single fragment that appears to be of this species.

These plants are all abundantly typical of the so-called Arctic Miocene, now believed to belong to the upper Eocene."

The conglomerate which appears to be at the base of this Eocene section may be older than the horizon from which the collection was made, but, until further evidence is gathered, it is assigned to the same period.

OCCURRENCE AND CHARACTER IN OTHER LOCALITIES.

In the channel of Slate Creek, the mining operations have revealed a bed of lignite which has been used locally as fuel. Associated with it are sandstones and shales, carrying dicotyledonous plants, too badly preserved, however, for collection. In the canyon of a small northern tributary of the upper Chisna, called by the prospectors Coal Creek, two or three hundred feet of similar sediments with thin beds of lignite appear unconformably upon the Permian black shales. They likewise carry plant remains, and are referred with much confidence to the Kenai.

Along the middle Cheshnina Valley, about the upper end of the canyon of that stream, soft feldspathic sandstones are found, which strike N. 50° W. and dip 25° downstream. Prospectors reported to the writer the presence of lignite in this valley. There is little doubt that a folded Tertiary series has been buried here beneath the Wrangell andesites and is now partly revealed by modern stream cutting.

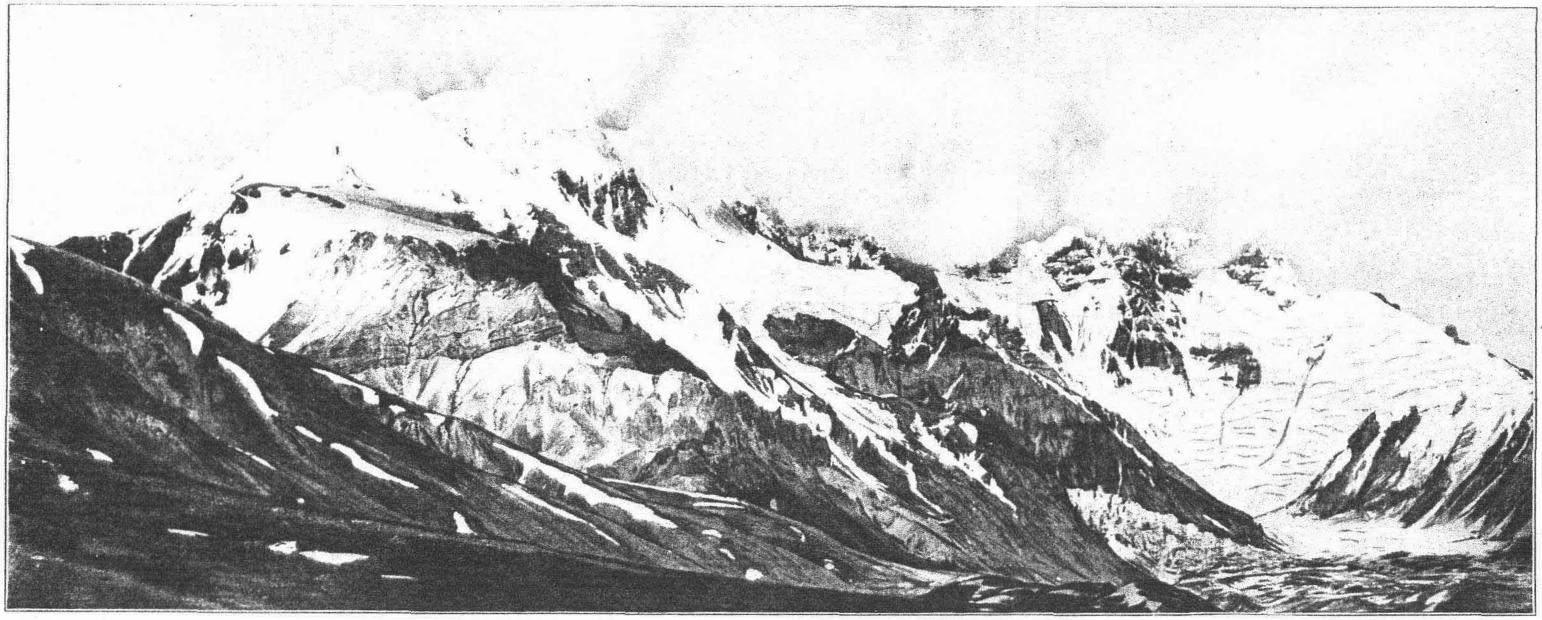
On the Chetaslina, about 2 miles below the mouth of the Chichokna, there are isolated outcrops on either bank of the river of a greenish conglomerate carrying rounded pebbles of quartz and of greenstone embedded in a feldspathic sandstone matrix. The beds are not folded and are assigned very doubtfully to the Kenai. The conglomerates are similar to those so abundant everywhere in this formation, which is widely distributed in Alaska, but beds which are not unlike them are found in the Kennicott (Jura-Cretaceous) and among the tuffs of the recent lavas. In the absence of fossil evidence, the correlation is to be regarded as suggestive rather than final.

About 2 miles southeast of Snider Peak, high up on a spur between two branches of an important tributary of the Dadina, there is an exposure of 100 to 200 feet of soft sediments, including muddy sandstones and thin, buff-colored shales, with lenticular concretions of black limestone. No fossils were found, and the sediments are surrounded on all sides by recent andesites. A bed of similar shales appears on the south slope of the ridge separating Chetaslina River from its east fork. It is not possible now to prove the age of these beds. They may even represent unusually well-assorted water-laid phases of the tuffs associated with the Wrangell lavas, but it is perhaps somewhat more probable that they represent outcrops of an older sedimentary series, accidentally revealed by erosion. This is the more likely since both exposures are along the line of the ridge of earlier rocks which the Wrangell lavas have buried, and which modern erosion has partly uncovered.

WRANGELL LAVAS.

OCCURRENCE.

Much the most extensive single hard-rock formation of the central Copper River region is the series of lavas, the products of recent volcanism, to whose accumulation the entire western portion of the Wrangell group of mountains owes its origin (Pl. IV). Mount Wrangell, Mount Drum, and Mount Sanford,



VIEW OF THE AMPHITHEATER OF MOUNT DRUM.

appear to be a succession of lavas, with little or no interbedded fragmental material. These hard beds are especially well displayed in the narrow eastern horn of the crescentic summit.

Tuffs and flows alike have a slight western and northern dip, as though the center from which they issued lay south and east of the present mountain. The same bedded character which is so prominent in Mount Drum may be seen even from a distance in the upper part of Mount Sanford, and is displayed about the lower slopes of Mount Wrangell, along the headwaters of the Chetaslina, where erosion has cut sections in the flows. Reds, yellows, browns, and grays in many shades are displayed by both the tuffs and the more massive flows.

Columnar structure is frequently developed. Good examples are to be seen in Ruddy Mountain just west of Klawasi Glacier, in the gorge of Chetaslina River, and at the northern end of the nunatak in Chetaslina Glacier. Very frequently in cooling a thin-sheeted structure has developed in the lava, so that it breaks down into flags like paving stones. An excellent example of this habit was observed just east of Dadina River, and others occur at the head of the Chetaslina, where a peripheral columnar structure may also be seen. It is conceived that this latter habit is due to the outflow of a lava stream under the ice cap, so that it was suddenly cooled on all sides except the bottom, producing the radiating columns which make up the shell of the small flow in which it was observed.

PERIOD OF ERUPTION.

The volcanic activity which has produced the Wrangell lavas is all of very recent date, geologically speaking. The latest flow is not historical, but authentic history extends back only a few years in the Copper Valley. Grewingk states that the Chechitno (Chitina) volcano, now called Mount Wrangell, smoked in 1760 for the first time in history, and that an eruption took place from it in July, 1784, but the unreliability of these early accounts is proved by the fact that in 1839 Mount St. Elias, which is not volcanic, was reported in eruption. Apart from these questionable reports, the inference from the intermittent mild activity of the mountain at present is, of course, that the last flows are very late. The freshness of the volcanic products and the very slight modification by glaciation of the latest flows now visible bear out this supposition.

Although it has no historical bearing, the outlines of the mountain testify to the geologic recency. Except about the base, where glacial erosion has modified it slightly, the peak preserves the form of a constructional cone of rather fluid lava.

The other high peaks of the group have been greatly modified by erosion and are therefore older than Wrangell. If they were all equally favorably situated wherever it was possible to examine the rocks of which they are composed, and much the greater part of the deeply dissected foothill belt which surrounds them, exhibit practically nothing but a waste of these lavas and their associated tuffs.

From Long Glacier northwestward, nearly to the base of Mount Drum, the flows partly cover a pre-Wrangell ridge of old rocks, whose disconnected outcrops now appear in the deeply cut modern stream gorges, but from Nadina River northward and eastward to the source of the Copper, no older rocks appear from beneath the lavas to give variety to the geology. In this direction the effusive material has been poured out into a lowland, whose level modern erosion has not reached.

In addition to the great eruptive centers, whose positions are now marked by some at least of the higher peaks, many local centers of relatively little importance have no doubt existed about the borders of the mountains. The effusive mass south of the lower Cheshnina, that between the forks of the Chetaslina, the Capital Mountain mass north of Mount Sanford, and the lava mound southeast of the Chistochina may be due to independent eruptions.

Toward the east the recent effusives apparently extend along the crest of the range to some point between the head of Rohn Glacier and Skolai Pass, because where Rohn crossed the summit he describes porphyritic lavas, like those of which the formation farther west consists, while Hayes mentions only sediments with their intrusives in Skolai Pass. In short, the western end of the group is made up almost wholly of the Wrangell lavas, which form the foothills as well as the high peaks in this part of the field, while eastward the foothills are made up more and more of older rocks, and the lavas are confined to a constantly narrowing belt along the axis of the range, from which they seem to disappear before Skolai Pass is reached. Beyond the pass the distribution of the white volcanic ash leads Brooks to suppose that there may be another local volcanic center.

GENERAL ASPECT.

The extensive erosion at the sources of Nadina and Sanford glaciers has cut deeply into Mounts Drum and Sanford and has revealed the succession of beds by which these mountains are built up. (Pl. VII.) The lower part of the section thus revealed in Mount Drum it is possible to examine in detail, but the Sanford section is probably not accessible because of the avalanches and the rough ice at its base.

The succession in Mount Drum, as roughly estimated from below, is a basal series of varicolored tuffs approximately 1,000 feet thick, above which are 300 or 400 feet of massive flows, succeeded in turn by another series of variegated tuffs from 1,000 to 2,000 feet thick. The upper 4,000 or 5,000 feet of the mountain more or less subordinate amount of the dark minerals, basaltic hornblende, hypersthene, augite, biotite, or olivine. Not rarely two or three of the bisilicates occur together in the same specimen. From such a usual type of hypersthene or hornblende-andesites more basic and more acidic variations occur, ranging from basalts to dacites. A few of the types will be briefly described.

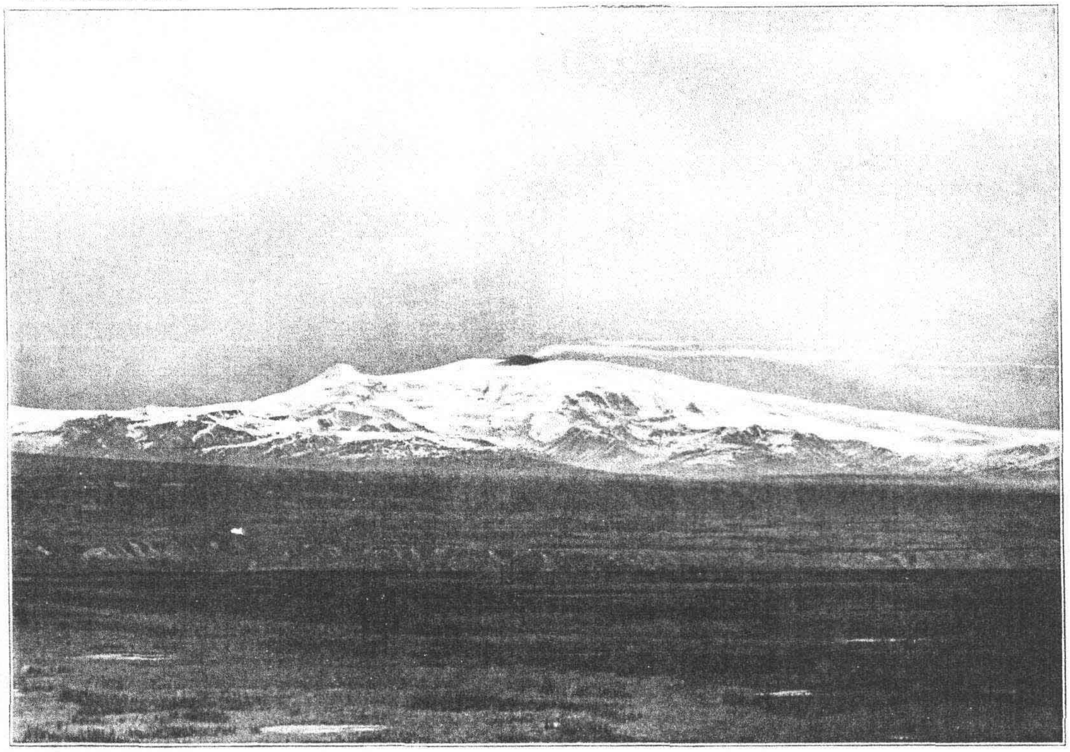
The walls of the canyon of the Chetaslina, which begins about 5 miles below the mouth of Chichokna Creek, are made up of a series of cliffs of a dark, fresh hypersthene-andesite, exhibiting beautiful columnar structure.

The rock has a pronounced hackly fracture and exhibits numerous clear tabular-twinned feldspar phenocrysts, not exceeding 3 mm. in diameter, in a dull black groundmass in which small amounts of an amber-colored mineral may also be detected megascopically.

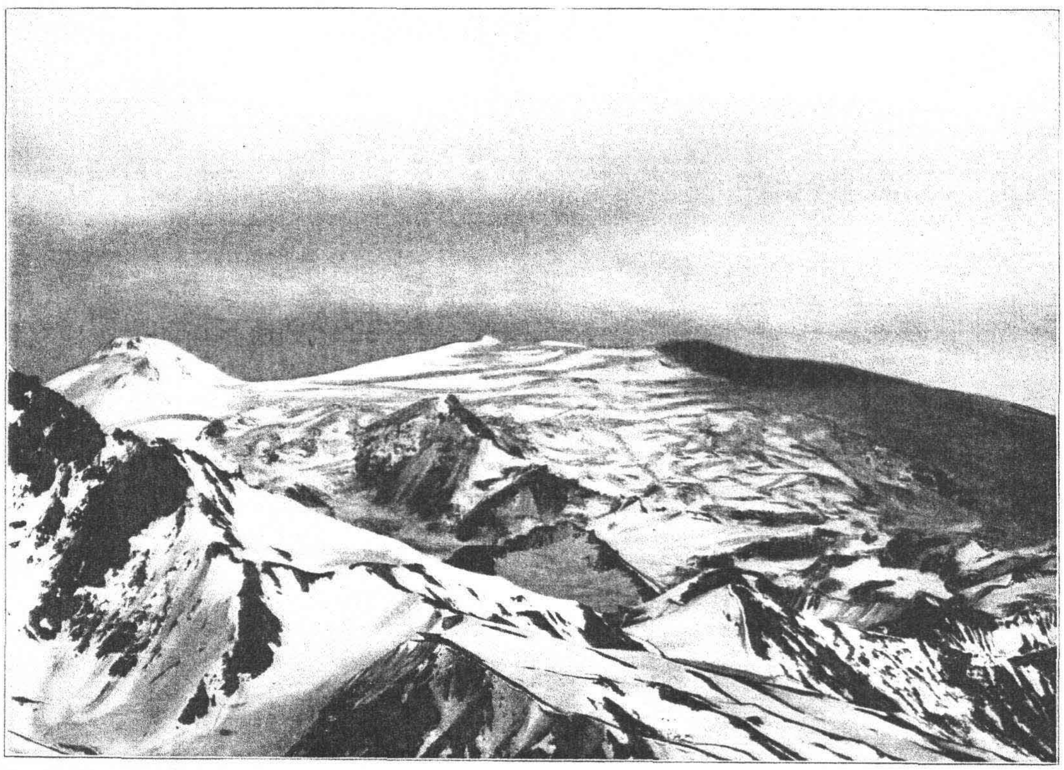
Under the microscope the plagioclase phenocrysts prove to belong to the labrador-andesine series, with composition from Ab_2An_3 to Ab_3An_2. They are usually tabular, through the development of the brachypinacoid, and frequently contain abundant inclusions of glass and unresolvable crystalline material. These inclusions, although decidedly irregular, frequently have their greatest dimension in the direction of the twinning plane. They give to the phenocrysts a graphic effect.

In addition to the plagioclase, a few short thick prisms of hypersthene, with its characteristic pleochroism, cleavage, and extinction, and an occasional crystal of magnetite, are present. The groundmass, which considerably exceeds in amount the combined mass of the phenocrysts, is not a glass but a dark-greenish submicroscopic aggregate of incipient crystals too small for determination but probably representing both the feldspars and the bisilicates. This greenish aggregate is filled with tiny cubes of magnetite, which give the general black color to the rock.

On the southern slope of Mount Wrangell, near the head of Cheshnina Glacier, at an elevation of between 7,500 and 8,000 feet above tide, is a vesicular augite-bearing hypersthene-andesite, which is presumably a recent flow. In the hand specimen the rock is seen to be very porous, with abundant square and lath-shaped feldspar sections of all sizes up to 5 mm. in diameter, imbedded in a jet-black glassy base. Under the microscope the larger plagioclase phenocrysts prove to be basic labradorite, Ab_3An_4 usually. One test gave the more acidic variety, and the presence of one or two zoned sections indicates some range in species. From the largest phenocrysts there is a gradation in size to laths too small for determination. The hypersthene is very subordinate to the feldspar in amount, and occurs usually in grains and imperfect crystals. Only one or two fragments of augite were observed. The groundmass is an opaque brown glass,



A. GENERAL VIEW OF MOUNT WRANGELL FROM STÜCK MOUNTAIN.



B. SUMMIT OF MOUNT WRANGELL AFTER AN ASH SHOWER.

containing an abundance of minute crystals. A specimen of this lava was submitted to Dr. W. F. Hillebrand, of the Survey laboratory, for complete analysis, with the following result:

Analysis of lava from Mount Wrangell, Alaska.

SiO_2	61.31
Al_2O_3	16.70
Fe_2O_3	1.30
FeO	4.08
MgO	3.44
CaO	6.10
Na_2O	4.05
K_2O	1.58
H_2O	.22
H_2O+	.36
TiO_2	.73
ZrO_2	.01
CO_2	None.
SO_3, Cl, F	Not looked for.
S	None.
Cr_2O_3	
NiO_2	.02
MnO	.14
BaO	.05
SrO	.02
Li_2O	Faint trace.
Total	100.29

Calculating from these values the corresponding norm[a] we have:

	Per cent.
Quartz	12.78
Orthoclase	9.45
Albite	34.06
Anorthite	22.80
Diopside	5.66
Hypersthene	11.39
Magnetite	1.86
Ilmenite	1.37

From this norm and the analysis, the rock is determined to belong to the subrang tonalose, of the order austrare, a subrang which includes tonalites, andesites, latites, and dacites of the current system of classification.

[a] Quantitative classification of igneous rocks, by Cross, Iddings, Pirrson, and Washington, p. 188 et seq.

This rock is particularly interesting, because its composition is near that of the average igneous rock, as determined by Clarke and Harker.[a] Rocks which are very similar to this Wrangell lava were collected from outcrops or from glacial drift derived from each of the peaks, Wrangell, Drum, and Sanford, so that the type is abundant everywhere.

From Nadina River Glacier, flowing out of the heart of Mount Drum, an abundantly but not coarsely porphyritic lava was collected, which is gray in color, with prominent white feldspar phenocrysts and less numerous brown biotite and glossy black amphibole crystals in a gray groundmass. The short, thick feldspar prisms seldom exceed 5 mm. in cross section, while the much less abundant biotite plates are occasionally 1 cm. in diameter. The amphibole needles are smaller, being usually only about 1 mm. in length.

Under the microscope the broad prisms of plagioclase, usually twinned and frequently zoned, varying in size up to about 5 mm., are seen to make up 40 or 50 per cent of the rock mass. Tested optically, the majority of them prove to be labradorite, but the zoned species give the extinctions for andesine in their more acid bands.

The most abundant mineral, except the plagioclase, is a greenish-brown hornblende, with a low extinction angle, which occurs in large and small phenocrysts. A red-brown biotite is less abundant, and there are numbers of small phenocrysts of hypersthene. Magnetite, apatite, and zircon are accessories.

The base is a gray glass, which, under a high power, exhibits abundant microlitic forms. There is practically a complete gradation in size between the phenocrysts and the minute crystals of this groundmass.

An analysis of this rock by Dr. W. F. Hillebrand gave the following results:

Analysis of lava from Mount Wrangell, Alaska.

SiO_2	62.67
Al_2O_3	16.62
Fe_2O_3	3.25
FeO	1.17
MgO	3.08
CaO	5.56
Na_2O	4.24
K_2O	1.67
H_2O	.23
H_2O+	1.01
TiO_2	.48
ZrO_2	.01

[a] Washington, H. S., Chemical analysis of igneous rocks: Prof. Paper U. S. Geol. Survey No. 14, p. 78. Clarke, F. W., Bull. U. S. Geol. Survey No. 78, 1891, p. 34; Bull. U. S. Geol. Survey No. 168, 1900, pp. 14-15. Harker, A., Geol. Mag., vol. 36, 1899, p. 220.

CO_2	None.
P_2O_5	.15
SO_3	
Cl, F	Not looked for.
S	None.
Cr_2O_3	
NiO	.01
MnO	.11
BaO	.06
SrO	.03
Li_2O	Faint trace.

The corresponding norm contains:

Quartz	16.56
Orthoclase	10.01
Albite	35.63
Anorthite	21.41
Diopside	4.47
Hypersthene	5.60
Magnetite	2.78
Hematite	1.38
Ilmenite	.91
Apatite	.31

This norm is markedly higher in quartz and magnetite and lower in hypersthene than that of the Mount Wrangell lava, but the difference is probably partly due to the unfresh condition, to which the high water content bears testimony. The ferrous iron has been in part altered to hematite, and appears as this mineral instead of as hypersthene in the norm, thereby leaving a larger proportion of the quartz free, and making the apparent difference in quartz content greater than the actual.

But despite the slight alteration the rocks fall in the same subrang, both being tonaloses. The difference in norm does not affect the classification until the subgrad is reached, the Mount Drum lava being just within the limits of the alkalimirlic subgrad of the prepolic grad of the tonaloses, while the Wrangell specimen belongs in the premirlic subgrad of the same grad.

The close relationship indicated by the analysis and by the norm could scarcely be suspected from the hand specimen, the mode in the two cases being very different.

Among the lavas discharged by Sanford Glacier, which are usually andesites of one of the types described, is a porphyritic basalt. In the hand specimen the prominent white, single, or grouped tabular feldspars, as much as 15 mm. across, are embedded in a vesicular, brownish-red base, in which a clear greenish mineral is also conspicuous. The microscopic tests prove the feldspars to be basic. Those examined gave the extinctions of bytownite and basic labradorite on the positive and negative bisectrices. They are twinned and occasionally zoned. Some of the phenocrysts consist of bundles of thin tabular feldspars in a radial arrangement. Abundant, but less so than the feldspars, are phenocrysts of olivine, which with augite also exists in granular form. The rock contains also about 50 per cent of opaque glassy base in which the phenocrysts, an abundance of divergent feldspar microliths, and the grains of olivine and augite are embedded. This rock is the most basic found among the lavas, among which true basalts are rare, although the basic phases of the andesite approach the basalts in character.

West of Dadina River, 4 or 5 miles below the foot of the glacier, is a hill made up of a much lighter-colored and more acidic-looking rock than those which surround it. It is very light gray and fine grained, with a few inconspicuous feldspar phenocrysts and a number of biotite flakes, the latter being the only dark constituent visible. Under the microscope the few phenocrysts prove to belong, in part, at least, to the andesine series. The groundmass, which is unusually well crystallized, consists of numerous very small bipyramidal quartzes and fine feldspar laths, embedded in an interstitial cementing material, which is probably in large part orthoclase. The rock is no doubt properly regarded as a dacite. It is the most acidic phase recognized among the Wrangell lavas of the central Copper River region. The relation of this particular body to the more basic surrounding flows is not certainly known. It is probable, however, that it represents a thick flow which issued somewhat earlier than the neighboring andesites.

