DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 536

THE NOATAK-KOBUK REGION ALASKA

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

The part of Alaska north of the Arctic Circle, including about 150,000 square miles, or 25 per cent of the total area of the Territory, is relatively little known. Its shore line, however, has been explored by various navigators. The first of these was Capt. Cook, who in 1778 skirted the western coast as far north as Icy Cape, where farther progress was blocked by the ice pack. In the succeeding half century practically the entire Arctic coast line from Bering Straits northward and eastward to the international boundary was examined in some detail by navigators of various nationalities, chiefly English, but knowledge of the inland regions was limited to that gained by short journeys up the lower courses of some of the larger rivers. Much of this information was obtained only incidentally by expeditions whose object was to reach the pole or by those sent out as relief expeditions. Thus, Sir John Franklin explored a part of the northern coast line in 1826, and the many Franklin relief expeditions contributed much toward making the shore line known. A generation later public interest was again aroused in this part of the polar sea by the ill-fated *Jeannette* expedition. This led to explorations into the Kobuk Valley and adjacent region under naval auspices (see pp. 12–14), which included a journey to Point Barrow by way of the upper Noatak and Colville River basins. About the same time the Revenue Cutter Service made some important explorations in the same field. (See pp. 13–14.) The eastern margin of the area was traversed in 1890 by J. H. Turner, of the Coast Survey, preliminary to the location of the international boundary.

The part of northern Alaska south of the Arctic Ocean-Yukon divide has been explored by prospectors, by Henry T. Allen of the United States Army, and later by several parties from the Geological Survey. The Cape Lisburne region has also been explored by the Geological Survey. In 1901 Schrader and Peters (see p. 18) carried the first instrumental survey across northern Alaska from the Yukon basin to the Arctic Ocean at the mouth of Colville River, while Mendenhall and Reaburn (see pp. 15 and 18) made a similar survey to Kotzebue Sound, at the mouth of the Kobuk. This work was far more important than any previously done, because it included both accurate topographic surveys and systematic geologic observations. In fact, the reports based on these explorations furnished the first clue to the geography and geology of the part of Alaska north of the Yukon basin.

For eight years after these explorations the Geological Survey was too busily engaged in surveying regions of greater mineral promise to continue work in northern Alaska, but it resumed that work in 1910 and continued it in 1911. The surveys of 1911 included an exploration of the Noatak Valley, much of which was previously almost unknown. The results of these surveys are here set forth.

This bulletin, then, contains the first account of the geology and resources of Noatak River, which is among the largest streams of Alaska. The rocks of the region have been subdivided into several groups and formations, and these have been at least provisionally correlated with the cartographic units used in mapping adjacent areas. This stratigraphic subdivision is remarkably detailed, considering the very hurried character of the field investigations. Some valuable data have also been obtained on the extent of existing glaciers and of the former period of glaciation. Data were also obtained bearing on the occurrence of placer gold and other mineral deposits.

The brief outline given of the scientific exploration of northern Alaska shows that, although much has been accomplished, much remains to be done. Plans formulated for further work in this field are already in part in execution. In 1911 and 1912 A. G. Maddren carried geologic surveys from Porcupine River northward to the Arctic Ocean, in cooperation with the International Boundary Survey. It has also been planned to make a survey from the head of Alatna River across the upper Colville basin and down Chipp River to the polar sea. This plan was to have been carried out in 1912, but unfortunately the appropriation for the Alaska surveys was not made in time to permit it.

Mention should also be made of the investigations of this region by E. de K. Leffingwell, now being carried on under private auspices. Leffingwell has spent seven years in the exploration of the region tributary to the Arctic coast east of Colville River. His results will be of great value, as they should make it possible to establish correlations between the work of Maddren along the boundary and that of Schrader and others who have explored the region farther west.

When the results of all these surveys are available northern Alaska will no longer be an unknown land. It should then be possible to express its geologic features fairly definitely, at least in terms of its larger stratigraphic units. All this will have an important bearing on the larger problems relating to the geology of the North American Continent.

THE NOATAK-KOBUK REGION, ALASKA.

By Philip S. Smith.

INTRODUCTION.

SCOPE OF REPORT.