COPPER VALLEY PLEISTOCENE.

OCCURRENCE.

The interior plain of Copper River from the head of Wood Canyon northward, eastward, and westward to the sources of the Copper and of each of its tributaries is underlain by a mass of unconsolidated material which presents widely different aspects at different points. The present surface of these beds, which generally coincides with the original surface, forms the plain of the Copper Valley and extends in many instances well up the slopes of the surrounding limiting mountains. The maximum thickness is not known. The maximum measured thickness, as revealed in the recent gorge cut by the Copper in the basin terrane above the mouth of the Chitina, is about 600 feet. This point is approximately 100 miles south of the mouth of the Gakona or the Sanford, where the Copper is nearest the geographic center of its basin. How great the thickness may be in this vicinity it is not possible to tell. If the basin of the Copper is a warped depression, as it is conceived to be, a consideration of stream grades throws no light upon the depth of bed rock beneath the Pleistocene. It seems not improbable, however, that there may be at least as much as 1,000 feet of sands, silts, and clays where the basin is deepest.

From some such maximum the beds thin out toward the margin of the valley and at the same time extend up on the lower slopes of the surrounding mountains to heights of 5,000 or 6,000 feet. They form great rays about the periphery of the Copper River plain as they enter the surrounding mountains along the tributary valleys, whose lower portions are filled to unknown depths. In many directions they extend across the divides to neighboring drainage basins, effectually masking the bed-rock water parting. The most conspicuous example of this is along the divide between the Copper basin and that of the Sushitna, much of which is in the broad ill-drained gravel plain crossed by the one hundred and forty-seventh meridian, between the Chugach Mountains and the Alaska Range. The divides between the Copper and the Matanuska, the Copper and the Delta, and the Copper and the Nabesna are likewise in the Pleistocene terrane which in each of these cases conceals the rock divide. About the borders of the basin, particularly in the northern part, and as reported by Schrader and Spencer in the central part of the Chitina Valley, the gravels and silts surround and partly cover the outlying bed-rock hills, which rise as islands from the Pleistocene plain.

The general surface of the Pleistocene slopes gently in two directions—from the sides of the valley which it fills toward the center occupied by the draining stream, and from the head of the valley toward its outlet. The slope in the latter direction, whether in the valley of the Copper or in that of one of its tributaries, is less than the grade of the stream, as the latter usually flows upon the Pleistocene surface at its source and is well incised in it near its mouth.

In character the beds exhibit great variety, and the variation shows a general, but by no means regular, relation to their distribution. They vary in coarseness from impalpably fine silts to coarse bowlder beds, and in arrangement from finely laminated still-water deposits to tumbled morainal heaps. The fine deposits and the evenly bedded deposits make up a relatively greater proportion of the terrane along the lower courses of the streams and along the middle of the valleys, while the coarser and the unstratified deposits are relatively more important near the sources of the streams and near the sides of the valleys. This distribution conclusively proves the intimate dependence of the terrane on the present drainage, but offers no hint as to its relations to the underlying bed rock.

CHARACTER OF DEPOSITS.

Along the military trail south of Mosquito Creek, 6 or 8 miles above Tonsina Bridge, Schrader and Spencer describe banks of blue glacial bowlder clay.

Just opposite the north end of Tonsina Bridge is a section 340 feet high (fig. 4), the lower 300 feet of which consists of a fairly uniform body of fine unlaminated silt, which has scattered sparingly through it pebbles that vary in size from sand grains to a diameter of 2 or 3 inches. These are usually well rounded, but occasionally are subangular. No striations were observed on them, although this phenomenon was expected and looked for. The character of the deposit suggests rapid deposition in quiet water, either in a large water body or in the ponds of a broad flood plain, during a period of severe climatic conditions with consequent abundant floating ice. Stream or shore ice is the only satisfactory medium to appeal to for the distribution of the rounded pebbles through the fine silts. They must have been scattered over a lake bottom from a floating carrier which was not a berg, as the gravel is not glacial, but belongs to the stream type.

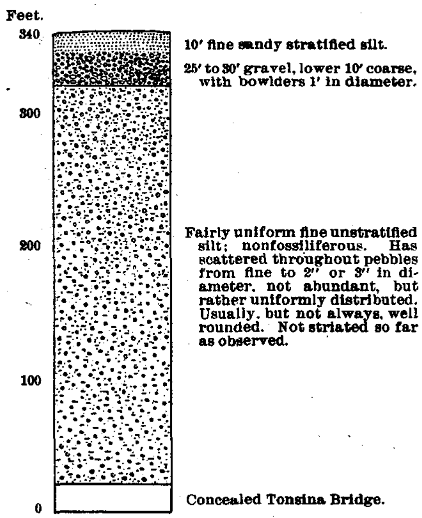


FIG. 4.—Section of Pleistocene at north end of Tonsina Bridge.

Above the silts are 25 feet of coarse, rounded, river cobbles, capped by finely stratified sand. Evidently the lacustrine conditions represented by the body of fine deposits were succeeded abruptly by those of rapid flow, the beginning, no doubt, of the gorge cutting of the present.

One and one-half miles above the mouth of the Klawasi, which flows into Copper River opposite and a short distance above Copper Center, is a section of 320 feet (fig. 5), of which all but the basal 40 feet are sufficiently well exposed for examination. This section exhibits much greater heterogeneity than that at Tonsina Bridge. Above the 40 feet at the base, which are concealed, is a 10-foot bed of rounded gravel, over which are 20 feet of fine-bedded sands, underlying 20 feet of blue bowlder clay. The succeeding 100 feet consists of interbedded fine clays and sands. Above this member are a bed of bowlder clay and some stratified pebble-bearing clays

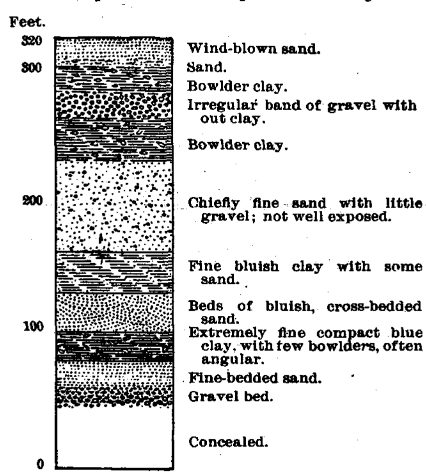


FIG. 5.—Section of Pleistocene on Klawasi River.

similar to those at Tonsina Bridge. The top of the section is a wind-blown sand drift (Pl. X, *B*).

This section reveals a succession of rapidly deposited water-laid beds, with at least two short epochs of ice invasion represented by the sheets of till near the top and bottom of the bluff. The water-laid deposits are usually sands or gravels, and may well have accumulated just beyond an ice front as a sand or gravel plain. The later ice tongue, whose presence here is indicated by the upper till sheet, came from the Wrangell Mountains and probably from Mount Drum, as the till has a pink tint, presumably imparted by the red lavas and tuffs from this peak. The great majority of the bowlders are andesites, a type common throughout the Wrangell Mountains.

On the north bank of the Klutina, about 6 miles above Copper Center, is a bluff 400 feet high, the beds of the upper 300 feet being fairly well exposed (Pl. IX, *A*). The lower 100 feet of this exposure consist of compact, structureless, pebble-bearing clays, without lamination. The pebbles are well rounded, are sparingly distributed through the clays, and represent a variety of rock types. The deposit is very similar to that at Tonsina Bridge, already described, and is interpreted in the same way. Overlying it are about 85 feet of well-laminated beds, entirely free from coarse material. They are believed to indicate lacustrine conditions. Above these is a bed of typical till 40 feet in thickness, full of striated and rounded bowlders (Pl. X, *A*). This is succeeded in turn by lenses of river cobbles overlain by more clays with embedded pebbles. The highest member of this section, as of most, is a bed of cobbles immediately under the peat and moss of the surface.

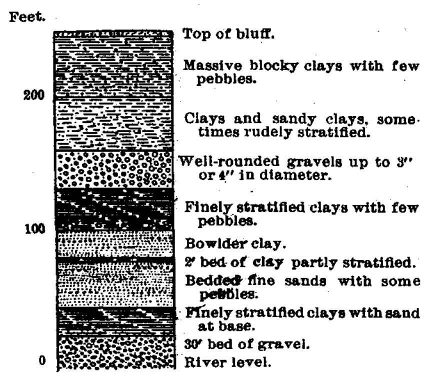
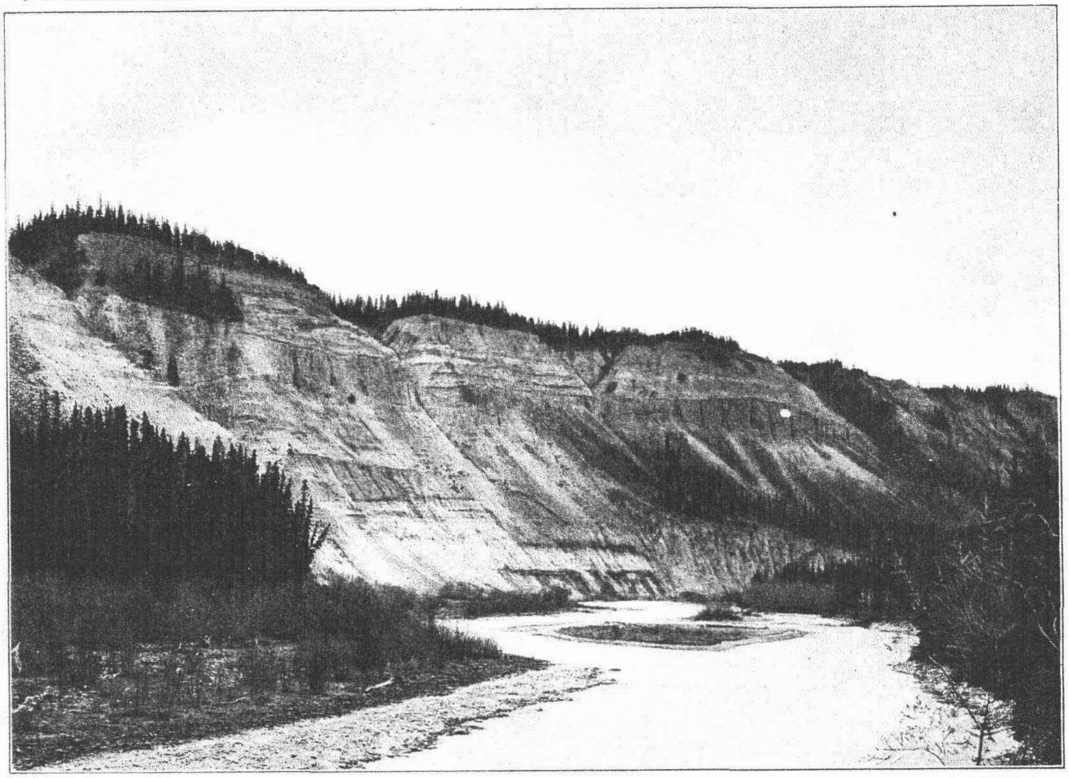


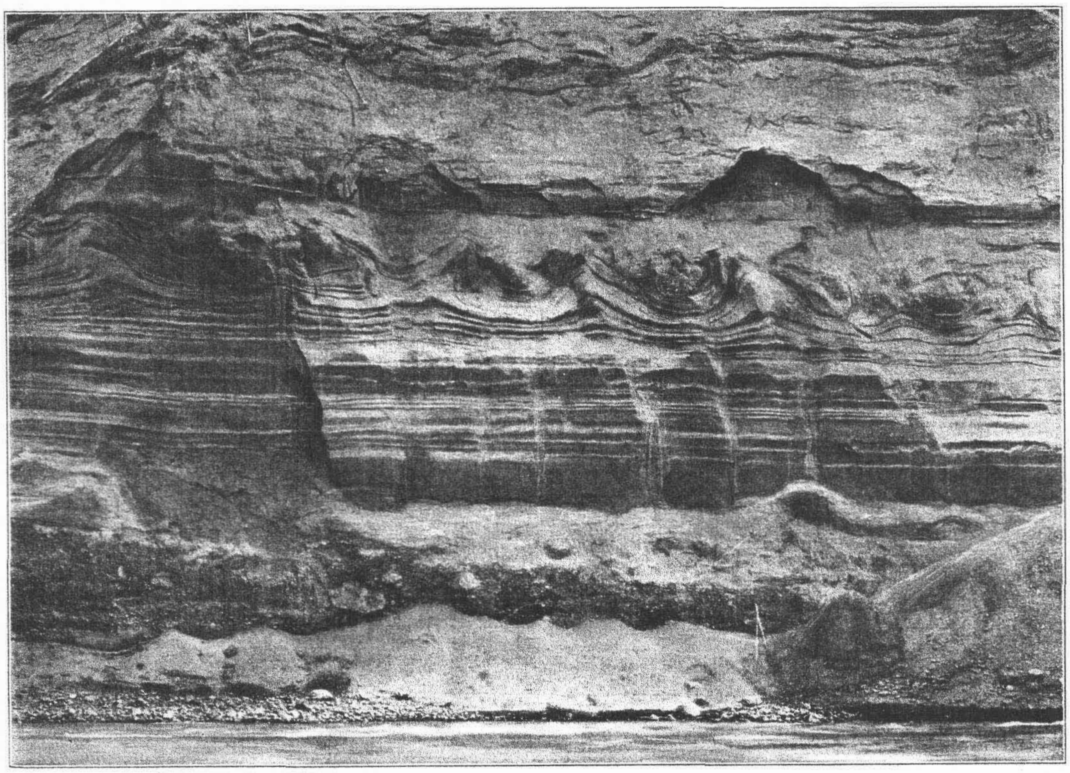
FIG. 6.—Section of Pleistocene on west bank of Copper River.

The basal 200 feet of this section indicate tranquil waters, in which rock flour quietly settled; while in the upper portion at least one actual glacial invasion is proved by the record preserved in the 40-foot bed of bowlder clay.

Three or four miles above this point on the Klutina another section of the river bluffs, estimated to be 275 feet high, has at the base a roughly stratified series of gravels and sands, succeeded by 50 feet of laminated silts free from pebbles (Pl. IX, *A*). Over these are interbedded, stratified, and massive silts, the latter weathering into pinnacles and towers. This section was not accessible for a detailed examination, but careful study from the opposite side of the river failed to show any true bowlder clay.



A. BLUFF OF STRATIFIED SILT AND GRAVEL ON KLUTINA RIVER.



B. STRUCTURE INDUCED IN PLEISTOCENE SILTS BY OVERRIDING GLACIER, TAZLINA RIVER.

Just below the mouth of the Tazlina (fig. 6 and Pl. V, *B*), in a bluff on the west side of the Copper, is an excellent exposure of 250 feet, which includes stratified sands and gravels, laminated clays, pebble clays, and one 10-foot bed of bowlder clay about 100 feet above the base of the section.

About halfway between the base and the top of a 100-foot bluff on the Tazlina, opposite the old telegraph station, an ice advance, probably the same one which deposited the till in the section just described, has left an interesting record in a series of folds (Pl. IX, *B*) in the laminated silts of the bluff. The originally horizontal layers have been thrown into a series of anticlines and synclines, usually, but not always, with the overturn toward the east, as though the thrust had come from the west. Gravels were deposited in the synclines, and the structures were planed off, after which the deposition of stratified beds was resumed.

The hypothesis of an overriding glacier is presented as the most probable one to account for these structures when considered in connection with the till in a near-by section, but other agencies are probably competent. If the laminated beds were deposited in a shoal-water body, a heavy mass of floating ice dragging on the bottom might push the clays into the attitude in which we now find them. The depth, 6 or 7 feet, to which the folds extend, makes it necessary to appeal in such a hypothesis to bergs, since such floe ice as would be likely to be found in a small water body is probably not competent.

The silt bluffs at the mouth of the Gakona, about 300 feet high, consist generally of fine, massive clays, through which pebbles are scattered. A few of the beds are laminated, and the general effect given at a distance is one of stratification in broad units.

The gorge cut by the Copper in the Pleistocene beds grows gradually shallower upstream, until above the mouth of the Slana the river is spread out over broad gravel bars, which are practically upon the surface of the Pleistocene plain. Between the mouth of the Slana and the mouth of the Gakona the sections revealed in the banks of the Copper have not been measured in detail. Where casually examined they show fine-grained silts and clays, often pebble bearing, and associated with coarser beds similar to those in the sections described.

In the lower part of the Copper basin, between the Tonsina and the Chetaslina, Schrader and Spencer[a] describe glacial till as forming the principal masses of the basin terrane, but associated with subordinate amounts of bedded gravels, volcanic materials, and silts, the latter sometimes quite well indurated. They also find flows of andesite lying upon Pleistocene deposits and covered by gravels,

[a] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901, p. 59.

and one instance is mentioned of andesite which is regarded as intrusive in the Pleistocene.

Along Nadina River, 5 or 6 miles below the foot of the glacier, the cut banks, 150 feet high, appear to consist of bowlder clays from top to bottom. The greater part of this exposure exhibits the same pink tint which has been regarded in other more distant localities as evidence of the origin of the material in the red lavas and tuffs of the Wrangell Mountains.

East and west of Nadina Glacier the lateral moraines, which were deposited when the ice level was 500 or 1,000 feet higher than it is at present, bury all rock outcrops up to elevations of over 5,000 feet. The eastern moraine is particularly heavy, and the materials, rudely stratified, consist of irregular sands alternating with beds of angular lava blocks of various colors and sizes. The western moraine is, on the whole, of finer material and more uniform character.

Other streams flowing southwest from the Wrangell Mountains do not exhibit such extensive morainal deposits, although minor ridges of loose material terrace the upper Chetaslina and Dadina valleys at various points.

In the neighborhood of Sanford River and its immediate tributaries the gravel filling is deep and extends upward usually to 5,000 feet or more above sea level. One or two of the northern tributaries of the Sanford join the main stream through deep valleys whose lower courses are cut entirely in gravels and bowlder clays.

North of the Copper, among the foothills of the Alaska Range, the deposits are present in all the valleys, but seem to be free from the fine laminated silt phase which is prominent nearer the center of the plain. On the Slana, at the mouth of Ahtell Creek, is an exposure of 200 feet of washed gravels. A 100-foot bluff on Indian Creek, about 5 miles from Copper River, consists of 40 feet of rounded gravels and clay at the base, succeeded by 30 or 40 feet of interstratified sands and clays capped by 20 or 30 feet of fine sand.

The Chistochina bluffs near the mouth of Middle Fork apparently contain till with washed gravel and sand. Higher up in this drainage basin, a short distance below the source of West Fork, is another instance of structure induced in earlier deposits by glacial movement. Locally the beds of sand and gravel have been given dips of 45° and the cross-bedding in the individual strata now stands in some instances at angles of 80° and 90°.

In 1898 the writer, in crossing from the head of the Gulkana to that of the Delta, measured near the headwaters of the latter stream a section of about 600 feet of coarse- and fine-bedded gravel and sand, which buries the rock divide between this part of the Copper and Tanana river systems.

The upper course of a western tributary of the Gulkana, which rises near an eastern branch of the Sushitna, is incised 150 feet in gravels of a similar character.

These descriptions serve to bring out the fact that in the southern and central parts of the Copper basin the Pleistocene filling consists of laminated and massive silts, pebble-bearing clays, stratified sands, gravels, and till in greatly varying proportions, and that in the northern and marginal parts of the basin it consists of sands, gravels, till, and morainal deposits.

PLEISTOCENE SURFACE.

The Copper basin, viewed in a broad way, is a plain which slopes toward the stream channels and with them. Examined in detail it exhibits considerable minor diversity. Along the military trail northward from Copper Center are stretches of prairie and marsh land, level, lake-dotted, and undrained. Such areas are found between the Tazlina and the Gakona and near the mouth of the Tulsona, where an unusually large grass land area is called Tulsona Prairie. West from the Copper toward the Sushitna divide the country is little known, but other extensive level areas are reported in this direction. Along this divide, which was traversed by the writer in 1898, the surface consists of a confusion of gravel ridges, mounds, and undrained depressions, such as are characteristic of heavily glaciated areas generally.

In following the Mount Drum trail eastward from Copper Center toward the Nadina, one rises gradually but not regularly, the general slope being interrupted by low, rounded cross ridges, and gentle east-west undulations, the depressions between which are swamps, with uncertain drainage. The ridges are probably moraines. They consist of rounded gravels and angular blocks, the latter very subordinate in amount, but often large.

East of Stück Mountain the general slope toward the Copper is similarly interrupted by a confusion of gravel ridges.

In the northern part of the basin, where the bed-rock islands rise through the Pleistocene deposits, the slopes of the former merge with those of the latter, so that it is difficult to determine from the topography where a line is to be drawn between gravel and rock. Toward the bases of the high mountains which surround the basin, and which have been the sources of the greater glaciers of the past, as they are of the lesser ones of the present, the Pleistocene filling of the valley merges with the apron of overwash in front of the retreating existent glaciers and with the lateral moraines of these, and thus often extends up to elevations of between 5,000 and 6,000 feet, finally thinning out as a film of scattered pebbles. But this marginal distribution is not regular. Along the northwestern base of Mount Sanford, for instance, the lava flows, although they have been glaciated, are exposed relatively free from Pleistocene covering down to 2,500 feet or below in the direction of the Chistochina River. The absence of heavy accumulations in this direction is probably due to the configuration of the mountain, and the consequent arrangement of the ice drainage. A heavy glacier having covered this slope until late in the ice retreat, its débris was dropped to the north and south, accounting at the same time for the great accumulations in these directions and the relatively light gravel coating on the slope in question. It is to be added, however, that the great amount of gravel near the Sanford is no doubt in large part due to a great glacier which has continued until late in glacial history to flow out from Mounts Drum, Wrangell, and Sanford through the Sanford Valley.

SOURCES OF THE MATERIAL.

Upon a correct determination of this factor depends the unveiling in large part of the history of the glacial movements and of the Pleistocene deposits which are so intimately connected with them. The rock masses of the surrounding mountains seem to be sufficiently distinct to give data for the solution of the problem, but not enough evidence has thus far been collected to determine with certainty in all instances what the source of a particular rock fragment may be. One fact is made patent, however, by the collections at hand, namely, that the rock types have been so mingled by the processes which have deposited the Pleistocene that generalizations as to glacial movements, based upon the finding of a particular rock associated with other types in a particular locality, must be made with great caution.

In the section at Tonsina Bridge the pebbles collected are all of types which probably occur in the Chugach Mountains. The great majority are typical Valdez rocks, fine-grained feldspathic sandstones or graywackes, not rarely schistose, with occasional dark slates, quartzites, or massive granitic rocks. Pebbles of the same character were observed by the writer 2 miles below Tonsina Bridge in the top of the river bluff, but 3 or 4 miles farther down Schrader and Spencer report that the gravels and till contain much andesitic material similar to that forming the Wrangell Mountains.

Trout Creek enters the Tonsina at Tonsina Bridge from the northwest toward Klutina River. The gravels which it carries were carefully examined and were found to represent a number of types. The rocks of the Valdez formation from the Chugach Mountains predominated, but a much larger proportion of granitic pebbles was found than in the Tonsina silts, and occasional pebbles of a reddish andesitic effusive of the Wrangell type were mingled with the others.

The pebbles scattered as wash over Stück Mountain, whose elevation is somewhat more than 3,000 feet, again are mostly of known Chugach types, but include jaspers and crystalline limestones, which are among the rarer Chugach rocks. One pebble of a porphyritic type was observed, which may have come either from the Wrangell Mountains or from the northern face of the Chugach Mountains, farther west.

From the section of silts measured on Klutina River, 6 miles above its mouth, collections were made at two different horizons for later comparison with rock specimens. These collections include a number of rocks of the Valdez types, a few granitic pebbles, a number of dark-red, black, and green quartzitic pebbles of unknown source, and some porphyritic igneous specimens like many aspects of the Wrangell lavas.

In the Pleistocene about Copper Center and the mouth of the Tazlina there is a distinct mingling of types. Schists, crystalline limestones, Valdez graywackes, and Wrangell lavas are all recognized.

Eastward toward Mount Drum the morainal ridges carry occasional blocks of crinkled schist (similar to the rocks of the Alaska Range) although andesitic itic lavas predominate. These massive lavas and associated tuffs occur almost exclusively in the walls of the Nadina Valley and in the moraines of the glacier.

On the west slopes of Mount Sanford, at elevations of from 5,000 to 6,000 feet, in the thin and patchy sheet of gravel which occurs on these slopes, associated with pebbles of the local rocks, the andesites, there are representatives of such diverse types as white limestones, greenstones, granite, schists, and quartzites.

In the tumbled gravel ridges of the Sushitna-Copper divide, schists, vein quartz, and granitic rocks were recognized, while in the valleys adjacent to the Alaska Range generally the rocks present in place within the valley are represented in the gravels, mingled in the majority of cases with types whose sources are unknown.

CONDITIONS OF DEPOSITION.

It is evident from the character of the Pleistocene terrane which has been described that still water, running water, and ice have all contributed directly in its accumulation. As a whole the material is recognized as belonging to that type of deposits which accumulates under favorable conditions in front of retreating ice masses.

In the Copper River basin the conditions have been peculiarly favorable for this accumulation. The wide lowland is surrounded on all sides by high mountain ranges, from which as centers the glaciers have pushed out into the valley from every direction, burying it deeply. In addition to the fact that from its situation it became the dumping ground for glacial débris from north, south, east, and west, its depth and its narrow outlet at Wood Canyon have acted unfavorably upon the processes of removal, so that a relatively large proportion of the total supply has been retained within the basin.

The conditions under which the different classes of material were deposited are usually easily inferred from their character. The fine laminated silts must have accumulated in bodies of still water which existed at many times and places within the basin, as results of obstructions to drainage ways by glaciers, by moraines, by shifting stream channels, by unmelted residual ice blocks, or perhaps occasionally in the later stages, by vegetable accumulations. Conditions under which silts accumulate are probably represented now in the lakes at the head of the Tonsina, the Klutina, the Tazlina, and the Gulkana. These large water bodies fill rock basins or gather behind débris dams, which express temporary ice advances or uneven rates of retreat. In them the rock flour settles near the lower end, while at the upper end they are gradually filled by coarser material, supplied by the rapid glacial tributaries.

The fine massive silts and clays, which are unlaminated and frequently have pebbles scattered through them in more or less abundance, are a familiar phase of the deposits, but one whose origin is less clear. They appear to indicate rapid deposition, and but for the presence of the pebbles might be readily duplicated in the flood plains of many streams in the United States outside the glaciated regions. They may, indeed, indicate flood-plain conditions which have been the last stages of filled lakes, or have been brought about by obstructions in a river's course sufficient to cause it to build and meander, but not adequate to pond it, or they may be lacustrine deposits similar in origin to the finer laminated silts, but presumably representing more rapid deposition in shallower water. The pebbles which they contain, and which are sometimes found in the laminated silts also, were probably dropped from a floating carrier, ice being the one to which the student most naturally appeals.

The sands and gravels are usually fluviatile or represent the sand plains and aprons of overwash which often extend out for miles beyond a glacier front.

The till is, of course, a direct ice deposit. Its occurrences, interstratified with the other beds, indicate reinvasions of the ice after or during the general withdrawal. It is likely that a large proportion of the till originally deposited has been cut away by the active streams that issue from the glaciers as they retreat. It is more a matter of surprise that so much has been preserved than that there is not more.

The surrounding heights—the Chugach Mountains, the Wrangell group, and the Alaska Range—have supplied the material. Generally, as the base of either of these mountain ranges is approached, fragments of the local rocks which occur in it become more prominent in the Pleistocene, but in the lower southern part of the basin all types are mingled, since the glaciers and streams draining from all portions of the rim have there contributed to the supply.

SUMMARY.

The general facts established by the studies of the Pleistocene terrane may be summarized thus:

(1) The material has been supplied largely by glaciers from the surrounding mountains and has accumulated during the glacial occupation and retreat.

(2) The immediate agents of deposition, in the order of their importance, have been streams, lakes, and glaciers.

(3) During the maximum glacial accumulation the entire Copper basin was probably occupied by ice.

(4) The glacial retreat has been interrupted by advances, as is proved by the superimposition of till upon silts and by the structures induced in the latter.

(5) The general Pleistocene surface has been molded in part by the ice itself, but in greater part by the drainage that developed with the withdrawal of the ice and followed practically the lines of the present streams.

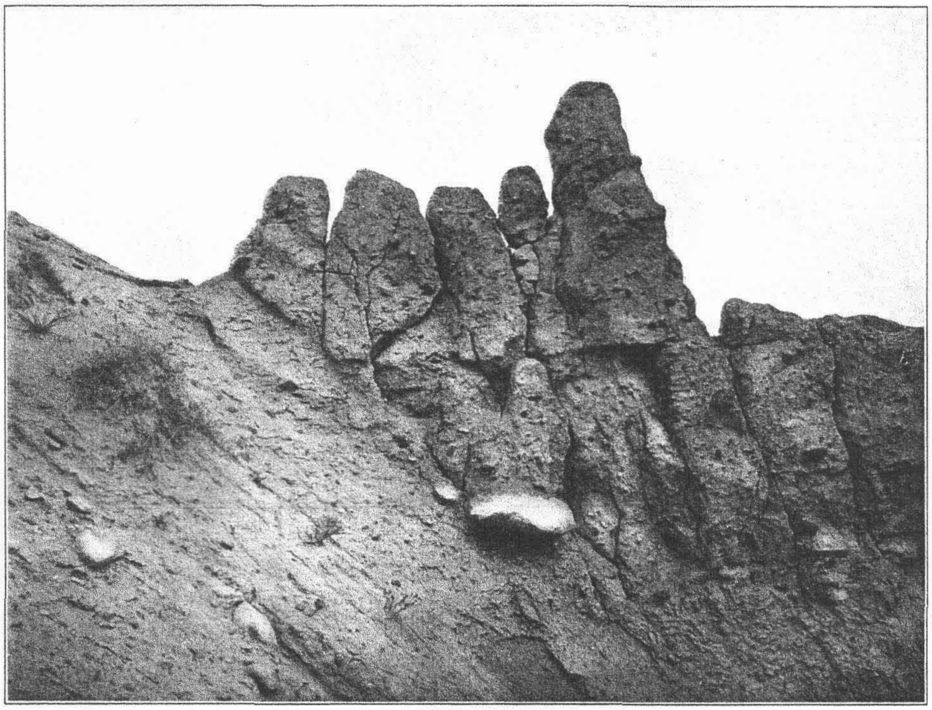
These conclusions, based primarily upon studies in the central and northern parts of the Copper basin, are in substantial accord with those reached by Schrader and Spencer, whose studies were confined to the southern part of the basin, including the Chitina Valley.

SAND DUNES, LANDSLIDES, AND TERRACES.

Two frequently observed minor phenomena in that part of the central Copper River region covered by the Pleistocene are the sand dunes and the landslides, each producing its characteristic topography.

The sand dunes usually form drift crests at the tops of river gorges cut in the Pleistocene. These beds and the river sands dry quickly in the spring and after storms, and their finer materials are swept up over the edges of the bluffs by the winds and dropped in the borders of the forest, where the trees check the air currents. In this way the height of a bluff is sometimes increased 20 feet or more and the later stream cutting reveals the stumps and trunks of trees which have been buried in the drifting silt and killed (Pl. X, *B*).

The best examples of landslides were seen in the Klutina Valley, although no doubt they occur along many of the streams which are deeply cut into the Pleistocene About 6 miles above Copper Center the Klutina bottoms are from one-fourth to one-half mile wide, with clay and gravel bluffs on either side. At this particular point the river is near its south bank and the bottoms between it and



A. DETAIL IN BOWLDER CLAY ON KLUTINA RIVER 6 MILES ABOVE COPPER CENTER.

B. WIND-BLOWN CREST OF PLEISTOCENE BLUFFS ON KLAWASI RIVER.

the bluffs to the north are occupied almost entirely by the disheveled topography, so characteristic of landslips. As the clay is impervious the irregular depressions are often occupied by ponds. The slips are in all stages of preservation, from those which are so old as to be scarcely recognizable to those so recent that the trees torn loose by them are still green.

One instance was noticed above Cook Bend on the Klutina, where several small slides have accumulated on one side of the river, though evidently derived from a cut bank on the other. The process by which this material accumulates is thought to be as follows: Throughout the winter the snowslides from the steep bluffs, 300 or 400 feet high, accumulate at their bases as snow fans, which in favorable instances extend entirely across the river on the ice. In the early spring, since thawing begins on the exposed bluff long before the ice leaves the river, the first landslides are carried across the stream on the snow fan to the opposite bank, where they later appear without any visible connection with their source.

At many places along the Copper and its tributaries terraces appear within the canyons which are cut in the Pleistocene filling. These are usually narrow benches at various levels between the river and the surface of the plain; they are especially abundant near the mouths of tributaries. No widespread features of this character were observed and no general significance is attached to the local ones studied. They have been attributed by Schrader and Spencer[a] to minor climatic changes resulting in a varying rate of retreat on the part of the glaciers and a consequent alternate aggrading and degrading of the stream beds, a cause unquestionably competent to produce the results observed.

It is conceived, however, that they may have an even simpler origin, for a progressive retreat of the ice, with a consequent lessening of the stream load, permitting it to cut gradually into the material which has accumulated earlier, gives conditions under which terraces will form. Every stream has a tendency to meander, originating in obstructions in its channel which throw the current toward one or the other bank. Such a swing once inaugurated constantly tends to increase in amplitude by cutting on the outer curve and depositing on the inner. This tendency expresses itself most freely in a slightly overloaded stream which is building up its bed. It is least fully expressed in a rapidly degrading stream, whose energy usually removes the initiating obstruction before lateral cutting is accomplished. That it may be very effective, however, in rapidly down-cutting streams is abundantly proved by the many cases of meandering rivers which have been rejuvenated. As the curves are incised with the degrading channel, the concave bank becomes much steeper than the

[a] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901, pp. 80 and 81.

convex bank, proving that the meandering habit persists through the revival. It is not unusual to assume that meandering ceases sharply as a river passes that invisible boundary between slight aggrading and slight degrading. It seems much more logical to suppose that the expression of the meandering tendency passes gradually from its maximum in a notably aggrading stream to its minimum in one notably degrading, and that the difference in the amount of meandering between a stream aggrading very slowly and one degrading very slowly is but slight.

If this principle be accepted and it be granted that a slowly degrading stream will meander, then we have in secular decrease in precipitation without minor climatic changes an adequate explanation for the Copper River terraces. With decreasing precipitation there is diminishing glacial activity and a diminishing load furnished the streams at their sources. As this initial load decreases the power of the streams to pick up and remove material farther down their courses is increased. In other words, they begin to reduce their grades. If they meander even slightly in this process, they will inevitably leave stranded here and there, at any level, remnants of a channel which has been deserted through the meandering process. These deserted remnants become terraces as the river sinks below them. Such terraces produced by a steadily degrading stream would not be expected to be extensive, since meandering under these conditions is not particularly effective. They should be more numerous near stream junctions, where opposing currents of differing power offer more favorable conditions for wide swings in the stream's course. Both of these conditions are realized in the terraces of Copper River, so that this alternative hypothesis seems to have a sufficient basis both in theory and in fact to justify its presentation.

OUTLINE OF GEOLOGIC HISTORY.

Under the above heading that succession of early events in the evolution of this part of the continent which is recorded chiefly in the rock masses that have been described will be discussed. Under the heading of Physiographic Development those later events whose records are found chiefly in the land forms will be outlined. These two are the ancient and the modern history of geology. They occasionally overlap in time, particularly along that neutral zone in the Tertiary and the Cretaceous, where we sometimes have both land forms and rock records from which to decipher the story of continental evolution; but in general each has its distinct field. Physiographic records of any except the latest events, geologically speaking, are usually not preserved. Stratigraphic records for much more remote periods exist, although even these are more and more imperfect as we delve further into the past.

In northwestern America, particularly, the comparatively recent geologic events have been so revolutionary that beyond the uppermost Paleozoic we generally find ourselves groping blindly. The records are gone or are so obliterated that we can not decipher the story. Upon the same rock palimpsest so many histories have been written that the latest inscription is obscure and the earliest is undecipherable.

In the account to follow it must be remembered that the rocks have been described and the evidence has been discussed for their assignment to a particular part of the stratigraphic column. That evidence is often weak and fuller future investigations will in many cases alter the tentative conclusions reached, but for the purpose of this outline these conclusions will be accepted and the doubts largely left unexpressed to avoid the constant introduction of conditional clauses with their obscuring effect.

The first event whose record is preserved is a period of deposition in the earliest Paleozoic time or before. In the areas now occupied by the Tanana schists and the Klutena beds north and south of the Copper River basin, as well as in other extensive areas in Alaska occupied by the Birch Creek and Fortymile rocks and their equivalents, calcareous, siliceous, and carbonaceous sediments were deposited in an ancient water body of wholly unknown outline and extent. At the close of such a period of deposition those forces which are frequently responsible at the same time for metamorphism in rocks and for the building of continents and mountain ranges began to work and these old sediments were subjected to intense pressures until schistosity was developed in them and new minerals were formed from the materials of which they were composed. Late in this process abundant fissures were opened and filled with quartz and other minerals, and at least a part of the gold which is derived from the ancient schists was introduced. Much of this fissuring preceded the close of the period of stresses, as the earlier quartz veins themselves are shredded and squeezed into lenses and knots, but in general the process came at the end of the period.

After a long interval whose events are unknown a second great period of sedimentation, represented in the slates, conglomerates, and feldspathic sandstones of the Valdez formation, began. These sediments, although they contain calcareous members, are generally arenaceous or argillaceous, as though they had been deposited off the shore of a land mass, whose position and extent we do not now know. It may have been formed in part of the older schists which have been described, but the fresh angular feldspar fragments so prominent in some of the Valdez sediments indicate that near the shore, off which these beds were being laid down, there was abundant igneous activity. This activity contributed directly in places to the accumulations by the addition of great bodies of basaltic flows or intrusives now represented by greenstones.

After the piling up of the Valdez sediments, or perhaps before the end of the period of their deposition, another important epoch of contraction and deformation set in, rendering the Valdez rocks generally somewhat schistose. The action during this period was less intense than that following the deposition of the Klutina, Dadina, and Tanana rocks, since the bedding, the sedimentary character, and the minerals of the rocks affected were not destroyed. Nor was it so uniform or so general in its action, certain areas in the Valdez rocks being affected to a much greater extent than other areas.

Presumably some time after the Valdez deposition another outburst of igneous activity was in progress. Its center can not be definitely located, but its products reached north of the present upper Copper, where in the basins of Indian and Ahtell creeks it is represented by the Tetelna volcanics, whose fragmental representatives, with interbedded true sediments, are considered to extend northwestward along the base of the present Alaska Range as the Chisna beds. These volcanics and the tuffs, conglomerates, and quartzites associated with them indicate land and shore conditions in this part of Alaska during middle or upper Paleozoic time. In fact the absence of those types of deposit ordinarily recognized as representing deep-sea conditions, with the presence of littoral and subaerial accumulations like the Valdez, the Tetelna, and the Chisna rocks, is regarded as indicating that in early and middle Paleozoic time the central Copper River area was probably part of a great land mass, whose topography and outlines underwent many variations as the effusives accumulated on its surface, and the shores shifted for the widespread deposition of the littoral. The same general history seems to be recorded in the Yukon province, where the interval between the schistose sediments of the Fortymile and Birch Creek formations and the unaltered Carboniferous limestones of the Tahkandit formation is occupied only by the Rampart rocks, largely basic lavas.

Following this epoch of rapid accumulation in the central Copper River district, but probably after a considerable interval, there was poured out quietly and rapidly in what is now the basin of the Chitina and the region north of it a great accumulation of basalt, which piled up to at least 4,000 feet. This was the culminating effort of the great middle and late Paleozoic volcanism, whose products are the Rampart basalts of the Yukon basin, the Tetelna volcanics and the Nikolai greenstone.

After this outflow a great change took place in the character of the development of the region. We have seen that the earlier and middle Paleozoic history seems to have been largely continental—that of a land mass, or its shore lines, with coarse sediments and volcanic materials; but with the end of the Paleozoic the sea invaded the province through a general subsidence following the outflow of the Nikolai greenstone, and although no doubt varying in depth and shifting its outlines, practically maintained control until the middle of the Mesozoic.

In the northern part of the province the sea seems to have only gradually invaded the land areas. The earliest Permian sediments there are shore deposits in part, and include sands, tufaceous beds, and flows, which denote the dying out of the earlier eruptive epoch, perhaps the last feeble activity of the Tetelna stage. But toward the middle of the period represented by the Permian rocks truly marine conditions prevailed and abundant marine life existed, while heavy limestones and fossiliferous black shales were being laid down in what is now the upper Copper River Valley. It is probable that this Permian sea was widespread in eastern Alaska. Its records are preserved on the middle Yukon, in the Copper Valley, in the valley of the upper White, and east of there toward Pyramid Harbor. It extended also to southeastern Alaska, where, however, the recognized beds belonging to it are marine sandstones instead of limestone. The even, exclusively marine phase of the upper part of the deposits makes it wholly improbable that there existed at this time any marked relief where the present great ranges stand. They may have been mountains before the Permian and after, but probably not during this era.

In the Chitina Valley a shallow sea held possession through the Permian epoch and well into the Triassic, the deposition of thin, dark limestones and black shales continuing uninterruptedly. The area of Triassic deposition was widespread, particularly toward the south and west in the direction of Prince William Sound and the Kenai and Alaskan peninsulas, and may, indeed, have been more extensive than that of the Permian.

It is probable that the change from Permian conditions to those prevailing in Triassic time was the slow change accompanying a gradually shoaling sea. The Permian limestones are thick, massive, relatively pure beds; the Triassic limestones are dark, thin, impure strata, interbedded with black shales, and these occur chiefly near the base of the system. Later in Triassic time limestones were no longer deposited, but only the black muds, sometimes containing arenaceous bands, which probably are to be interpreted as representing shoal sea water, with a not far distant land of faint relief, which supplied an abundance of carbonaceous matter.

A succession of rapidly recurring revolutions began with the close of the Triassic. The first of these is recorded in the folding of the previously deposited sediments, their elevation into a land mass, their erosion, and finally the reinauguration of a period of sedimentation in Jura-Cretaceous time. But this Jura-Cretaceous sedimentation represents wholly different conditions from those which prevailed in the earlier Permian epoch. The rocks generally are coarse conglomerates, with only thin, intercalated sand and shale strata. (In the Chitina occurrences they are supposed by Spencer to have been deposited in narrow basins, whose shores must have been steep to yield the coarse bowlders now forming the Jura-Cretaceous conglomerates.) But the shores along which this rapid erosion and concurrent deposition took place were marine and not fresh-water shores, since the life records preserved are of marine creatures exclusively. The beginning of Jura-Cretaceous time then is marked by high land masses and rapid erosion and deposition, but toward its close more placid conditions again ruled. It may be supposed that as the high relief was rapidly reduced, the products yielded became finer, and the way was prepared for the deposition of the lower Cretaceous limestones of the Talkeet Mountains and the fine dark shales which succeeded them. The inference from the limited evidence that we now have is that the topographic effects of the first post-Triassic revolution were gradually removed during Jura-Cretaceous time, and had been quite thoroughly effaced by the end of the lower Cretaceous.

With the close of the lower Cretaceous the marine conditions which had predominated within the Copper basin since Permian or before vanished and have not since prevailed. This part of the continent then became a land mass and has remained one to the present, except as more or less extensive fresh-water bodies have existed from time to time.

We have no evidence that there was any sedimentation between the marine lower Cretaceous and the fresh-water upper Eocene, and infer that the reduction of what remained of the late Jurassic relief continued until the region became a featureless plain, well reduced toward the base-level of erosion.

We can not now restore the continental outlines of this time, but it is highly probable that the shores lay entirely without the district under consideration and far to the north and west, since upper Cretaceous marine forms are found in the lower Yukon Valley.

The first direct evidence which we have of the disturbance of this late Cretaceous and early Eocene quiescence is furnished by the widely distributed late Eocene Kenai sediments: conglomerates, sands, clays, and lignites. They are fresh-water exclusively and seem to have been deposited in isolated basins, which may well have originated in a series of flexures that warped the earlier plain. Some of the Kenai strata are coarse and indicate conditions of well-marked relief and rapid erosion, while frequently the higher beds are fine clay shales. Lignites are abundantly distributed throughout. The featureless pre-Kenai landscape seems to have been transformed into a rolling country, with active revived streams and large lakes about whose borders lignite bogs abounded, but there is no good reason for supposing that a relief comparable to that of the present existed.

The belief that the deformation immediately preceding the Kenai was slight, and was represented by gentle folding or uplift en masse, is supported by the fact that the later Mesozoic sediments are but gently flexed, and exhibit structures but little more marked than those which affect the Kenai rocks themselves.

The movements which have occurred since the Kenai deposition were sufficiently pronounced to bring about well-marked structures in the Kenai rocks. Beds of this age in the north edge of the Copper basin have maximum dips of 70°, although generally 25° or 30° is the highest, and 10° is more usual. In the valley of the Cheshnina dips of 25° are recorded, and along the lower Matanuska folds of about the same intensity exist in beds of this age. Sometime after the close of the period of deposition of the Kenai fresh-water lakes of the interior a series of continental movements began, to which we owe in large part the present physical features of the country—the great mountain ranges, the major valleys which separate them, and perhaps the general outline of this part of the continent. The discussion of these processes belongs rather to physiographic than to geologic history, and they will be more fully treated under that head, since the evidence for them is found in land forms rather than in stratigraphic records.

Accompanying these movements, and perhaps causally related to them, was the most spectacular of the recent truly geologic events, the effusion of the hundreds of cubic miles of Wrangell lavas and the building up of the great central group of mountains, now the most conspicuous feature in the Copper basin. This event is a very late one in geologic history. It may have begun as far back as early Tertiary. It has continued to the very present.

Contemporaneous with the latest of the Wrangell volcanic phenomena, but more recent than all except the latest, has been the filling up of the earlier formed Copper Valley by the Pleistocene silts, clays, sands, and gravels. This process has accompanied and followed glaciation. It is operative now around the borders of the basin, while through its lower and central parts the reverse process, that of degradation, has begun, and the Pleistocene filling is being removed.

PHYSIOGRAPHIC DEVELOPMENT.

PHYSIOGRAPHIC DIVISIONS.

Physiographically the central Copper River region falls naturally into four distinct subdivisions, the Chugach Mountains along the southern edge, the Wrangell Mountains in the east central part, the Alaska Range along the northern border, and the Copper River basin in the western and central portions (Pl. XI and fig. 7).

The Pacific Mountain system, represented in the longitude of Yakutat by the St. Elias Range, trends northwesterly beyond the international boundary, and divides into two wings. The southern wing curves about the Gulf of Alaska, as the Chugach Mountains, gradually changing its direction from northwest to southwest, and is continued through Kenai Peninsula in the Kenai Mountains. Near the point where it makes its great bend to conform to the general curve in all the major physical features of Alaska, the Talkeet group of mountains makes out from it toward the northwest, between the lower Sushitna and lower Copper basins.