Investigations by the United States Geological Survey have closely followed the pioneer's search for deposits of valuable minerals in Alaska. In accordance with this practice, expeditions have visited parts of northwestern Alaska where mining has been in progress or where there was probability of mining in the future, and a series of reports has been published setting forth both the geologic and the geographic results obtained. The present paper is one of this series and aims to describe the main features of the Noatak-Kobuk region. The area included in this indefinite tract is shown on Plate I. It is not proposed, however, to describe all the region mapped, but rather to give attention only to the Kobuk and Noatak basins and the immediately contiguous territory. Therefore the Koyukuk and its tributaries, except Alatna River, will in the main be excluded, together with the Selawik River basin and Seward Peninsula. Though reference is made to these places, they are not part of the area considered in this bulletin. Reports on certain of these other areas have already been published and are available.[1]

The present report treats mainly of the economic geology and the geographic features that have important control of the development of the mining industry. The statements are based on investigations made by the writer in the field seasons of 1910 and 1911, during which the Kobuk Valley was traversed from upper Reed River to its mouth, the Alatna was ascended nearly to its head, and the Noatak was descended for its entire length. In the Kobuk region the early work of W. C. Mendenhall left a record of observations that would not require restatement except for the fact that the edition of his report

[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905.

Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts: Bull. U. S. Geol. Survey No. 328, 1908.

Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 284.

Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911.

has been exhausted and is therefore no longer available. In large measure, therefore, the parts dealing with the Kobuk have been based on the observations of Mendenhall, supplemented or modified by the later work.

ACKNOWLEDGMENTS.

It would be impossible to acknowledge individually the aid of all those who have furnished information for this report or who have otherwise assisted in its preparation, either in the field or in the office.

To the prospectors throughout the region thanks are due for unfailing courtesy and assistance. This was especially true in the placer camps on the Kobuk, where the services of Commissioner M. J. Moran, Michael Tuohey, Frank Knight, Asa Wilcox, and many others have added greatly to the writer's knowledge and personal comfort. On the upper part of Alatna River, Joseph Demandel and L. B. Cassel materially assisted the expedition of 1911 by transporting supplies in their poling boat and by helping in the back packing across the Alatna-Noatak portage. Assistance in the latter work was also afforded by Isaac Spinks, Roy King, and William McCarmant.

The pioneer work of W. C. Mendenhall and his party from the Geological Survey has been of incalculable aid in formulating plans and interpreting observations, and sincere appreciation of this help is expressed. Although it has been intended to credit to him the various passages in the following pages actually derived from his published reports, it has not everywhere been possible to do so consistently and his influence has been much greater than is indicated by the specific references.

To the members of the Survey who have served with the writer in the field or in the office hearty acknowledgments are due. H. M. Eakin, of the party of 1910, completed a very creditable topographic map of the region between the Koyukuk and Kobuk and did practically all the petrographic work in the office, besides supplementing the writer's geologic observations. Special credit is due C. E. Giffin, topographer, of the expedition of 1911, whose energy and resourcefulness carried along mapping rapidly without sacrificing accuracy. Deep obligations are also expressed to Messrs. E. O. Swedberg, T. A. Saling, H. M. Saling, and J. C. Doyle, temporary employees throughout the field season, who with unfailing cheerfulness and effectiveness contributed largely to the completion of the work undertaken. The microscopic examinations of the rock specimens collected by this expedition were made by J. B. Mertie, and the paleontologic determinations by T. W. Stanton, George H. Girty, and E. M. Kindle, of the Survey.

GEOGRAPHY.

HISTORY OF EXPLORATION.

EARLY EXPEDITIONS.

The earliest explorations of the area were made in the more accessible coast regions. By the close of the first quarter of the nineteenth century various naval expeditions had charted the shore line, so that subsequent surveys have added little more than details. Lieut. von Kotzebue,[1] in search for oceanic connection eastward to the Atlantic, in August, 1816, discovered the sound that bears his name. Many topographic features escaped his notice or were so crudely sketched that it remained for Capt. Beechey in 1826 to make a more accurate map. Considering the conditions under which this work was done the chart by Beechey is remarkable and has been the base from which all subsequent maps of this coast have been made. Not only were portions of the shore line surveyed, but in addition Hotham Inlet was discovered and some of the higher points inland were located, many of the present names being given by members of this expedition. A large river or narrow bay was indicated at the place where the Kobuk enters Hotham Inlet, but no mention was made of this river or of the Noatak.[2]

During the search for Sir John Franklin many ships visited parts of northwestern Alaska and the reports of their investigations [3] afford some information about the region. Probably the most important contributions to the accurate knowledge of the region here considered were made by John Simpson, surgeon of the *Plover*. In the winter of 1849–50 he visited Hotham Inlet and vicinity, and his account of the region contains the first mention of Kobuk or, as he called it, Kowuk River.[4] He measured the width of the main channel, traced the course for many miles by the "pines" (spruce), and learned of a village seven days' journey upstream. The first map indicating the presence of a large river in approximately the position of the Noatak was also made by Simpson. During the winters of 1852 and 1853 he lived at Point Barrow and gathered from the natives much information which he assembled and published.[5] Although of interest, his map serves little more than to suggest the larger drainage features. On this map the Noatak is called Nunalak or Inland River, and the Kobuk is Kowuk. Only the lower part of these rivers is mapped,

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[1] Kotzebue, Lieut. Otto von, Voyage of discovery into the South Sea and Bering Straits, 1815–1818.