The northern wing of the Pacific Mountain system, the Alaska Range, diverges from the St. Elias Mountains, from which it is separated by the valley of the upper White River, near the international boundary, and trends north and west around the basins of the Copper and Sushitna. This important range consists of

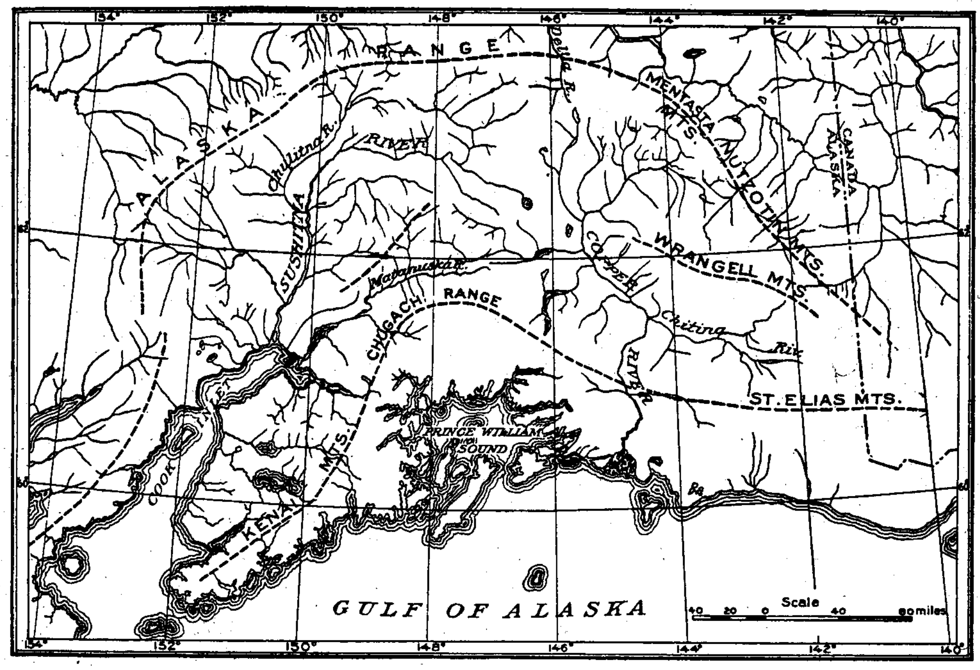
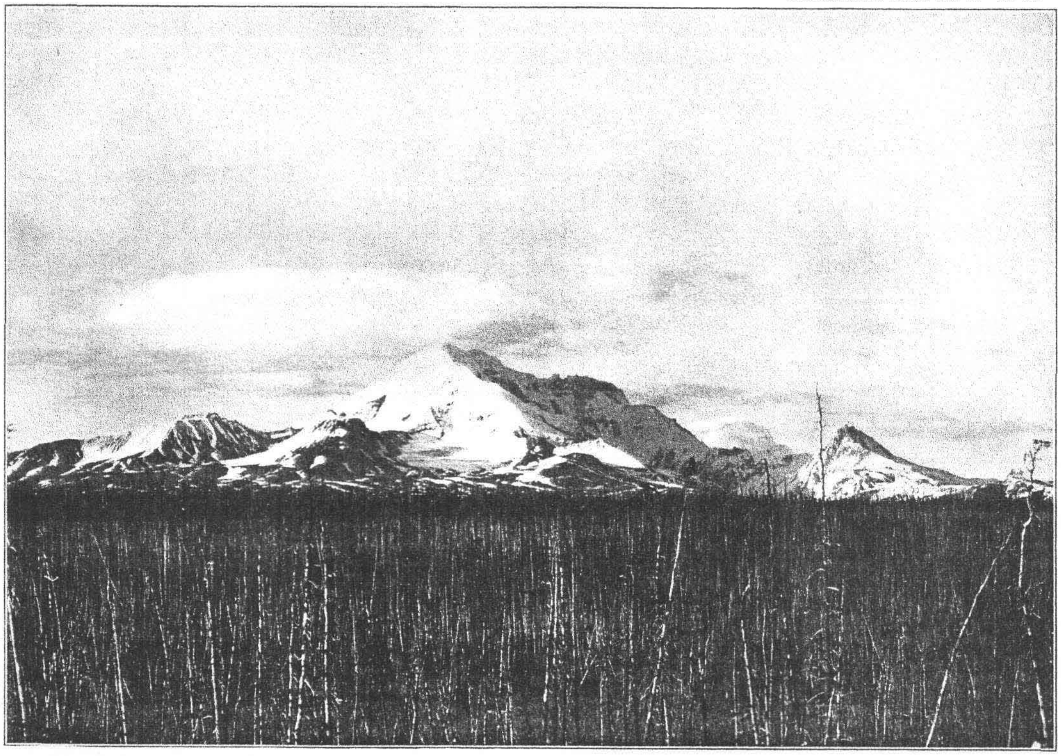


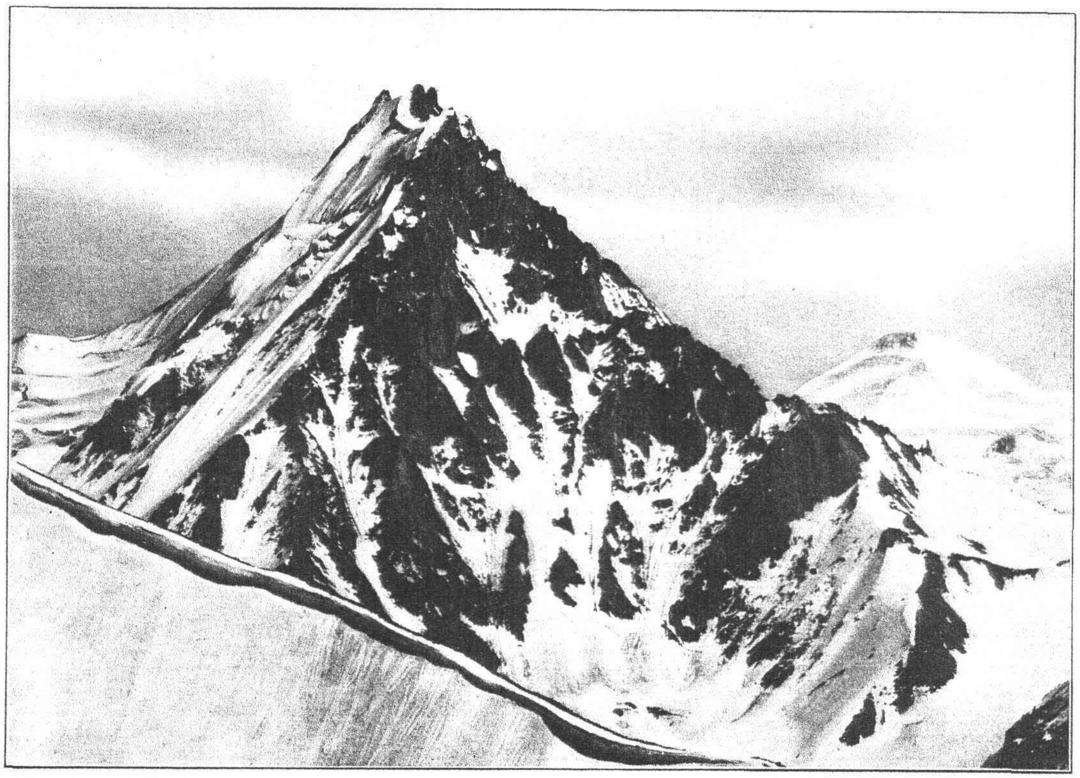
FIG. 7.—Sketch map, showing relations of mountain ranges, lowlands, and larger streams in the region tributary to Prince William Sound and Cook Inlet.

a number of smaller groups, to some of which separate names have been applied. Among them are the Nutzotin Mountains, the Mentasta Mountains, and the Tordrillo Mountains. Toward the southwest, along a slightly different axis, the Aleutian Mountains continue the same general line of height, through the Alaska Peninsula and the Aleutian Islands, toward the Asiatic Continent. In the development of these ranges no doubt a number of physiographic processes have been involved.

Within the angle formed by the divergence of the Chugach and Alaska ranges is the Wrangell group of mountains, entirely different in its genesis from the near-by parts of either. It is separated on the south from the Chugach



A. MOUNT DRUM FROM THE NADINA TRAIL.



B. SNIDER PEAK.

of either of its more important upper branches, cut a canyon-like valley but 3 or 4 miles in width across the uplifted Chugach plateau, the middle portion of the same stream reduced an area 60 or 70 miles wide nearly to base-level. The difficulty is lessened, but not removed, if we suppose weaker rocks to have been distributed over the area now occupied by the interior valley. Such an hypothesis is not supported, though not disproved, by what we know of the bed-rock geology of the region.

WRANGELL MOUNTAINS.

As to the origin of the Wrangell Mountains there can be no question. The individual peaks and ridges are masses of extravasated igneous material, which has been ejected during a period of eruptive activity that began in the recent geologic past and has continued to the present. The western end of the group came into existence after all the earlier rocks, including Jura-Cretaceous and probably upper Eocene, had been consolidated, folded, reduced, uplifted, and again dissected. The lavas of Drum and Wrangell were poured out over a topography quite comparable to that which now exists in the Chitina Valley just without the andesite border, a topography which is the product of the present general cycle of erosion, although a more recent post-lava system of modern gorges cuts across the earlier system from the slopes of the mountains to the Copper. The peaks themselves are so late in origin that their forms are not by any means all erosional, in spite of their height and their favorable situation for attack. They are the products of volcanism and erosion combined. Either predominating gives a distinct type, while intermediate forms are due to the partial ascendency of one or the other process. Mount Wrangell is an almost perfect constructional peak (Pl. VIII, *A*), and erosion has modified its original form but little. Mount Drum's contour, on the contrary, is due entirely to denuding agencies; the original built-up form is gone. Mount Sanford is a volcanic dome, one-half of which has been mined away by a sapping glacier (Pl. III, *B*), while Mount Blackburn has been etched on all sides until only its summit has the gentle original slope; all below this is a precipitous wall due to undercutting ice.

The peaks bear the same relation to the basement upon which they are piled as the great volcanic cones of the Cascade Mountains bear to the range proper. They are in both cases modern excrescences, and are probably nearly contemporaneous in origin.

ALASKA RANGE.

That part of the Alaska Range north of the Copper Valley differs wholly in form from both of the great ranges south of it, but is believed to owe its present relief to a process similar in some respects to that which has produced the Chugach Mountains (Pl. XIII).

of either of its more important upper branches, cut a canyon-like valley but 3 or 4 miles in width across the uplifted Chugach plateau, the middle portion of the same stream reduced an area 60 or 70 miles wide nearly to base-level. The difficulty is lessened, but not removed, if we suppose weaker rocks to have been distributed over the area now occupied by the interior valley. Such an hypothesis is not supported, though not disproved, by what we know of the bed-rock geology of the region.

WRANGELL MOUNTAINS.

As to the origin of the Wrangell Mountains there can be no question. The individual peaks and ridges are masses of extravasated igneous material, which has been ejected during a period of eruptive activity that began in the recent geologic past and has continued to the present. The western end of the group came into existence after all the earlier rocks, including Jura-Cretaceous and probably upper Eocene, had been consolidated, folded, reduced, uplifted, and again dissected. The lavas of Drum and Wrangell were poured out over a topography quite comparable to that which now exists in the Chitina Valley just without the andesite border, a topography which is the product of the present general cycle of erosion, although a more recent post-lava system of modern gorges cuts across the earlier system from the slopes of the mountains to the Copper. The peaks themselves are so late in origin that their forms are not by any means all erosional, in spite of their height and their favorable situation for attack. They are the products of volcanism and erosion combined. Either predominating gives a distinct type, while intermediate forms are due to the partial ascendency of one or the other process. Mount Wrangell is an almost perfect constructional peak (Pl. VIII, *A*), and erosion has modified its original form but little. Mount Drum's contour, on the contrary, is due entirely to denuding agencies; the original built-up form is gone. Mount Sanford is a volcanic dome, one-half of which has been mined away by a sapping glacier (Pl. III, *B*), while Mount Blackburn has been etched on all sides until only its summit has the gentle original slope; all below this is a precipitous wall due to undercutting ice.

The peaks bear the same relation to the basement upon which they are piled as the great volcanic cones of the Cascade Mountains bear to the range proper. They are in both cases modern excrescences, and are probably nearly contemporaneous in origin.

ALASKA RANGE.

That part of the Alaska Range north of the Copper Valley differs wholly in form from both of the great ranges south of it, but is believed to owe its present relief to a process similar in some respects to that which has produced the Chugach Mountains (Pl. XIII).

Mountains by the broad valley of the Chitina, but on the north the topographic break between it and the Alaska Range, while entirely distinct, is a much less conspicuous feature than the Chitina Valley. Skolai Pass is regarded as its eastern limit.

Westward from the Wrangell group extends the fourth great subdivision, the Copper River basin, which, continuing across the divide between the Copper and the Sushitna rivers, includes a large area drained by the latter stream, and is regarded as a continuation inland of the wide depression occupied by the Sushitna system and by Cook Inlet.

CHUGACH MOUNTAINS.

The physiographic character and history of the Chugach Range is thus satisfactorily explained by Schrader[a] and Spencer:

Sometime after the close of Kennicott (Jura-Cretaceous) deposition, the region was uplifted and erosion began. This continued until the present Chugach Mountains were reduced to a region of low relief. Since the reduction a succession of uplifts has brought this plain to an elevation of 6,000 or 7,000 feet above sea level, and although modern stream and glacial action have dissected it most thoroughly, evidence of its original even surface is retained in its uniform sky line.

In a later interesting and suggestive paper Spencer[b] correlates this peneplain with the Yukon plateau of early Tertiary age, the suggestion of the equivalence coming in part from the continuance of rivers which, like the Alsek, are regarded as antecedent, across the coastal mountains from the interior plateau, and in part from the geographic and physiographic relations existing between the various dissected plateaus of the interior and the Pacific border.

INTERIOR VALLEY.

The Copper Valley is explained by the same authors as an erosional feature mainly produced during a halt, which occurred after an uplift of the Chugach peneplain to a point about 3,000 or 3,500 feet above the sea, but dissected somewhat after a subsequent uplift, and finally scoured out to its present form during the glacial occupation. The evidence adduced in support of this hypothesis is less clear cut and satisfactory than that for the origin of the Chugach Mountains, and some of the difficulties in which it involves the student seem to the present writer to preclude its unqualified acceptance. The principal one of these is the necessity for believing that while the lower Copper, with nearly twice the volume

[a] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901, p. 64 et seq.

[b] Spencer, A. C., Pacific mountain system in British Columbia and Alaska: Bull. Geol. Soc. America, vol. 14, pp. 117-132, 1903.

that the summits along the upper Chistochina and Gakona are near the original Eocene surface, for this region is farther from master streams than the Chugach Plateau remnants, and so has been less liable to attack and dissection since its uplift. And, again, a surface due to warping, even though it be local and relatively abrupt, and one due to degradation, even though the forms be the smooth, rounded ones developed in the old age of a drainage system, should be distinct. The element of doubt in the attempt to distinguish between these two in the region in question is due to the modification of the original surface by recent glacial action. But after all of these possible sources for the present forms are considered, the impression remains strong that the larger irregularities in the relief south of the fault line in the valleys of the Gakona and Chistochina are inherited from the old surface, which here was not fully reduced before its deformation.

In short, it is probable that the Alaska Range was an unreduced divide previous to the deformation, and that its present height is due not alone to localized differential uplift since the great Eocene and post-Eocene base-leveling epoch but to this plus an earlier relief which had not entirely disappeared in the base-leveling process.

SUMMARY.

The idea which it is intended to present in the preceding pages as to the development of the four provinces, the Chugach Mountains, the Alaska Range, the Wrangell Mountains, and the Copper basin, which are so widely different in form but seem to be related in genesis, may be summarized thus:

An old land surface, due to the combined processes of denudation and deposition in upper Eocene and later time, but probably containing extensive unreduced remnants, was deformed at a still later date by orogenic movement. This movement was markedly differential, a central part of the affected surface sagging far below the marginal uplifted portions. The northern limit of this central depressed basin is a zone of profound faulting, and its southern edge is probably a fault or a sharp flexure. The uplift south of it resulted in the elevation of a portion of the old surface without pronounced warping. It now stands at 6,000 or 7,000 feet above the sea as the Chugach Plateau. The uplift north of it was different in character. It resulted in a great tilted block, from which the Alaska Range has been carved by modern erosion.

Associated with this movement, and perhaps intimately related to it as cause or effect, came the outpouring of the Wrangell lavas. As the central area subsided, volcanic material issued from the depths and accumulated upon the surface until the Copper basin was formed and the Wrangell Mountains were piled upon its eastern margin.

These suggested relations are graphically represented in the following diagrammatic sketch (fig. 8):

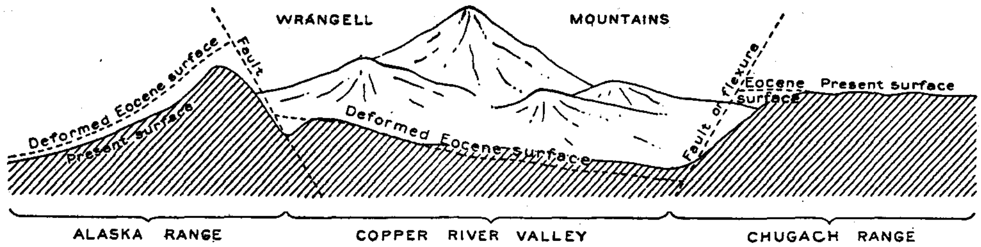


FIG. 8.—Diagrammatic sketch, showing relations of present and Eocene land surfaces in the Copper River Valley.

GLACIATION.

At present the higher areas within the central Copper River region are well above the line of perpetual snow and act as centers of accumulation from which alpine glaciers flow out into the lowlands. The most extensive of the snow fields in the interior are on the east slope of Mount Wrangell and the north slope of Mount Blackburn. Nabesna and the Chisana glaciers, 40 and 30 miles long, respectively, draining northward from this great snow field, and Kennicott Glacier, 25 miles long, draining southward from it, are the largest in the Wrangell Mountains.

The glaciers of the west slope of Mount Wrangell are much smaller than those draining in other directions from the peak. This fact is probably due in part to the lesser extent and greater steepness of the western slope, but is believed to be in part dependent upon the fact that the rocks of this face of the great volcano are still heated. On a clear morning, from many of the foothills about the upper Chetaslina and Dadina valleys, a dozen steaming rock points may be seen projecting above the ice fields of the Chetaslina and Dadina névé. Chetaslina Glacier itself is only about 10 miles in length, measured from its foot to the summit of the mountain, but the river which issues from it is nearly equal in volume to that which flows from Long Glacier in the Kotsina Valley, although the latter is at least 25 miles in length. That is, although the drainage basins of the two glaciers are approximately equal in size, if the volume of water discharged be accepted as a safe criterion, one flows much farther out into the lowlands as an ice stream than the other. It is suggested that this difference is at least partly due to the area of heated rocks underlying the upper Chetaslina snow fields.

The longest of the Mount Drum glaciers is that which flows from the great cirque on the south side of the mountain. It is about 9 miles in length and is the source of Nadina River. Other shorter glaciers drain from this peak westward and northward into Klawasi and Sanford rivers, but none of them is of especial importance.

The Mount Sanford glaciers are more numerous and more extensive than those of the lower peak to the southwest, but do not compare with others found farther east in the Wrangell group. Among the more important of them are Sanford Glacier, Drop Glacier, and West Glacier.

The greater part, but not all, of the drainage from the Alaska Range into the Copper basin is glacial. That part of the range lying east of Delta River is less than 10,000 feet high and is nearly 200 miles from the Pacific and its moisture-laden winds, which lose much of their burden in passing over the intervening Chugach Mountains. In consequence of this situation and the moderate elevations the glaciers are generally small. The most conspicuous of them is the one in which Gakona River rises. It is perhaps 12 miles long and expands near its foot to a width of 3 miles. This lower portion is a rough, pinnacled mass of ice which rises several hundred feet above the valley floor on either side and is visible for many miles in either direction.

Chistochina Glacier fills the greater part of the narrow piedmont valley north of Slate Creek and the upper Chisna. It flows east and west into branches of Chistochina River and receives as tributaries a number of smaller glaciers which flow down from the crest of the range. Gulkana Glacier is worthy of mention because part of the water which flows from it finds its way northward by way of Phelan Creek and Delta River to the Yukon, while another part flows down the Gulkana to the Copper. It is probable that the slight changes which occur from time to time in the gravel plain in front of the glacier cause this drainage to shift irregularly from one to the other of these two widely divergent routes to the sea.

The glaciers from the Chugach Mountains are much less extensive on the north slope than on the south, since the latter receives the greater amount of precipitation, and they are less important near the valley of the Copper than east and west of there, where the mountains attain greater heights. Tazlina and the Klutina rivers, tributaries of the Copper, each rise in glaciers in the Chugach Mountains and flow northward, as do several branches of the Chitina.

The glaciation of the past appears, as far as the evidence at hand has been interpreted, to have been simply an expansion of the present system. Southward from the Alaska Range, westward from the Wrangell group, and northward from the Chugach Mountains ice streams flowed out through the mountain canyons and coalesced in the Copper Valley into great ice fields comparable to those of Bering and Malaspina glaciers of the Pacific coast. The interior valley was probably buried entirely under these encroaching ice masses at their period of maximum advance. Wherever bed-rock hills are now found rising above the Pleistocene accumulations they are polished and striated, and the lower ones have smooth and rounded outlines. Along the Copper-Sushitna divide the gravel knolls are irregular in their distribution and the tracts between them are undrained. The type of topography is strictly glacial.

In the discussion of the Pleistocene deposits of the central portion of the Copper Valley it has been shown that while a relatively small portion of these were deposited directly by the ice, all are regarded as recording phenomena connected with its presence or its retreat. The formation of sand plains, gravel plains, and ponded areas, in which silt was deposited, and the occasional advances of the ice during its interrupted withdrawal, are among the incidents proved by a study of these unconsolidated beds.

ECONOMIC GEOLOGY.

INTRODUCTION.

Immediately after the close of the season of 1902, during which the field work was done on which this paper is based, Mr. Schrader and the writer prepared a joint report on the mineral resources of the Mount Wrangell district, which was published by the United States Geological Survey as Professional Paper No. 15. In this report, prepared for immediate issue in order that it might be placed in the hands of those interested as soon as possible, all the known occurrences of valuable minerals within the drainage basin of the Copper and the contiguous regions north of the Wrangell Mountains were discussed. In the pages which follow, that part of this paper which pertains to the central Copper River region and the adjacent Chitina Valley, for the preparation of which the writer was most directly responsible, is republished with slight changes, in order that all the geologic material for this area may be brought together in one volume. Similarly the economic geology of the region studied by Mr. Schrader personally will be republished substantially in its earlier form in a forthcoming report on the upper Copper, Nabesna, and Chisna regions.

In the succeeding pages the important metalliferous deposits will be discussed in the order of their importance, copper taking first place, because of the extensive and promising occurrences in the Chitina Valley. Gold, which thus far has been found only in placer form, is next in importance, and the other metalliferous and nonmetalliferous products will be treated in turn.

In connection with the discussion of the more important occurrences, brief descriptions of the routes usually followed in reaching them are introduced.

COPPER.

LOCATION.

The area in which the important copper deposits occur (see Pl. XIV) lies in the foothills that form the southern flanks of the Wrangell Mountains. It is drained by the Cheshnina, the Kotsina, and the Chitina and its tributaries. Since it is largely in the drainage basin of the latter stream, it is frequently referred to as the Chitina copper belt.

ROUTES AND TRAILS.

The field is so well known that it is not considered necessary to do more than mention briefly the routes usually followed in reaching it. For the movement of freight and supplies the early spring, from February until late April, is utilized, the frozen condition of the streams and the abundance of snow at this season greatly facilitating transportation. The military trail is followed from Valdez to Tonsina Bridge, and the Tonsina is descended over the ice; or this route may be followed only to the head of Lowe River, whence Marshall Pass is crossed and the Tasnuna descended to the Copper. After reaching the Copper the routes diverge to different parts of the field, but in general the rivers are the highways. Heavy loads can be hauled over them, and supplies may thus be landed in the various camps at a minimum cost.

During the summer season travel is less easy. The streams are then open, swift, and frequently difficult to ford, and, during the early part of the season particularly, the trails through the marshy areas are often mere sloughs. During the winter season the military route is utilized as far as Tonsina Bridge. From this point a summer trail leads down the north bank of the Tonsina to a road house on the Copper, where there are always small boats to ferry the traveler across. From the crossing of the Copper there are two routes to Strelna Creek. The southern one is very direct, but crosses the Kotsina within 7 or 8 miles of its mouth, at a ford which is considered unsafe during the midsummer high-water season. The other, known as the Kotsina trail, ascends the Kotsina nearly to its head and crosses to upper Strelna Creek by way of Pass Creek and the upper course of Rock Creek. These two routes converge at the Strelna and continue eastward as the McClellan trail to the Nizina, in the vicinity of the Nikolai mine.

Another route, sometimes followed, leaves the military trail in Kimball Pass and crosses the Copper at Taral. Ascending the mountains back of Taral it continues eastward by way of the Hanagita Valley to the Chitina, near the mouth of Tana River. Any portion of the valley of the Chitina or its tributaries may be reached from one or the other of these routes

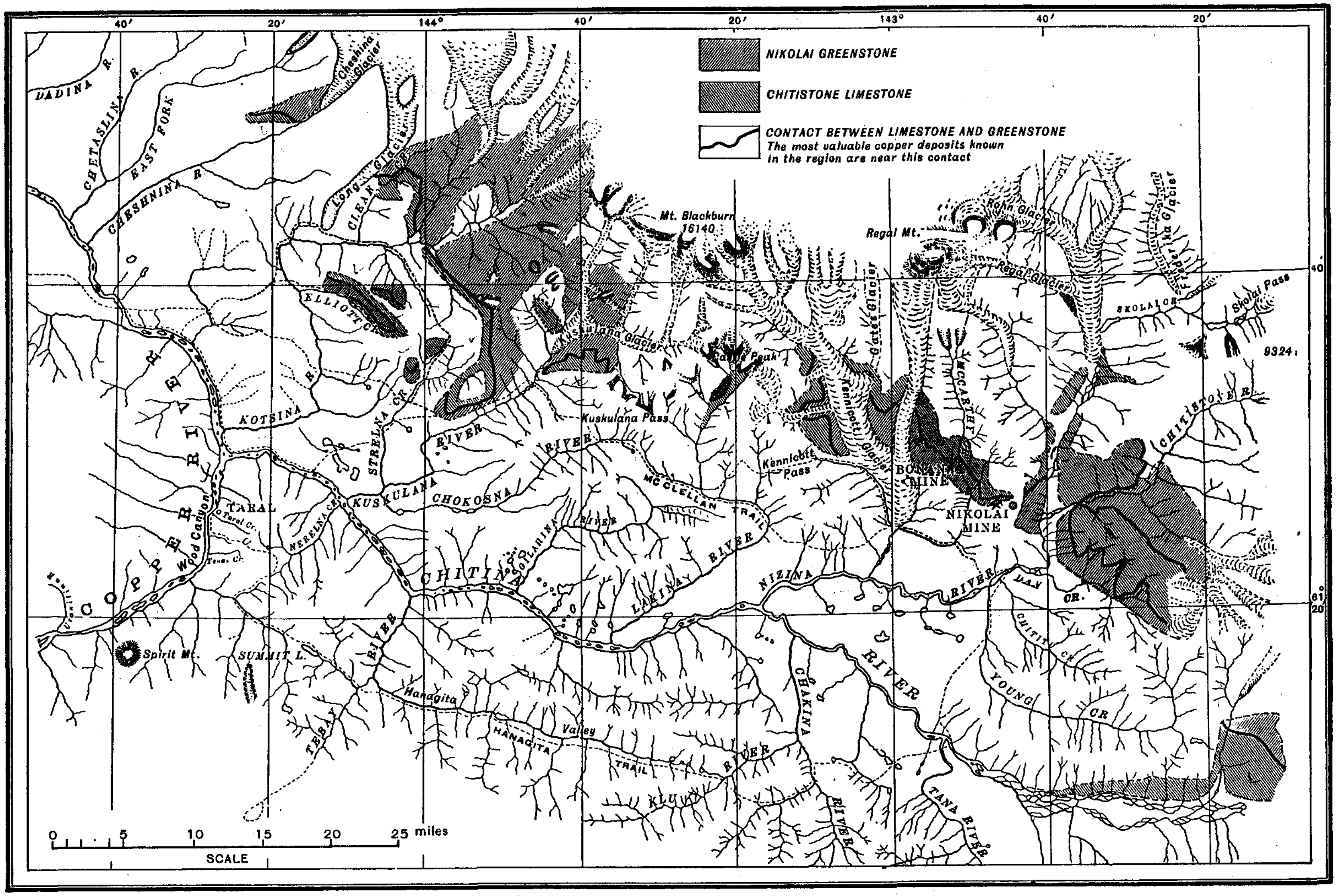
CHARACTER AND RELATIONS OF THE ORES.

The copper deposits everywhere within the Chitina district are closely associated with the body of altered igneous rocks which has been described as the Nikolai greenstone. It is believed that the copper was originally disseminated in minute quantities throughout this formation and that the valuable deposits now recognized are concentrations, in various forms, from this original widely disseminated condition. These concentrations are found at different horizons, but the richer ore bodies seem generally to have formed near the contact with the overlying limestone, usually in the upper part of the greenstone, but in one or two notable instances in the limestone itself, a short distance above the contact. This contact is easily followed and has been recognized by prospectors as marking an important economic horizon throughout the district. Its position, so far as it is at present known, is indicated on the accompanying map (Pl. XIV).

Owing to the limited amount of development in the region and the general character of the work done in the study of the deposits, it is not now possible to classify genetically the various occurrences or to give in detail the mineral association or the chemical processes that have accompanied the deposition of the various forms of copper ore. Such work must be left largely to the closer studies which may follow the mining developments of the future. For convenience of discussion, however, the ore bodies may be divided, on the basis of their form, into two general classes, the vein deposits and the "bunch" deposits. Such a division is believed to indicate in a measure the economic value of the ore bodies, those of greatest prospective worth falling in the first class.

The term "vein deposits" as it is used here is so defined as to include all tabular ore masses. This type is best represented by the Bonanza and Nikolai mines, in the eastern part of the area, and by the Goodyear and Henry Prather prospects, on Elliott Creek. With these are classed the ore bodies along bedding planes in the limestone, where they occur, as they do sometimes, in association with fissures, and the deposits along joint and fault planes and in sheer zones in the Kotsina basin. The ores may be found only in shoots within the planes that have controlled their form, but are characteristically of indefinite extent in one or two directions.

The "bunch" deposits, on the other hand, are irregularly bounded masses of ore, from a few inches to a few feet in diameter, which are usually not obviously related to fractures or fissures or joint planes, but in form are much like basic segregations in igneous rocks—that is, they generally have indefinite limits, grading from masses of practically pure ore at the center, through leaner and leaner phases, into the entirely unmineralized inclosing country rock. These "bunches" are so numerous in certain parts of the field within the upper part of the green-



MAP OF THE CHITINA COPPER AREA.

stone that prospectors who had opened a number of them 400 or 500 feet below the base of the limestone have been led to conclude that a "ledge" of ore parallels the contact at this horizon. In some places tiny fissures filled with the sulphides were traced upward into "bunches" of this character, so that it is probable that they represent replacements of the greenstone (they have not been observed in the limestone) that have grown outward in all directions from such a fissure; but, although they may originate in fissures and in exceptional cases may grade into deposits of the tabular vein type, they normally constitute a class quite distinct in form and in value.

The copper of the Chitina district occurs native and as the sulphides—chalcocite (or glance), bornite, and chalcopyrite—which are superficially altered into oxides and carbonates.

Native copper is reported by Schrader and Spencer in the country rock bordering certain well-marked veins which carry metallic sulphides. On the upper Kotsina it is found in small quantities near the base of the greenstone, in compact quartz veins, and is reported to occur as a filling of the amygdaloidal cavities in the greenstone. The source of the big nugget of Nugget Gulch (p. 103) has not been discovered, and the manner of its occurrence is not known.

The best known deposit of chalcocite is on the Bonanza claim, where the vein in limestone carries practically nothing but this rich sulphide. It occurs occasionally associated with bornite in the "bunch" deposits of the Kotsina and Elliott Creek, and in quartz stringers on the Kotsina, but is of importance only at the one locality.

Bornite is the usual surface ore of the district. The ore of the Nikolai vein, the greater part of the Elliott Creek ores, and the innumerable bunches near the top of the greenstone are chiefly of this sulphide. It is sometimes associated with quartz and calcite, particularly in fissure veins, and frequently small quantities of chalcopyrite are found with it, but it constitutes the greater part of the majority of the deposits, often with little or no trace of other copper minerals.

Chalcopyrite is found in bands 3 or 4 inches thick in the bornite of the Nikolai mine. It occurs sparingly associated with bornite and calcite on Elliott Creek, and has been brought from the upper Cheshnina in small, practically pure masses. It is not generally important in the surface phases of the deposits, which alone it is now possible to examine, but may be expected to become more important with increasing depth.

The carbonates, malachite and azurite, occur almost universally as surface stains upon the other copper minerals, and sometimes malachite appears in thin sections in veinlets in the ore masses, or as a coating, inclosing a kernel of bornite. Copper oxide, probably cuprite, is found in small quantities in the earthy condition as a surface product.

DESCRIPTION OF PROPERTIES.

CHESHNINA RIVER.

On the south side of the Wrangell Mountains the western limit of the Nikolai greenstone and the Chitistone limestone, the copper-bearing formations of the district, is exposed in the upper basin of Cheshnina River. Beyond this point the only older rocks that are revealed by the cutting of the streams beneath the lava covering are schists and massive intrusives.

On the Cheshnina some prospecting was done by Mr. A. W. Tibbitts and associates during the season of 1902, and fair indications are reported, both of ores and native copper, although developments are not sufficiently extensive to determine the magnitude of the deposits. The ores that were shown to the writers consist of solid masses of chalcopyrite, or of the same mineral associated with epidote and quartz, from Bear Creek, and of bornite in quartz from Mount Chitty. A selected sample of the bornite proved upon assay to carry $\frac{1}{10}$ ounce of gold and 4.52 ounces of silver per metric ton of 2,204.6 pounds. The chalcopyrite has a trace of gold and 1.8 ounces of silver per metric ton. Nuggets of native copper are found also in the stream wash.

KOTSINA RIVER.

Schrader and Spencer[a] report having seen bornite ore from the heads of Clear (Chitty) and Barrett creeks, where the greenstone outcrops, and the same writers report on the Warner prospect[a] at the mouth of Rock Creek and on the Hoffman prospect on Copper Creek. These two prospects were revisited in 1902, and in addition several other localities on the upper Kotsina were examined. It is to be regretted that practically no development work has been carried on in this section since 1900, so that nearly all the properties are mere prospects as yet, and must be judged accordingly. The Kotsina properties which it was possible to examine are described below, in the order of their occurrence from the head of the stream down.

Keystone claim.—Two short forks, both glacial streams, unite to form the main Kotsina. The southern one of these drains two glaciers. Just below the foot of the northernmost of these glaciers, in a sharp little post-Glacial gorge, is the Keystone claim. Here, in the wall of the canyon, in the greenstone, 4,000 or 5,000 feet stratigraphically below the limestone contact, are some compact quartz stringers and lenses, varying in width from a mere thread to 5 or 6 inches. They strike east and west and are approximately vertical.

[a] Schrader, F. C., and Spencer, A. C., Geology and Mineral Resources of a Portion of the Copper River District, Alaska; a special publication of the U. S. Geol. Survey, 1901, p. 84.

Epidote as a gangue mineral in the veins is associated with the quartz, which it sometimes equals in amount. Native copper occurs as grains inclosed in the epidote and in single quartz crystals, but is more abundant in later irregular crevices running through both minerals of the gangue. A small amount of chalcocite is present also, and in one prominent example fills a narrow fissure which intersects masses of epidote and quartz and is evidently later than either, so that the order in which the vein materials were deposited seems to be: Epidote, quartz and copper, copper and chalcocite. In the greenstone of the wall rock the principal change seems to have been a uralitization of the augite.

The occurrence is thus interesting genetically, although of no economic importance.

Copper King claim.—This prospect is situated on the north side of the Kotsina Valley, about one-fourth mile west of the Keystone claim and 700 or 800 feet above the river level. It consists of an altered belt of greenstone, in part amygdaloidal, extending several feet east from a well-defined north-south vertical crevice, along which there has probably been some movement. The greenstone within this altered zone has been rendered quartzose, the quartz occurring as stringers and as a filling of the amygdules. The septa between the latter are sometimes changed to granular epidote and chlorite.

Native copper occurs here and there in the mass in grains and flakes, sometimes intimately associated with chalcocite. The latter mineral occurs with the native copper and in tiny crevices, which seem to be later than the general alteration and silicification.

Eleanor, Davy, and associated claims.—The sharp ridge south of the upper Kotsina, separating Peacock and Roaring Gulch creeks, is capped near its southern end by a picturesque remnant of the Chitistone limestone, while the underlying greenstone outcrops along all of the lower slopes. A number of claims have been staked on the Peacock Creek side of this divide, about 2,500 feet above the Kotsina Valley, in that belt in the greenstone, a few hundred feet below the limestone contact, which seems everywhere to carry "bunches" of copper ore. No development work has been done here, but the exposures on the faces of the greenstone cliffs show small, irregular ore bodies from a few inches to 2 or 3 feet in diameter. They usually have cores of nearly pure bornite or chalcocite, but marginally these copper minerals become mingled with the surrounding greenstone, as though the replacement of the greenstone had been less complete near the limits of the mass.

In one or two instances narrow fissures from one-half inch to 1½ inches wide, filled with copper sulphides, were noted, extending downward from ore pockets, but in the majority of cases no such connection between pocket and veinlet is to be seen.

The sulphides carry small quantities of silver, one assay showing 3.3 ounces per ton.

Skyscraper claim.—A shallow open cut has been made on this claim just across the crest of the ridge west of the Eleanor, Davy, etc., and in it ores of the same general character and mode of occurrence are revealed.

Warner prospect.—This property (see Pl. XV, *B*) is on the west bank of Rock Creek near water level and about one-fourth mile from Kotsina River. It was visited and described by Schrader and Spencer in 1900, but development work was continued for some time after their visit, and the character of the deposit is therefore somewhat more clearly revealed at present.

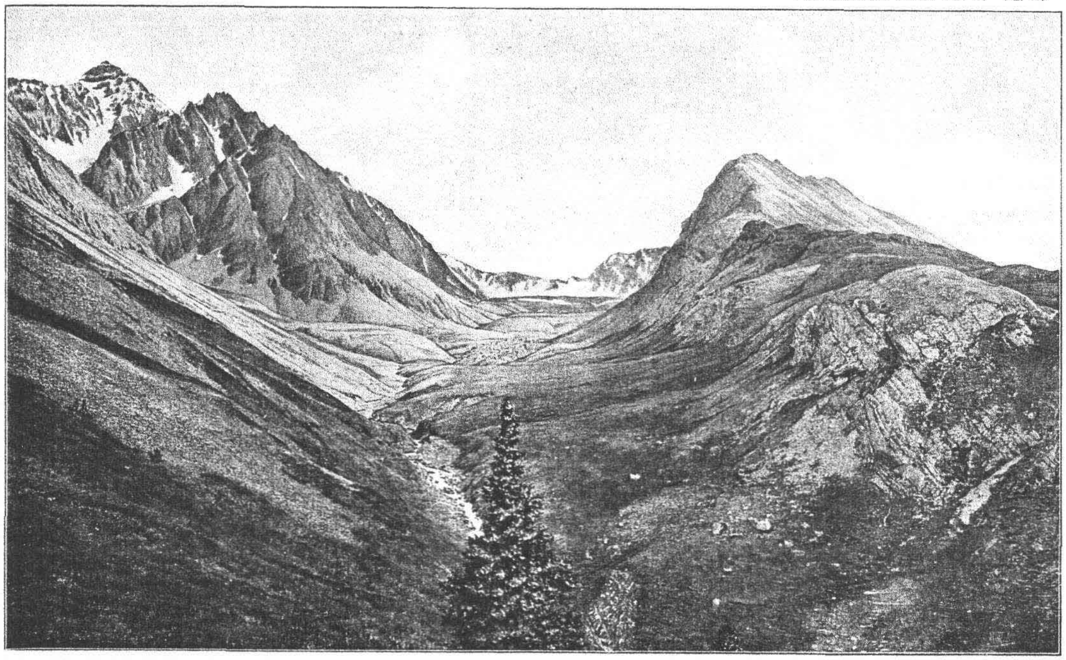
The face of the greenstone bluff adjoining Rock Creek has been stripped over an area about 25 by 40 feet, and a tunnel, running S. 40° W., has been driven for a distance of 18 feet along a zone of slight movement in the greenstone. This zone is from 1 inch to 1 foot wide and is marked by crushed country rock, considerable calcite filling (the bodies of calcite usually being lenticular in form), and a relatively small amount of quartz in stringers, closely associated with the occasional small ore bodies.

On the face of the bluff above the tunnel, the main lead, fairly well defined, is marked as in the tunnel by a succession of calcite lenses, measuring up to 1 foot or more in cross section. The main lead is paralleled at a distance of 3 or 4 feet by a second plane of movement, along which occur quartz stringers from one-fourth to one-half inch in width, with which are associated limited quantities of copper sulphides. The adjacent and intersecting joint planes in the greenstone all show evidence of some mineralization by copper-bearing solutions.

Bornite, the principal copper mineral present, is accompanied by a little chalcopyrite. The ore occurs in small irregular bodies along the crushed zone, masses 8 inches to 1 foot in thickness having been encountered while driving the tunnel. The deposit, however, does not appear to be continuous.

G. & B. and United Verde claims.—Rock Creek is joined, about 1¼ miles above its mouth, by its principal eastern tributary, Lime Creek, which flows nearly west along the contact between the greenstone and the overlying limestone. On the north side of the valley of Lime Creek (Pl. XV, *A*), one-half mile above its mouth and a few hundred feet stratigraphically below the top of the greenstone, is the G. & B. claim.

Early in July, 1902, work had been started on an open cut, but had not been carried far enough to give a definite idea of the extent of the ore body



A. VALLEY OF LIME CREEK, A TRIBUTARY OF ROCK CREEK.

B. WARNER PROSPECT AND TUNNEL, NEAR MOUTH OF ROCK CREEK.

tapped. From the partial exposures, however, it appears highly probable that the ores of bornite and chalcopyrite belong to the "bunch" type and not to the fissure-vein type, although small amounts of quartz are present, both in the ores and in the surrounding greenstone. The ore body appears to represent a replacement of an area within the greenstone, the replacement being in places sufficiently thorough to give blocks 1 or 2 feet in diameter, which contain at least 50 per cent of copper minerals. Some material taken from the dump yielded 10.64 per cent of copper and 0.75 ounce of silver per ton.

A few hundred feet above the G. & B. is the United Verde claim. Here, on a cliff of greenstone, is exposed a small body of bornite ore. Perhaps its outcrop covers 4 or 5 square feet of surface. Just below the exposure is a narrow quartz stringer, but there is no surface connection between them. Other smaller isolated ore bodies occur here and there in the greenstone. None of them, however, are in vein form.

KLUVESNA CREEK.

Native copper and bornite ores are reported along lower Kluvesna Creek, where the limestone-greenstone contact outcrops. A number of claims have been staked in this section, and sufficient work has been done on them to hold title, but lack of time prevented a visit to any of the holdings.

COPPER CREEK.

On a western tributary of Copper Creek, about 3½ miles from the mouth and 1,500 or 1,600 feet above Kotsina River, on a spur in limestone 125 feet above the nearest exposure of greenstone, is a shallow open cut, with a shaft 6 or 8 feet deep at one end. The shaft has been dug in a poorly defined shoot in a shattered zone in the limestone. Mr. Schrader visited the property in 1900, since which time there has been no development, and the following is quoted from his description:[a]

"The excavations have disclosed three poorly defined zones of mineralized material, each from 1 to 3 feet in thickness, and apparently made up of altered limestone rather than of ordinary vein materials. There is no well-defined vein, but a general north-south trend is observed, and there is a cleavage in the rocks having a steep dip toward the east. The deposit is made up of chalcopyrite and bornite somewhat stained with malachite and iron oxide. The ore appears to be a replacement of the limestone which forms the country rock."

[a] Geology and Mineral Resources of a Portion of the Copper River District, Alaska, p. 85.

ELLIOTT CREEK.

LOCATION AND ACCESSIBILITY.

Elliott Creek heads near the sources of Rock and Strelna creeks, and flows for a distance of 10 miles a few degrees north of west in a narrow but picturesque valley. It then turns southwest through a succession of canyons and joins the Kotsina 15 or 16 miles above its mouth.

Practically all of the tributaries of Elliott Creek enter it from the north. None of them is more than 2 miles long. In consequence the drainage basin is narrow, and, walled in, as it were, on the north and south by abrupt mountains, its existence is scarcely suspected until one surmounts one of the bounding ridges.

The Elliott Creek Valley was first entered by Messrs. Elliott and Hubbard from Copper Creek, in 1899, and the same route into the valley was used during the following year. But during 1901 and 1902 the necessity for crossing the steep

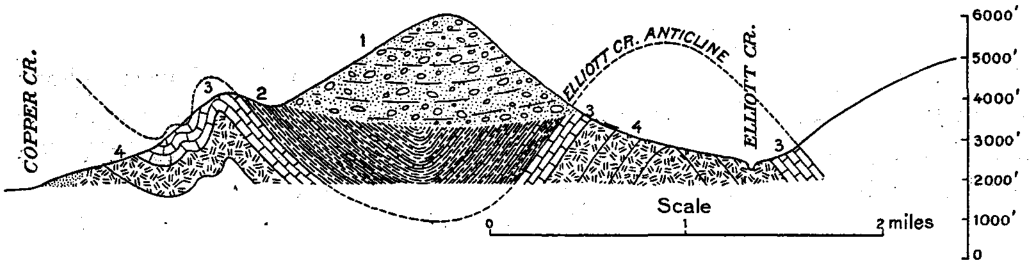


FIG. 9.—Profile and section from Copper Creek to Elliott Creek. 1, Kennicott conglomerate; 2, Triassic shale and limestone; 3, Chitistone limestone; 4, Nikolai greenstone.

and high divide separating it from Copper Creek was obviated by the construction of an excellent trail along the north slope of the Elliott Creek Valley to a point 3 miles above its mouth, where the Kotsina is fordable at any except the highest stages of water. West of the ford the new trail joins the well-established upper Kotsina trail leading to Valdez by way of Tonsina Bridge and the military trail. Elliott Creek may also be reached from the head of the west fork of the Strelna and from upper Rock Creek.

GEOLOGY.

A section from lower Copper Creek to Elliott Creek (fig. 9) shows a succession of folds in the conformable greenstone, limestone, and Triassic beds, with a great body of Kennicott conglomerates overlying the eroded edges of these older rocks and forming the crest of the ridge separating Elliott Creek from the other streams to the north. On the Copper Creek side of this ridge a syncline and its succeeding anticline may be seen in the pre-Kennicott beds, before the structures are obscured by the overlying conglomerates, and on the Elliott Creek side the limestone and greenstone emerge from beneath these younger formations in an unsymmetrical anticline near whose axis Elliott Creek flows. As one consequence of this anticlinal relation, the head of Elliott Creek is encircled by a scarp of white limestone, separating the gray Kennicott conglomerates above from the dark Nikolai greenstone below. This scarp continues westward along the north slope of the Elliott Creek Valley, rising higher and higher relative to the stream, until it passes from view in the direction of Kotsina River. Whether its disappearance is due to the introduction of complex structures or to a simple overlap of the Kennicott beds was not determined.

The south slope of the valley of Elliott Creek is not broken by the limestone scarp, which is so conspicuous a feature of the opposite wall, except near the source of the creek; for, while the axis of the narrow anticline and the course of the stream coincide there, they diverge downstream until Elliott Creek is found

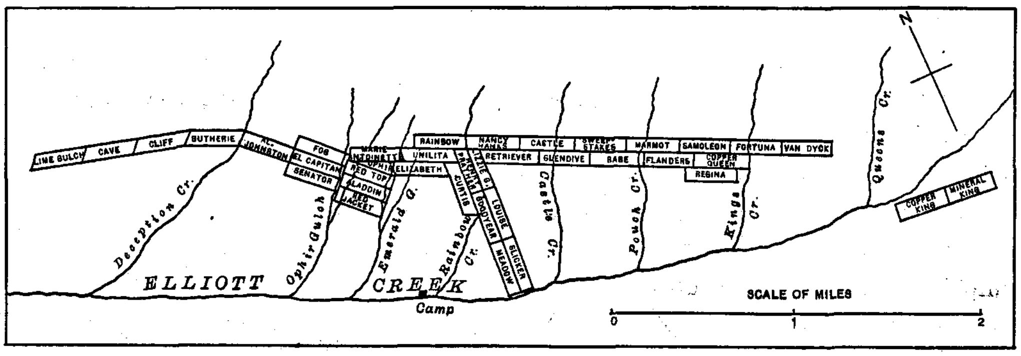


FIG. 10.—Map of the Elliott Creek copper claims.

flowing well to the south of the ridge of the anticline, and the limestone bed on the south side of the valley gradually disappears from view near creek level, beneath the overlying formation.