[2] Beechey, Capt. F. W., Narrative of a voyage to the Pacific and Beering's Strait.

[3] Ketlett, Capt., Narrative of proceedings of H. M. S. *Herald* and *Plover:* Great Britain Parliamentary Papers, sessions of 1854-55, vol. 35.

[4] Simpson, John, Journal of John Simpson, in command of a detached party to the eastern head of Hotham Inlet in May, 1850: Great Britain Parliamentary Papers, session of February 3 to July 1, 1852, vol. 50.

[5] Simpson, John, Observations on the western Eskimo and the country they inhabit: Great Britain Parliamentary Papers, sessions of 1854–55, vol. 35, 1855.

but they are indicated, "on native authority," as extending far inland.

A good idea of the state of geographic knowledge of this part of Alaska as late as 1869 is afforded by the map prepared by Dall and published in that year. This map was compiled from all authoritative sources, including Dall's own observations while attached to the Western Union Telegraph Expedition. On this map the Koyukuk is shown as extending only 75 miles from the Yukon (measured along the stream), whereas steamboats now ascend the river for over 500 miles and the headwaters are a hundred or more miles farther. The lower parts of the Kobuk and Noatak (called the Inland) rivers are shown, but they are described[1] as "small unexplored streams. They are prolonged far into the interior to fill up the unexplored spaces on most maps." No disparagement is intended by this quotation from Dall, but it shows the lack of knowledge of most of the interior region covered by this report at the time his authoritative article on Alaska was prepared.

KOBUK BASIN.

Little additional information was acquired during the next 10 to 15 years, but in 1883 interest in the exploration of the region was renewed. In describing these later explorations it has proved desirable to separate the work on the Kobuk, Noatak, and Koyukuk and to treat each basin in a measure by itself.

Lieut. G. M. Stoney appears to have been the first white man to go any distance up the Kobuk. In 1883, with one other white man and two natives, he spent eight days going upstream as far as Squirrel River. After having spent about 15 days in the country he returned to the States. The interest aroused by his short expedition encouraged him to undertake further exploration of the river. He was successful in getting orders from the Navy Department to investigate the Kobuk and was authorized to take the schooner *Ounalaska,* of 49 tons, and a steam cutter, his party including three petty officers and eight men. After difficulties with ice he reached Hotham Inlet on July 10, 1884. On July 19, with three white men and five natives, Stoney started up the river in the steam cutter or launch towing a skin boat and dinghy. After a journey estimated at about 275 miles the party had to leave the launch and proceed in the skin boat. In this manner the party went for five days farther upstream and reached the tributary flowing from Lake Selby. It is not possible to state exactly what was accomplished on this trip, as no report of the expedition was made and the results were combined with later surveys.

[1] Dall, W. H., Alaska and its resources, p. 285.

During 1884 another expedition, under the leadership of Lieut. J. C. Cantwell, of the Revenue-Cutter Service, visited the Kobuk. On this trip Lieut. Cantwell and Second Asst. Engineer S. B. McLenegan, with three other white men and one native, started up the river on July 8 in a steam launch. Difficulty with the launch forced them to leave it behind and continue in a skin boat. In this way they nearly reached the mouth of Pah River where, as supplies were nearing exhaustion, they turned back on July 29 and arrived at Hotham Inlet on August 7, passing Stoney upward bound on July 31. As a result of this expedition a report in the form of a journal was prepared by Cantwell, with notes by McLenegan on the resources and natural history, including ornithology. These observations gave a fairly complete account of the country near the river. Unfortunately, however, the report [1] included no map, and delay in publication prevented its appearance until 1889, two years after the report on the succeeding year's exploration was published.

In 1885, again under orders from the Navy Department, Lieut. Stoney, with 5 officers and 12 men in the 390-ton schooner *Viking*, a stern-wheel steamboat, the *Explorer*, and a steam cutter, the *Helena*, was detailed to explore the region. The object was to establish winter quarters and to make surveys of the surrounding country. The party reached Hotham Inlet on July 9 and started up the river on the 17th. The outfit was moved by short stages to a point now called Cosmos Creek, where cabins were erected, the settlement being called Fort Cosmos. After the last of the supplies had reached this place—August 17—the party spent the next three months in preparing for the winter.