RELATION OF ORE DEPOSITS TO GEOLOGIC STRUCTURE.

As all of the Elliott Creek deposits on which work has been done are in that belt in the greenstone which extends downward a few hundred feet from the contact with the limestone, the position of these deposits relative to the stream is dependent absolutely upon the structure. As a consequence, they all occur in a zone which extends along the north side of Elliott Creek, well up the valley slope, encircles the head of the valley, and disappears below water level on the south side of the stream, a short distance below its source (see fig. 10). This position in a belt encircling the valley means that the deposits are well situated for economical exploitation, should their richness justify their development.

DESCRIPTION OF PROSPECTS.

Mineral King.—The Mineral King claim is near the head of Elliott Creek, 12 miles from its mouth, on the south side of the valley, and about 215 feet above creek level. About 300 feet vertically, and about the same distance stratigraphically above it, the massive limestone strikes east and west and dips 45° S.

The development on this claim in early July, 1902, consisted of an open cut about 20 feet long and 6 feet deep toward the back, in which a mineralized zone is laid bare. Several tons of ore had been taken from the cut and were piled up on the side next the valley. The prospect is developed along a rather indefinite belt in the amygdaloidal greenstone, which trends N. 60° W. and is nearly vertical. The rock in this belt is somewhat crushed, but whether this effect is due to mechanical strains or to changes in volume accompanying the mineralization is not evident. The ore impregnations coincide roughly with this crushed zone and, like it, are without sharp boundaries. There seems to be no definite vein filling, the greenstone within the mineralized belt differing from the normal rock without only in its partial replacement by the sulphides, chalcocite and bornite. The extent of the mineralization along this belt in the greenstone seems to be limited, since at a point 25 feet west along the strike it is no longer evident, so that the deposit probably represents an ore shoot. The ore body which it is intended to exploit is about 4 feet wide in the cut, and a sample taken at intervals of 4 or 5 inches across this zone yielded, when assayed, 10.85 per cent copper. Surface staining by carbonates is extensive in the vicinity.

Copper King.—This prospect is about 800 feet southwest of the Mineral King and, like it, is on the south side of Elliott Creek, in the greenstone lying about 300 feet stratigraphically below the base of the limestone.

The development work here consists of a cut about 15 feet long, penetrating 6 or 8 feet into the greenstone. The prospectors have what they call two "ledges"—i. e., two irregular mineralized masses, showing considerable bornite and smaller quantities of chalcopyrite, and separated by perhaps 15 feet of greenstone. There is no trace of vein matter and no evidence of definite fissuring, the ore bodies being more or less thoroughly impregnated portions of the greenstone mass, without sharp boundaries or definite limits. The greater diameters of the visible ore bodies appear to lie in planes which are parallel to the limestone-greenstone contact and to the pseudobedding in the greenstone. The copper-bearing solutions followed of course the easiest channels. These were often the bedding planes, the surfaces of the old basalt flows, but were sometimes irregular cracks, due to cooling or folding or later chemical alteration of the lavas. These channels were thus essentially irregular, as compared with true fissure veins, and the ore masses which derive their form in part from them are likewise very irregular.

Copper Queen.—This prospect is on the west slope of King Creek, about 1 mile below the Copper King claim. No development work had been done upon it at the time of our visit. The surface showing consisted of a small outcrop of greenstone impregnated with chalcopyrite.

Marmot.—This is situated on the west side of Pouch Creek, within 25 feet of the base of the limestone. It was undeveloped at the time of our visit, but appears from the scanty outcrop to be the same character of deposit as the Mineral King and Copper King, except that chalcopyrite instead of bornite is the principal ore.

Louise.—This claim is on the east side of Rainbow Creek, nearly half a mile above its junction with Elliott Creek and about 3 miles from the head of the valley. The open cut, which represents the development work done in the midsummer of 1902, is on a steep hillside 75 or 100 feet above the bed of Rainbow Creek and stratigraphically several hundred feet below the base of the limestone. Here, in the shallow cut, a slickensided face of greenstone, forming a well-defined and (so far as exposed) regular foot wall, is to be seen. This face strikes S. 10° W. and dips 70° W. The cut does not expose an equally definite hanging wall, but adjacent to the foot wall is a crushed zone which has a maximum width of 15 or 16 feet. Within this zone the greenstone is generally irregularly fractured, but at the present surface there exists in the center of this crushed mass a "horse" of solid greenstone about 7 or 8 feet wide. It is probable that the slickensided foot wall is a fault plane, but since no displacement was observed in the limestone above, its throw can not be great. The mineralization within this belt consists of an impregnation of chalcopyrite and bornite, the latter mineral being more abundant. The impregnation follows the fractures and partakes of their irregularity, the exposed surfaces of the greenstone fragments generally showing more or less ore.

A commercial sample taken across the 16-foot face is reported by the owners to have yielded 20 to 25 per cent copper. Although without more development work it is not possible to predict the future of this claim, its situation along a definite zone of crushing, which provides an easy channel for mineralizing solutions, gives a basis for the hope that it may contain fairly continuous ore bodies.

Goodyear.—Across Rainbow Creek from the Louise claim, and a few feet below it, an open cut reveals a well-defined fissure vein 4 to 5 feet wide, striking N. 12° E. and dipping 45° SW. The vein can be traced 50 or 75 feet up the slope directly toward the limestone contact before it is buried under the talus.

The gangue minerals are quartz and calcite, entirely distinct from the perfectly definite walls of greenstone. This gangue carries heavy bodies of bornite and a smaller quantity of chalcopyrite. While the heavy ore bodies are confined to the vein, the shattered hanging wall and the more massive foot wall are impregnated with copper sulphides for some distance above and below.

In the upper part of the open cut, which represents the assessment work done on this claim at the time of our visit, a slight horizontal fault has displaced the vein laterally, so that the hanging wall above the displacement is continuous with the foot wall below it. This illustrates well the tendency of the greenstone mass to accommodate itself to stresses by faults of slight throw.

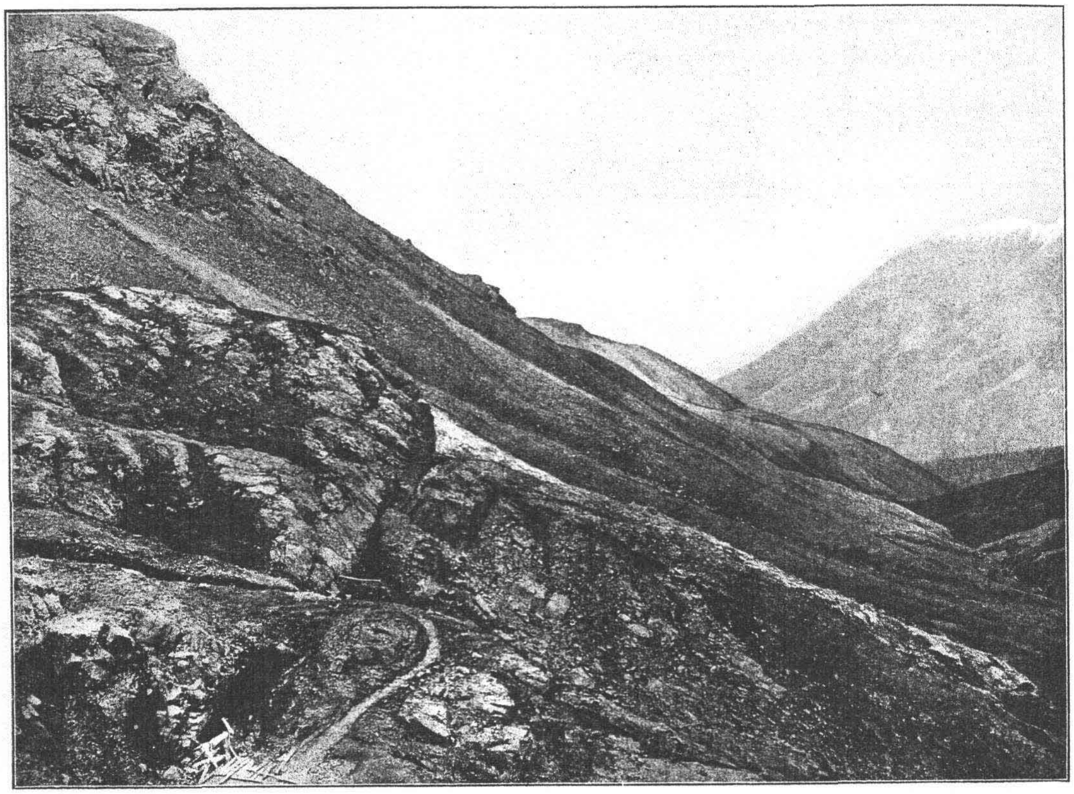
Henry Prather.—About 25 feet above the Goodyear claim, and practically parallel with it, is another similar deposit which has been exposed in an open cut. Here a fissure about 4 or 5 feet wide is filled with a quartz-calcite gangue carrying rich bornite ore with some associated chalcopyrite. This filling, while very definite in the cut, pinches out about 20 feet higher up the slope, then reappears as a lens. There has probably been slight faulting along the fissure, the condition of the greenstone forming its hanging wall indicating movement, and probably the latest portion of this faulting postdates the vein filling, as is so evidently the case in the Goodyear claim just below.

Elizabeth.—High up in Emerald Gulch, but several hundred feet below the limestone, is a striking outcrop, on which no work had been done in early July, but which resembles, so far as it is exposed, the type of deposit exhibited in the Goodyear and Henry Prather cuts.

Encircling the hill for a distance of 30 or 40 feet is a succession of small outcrops showing copper indications through a vertical interval of from 2 to 6 feet. The exposures show a definite gangue entirely different from the greenstone mass, and in this gangue are bodies carrying a large percentage (estimated to be from 40 to 75 per cent) of bornite and chalcopyrite, and measuring 2 to 3 feet in greatest diameter. Presumably a vein of some importance gives rise to these fragmental exposures. Other small outcrops of ore-bearing rock in the vicinity are insufficiently exposed for any sort of determination. A small specimen of selected ore assayed 1.87 ounces of silver per metric ton, and 21.69 per cent of copper.

Fog.—On the crest of the ridge separating Ophir Gulch and Deception Creek the Fog claim has been staked. The outcrop shows a heavy calcite lens in the greenstone, associated with which is a small amount of chalcopyrite. This weathers and gives the rusty and green stains of iron and copper.

Albert Johnson.—This is a natural exposure of greenstone in Deception Creek, showing green carbonate stains and exhibiting some bornite along crevices. The exposures here are of the Mineral King type.



A. VIEW OF NIKOLAI MINE ACROSS UPPER NIKOLAI CREEK.

B. VIEW OF BONANZA MINE FROM HORSESHOE TRAIL.

CHITINA DRAINAGE BASIN.

The writer was unable to visit the copper belt south and east of the Kotsina during the summer of 1902, so that descriptions of the occurrences there are quoted from the report of Messrs. Schrader and Spencer, who saw these deposits in 1900. Since that time assessment work has been done on the important properties each season, but, except in the statements as to the amount of development, these earlier descriptions are adequate.

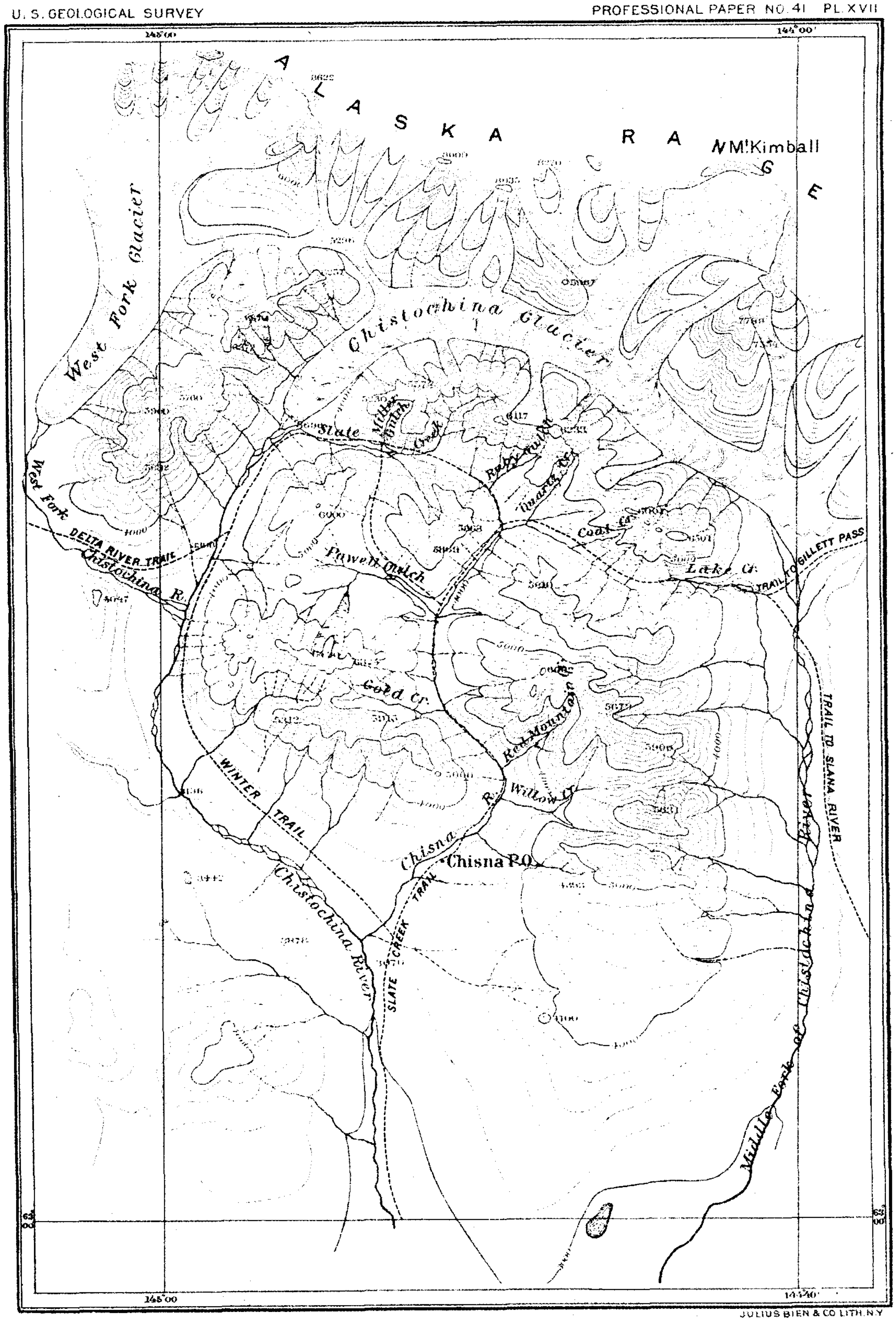
Strelna Creek deposits.—A considerable amount of prospecting has been done within the region drained by Strelna Creek, several mineral-bearing veins have been recognized, and some good prospects have been located. The ores comprise bornite, chalcopyrite, and native copper.

"About 2 miles above the fork the north branch of this stream is crossed by the contact of the massive limestone and the greenstone, along which there is a mineralized zone some 40 feet or more in width. This zone is impregnated to a greater or less extent throughout with sulphides of iron and copper, but the 8 or 10 feet of limestone next to the contact is considerably altered and contains a larger amount of the sulphides than the neighboring rock. The greenstone is mineralized only a short distance from the contact.

"There are many evidences that movement has taken place in this vicinity, since the rocks are folded and crushed and the planes of shearing show slickenside surfaces. In one case a considerable fault was observed dislocating the base of the limestone. This mineralized zone is an example of the contact as a favorable position for the deposition of ores.

"*Kuskulana River.*—At the time of the writer's visit there had been no effective prospecting along the tributaries of the Kuskulana, but in traversing the region good float was noticed in many places, and in one instance a well-marked vein was found. In the bed of the stream that has been named Nugget Gulch a large mass of copper was discovered partly buried in the gravel. This was afterwards uncovered by prospectors and reported to be about 8 feet in length, with other dimensions from 3 to 5 feet. Along the southeastern side of the glacier fragments of copper ore were also observed at several places, and there can be but little doubt that good discoveries will be reported from the Kuskulana drainage.

"*Bonanza mine.*—The Bonanza mine is located upon a high ridge between Kennicott Glacier and McCarthy Creek, at the contact of the greenstone and the limestone [see Pl. XVI, *B*]. It is 6 miles or more above the foot of the glacier and about 8 miles west of the Nikolai mine. Here, upon the western slope of the ridge, is exposed the largest and richest body of ore thus far reported from the Chitina region. The vein occupies a true fissure, which cuts across the contact of the greenstone and limestone, though for some distance below the contact the vein is barren. The mass of the ore occurs in the limestone, from the contact to a height of perhaps 150 feet along the slope, and is exposed for a horizontal distance of nearly 400 feet. In width the vein is irregular, varying from 2 to 7 feet. Its course is N. 40° E. There is no quartz or other vein mineral associ-



JULIUS BIEN & CO. LITH. N.Y.

MAP OF CHISTOCHINA GOLD FIELD, ALASKA

T. G. Gerdine, topographer

Scale

1 0 1 2 3 4 miles

Contour interval 200 feet

products in depth, as oxide or sulphide enrichments. The low temperatures of interior Alaska at present and the lower temperatures, or at least the more uniformly low temperatures, during the recent geologic past, when glaciation was much more extensive than now, are conditions unfavorable to those chemical processes, to which certain important enrichments—the secondary bonanzas of many copper camps—are believed to be due.

The region is extensively glaciated, but the present glaciers are but insignificant remnants of their predecessors. Probably no single occurrence of ore is described here which has not recently been buried under an ice mass and subjected to an unknown amount of ice erosion, resulting in the removal of those surface forms of the ores which may previously have accumulated.

The present surface ores are usually the richer sulphides, bornite, and chalcocite. No gossan cap over any of the veins and no extensive deposits of oxides or carbonates have been observed, the latter minerals, where seen, being mere surface films and obviously due to recent atmospheric action.

It is probable, then, that there has been no deep alteration, because of climatic conditions, and that glacial action has recently removed much of that shallow altered zone which perhaps did exist, these conditions together resulting in the presence of bornite and chalcocite as the surface ores, and leading us to expect no general increase in richness with depth. The present surface zone is the one that corresponds to the bonanzas due to secondary enrichment, in mines farther south, and the changes to be expected in deeper explorations are changes from the richer sulphides to chalcopyrite.

GOLD.

CHISTOCHINA GOLD FIELD.[a]

LOCATION.

The Chistochina gold field (Pl. XVII) covers a small area in the northwestern part of the Copper River basin. It lies just south of the main mass of the Alaska Range, near the headwaters of a few small streams that are tributary to Chistochina River. It is crossed by the one hundred and forty-fifth meridian of west longitude and is a few miles north of the sixty-third parallel of north latitude.

GEOGRAPHY AND DRAINAGE.

The gold field does not lie in the Alaska Range proper, but in a group of foothills that are separated from the main chain by a conspicuous piedmont valley, which extends 20 or 30 miles east of the head of the Chistochina River and is occupied by Chistochina Glacier and the upper courses of the

---

[a] The writer is indebted to Messrs. Hazelet, Meals, Tully, Jacobson, Dempsey, and others, for information concerning this district.

Middle Fork, the Slana, and the Tok, and the various passes which connect these streams.

North of this feature the peaks of the great range rise abruptly to elevations of 8,000 or 9,000 feet. South of it the nearest foothills are 6,000 or 6,500 feet in height, but decrease in altitude as their distance from the axis of the range increases. These foothills are in detached groups, which, near the main range, occupy relatively large areas, the valley lowlands separating them occupying relatively small areas. This relation is in a measure reversed along the lower Chistochina near the Copper, where the foothills are often small islands rising above the general gravel plain of the Copper Valley.

The particular foothill group in which are found all of the producing claims of the district lies between the main Chistochina and Middle Fork and south of the western end of the piedmont valley that has been described. It is drained by tributaries of one or the other fork of the Chistochina, the largest of these tributaries being the Chisna. This small river rises in a cirque 3 or 4 miles south of the east end of Chistochina Glacier. It flows north of west for 2 miles or more, directly toward a low pass leading to Slate Creek, then turns abruptly southward and joins the Chistochina 7 or 8 miles below the mouth of West Fork. Its total length is only 12 or 13 miles. Slate Creek lies west of the upper Chisna, its lower course occupying the western end of the same depression which has controlled the upper course of the larger stream. Before entering this cross valley it flows southward for a little more than 1½ miles from the two small glacial remnants in which it rises, and after entering it follows it westward for 2 miles to the Chistochina, which it joins just at the foot of the glacier. Its total length, therefore, is not over 4 miles. Miller Gulch, the most important producer of the district, is a small northern tributary of Slate Creek, less than a mile long.

HISTORY.

The first locations in the Chistochina gold field were made by Hazelet and Meals, in the summer of 1899. These gentlemen were among the army of argonauts who crossed the Valdez Glacier in the spring of 1898 with the idea of prospecting within the Copper River basin. Building a boat on the Klutina, they descended that stream and ascended the Copper and the Chistochina, reaching the present location of Chisna post-office in early July. They found encouraging prospects here, but their provisions becoming exhausted, they returned to Copper Center for a larger supply, reaching the Chisna again in August of the same year. In September they returned to Copper Center and during the following winter sledded supplies to a point on the Chistochina near the mouth of the East Fork, and from this base continued their work on the lower Chisna throughout the summer of 1899. Coarse gold was discovered at this time, and several locations were made.

In the spring of 1900 these operators, together with a number of the present Miller Gulch and Slate Creek claim owners, returned to the Chistochina with a good stock of supplies, a sawmill, and some hydraulic machinery. During this summer gold was discovered on Slate Creek and Miller Gulch by Coles, Jacobson, Kramer, and Levell, the ground staked at that time having since proved to be much the richest in the district.

Since that time the activities within the district have been chiefly in the form of development of properties already staked, although some further locations have been made in the region between the Gakona and the Chistochina on Excelsior Creek and the headwaters of the Shnu.

TRAILS.

The route usually followed from Valdez to the Chistochina gold field is along the well-established military trail to the mouth of Chistochina River. From this point the Slate Creek operators follow the Chistochina to the mouth of the Chisna, and, ascending this stream, pass through Powell Gulch to Slate Creek, at the mouth of Miller Gulch. The total distance from Valdez to Slate Creek by this route is about 225 miles.

A shorter route was established by Hazelet and Meals in 1900 by way of Gakona River. This so-called Gakona trail leaves the military trail about 5 miles north of the Gakona ford and swings westward to the bank of Gakona River, which it follows northward to a point almost directly south of Chisna. Thence it crosses to the Chistochina through a series of low passes which afford a very direct route, but are reported to give soft footing during the early summer months.

In addition to these direct lines of approach from Valdez, the Chistochina field may be readily reached from Tanana River by way of the Delta, which is ascended through the Alaska Range to the head of its east fork, known as Phelan Creek. From the foot of the glacier, in which the latter stream and a branch of the Gulkana rise, a route leads eastward across the headwaters of another branch of the Gulkana to the Gakona, at the foot of the glacier, and, crossing this stream, descends the West Fork of the Chistochina to its junction with the main river, which is reached in a distance of about 26 miles from the source of the Delta. This route lies entirely above timber line from the Delta to the Chistochina, but does not involve high climbs and throughout the greater part of the distance is marked by a well-established trail followed by the Delta River stampeders of 1901.

The military trail to Eagle is easily reached from the Chistochina district by ascending the Chisna to the low pass leading from its head to the Middle Fork of the Chistochina, whence Gillette Pass and Tok River are approached by either of two routes. The northern route follows the Middle Fork to its head and crossing a low pass to the upper Slana descends the latter 5 or 6 miles to the mouth of the small stream draining from Gillette Pass. The southern route involves the descent of Middle Fork for a distance of about 5 miles to the Mankomen Valley. Following this eastward the trail reaches the Slana 4 or 5 miles below Gillette Pass, at a point where its course changes from south to east. Having reached the Slana, the traveler may ascend it and cross to the Tok by way of Gillette Pass, or descending it may reach the military trail just below Mentasta Pass. The total distance from Miller Gulch to the Slana by way of the more southerly route is not over 25 miles. The northern trail is somewhat shorter. Either is entirely practicable for packers or pack animals.

MAIL AND TELEGRAPH FACILITIES.

With the establishment of the United States mail route from Valdez to Eagle, and later of the Signal Service telegraph over the same line, facilities for communication with the outside world were greatly improved for the Chistochina field, as for the Copper Valley generally. A telegraph office at the mouth of Chistochina River is only about 35 miles from the gold field, and a post-office—Chisna—with service twice a month in summer and once a month in winter, has been established 1½ miles above the mouth of Chisna River, in the southern edge of the district.

GOLD OCCURRENCES.

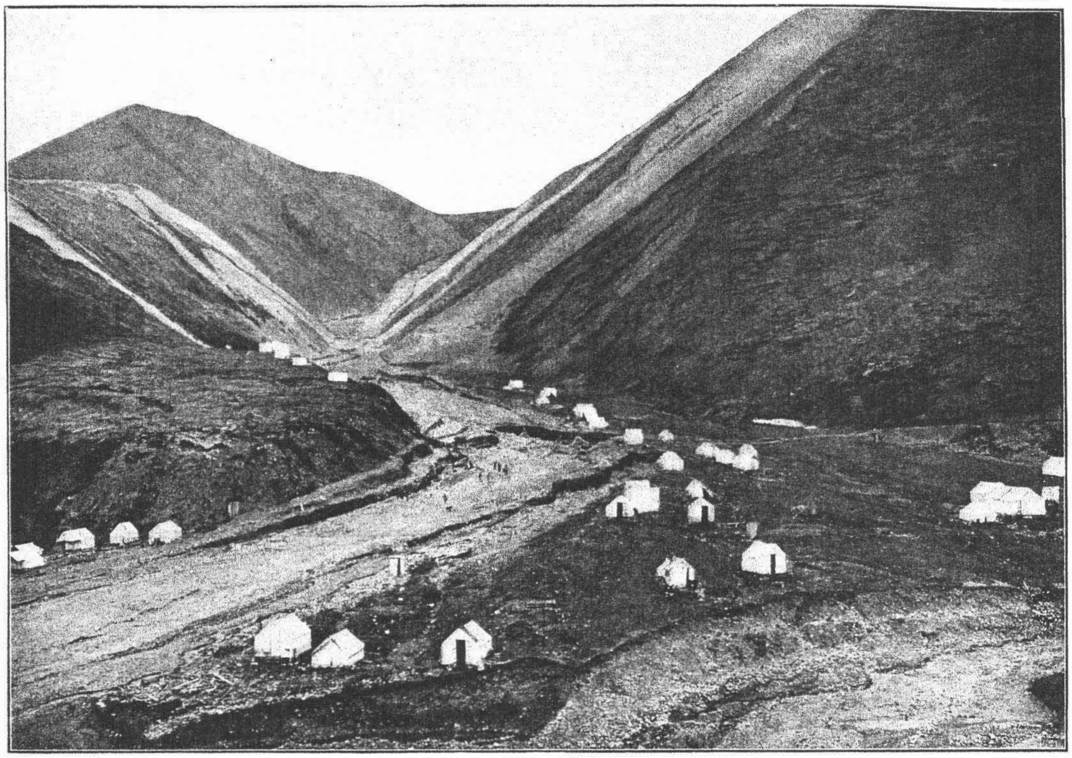
OUTPUT.

It is estimated by Mr. G. C. Hazelet that the camp produced $25,000 in 1900 and $115,000 in 1901. Placing the yield for 1902 at $225,000, the total output since the discovery of the district becomes $365,000.

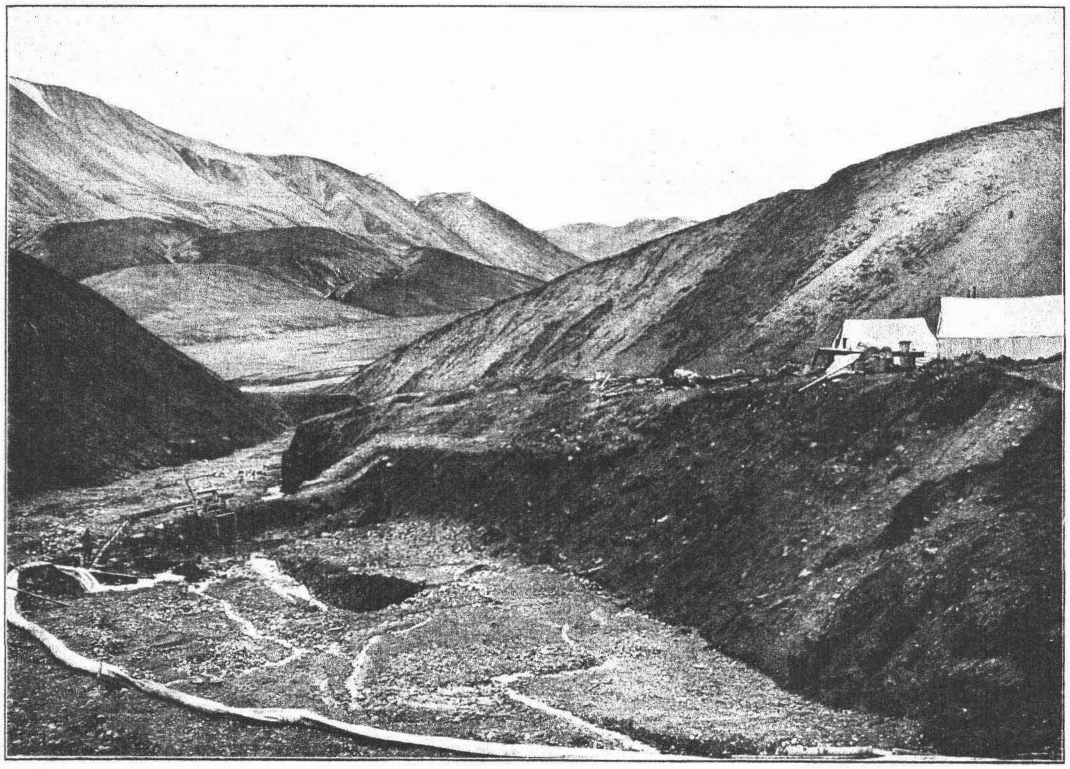
Of the yield for 1902, Miller Gulch probably furnished $175,000, the balance, $50,000, being divided between Slate Creek and Chisna River.

MILLER GULCH.

This narrow gulch (Pl. XVIII, *A*), whose yield is thus seen to be much greater than that of all other streams in the district combined, is a steep ravine less than a mile long. Eight 600-foot claims have been staked upon it, this length having been agreed upon by the original discoverers in order that each might secure a share of the property there. The eight claims cover the gulch from source to mouth, and each is worked with profit when there is sufficient water;



A. MILLER GULCH.



B. VIEW OF UPPER RUBY GULCH, SHOWING LOWER END OF JACKPOT CLAIM.

but during dry seasons the claim holders near the source of the gulch are forced to close during a part of the summer.

The bed-rock floor of the gulch is sheeted over with coarse gravel to a depth of from 4 to 8 feet. This gravel is derived principally from the slate country rock and its diabasic and "bird's-eye porphyry" intrusives, but contains also noticeable percentages of granitic cobbles derived from the "round wash" which covers the surrounding hills. The gold is reputed to be generally distributed horizontally across the gulch, without definite pay streaks, but vertically it exhibits the usual concentration near bed rock. Ill-defined benches exist on either side of Miller Gulch at 100 or 200 feet above creek level. They are reported to prospect well, but are not now worked for lack of water. Their origin is probably connected with the glacial history of the region.

The gold of the gulch is usually flat and smooth and is very rarely found attached to quartz or country rock. It occurs as rather coarse dust and small nuggets, the largest of these reported so far weighing about 4 ounces. One-ounce nuggets are not at all rare. The gold increases in average coarseness toward the head of the gulch, whence most of the finer dust has been removed. Its assay value is said to be about $18 per ounce.

Small copper nuggets, bits of cinnabar, magnetite grains, and an occasional silver-white fragment of osmiridium are found associated with the gold in the sluice boxes.

The estimated output of $175,000 includes the gold taken from the rich claim at the mouth of the gulch, which lies partly on Slate Creek. This relatively heavy output is, of course, due primarily to the superior richness of the Miller Gulch gravels, but other factors have been their shallowness and the gradient of the stream, which have made it easy to win the gold by simple, inexpensive sluicing methods. These combined factors have caused the early development of Miller Gulch to a maximum of production, while the poorer or deeper diggings in other creeks, where in some instances expensive plants are required, have been neglected. It is estimated that the present rate of output should be maintained for two or three years to come.

SLATE CREEK.

Slate Creek, like Miller Gulch, has been staked throughout its length, but as most of the claim owners are also interested in the richer Miller Gulch property, where they have concentrated their energies, it has received comparatively little attention. Furthermore, conditions are not so favorable on this larger stream for placer operations, both because of the comparative scarcity of gold except in two or three of the claims immediately below the mouth of Miller Gulch, and because of the generally greater depth of gravel and irregularity of bed rock throughout much of its length.

claims at varying and usually not excessive depths, and wherever found it carried sufficient gold to enable the operators to wash the gravel at a profit.

Throughout the intermediate portion of the river the bed rock lies at unknown depths beneath a mantle of glacial material. In one place, one-half mile above the mouth of Powell Gulch, a shaft was sunk from creek level through 21 feet of compact till into an underlying bed of sand which admitted water and forced a suspension of operations. It is improbable that the sorting and concentrating effect of water throughout this middle portion of the Chisna Valley has at any post-Glacial time been operative down to bed rock, so that, even could the latter be reached, it is unlikely that gold in sufficient quantities for profitable exploitation would be found. The clay layers within the glacial deposits which are reached in prospecting carry colors, but are not sufficiently rich to invite extensive operations.

Upper Chisna–Ruby Gulch.—The operations in 1902 on the upper Chisna were confined to the small tributary known as Ruby Gulch. On the lower portion of this brook ground sluicing was in progress, and 3 or 4 feet of gravel were removed to a "clay bed rock." The operations were chiefly in the nature of development work, but the operators report that the clean-ups about paid expenses.

In the upper portion of the gulch, on the Jackpot claim (Pl. XVIII, *B*), the stream is confined to a narrow but shallow canyon, 20 to 40 feet wide, with gravels generally 2 to 4 feet deep. Near the lower end of this claim there is a deep hole, perhaps representing a large glacial mill, which has been explored to a depth of 20 feet without finding bottom. Below this hole bed rock is again within reach of the operations, and here, as above, mining has proved profitable. The gravels are derived generally from the slightly metamorphosed Permian shale bed rock, but there is some admixture of granitic and greenstone bowlders, derived from the "round wash" which is found on the divide at the head of the gulch.

One line of sluice boxes serves to handle the gravel, and a small glacial remnant at the upper end of the gulch supplies water throughout the season.

The gold is similar to that of Miller Gulch, bright yellow, smooth, and flat, only occasionally rough or in rounded pellets. A number of small nuggets have been found, the largest of which is worth $12.75. The assay value of this gold is reported to be $18 or $18.50.

Lower Chisna.—The operations along this portion of the Chisna Valley are confined to a group of properties within 2 or 3 miles of the mouth of the river. They extend through the canyon and for short distances above and below it, where alone bed rock is accessible. More capital has been expended here in systematic development than elsewhere within the Chistochina field, and as a result the principal operators, Hazelet and Meals, now have in operation just below the canyon a hydraulic plant with a head of 125 feet. The ditch that furnishes this pressure taps the Chisna some distance above the canyon and follows the south bank to the lower end of the gorge. Water may be taken from it for use through and above the canyon, or greater head may be secured by a longer ditch, the Chisna having abundant fall.

Bed rock is easily accessible through the canyon, but the latter is so narrow that the bars not swept by the swift current are very small and probably carry but little gold. At the mouth of the canyon bed rock is easily reached, but having a somewhat greater slope downstream than the river, it soon passes below a point where it is at present practicable to reach it in sluicing. It is reported that bed rock lies only from 4 to 8 feet below the surface of the flood plain for a considerable distance above the canyon, but since there are many coarse bowlders in the flood plain material, it can not be handled to advantage by ordinary sluicing methods. It is believed that hydraulic work at this point will prove profitable.

The gravels contain a considerable variety of rock types, contrasting strongly in this respect with those of Slate Creek, Miller Gulch, and the upper Chisna. Such a contrast is of course to be expected, because the gravels of the latter streams are derived from limited areas within the small drainage basins of the creeks themselves, where few rock varieties are known, while the gravels of the lower Chisna are of all the various types in the much larger Chisna basin, and probably also of material brought from outside sources by glacial action.

The gold from the lower Chisna is much like that from Slate Creek and Miller Gulch in general appearance, but is finer and somewhat more uniform in grain. Nuggets are rare, but flakes one-eighth inch or more in diameter are abundant. An assay value of $18.72 per ounce is reported.

The developments have not yet determined fully the values to be won, but the gravels below the canyon are said to run from 1.7 to 5.5 cents per pan, with a maximum of $1 on bed rock. A small corner of Discovery claim, just at the head of the canyon, is reported to have yielded $1,000 as the result of a few weeks' work with a short string of sluices, so that the available gravels here, if carefully handled by hydraulic methods, should yield good profits.

ORIGIN OF THE GOLD.

The coarsest gold of the Chistochina field is found in Miller Gulch, in Slate Creek, and at the head of the Chisna. That taken from the lower Chisna is finer in grain and has a higher assay value, although in other respects it resembles the product of the headwaters. It is therefore considered probable that all of the gold of the field has been distributed from the region about the sources of the producing streams, but there is a lack of unanimity as to the manner of its occurrence there.

Many operators very plausibly maintain that it is derived from the "round wash," which is particularly heavy about the head of Miller Gulch and Slate Creek. This deposit of cobbles is also present on the divide between Ruby Gulch and the stream next east, so that the advocates of this theory are able to prove that each stream at present worked to a profit drains an area in which the "round wash" is found. They likewise regard the smooth surface of the gold as evidence that it is waterworn and has therefore been brought, like the "round wash," from some extraneous source.

Some facts, however, are distinctly opposed to this hypothesis. Others seem to admit of as ready explanation on another basis.

A small stream on which a group of claims known as the "Big Four" has been staked heads opposite Miller Gulch and flows down to Chistochina Glacier. The heaviest deposit of the "round wash" known in the region occurs on the slopes drained by this brook, which seems therefore to be more favorably situated than Miller Gulch relative to this deposit as a source of gold; but the Big Four claims yield fine gold in moderate amount and are not to be compared in richness to Miller Gulch. Furthermore, Ruby Gulch and the creek next east of it seem to be equally favorably situated in relation to the deposit of the "wash" which occupies the divide between them, yet one has yielded operators a handsome return and the other is not profitable.

It is even more significant that the sources of the gold-bearing creeks are all within an area whose extent coincides with a region of local metamorphism in the Permian shales and that no other metamorphosed areas of these beds and no other gold districts within them are known. Where they have been metamorphosed an incipient cleavage is developed and the shales carry a few narrow quartz stringers. It is believed that the flat, smooth character of much of the gold is sufficiently accounted for by its origin in these shales and by its purity and consequent softness, which lead to a rapid smoothing and polishing with but little transportation.

It is therefore concluded that the gold is derived from these Permian rocks and that in its genesis it is related to the local metamorphism which they have suffered. It is evidently post-Permian in age, and since Eocene beds deposited unconformably upon the Permian are but little folded and wholly unmetamorphosed it is probably also pre-Eocene.

INFLUENCE OF GLACIATION.

Ice has been an important and often disturbing agent in the distribution of the gold within the district. To this agent must be attributed the irregularities in depth of bed rock, the potholes which occasionally exist in the stream bed, and the changes in drainage which are to be inferred in many instances. The coarseness of the gold now found in the lower Chisna, if, as is believed, it has been derived from the district at the heads of the Chisna and of Slate Creek, is probably due in part to the action of the ice as a carrier. Furthermore, the canyon on the lower Chisna, with the short stretches above and below it within which bed rock is accessible, is no doubt due to the superposition of the stream, in the process of readjustment during the withdrawal of the ice from the lower Chisna Valley, upon the granite ridge through which the canyon is cut. To this agent again must be attributed the heterogeneous filling of the middle Chisna Valley and the burial of bed rock there beyond the reach of the miner.

ECONOMIC CONDITIONS.

One of the greatest difficulties which the prospector and later the operator have encountered in the Chistochina field is due to its remoteness from the source of supplies. Mining machinery and subsistence must be transported by trail from Valdez, a distance of 225 miles. The first prospectors reached the district in 1898 by sledding their outfits across Valdez Glacier and down the Klutina to Copper Center, where they transferred them to boats after the ice had run out of the Copper, and laboriously tracked up the latter stream and the Chistochina. The greater part of the first year was thus occupied in reaching the field of operations. Since that time transportation facilities have improved, a very important element in this improvement being the construction of the military trail from Valdez to the interior by way of Thomson Pass. It is customary for operators now to take in their supplies in the late winter by sled over this trail to Copper Center and thence over the ice of Copper and Chistochina rivers to the gold fields. If additional supplies are required during the summer, they may be secured by pack train, a more costly method of transportation than sledding, but very much cheaper than the original plan of tracking and packing on men's backs. Even now, under the improved conditions, supplies in the Chistochina field sell for from 50 cents to $1 a pound, and labor is proportionately high, the usual wage being $90 per month, subsistence and lodging furnished, or $1 to $1.25 an hour, the laborer supplying his own food and shelter. These conditions mean, of course, that only high-grade properties can be operated.

Another condition which tends to raise the cost of production in the region is the absence of wood on the upper Chisna and on Slate Creek and Miller Gulch. These streams lie well above timber line, and wood, for whatever purpose desired, must be hauled from the nearest timber, 5 or 10 miles distant. This work is accomplished in the early spring over the snow, before it is possible to begin mining operations, but with the high wages that prevail this increases considerably the cost of living. On the lower Chisna there is sufficient timber for all present needs.

The length of the working season is rather short on the upper creeks, where the water freezes in the sluice boxes usually by September 15 or 20, and it is sometimes as late as July before the snow is melted from the upper portions of the gulches, so that a working period of not more than three months is to be counted upon for this part of the district. Here again the lower Chisna is more favorably situated, since the fall freezing is delayed for two or three weeks and the snow melts away earlier in the spring.

DELTA RIVER DISTRICT.[a]

In July, 1900, two prospectors, Mr. Blix and Mr. Torgerson, started from Chisna River with three pack animals and worked westward to the head of Delta River, prospecting as they went. They found colors generally on the stream bars, and what they regarded as fair prospects on Wilder Creek, or, as they called it, Rainy Creek.

After the return of these men to the Chisna a larger party was outfitted and, returning to the region, organized the Eureka mining district.

In the following spring (1901), from 200 to 250 people entered the new district and 20 or 30 of them began sluicing, but the results being unsatisfactory the field was abandoned.

SUSHITNA DISTRICT.

Mr. Monohan, of Valdez, and four companions spent the summer of 1903 prospecting on the headwaters of Sushitna River, west of the Chistochina field. Late in the season a promising find is reported to have been made on a stream called Valdez Creek, from which it is stated that about 100 ounces of gold were taken in two weeks. Soon after making the strike the discoverers ran out of supplies and returned to Valdez. A number of parties, including some of the Slate Creek operators, visited the field during the following winter, and the reports brought out have generally been favorable.

The usual winter route to the new field is by way of Valdez and Copper Center to the mouth of the Tazlina, which is ascended to Tazlina Lake. The

[a] Information about the Delta River stampede has been furnished by Mr. R. Blix, of Copper Center.

route from the lake is a little west of north across the flat divide between the Copper and Sushitna systems. Another route from Copper Center is by way of the military trail nearly to the mouth of the Gulkana, whence an old Indian trail leads west toward the Sushitna.

NIZINA GOLD FIELD.

In June and July, 1902, reports reached Valdez to the effect that coarse gold had been found on the upper Nizina. The reports were sufficiently definite to cause considerable excitement in the town, and many who were free to go promptly stampeded to the new district, only to find that through the abuse of the power of attorney practically all of the available property had been staked.

The Nizina field (fig. 11) includes the drainage basins of three southeast tributaries of the upper Nizina River—Young Creek, Chititu Creek, and Dan Creek. The stream first staked and the one for whose richness most definite claims have been made is Chititu Creek, a small stream 10 or 12 miles long, which flows into the Nizina 20 miles above its mouth. It has two main branches, known as Rex Gulch and White Gulch, which unite to form the Chititu proper. Many minor tributaries have been staked and named by prospectors.

Dan Creek empties into the Nizina about 4 miles above the mouth of Chititu Creek. It rises east of the Nizina among the high peaks, whose glaciers are tributary to Chitistone River, to Young Creek, and to the upper Chitina. It is reported to carry a somewhat greater volume of water than the Chititu and to flow throughout the greater part of its course in a steep-walled canyon, so that during high water no work can be done along it.

Young Creek is considerably the largest of the three streams, and its crescent-shaped basin surrounds that of Chititu Creek on the east, south, and west. Calamity Gulch and Gold Run are among the tributaries of Young Creek most frequently mentioned. These flow south from the ridge whose north slope is drained by branches of White Gulch, one of the forks of Chititu Creek.

The rocks throughout the greater part of the district are reported by Schrader and Spencer to be the black shales and thin limestones of the Triassic, but in the northern part of the basin of Dan Creek the Nikolai greenstone and the overlying heavy-bedded Chitistone limestones outcrop. There is a doubtful region about the head of Young Creek where these older rocks may also be found.

The black Triassic shales are reported to be intruded in this region, as they are known to be in other localities, by abundant porphyritic dikes, and the gold may be found to be genetically connected with these intrusives.

Although the district was staked early in 1902, but little work, except hasty preliminary prospecting, seems to have been done in it during the summer. It is reported that only one short string of sluice boxes was in use, so that, although there can be no doubt tnat gold is present, the richness and extent oi the aeposits have yet to be proved.

The earliest and most definite reports are from Chititu Creek and its tributaries. The gravel is said to be from 2½ to 5 feet deep on this creek in the

FIG. 11.—Sketch map of Nizina gold field, reduced from map by Geo. M. Esterly.

vicinity of the forks, and to be free from large bowlders. The creek bottom is from 100 to 200 yards wide and water is plentiful. The gold which has been brought out is flat and is bright yellow in color, much resembling that of Chisna River, but somewhat cleaner looking.

The district may be reached by following the McClellan trail from the Copper at the mouth of the Tonsina nearly to the Nikolai mine, and then turning southward across the flats to the Nizina, which is crossed near the mouth of Chititu Creek. A southern route from Taral by way of the Hanagita Valley is also available.

The region is abundantly supplied with timber for the building of cabins or the construction of sluices, and, in the upper courses of the streams, at least, abundant fall exists to carry off the tailings. During the summer of 1903, in addition to the work in the creek beds a few bench diggings received attention. Some of the claim owners, reporting that they were able to make a fair profit, continued their development work, but the early reports of extravagant richness gave way to a more modest valuation, and the future of the district as a mining camp came generally to be regarded as depending largely upon the development of hydraulic property.

BREMNER DISTRICT.[a]

During the late summer of 1901 a party of seven prospectors from Valdez reached the head of Bremner River by way of Lowe River, Marshall Pass, and the Tasnuna. Pack animals were used for the first part of the trip, but these were abandoned 15 miles above the mouth of the Tasnuna and boats were utilized from this point to the forks of the Bremner.

The prospects found in 1901 were deemed promising enough to justify further work, and supplies were taken in over the snow during the winter and spring of 1902, but when news of the Nizina strike reached the camp the majority of the prospectors there joined the stampede to the new field. Work was resumed again to a limited extent in 1903, but the number of men in the district has never been large.