During the winter of 1885–86 seven exploring parties were sent out to reconnoiter different parts of the Kobuk and adjacent regions. These, in chronologic order, were as follows:

December 1, 1885, Stoney left for the Noatak by way of the Ambler; returning he arrived at Fort Cosmos December 18. On December 6 F. S. Nash, surgeon, left for the Yukon, but returned before completing his mission, reaching Fort Cosmos December 12. December 26 A. V. Zane, past assistant engineer, left for St. Michael by way of Pah and Koyukuk rivers; returning from St. Michael he arrived at his starting point February 25, 1886. December 29 Stoney left for a trip into the Selawik basin across the low hills south of the Kobuk, getting back January 7, 1886. February 28 Stoney went up the Kobuk, crossed to the Alatna and thence to the Colville, and returning reached Fort Cosmos April 6. March 10 Ensign M. L. Reed went to the hot springs on Reed River and returned, reaching the fort April 2.

[1] Cantwell, J. C., Report of the cruise of the revenue steamer *Corwin* in the Arctic Ocean in 1884, Washington, 1889, pp. 49–125.

April 12 Ensign (now Capt.) W. L. Howard went by way of the Ambler to the Noatak, thence to the headwaters of the Colville, down this stream to a portage to the Chipp, and thence to Point Barrow, where he took passage on a revenue cutter to the States.

As a result of these expeditions information about a large territory was obtained, but nearly 15 years elapsed before it was published, and it then appeared in a form so condensed that many facts were omitted, many discrepancies occurred between the text and map, and other inaccuracies were allowed to creep in.[1] Although it is always difficult to estimate fairly the accomplishments of an explorer it seems that considering the time spent in the region the results obtained by this expedition were not so full as they should have been. Nevertheless, the general knowledge of this part of Alaska was much increased, and an approximate idea of the topography was obtained that has been of great service in planning subsequent surveys.

In 1885 Cantwell also made another trip to the Kobuk. On this expedition he started from the mouth of the river July 2 in a steam launch, the *Pioneer*, and reached a point near the stream flowing from Lake Selby, where the launch was abandoned and the journey was continued in a skin boat. From July 12 the party traveled upstream until, on the 21st, it reached Walker Lake, or Carloogahlooktak. After making a crude survey of the lake and the upper part of the Kobuk Cantwell turned back, reaching Hotham Inlet August 22. During this trip notes were made of the ice cliffs below the Ambler, the Jade Mountains, and other facts of interest. C. H. Townsend, an assistant in the United States Fish Commission, was attached to the party and collected much information about the birds and fishes. The report[2] was published in 1887, thus being available two years before the report of the Cantwell expedition of 1884, which did not appear until 1889, and 13 years before the publication of Stoney's observations.

The map prepared by Cantwell was published on a scale of about 10 miles to the inch. The general geographic position of the Kobuk, or Koowak as it is called, is good, but the form of the river is unrecognizable. The topography away from the river is inadequately shown, as isolated conventionalized hachures are used. The main contribution is the recognition of a large river extending roughly along the sixty-seventh parallel from longitude 154° W. to Hotham Inlet. The text on the whole is better than the map, but its use is in large measure dependent on personal familiarity with the region and much space is taken up with details of no permanent value.

The discovery of gold in Alaska was followed by an influx of prospectors. Although many of these men doubtless ventured into the

[1] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900.

[2] Cantwell, J. C., Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, Washington, 1887, pp. 21–52, maps and illustrations.

unknown territory, the information they obtained has not been made available for others. A few prospectors' accounts have been published—for example, Joseph Grinnell's experiences in the Kobuk in 1898—and afford an interesting record of the early conditions.[1]

The first Geological Survey expedition to the Kobuk was sent out in 1901 in charge of W. C. Mendenhall, geologist, with D. L. Reaburn, topographer, and five camp hands. The party started at Fort Hamlin on the Yukon, ascended Dall River in canoes, portaged to Kanuti River, a tributary of the Koyukuk, descended that stream and went up the Alatna for 80 miles to Helpmejack Creek, which heads in a low saddle leading to the Kobuk. This pass was reached July 30 and the portage to the Kobuk was completed by August 8. The party then descended the Kobuk, arriving at Hotham Inlet September 3.

The report on this expedition, published in 1902, gives an accurate and systematic description of the region traversed and has been the source of much material contained in the present report. The topographic map prepared by Reaburn has been of special assistance and is the base used for the Kobuk Valley in Plate I. Although some corrections and differences in interpretation have arisen in the course of fuller investigations, the broader problems were recognized and stated by Mendenhall,[2] whose work has been of great service to those interested in this part of Alaska. As fuller reference is made to this report farther on, a more complete review at this place is unnecessary.

In 1910 the writer, accompanied by H. M. Eakin and two camp hands, with a six-horse pack train, left the Koyukuk near the mouth of the Hogatza on June 22 and traversed the mountains between the Koyukuk and the Kobuk. The Kobuk was crossed below the mouth of Beaver River and a few days were spent surveying the region adjacent to Beaver and Reed Rivers. The party then traveled along the northern margin of the lowland of the Kobuk, reaching Shungnak July 22. A delay of several days awaiting supplies allowed investigation of the geology in the neighborhood. On August 10 the party started down the Kobuk in a skiff and reached Kotzebue, where work for the season stopped on August 20. During this trip a visit was made to the newly discovered placers of Squirrel River, in the lower part of the Kobuk basin. A result of this expedition is a topographic map, on a field scale of about 3 miles to the inch, prepared by Mr. Eakin, showing 2,000 square miles of previously unsurveyed country. Some of the observations made on this trip have already been published[3] but others appear for the first time in the present report.

[1] Grinnell, Joseph, Gold hunting in Alaska, edited by Elizabeth Grinnell, Chicago, 1901.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, 68 pp., maps and illustrations.

[3] Smith, P. S., and Eakin, H. M., The Shungnak region, Kobuk Valley: Bull. U. S. Geol. Survey No. 480, 1911, pp. 271–305. Smith, P. S., The Squirrel River placers: Idem, pp. 306–319.

NOATAK BASIN.

After the early discoveries noted on page 11 the Noatak was not visited until 1885, when S. B. McLenegan, of the revenue-marine steamer *Corwin*, was detailed to explore the river. He was the first and only white man who traversed any considerable length of this river and left a permanent record of his trip prior to the Survey expedition of 1911. With only one companion, a seaman named Nelson, he started up the river July 2, 1885, in a 27-foot bidarka. By hard work they reached a point that they considered the head of canoe navigation on August 1, and after a day's rest they turned back and reached the mission at Kotzebue in eight days. A report of this trip was published in 1887 and has been practically the only source of information about the river. Although the point reached by McLenegan[1] was nearly 75 miles in an air line, or about 150 miles by river, below the real head of canoe navigation and was platted about 60 miles too far east, the general mapped form of the river was excellent. He spent so much time in forcing his way upstream that he made but few observations except along the immediate route. Although regret is felt that McLenegan did not obtain more data, credit must be given him for a good piece of work as far as he went, and his oversights are perhaps attributable to the bad weather he experienced throughout most of his trip.

The expeditions of Stoney and members of his party in the winter of 1885–86, as already stated on pages 13–14, explored parts of the upper Noatak Valley and gave the only available information about this region. Details were meager, and the delay in publication of the results and the incorporation of surveys by other expeditions make it impossible to determine satisfactorily the parts actually contributed by the Stoney party. It is stated that in the summer of 1886, on "July 12, Ensign Reed and party were sent to complete the work in the Notoark [Noatak] River. They were towed about 60 miles up the stream and left to carry explorations up to the point where I had left off in December. They returned on the 22d." Further information is not given, but as no mention is made of the Noatak Canyon, and as the party spent only a short time in the field, its explorations probably did not extend as far as longitude 162°. On Stoney's map the form of the lower part of the Noatak is good, but the middle and upper parts are unrecognizable.

During the open season of 1911 the first Geological Survey party to visit the Noatak went up Alatna River in canoes, portaged across to the Noatak, and descended that stream to its mouth. In addition to the writer the party consisted of C. E. Giffin, topographer, and four camp hands. Work was commenced at the mouth of the Alatna

[1] McLenegan, S. B., Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, pp. 53–83 and map, 1887.

July 1 and was finished at Kotzebue August 27, during which time an area of nearly 10,000 square miles, three-fourths of which was within the Noatak basin, was surveyed geologically and topographically. Three canoes were used in order to facilitate the movement of the different units of the party. Supplies for the entire trip were brought in from Seattle, and were sent by freight down the Yukon and up the Koyukuk to the mouth of the Alatna by the regular river steamboats. From this place the supplies were carried in the canoes or back packed. Game was abundant, so that sheep, caribou, and birds formed a considerable addition to the routine camp fare. The weather was especially favorable for the work; numerous slight showers kept the streams at a good stage, but did not make traveling disagreeable nor obscure the distant landscape except in the mountainous regions. As the present report is largely based on the results of this trip, more specific description may be omitted here.

ALATNA BASIN.