The Bremner is reported to be nearly 50 miles long, and to be navigable with difficulty by small boats to the forks, 25 miles above the mouth. Below the forks there is one canyon 3 miles in length, and the north branch issues at the forks from another, 9 miles in length and obstructed by several small falls. Above this obstruction the valley spreads out to a width of about 2 miles. The stream rises in a glacier, which is also the source of a branch of the Tana.

Golconda Creek, on which several claims have been staked, is a tributary of the North Fork. It is about 10 miles long and flows for the lower 2½ miles through a rough gorge. Near its headwaters, on two claims, No. 4 above on Golconda Creek and No. 1 above on Summit Creek, some work has been done. Little Bremner, Amy, Standard, and McGreal are other creeks that are mentioned.

---

[a] The writer is indebted to Mr. Ralph Wheaton for information concerning this field.

The region has been intensely glaciated, and as a consequence rock benches are found from 10 to 40 feet above the level of the creek, and some pay has been found on these. A few thousand dollars are reported to have been taken from the claims.

TIEKEL AND TONSINA DISTRICT.

The following statement concerning the Fall Creek and Quartz Creek placers is quoted from the report of Messrs. Schrader and Spencer, written in 1901:[a]

"*Fall Creek.*—Gold was discovered on Fall Creek, near the head of Kanata River, in 1898. It is estimated that $500 was produced during the summer of 1899. The diggings begin about a mile above Kanata River and extend for 5 or 6 miles up the creek. The gravels are from a few feet to 600 feet in thickness, and from their mode of occurrence are supposed to be of glacial origin. From these gravels the gold has been concentrated by the action of running water and is found where bed rock can be reached. Some of the gold is coarse, nuggets having been found up to $5 or $6 in value. It is hardly probable that the Fall Creek placers will ever become important producers.

"*Quartz Creek.*—Gold was discovered in the tributaries of Tonsina River in 1898, and assessment work has been done on a few claims each year since. The origin of the gold is probably similar to that suggested for the deposits of Fall Creek. The entire production of the creek to date [March, 1901] is probably not in excess of $1,200."

Since this account was written, practically no work has been done in these localities, the rich gold camps of the interior and the copper deposits of the Nizina attracting prospectors from these more readily accessible but low-grade diggings. With the further economic development of the country, however, work on a small scale may be resumed here.

OTHER MINERALS.

PLATINUM.

Since 1899, reports have been persistently circulated to the effect that platinum in considerable quantities exists in the gravels of Nadina River. In some cases most extravagant claims have been made, a St. Louis company professing to have tested sands that yielded over $29,000 per ton in platinum and a few dollars in gold. Another company, with headquarters at Chicago, advanced more modest claims, to the effect that from $100 to $135 in platinum was contained in a ton of screened sand, and that gold values of $16 to $20 were yielded by the same material.

Nadina River, where this platinum is supposed to have been found, rises in a glacier which flows from the precipitous amphitheater that forms the

[a] The Geology and Mineral Resources of a Portion of the Copper River District, Alaska, 1901, p. 90.

southern side of Mount Drum (Pl. VII). This glacier is about 8 or 9 miles long, and from its southern end several small streams flow. These unite presently, forming Nadina River, which joins the Copper about 16 miles from the lower end of the glacier. Throughout the upper 4 or 5 miles of the Nadina Valley the stream is overloaded and its valley is of the filled type. Below this upper portion it has cut into the Pleistocene terrane of the Copper River Valley, the gorge deepening toward the Copper. Platinum claims have been staked along the Nadina from its mouth to the foot of the glacier, and even up over the glacier and along the lateral valleys. The most active prospecting, however, has been carried on throughout the stretch extending 4 or 5 miles downstream from the foot of the glacier. Cabins have been built along this stretch, and shafts have been sunk at various places, one to a reported depth of 67 feet, but bed rock has not been reached, and the depth to it is entirely problematical, for the valley of the Nadina is incised in unconsolidated Pleistocene deposits of uncertain but probably considerable thickness. No rock that is certainly in place is encountered below a point 5 or 6 miles above the foot of the glacier.

The rocks that are represented in the recent Nadina gravels are derived almost exclusively from Mount Drum itself, and represent various phases of andesitic lavas and the tuffs which are associated with them, all entirely unaltered. An occasional bowlder of basalt, as fresh as the andesites, and here and there a pebble of some schistose or calcareous type, derived from the valley walls of heterogeneous Pleistocene wash, is found mingled with the andesitic gravel. Samples of pan concentrates were taken with care at various points along the Nadina Valley, both from the stream deposits and from the Pleistocene material forming the valley walls. These were submitted to Dr. E. T. Allen, of the Survey laboratory, for assay, and he reports that neither gold nor platinum is present, at least in commercial quantities. Pannings from the material thrown out of the various shafts yielded the same results, and not a single color of either of the precious metals was found at any time during the summer.

Platinum is usually associated with peridotites or other basic eruptive rocks, but has been reported in a few instances from gold-bearing veins and in others from certain copper minerals. It is not to be expected in wholly unaltered stratified rocks or in fresh effusive igneous rocks of andesitic character. Theoretically, then, the conditions in the Nadina Valley are not such as to indicate platinum. Practically all the tests made by the writers support this theoretical conclusion. The opinion is forced upon one that the assay returns which have led prospectors to believe that platinum exists in commercial quantities in the region and have furnished a basis for the organization of companies to exploit the reputed deposits must have been faulty.

TIN.

Tin has been reported at various times from different parts of Alaska, and the Copper River field has yielded its share of these reports. As early as 1899 tin deposits were reported from Surprise Creek, on the upper Kotsina, but subsequent work has failed to confirm these reports. In 1902 similar circumstantial accounts of the finding of tin ore from the upper Chetaslina basin were circulated in Valdez. Samples of the rock that was supposed to carry the tin were collected by the writer and submitted to assay tests, but proved not to carry the metal. Other specimens, submitted by Mr. A. W. Tibbitts, were subjected to similar tests with the same result, and although massive rocks, granitic or dioritic in character, somewhat veined and affected more or less by mechanical alteration, exist in the region, they have not been proved to be tin bearing.

MERCURY.

The sluice boxes in Miller Gulch catch small fragments of a soft, red mineral, which proved to be cinnabar, the sulphide of mercury. It has not thus far been reported from any other section of the Copper basin.

OSMIRIDIUM.

The Miller Gulch sluice boxes catch occasional scales of a hard, silver-white metal, which proved, when tested, to be a compound of osmium and iridium.

IRON.

The moraines of the eastern tributaries of Gakona Glacier and the western tributaries of West Fork Glacier contain quantities of a coarse-grained igneous rock consisting of large crystals of hornblende, basic feldspar, and magnetite. Fragments of the latter ore, as much as 4 inches in diameter, may occasionally be picked up. They probably represent a marginal facies of the coarse intrusive with which they are associated, and are to be sought in place among the ice fields high up on the ridge between the Gakona and the Chistochina drainages. It is not expected that they will ever have any practical value.

COAL.

Chistochina River.—Within 1½ miles of the head of the Chisna, along the north wall of the valley, from 600 to 700 feet above the stream, there is an outcrop of soft, greenish and buff shales with loose sandstone and fine conglomerates, the shales frequently exhibiting imperfect plant impressions. These beds strike about parallel with the Permian shales with which they are infolded, but have very much lower dips to the north, and are regarded as having been unconformably deposited on the older rocks. Fragments of glossy lignite showing conchoidal fracture were gathered from the gully below these outcrops and submitted to Dr. E. T. Allen for analysis. He reports:

Analysis of lignite from Chistochina River.

	Per cent.
Water	15.91
Volatile combustible matter	60.35
Fixed carbon	19.46
Ash	4.28

Fuel ratio, 0.32.

These constituents indicate a typical lignite of medium grade. The coal was collected by some of the Slate Creek miners and used in the forge for blacksmithing purposes. They report favorably upon its qualities as a fuel.

One-third of a mile below the mouth of Miller Gulch, along the bluffs of Slate Creek, there are imperfect exposures of coarse and fine sandstones and shales, containing plant impressions, and in the bed of the creek on the California claim an outcrop of coal has been exposed by mining operations. A few bushels of the fuel were mined and used locally with gratifying results. At the time of our visit the outcrop had been covered and the thickness of the bed could not be measured.

Gakona River.—The area between the head of the Gakona and the west fork of the Chistochina is occupied almost entirely by Miocene or Eocene clay and sand beds, with occasional thin conglomerates. The clays are well consolidated, locally becoming shales. They are usually blue, but are sometimes yellowish and iron-stained, and occasionally carry fragments of fossil leaves. Lignite occurs sparingly throughout this formation, generally as single trunks in the conglomerate or finer arenaceous beds. The woody fiber and structure are well preserved in the flattened trunks, which are often still flexible even when dry. Although the lignite is widely distributed throughout the Tertiary area, and all streams flowing from it contain the coaly float, no deposits were seen that possess any actual or prospective value as fuel.

Tazlina River.—In 1898 the writer described thin beds of coal which occur in the bluffs of Bubb Creek, one of the principal tributaries of the Tazlina, and the character of the formations about the head of this stream and in the adjacent portions of the Chugach and Talkeet mountains is such that it is believed that coal will be found here if a sufficiently urgent demand should arise to encourage a search for it.

Chitistone River.—During the summer of 1902 prospectors brought to Valdez from the upper Chitistone blocks of dark-gray coal which has some of the physical and chemical characteristics of cannel. It is reported to occur in the shales of the Triassic or Jura-Cretaceous formations and to exist in considerable bodies. A proximate analysis by Dr. E. T. Allen of the Survey laboratory yielded results as follows:

Analysis of coal from upper Chitistone River.

	Per cent.
Water	1.65
Volatile combustible matter	51.60
Fixed carbon	40.75
Ash	6.10

Fuel ratio, 0.79+.

The deposit has not as yet been examined by any of the geologists of the Survey, but its reported occurrence in rocks older than the Eocene, the usual lignite-bearing formation of Alaska, and its analysis, together indicate a fuel of unusually good quality for the Territory.

Cheshnina River.—Along the middle part of the Cheshnina, near the upper end of the gorge in which the lower portion of that stream flows, outcrops of soft, friable sandstones and conglomerates, dipping 20° or 30° downstream, were examined during the summer of 1902. These sediments are similar in character to the rocks of upper Eocene age which are so abundantly distributed thoughout the Territory and are so frequently coal bearing. Furthermore, prospectors report having found coal in this vicinity. No details as to bed sections are available.

INDEX.

O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 41.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

Most of the above publications may be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they may be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are allotted every member of Congress, from whom they may be obtained, free of charge, on application.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at practically cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the forty-seventh in Series A and the fifty-ninth in Series B, the complete lists of which follow. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

SERIES A, ECONOMIC GEOLOGY.

B 21. Lignites of Great Sioux Reservation: Report on region between Grand and Moreau rivers, Dakota, by Bailey Willis. 1885. 16 pp., 5 pls. (Out of stock.)

B 46. Nature and origin of deposits of phosphate of lime, by R. A. F. Penrose, jr., with introduction by N. S. Shaler. 1888. 143 pp. (Out of stock.)

B 65. Stratigraphy of the bituminous coal field of Pennsylvania, Ohio, and West Virginia, by I. C. White. 1891. 212 pp. 11 pls. (Out of stock.)

B 111. Geology of Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. 1893. 106 pp., 6 pls.

B 132. The disseminated lead ores of southeastern Missouri, by Arthur Winslow. 1896. 31 pp.

B 138. Artesian-well prospects in Atlantic Coastal Plain region, by N. H. Darton. 1896. 228 pp., 19 pls. (Out of stock.)

B 139. Geology of Castle Mountain mining district, Montana, by W. H. Weed and L. V. Pirsson. 1896. 164 pp., 17 pls.

B 143. Bibliography of clays and the ceramic arts, by J. C. Branner. 1896. 114 pp.

B 164. Reconnaissance on the Rio Grande coal fields of Texas, by T. W. Vaughan, including a report on igneous rocks from the San Carlos coal field, by E. C. E. Lord. 1900. 100 pp., 11 pls.

B 178. El Paso tin deposits, by W. H. Weed. 1901. 15 pp., 1 pl.

B 180. Occurrence and distribution of corundum in United States, by J. H. Pratt. 1901. 98 pp., 14 pls. (Out of stock.)

B 182. A report on the economic geology of the Silverton quadrangle, Colorado, by F. L. Ransome. 1901. 266 pp., 16 pls. (Out of stock.)

B 184. Oil and gas fields of the western interior and northern Texas Coal Measures and of the Upper Cretaceous and Tertiary of the western Gulf coast, by G. I. Adams. 1901. 64 pp., 10 pls. (Out of stock.)

B 193. The geological relations and distribution of platinum and associated metals, by J. F. Kemp. 1902. 95 pp., 6 pls. (Out of stock.)

B 198. The Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold. 1902. 43 pp., 1 pl.

PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred Hulse Brooks. 1902. 120 pp., 2 pls.

B 200. Reconnaissance of the borax deposits of Death Valley and Mohave Desert, by M. R. Campbell. 1902. 23 pp., 1 pl. (Out of stock.)

B 202. Tests for gold and silver in shales from western Kansas, by Waldemar Lindgren. 1902. 21 pp.
PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.
PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.
PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls.
PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.
B 212. Oil fields of the Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes and William Kennedy. 1903. 174 pp., 11 pls.
B 213. Contributions to economic geology, 1902; S. F. Emmons and C. W. Hayes, geologists in charge. 1903. 449 pp.
PP 15. The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.
B 218. Coal resources of the Yukon, Alaska, by Arthur J. Collier. 1903. 71 pp., 6 pls.
B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl.
PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.
PP 21. The geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.
B 223. Gypsum deposits in the United States, by G. I. Adams and others. 1904. 129 pp., 21 pls.
PP 24. Zinc and lead deposits of northern Arkansas, by G. I. Adams, assisted by A. H. Purdue and E. F. Burchard, with a section on the determination and correlation of formations, by E. O. Ulrich. 1904. 118 pp., 27 pls.
PP 25. The copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls.
B 225. Contributions to economic geology, 1903, by S. F. Emmons and C. W. Hayes, geologists in charge. 1904. 527 pp., 1 pl
PP 26. Economic resources of the northern Black Hills, by J. D. Irving, with contributions by S. F. Emmons and T. A. Jaggar, jr. 1904. 222 pp., 20 pls.
PP 27. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 122 pp., 15 pls.
B 229. Tin deposits of the York region, Alaska, by A. J. Collier. 1904. 61 pp., 7 pls.
B 236. The Porcupine placer district, Alaska, by C. W. Wright. 1904. 35 pp., 10 pls.
B 238. Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, Erasmus Haworth, and W. R. Crane. 1904. 83 pp., 11 pls.
B 243. Cement materials and industry of the United States, by E. C. Eckel. 1905. 395 pp., 15 pls.
B 246. Zinc and lead deposits of northwestern Illinois, by H. Foster Bain. 1904. 56 pp., 5 pls.
B 247. The Fairhaven gold placers, Seward Peninsula, Alaska, by F. H. Moffit. 1905. 85 pp., 14 pls.
B 249. Limestones of southeastern Pennsylvania, by F. G. Clapp. 1905. 52 pp., 7 pls.
B 250. The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. 1905. 65 pp., 7 pls.
B 251. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska, by L. M. Prindle. 1905. 89 pp., 16 pls.
WS 117. The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. 1905. 59 pp., 8 pls.
PP 36. The lead, zinc, and fluorspar deposits of western Kentucky, by E. O. Ulrich and W. S. T. Smith. 1905. 218 pp., 15 pls.
PP 38. Economic geology of the Bingham mining district, Utah, by J. M. Boutwell, with a section on areal geology, by Arthur Keith, and an introduction on general geology, by S. F. Emmons. 1905. 413 pp., 43 pls.
PP 41. The geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905. 133 pp., 20 pls.

SERIES B, DESCRIPTIVE GEOLOGY.

B 23. Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 124 pp., 17 pls. (Out of stock.)
B 33. Notes on geology of northern California, by J. S. Diller. 1886. 23 pp. (Out of stock.)
B 39. The upper beaches and deltas of Glacial Lake Agassiz, by Warren Upham. 1887. 84 pp., 1 pl. (Out of stock.)
B 40. Changes in river courses in Washington Territory due to glaciation, by Bailey Willis. 1887. 10 pp., 4 pls. (Out of stock.)
B 45. The present condition of knowledge of the geology of Texas, by R. T. Hill. 1887. 94 pp. (Out of stock.)
B 53. The geology of Nantucket, by N. S. Shaler. 1889. 55 pp., 10 pls. (Out of stock.)
B 57. A geological reconnaissance in southwestern Kansas, by Robert Hay. 1890. 49 pp., 2 pls.
B 58. The glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, by G. F. Wright, with introduction by T. C. Chamberlin. 1890. 112 pp., 8 pls. (Out of stock.)
B 67. The relations of the traps of the Newark system in the New Jersey region, by N. H. Darton. 1890. 82 pp. (Out of stock.)
B 104. Glaciation of the Yellowstone Valley north of the Park, by W. H. Weed. 1893. 41 pp., 4 pls.
B 108. A geological reconnaissance in central Washington, by I. C. Russell. 1893. 108 pp., 12 pls. (Out of stock.)
B 119. A geological reconnaissance in northwestern Wyoming, by G. H. Eldridge. 1894. 72 pp., 4 pls.
B 137. The geology of the Fort Riley Military Reservation and vicinity, Kansas, by Robert Hay. 1896. 35 pp., 8 pls.
B 144. The moraines of the Missouri Coteau and their attendant deposits, by J. E. Todd. 1896. 71 pp., 21 pls.
B 158. The moraines of southeastern South Dakota and their attendant deposits, by J. E. Todd. 1899. 171 pp., 27 pls.
B 159. The geology of eastern Berkshire County, Massachusetts, by B. K. Emerson. 1899. 139 pp., 9 pls.
B 165. Contributions to the geology of Maine, by H. S. Williams and H. E. Gregory. 1900. 212 pp., 14 pls.
WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles in eastern Wyoming and western Nebraska, by G. I. Adams. 1902. 50 pp., 11 pls.
B 199. Geology and water resources of the Snake River Plains of Idaho, by I. C. Russell. 1902. 192 pp., 25 pls.
PP 1. Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by A. H. Brooks. 1902. 120 pp., 2 pls.
PP 2. Reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. 1902. 70 pp., 11 pls.
PP 3. Geology and petrography of Crater Lake National Park, by J. S. Diller and H. B. Patton. 1902. 167 pp., 19 pls.

PP 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. 1902. 68 pp., 10 pls.
PP 11. Clays of the United States east of the Mississippi River, by Heinrich Ries. 1903. 298 pp., 9 pls.
PP 12. Geology of the Globe copper district, Arizona, by F. L. Ransome. 1903. 168 pp., 27 pls.
PP 13. Drainage modifications in southeastern Ohio and adjacent parts of West Virginia and Kentucky, by W. G. Tight. 1903. 111 pp., 17 pls.
B 208. Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California, by J. E. Spurr. 1903. 229 pp., 8 pls.
B 209. Geology of Ascutney Mountain, Vermont, by R. A. Daly. 1903. 122 pp., 2 pls.
WS 78. Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 51 pp., 2 pls.
PP 15. Mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall and F. C. Schrader. 1903. 71 pp., 10 pls.
PP 17. Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian, by N. H. Darton. 1903. 69 pp., 43 pls.
B 217. Notes on the geology of southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 83 pp., 18 pls.
B 219. The ore deposits of Tonopah, Nevada (preliminary report), by J. E. Spurr. 1903. 31 pp., 1 pl.
PP 20. A reconnaissance in northern Alaska in 1901, by F. C. Schrader. 1904. 139 pp., 16 pls.
PP 21. The geology and ore deposits of the Bisbee quadrangle, Arizona, by F. L. Ransome. 1904. 168 pp., 29 pls.
WS 90. Geology and water resources of part of the lower James River Valley, South Dakota, by J. E. Todd and C. M. Hall. 1904. 47 pp., 23 pls.
PP 25. The copper deposits of the Encampment district, Wyoming, by A. C. Spencer. 1904. 107 pp., 2 pls.
PP 26. Economic resources of northern Black Hills, by J. D. Irving, with chapters by S. F. Emmons and T. A. Jaggar, jr. 1904. 222 pp., 20 pls.
PP 27. Geological reconnaissance across the Bitterroot Range and the Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 123 pp., 15 pls.
PP 31. Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma, by J. A. Taff; with an appendix on reported ore deposits in the Wichita Mountains, by H. F. Bain. 1904. 97 pp., 8 pls.
B 235. A geological reconnaissance across the Cascade Range near the forty-ninth parallel, by G. O. Smith and F. C. Calkins. 1904. 103 pp., 4 pls.
B 236. The Porcupine placer district, Alaska, by C. W. Wright. 1904. 35 pp., 10 pls.
B 237. Petrography and geology of the igneous rocks of the Highwood Mountains, Montana, by L. V. Pirsson. 1904. 208 pp., 7 pls.
B 238. Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, Erasmus Haworth, and W. R. Crane. 1904. 88 pp., 11 pls.
PP 32. Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. 1905. 433 pp., 72 pls.
WS 110. Contributions to the hydrology of eastern United States, 1904; M. L. Fuller, geologist in charge. 1905. 211 pp., 5 pls.
B 242. Geology of the Hudson Valley between the Hoosic and the Kinderhook, by T. Nelson Dale. 1904. 63 pp., 3 pls.
PP 34. The Delavan lobe of the Lake Michigan Glacier of the Wisconsin stage of glaciation and associated phenomena, by W. C. Alden. 1904. 106 pp., 15 pls.
PP 35. The geology of the Perry basin in southeastern Maine, by G. O. Smith and David White. 1905. 107 pp., 6 pls.
B 243. Cement materials and industry of the United States, by E. C. Eckel. 1905. 395 pp., 15 pls.
B 246. Zinc and lead deposits of northeastern Illinois, by H. F. Bain. 1904. 56 pp., 5 pls.
B 247. The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. 1905. 85 pp., 14 pls.
B 249. Limestones of southwestern Pennsylvania, by F. G. Clapp. 1905. 52 pp., 7 pls.
B 250. The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. 1905. 65 pp., 7 pls.
B 251. The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska, by L. M. Prindle. 1905. 89 pp., 16 pls.
WS. 118. Geology and water resources of east-central Washington, by F. C. Calkins. 1905. 96 pp., 4 pls.
B 252. Preliminary report on the geology and water resources of central Oregon, by I. C. Russell. 1905. 138 pp., 24 pls.
PP 36. The lead, zinc, and fluorspar deposits of western Kentucky, by E. O. Ulrich and W. S. T. Smith. 1905. 218 pp., 15 pls.
PP 38. Economic geology of the Bingham mining district, Utah, by J. M. Boutwell, with a section on areal geology, by Arthur Keith, and an introduction on general geology, by S. F. Emmons. 1905. 413 pp., 43 pls.
PP 41. The geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905. 133 pp., 20 pls.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

SEPTEMBER, 1905.

LIBRARY CATALOGUE SLIPS.

[Mount each slip upon a separate card, placing the subject at the top of the second slip. The name of the series should not be repeated on the series card, but additional numbers should be added, as received, to the first entry.]

Author.

Mendenhall, Walter C[urran] 1871-

. . . The geology of the central Copper River region, Alaska, by Walter C. Mendenhall. Washington, Gov't print. off., 1905.

133, V p. illus., xx pl. (incl. maps, 3 in pocket). 29½ x 23^{cm}. (U. S. Geological survey. Professional paper no. 41.)

Series: A, Economic geology, 48; B, Descriptive geology, 60.

1. Geology—Copper River region, Alaska.

Subject.

Mendenhall, Walter C[urran] 1871-

. . . The geology of the central Copper River region, Alaska, by Walter C. Mendenhall. Washington, Gov't print. off., 1905.

133, V p. illus., xx pl. (incl. maps, 3 in pocket). 29½ x 23^{cm}. (U. S. Geological survey. Professional paper no. 41.)

Series: A, Economic geology, 48; B, Descriptive geology, 60.

1. Geology—Copper River region, Alaska.

Series.

U. S. Geological survey.

Professional papers.

no. 41. Mendenhall, W. C. The geology of the central Copper River region, Alaska, by W. C. Mendenhall. 1905.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.