The earliest survey of the upper part of the Koyukuk basin and the recognition of Alatna River was by Lieut. H. T. Allen[1] under orders from the War Department. This trip was perhaps the most remarkable of any that has been made in connection with Alaskan exploration. Starting from the south coast of Alaska, Allen with one companion, Fred W. Fickett, ascended Copper River, crossed the mountains, and descended the Tanana to its mouth. From this place the two white men, with seven natives and five dogs, started north July 28, 1885, reaching the junction of the Kanuti and the Koyukuk August 4. At this place they procured a boat and went upstream to the mouth of John River. Then turning back they descended the Koyukuk to its mouth, surveying the river as they went. This report is accompanied by a good map of the Koyukuk, on a scale of approximately 12 miles to the inch. The descriptive text, in addition to giving a narrative of the trip, has notes on the geology and meteorology and tables of distances.

Stoney's expedition to the middle part of the Alatna River valley, already referred to, afforded some general information about this part of the valley, but the details are so inexact and in places so erroneous that confidence can not be placed in his map. This is particularly unfortunate, for many parts are nearly correct, but it requires a visit to determine the fact, and therefore the map as a whole is practically of no service.

In 1899 a Survey party in charge of F. C. Schrader, with T. G. Gerdine and D. C. Witherspoon, topographers, ascended the Chandalar River from the Yukon, portaged to the Koyukuk and descended

[1] Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk rivers in the Territory of Alaska in the year 1885: Washington, 1887, 172 pages and maps.

that stream to its mouth. The results of this trip were the publication of a map on a scale of about 10 miles to the inch and a fully illustrated text,[1] describing the geology and geography and containing also notes on the mineral resources.

Two years later, in 1901, another Survey party, in charge of W. J. Peters, topographer, with F. C. Schrader, geologist, Gaston Philip, topographic assistant, and five camp hands, was detailed to make a trip from Bergman on the Koyukuk to the Arctic coast by way of John River. In order that the expedition should be under way as early as possible in the spring it was necessary for the men to leave Skagway in February and go to Bergman overland by dog team. While awaiting the break-up of the ice in the rivers a preliminary reconnaissance was made up Alatna River by Gaston Philip as far as the Kutuk. Unfortunately the original notes of his trip have been lost, so that, except a sketch map of his route and a general statement in the report,[2] no specific details of his trip are available. Although the route of the main expedition up John River and down the Colville lies outside the region directly considered in the present work, Schrader's report affords so much information on the near-by areas that many references are made to it in the following pages.

In 1901 the Mendenhall expedition to the Kobuk, already described (see p. 15), ascended the Alatna 80 miles, to the mouth of Helpmejack Creek. From the published account[3] of this trip, as well as from the original notebooks, many facts have been taken to amplify the present report. The topographic map prepared by Reaburn has been used as the base for the lower part of the Alatna as far as Helpmejack Creek and for that creek and the pass to the Kobuk.

The expedition of 1911, as already stated, traversed the Alatna from its mouth to the head of canoe navigation and spent nearly a month in the basin of this river. In addition to mapping the country immediately adjacent to the river, the party made side trips on foot into the hills and obtained a general view of the surrounding country. The results of this expedition are here stated fully for the first time, though a preliminary report on the mineral resources has been recently published.[4] As these observations are given in full on succeeding pages, further review of the work of this expedition will be omitted here.

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[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 441–486.

[2] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, 139 pp., maps and illustrations.

[3] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, 68 pp., maps and illustrations.

[4] Smith, P. S., The Alatna-Noatak region: Bull. U. S. Geol. Survey No. 520, pp. 315–338.

MAJOR FEATURES OF THE GEOGRAPHY.

Alaska has been divided by Hayes,[1] Brooks,[2] and others into several large geographic provinces, which, from south to north, have been called the Pacific Mountain system, the Central Plateau region, the Rocky Mountain system, and the Arctic Slope region. The Noatak-Kobuk region lies almost entirely within the third province—the Rocky Mountain system. Most of it is drained by Noatak and Kobuk rivers, which flow westward to Kotzebue Sound, but part of it is drained by the Alatna, a tributary of the Koyukuk, which forms a part of the Yukon drainage. Although mainly of mountainous topography, the region is so much diversified by highlands and lowland, by valleys and ridges, that in places the reason for assigning the country as a whole to the Rocky Mountain system is not apparent to one contemplating only the immediate details without regard to their larger relationship.

Schrader[3] has suggested that the Rocky Mountain system has two axes, one north and the other south of the Noatak. Not enough is known of the region to the north to verify this statement. Certainly there appears to be a major axis of deformation to the south, between the Noatak and the Kobuk. As a result of this structure, the larger streams have courses either normal to the constructional trend or parallel to it. It is not proposed, however, to go into these details here further than to suggest that the general north-south trend of the Alatna Valley may originally have been normal to this axis, whereas the general trend of the Noatak and the Kobuk valleys is parallel to it. Since this mountain building took place, however, so much normal erosion and glaciation has affected the region that few or none of the constructional slopes are preserved. The general east-west trend of both the topography and the geologic formations is still one of the most notable features of the region.

As practically the entire area comprising the Kobuk, Noatak, and Alatna valleys lies north of the Arctic Circle, and as the region as a whole is a mountainous province, its climate, vegetation, and fauna are mainly those characteristic of highlands in the frigid zone. This fact is perhaps even more striking than the mountainous topography or the general east-west trend.

It is proposed in the following pages, before the geology and the mineral resources are considered, to describe the general features of the geography and to give information of a relatively nontechnical character concerning the drainage, relief, climate, flora, and fauna, and the population and settlements. As each of three river basins differs

[1] Hayes, C. W., Expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 117–162.
[2] Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 17.
[3] Schrader, F. C., Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 41.

from the others in many respects, and forms a rather distinct unit, they will be described separately.

DRAINAGE AND RELIEF.

KOBUK BASIN.

For purposes of description the region adjacent to the Kobuk may be divided into three more or less distinct parts which are, from the mouth eastward, the delta, the Squirrel River to Reed River province, and the headwater mountain province. It should be noted, however, that these terms have reference only to the region near the river, for the so-called headwater mountains extend practically without interruption along the north side of the river all the way to its mouth, though in some places they are distant from the river and in others are close to it. It is evident that they form the highlands in which all the tributary streams rise, and therefore had exploration been more extensive it would be more logical to divide the basin into the highlands, the valley slopes, and the valley floors.

THE DELTA.

The delta portion of the Kobuk above water extends westward from a point a short distance below Squirrel River. It is approximately 35 miles long and from 20 to 30 miles wide. In this area the main stream splits into a great number of channels, which further subdivide and reunite, forming an untraversible network of streams. Stoney [1] notes that there are 13 mouths to the river, but so far as known only two or three are much traveled. Stoney, Mendenhall, and Smith traversed the middle channel, which enters Hotham Inlet nearly opposite Nimiuk Point, 28 miles from Kotzebue. Cantwell apparently ascended the southern channel, which enters almost at the beginning of Selawik Lake and is 25 miles farther away from Kotzebue; the northern channel has not been surveyed, but natives report that it follows along the southern flanks of the hills and is nearly as deep as the other channels. The middle route is the one most used and is therefore believed to be the best. One unacquainted with the river would have considerable difficulty in finding the way, for the current is slight and is often reversed by the tide during periods of high water or strong onshore winds. Stoney reports that 2 fathoms may be carried over the bar at the entrance to the middle channel, but from the reports of other travelers it is believed that there is usually little more than half as much water.

The islands between the different distributaries are low, few being more than 5 feet above the summer stage of the river. The natives report that these flats are usually overflowed in the spring and are

[1] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 49.

covered with blocks of ice discharged by the river. From the scars on the trees and the accumulation of driftwood brought down during the high stages it was evident that much of the region must have been recently under water. The immediate banks of the river are the best-drained parts of the delta and usually furnish sufficient dry ground for pitching camp, but farther away the ground in summer is a wet spongy mass of vegetation, into which one sinks at least ankle deep.

Some small tributaries rising in the hills north of the delta undoubtedly enter the northern channel, but nothing is known of them, as that part of the region has not been visited. North and west the delta of the Kobuk merges into the coastal lowland that skirts the northern hills and extends beyond the Noatak. To the south and east the delta merges into the low country around Selawik Lake. The presence of a delta at the mouth of the Kobuk is notable, for it is practically the only large delta on the west coast of Alaska north of the Yukon.

SQUIRREL RIVER TO REED RIVER PROVINCE.

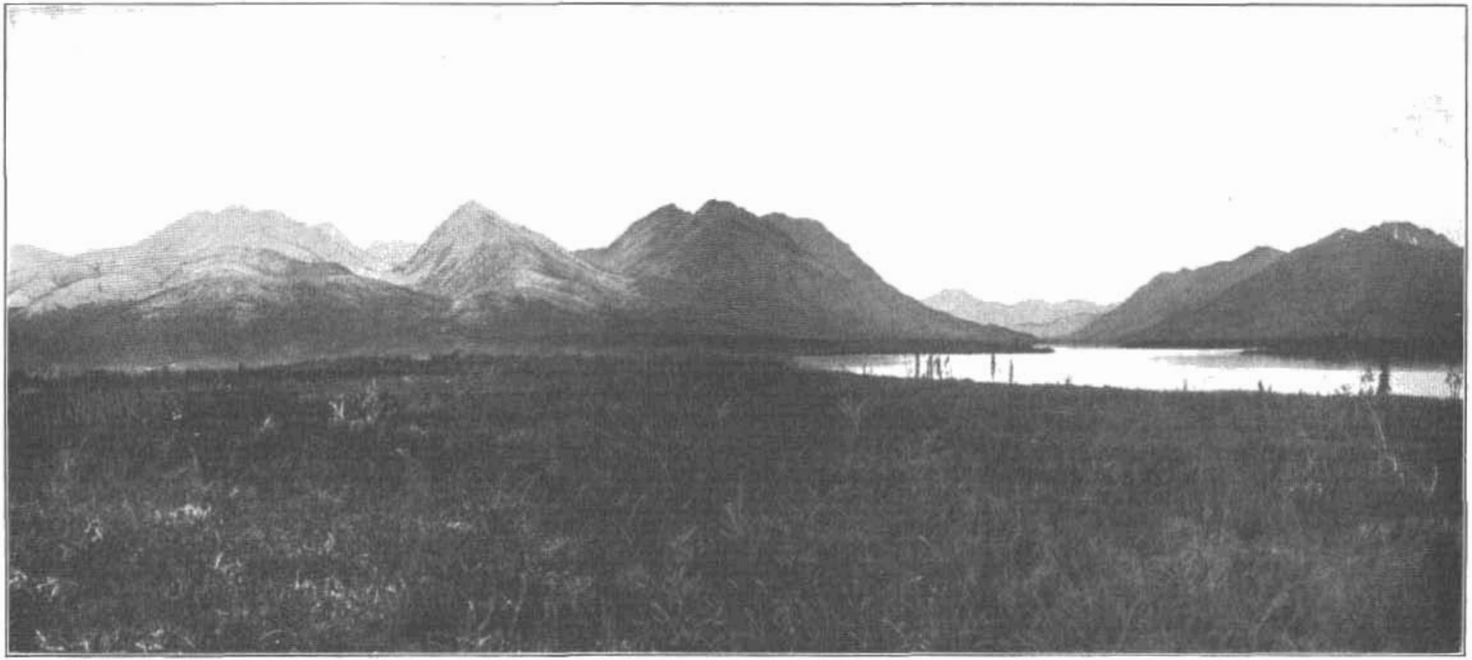
A short distance above Squirrel River the hills on the opposite sides of the river converge, and for 6 to 8 miles the valley floor is only 2 miles or so in width and rocks outcrop on both banks of the stream. Farther upstream the hills again recede and the floor averages 10 miles or more in width almost as far as the mouth of Reed River. Throughout most of this distance no rocks are exposed in the river banks, which are instead formed of sands, gravels, and silts, which here and there include ice masses 20 feet or more thick. The flood plain of the river is usually not more than 2 to 3 miles wide, and except in the part just above Ambler River the stream does not meander extensively. The river is from one-quarter to one-eighth of a mile wide and has no obstructions to navigation. The current is from 1 to 3 miles an hour, which, though not strong, makes tracking necessary. The river does not split up much into blind sloughs, so that it is easy to traverse, even by one unacquainted with the route.

Back of the flood plain there are prominent gravel terraces, which stand 100 to 200 feet above the river. Higher benches, the highest at an elevation of nearly 1,000 feet above the river, have been noted, but they are not so distinct as the lower ones. Traveling on these terraces is fairly good, as for the most part the gravels are well drained. Horses have been taken on these benches with little or no difficulty from Reed River to Shungnak, and similar country extends still farther west. Small lakes of irregular shape and size that were produced in an earlier stage of the valley development occur in places on these terraces. Here and there crescentic moraines opposite the mouths of the larger streams interrupt the nearly smooth gentle slope of the outwash plain.

North of the lowland of the Kobuk the hills rise with steep southward-facing slopes, the fronts of which are fairly well aligned, showing no long straggling spurs. This feature is particularly prominent in the stretch between Reed and Shungnak rivers, though it still appears here and there to the west. In this part the steep slopes lead to ragged peaks and ridges rising from 2,000 to 3,000 feet above the valley floor. Plate III is a characteristic view of the northern margin of the lowland, with the steep slopes and mountains in the background. The picture was taken from the gravel terrace 150 feet or so above the Kobuk, just west of Lake Selby. Except for the lake the picture is typical of the topography north of the Kobuk for about 100 miles.

One of the most peculiar features of the topography north of the Kobuk is the subordinate range of hills that lies between the Kobuk and the mountain area still farther north. This highland, which is called the Cosmos Hills, rises to an elevation of 4,000 feet and is separated from the Endicott Mountains by a lowland whose surface stands at an average elevation of less than 1,000 feet. The larger rivers rise in the Endicott Mountains, flow southward, enter the lowland, and then cut through the Cosmos Hills in steep-sided gorges, some of which are narrow floored, though others are broad. The divide between the streams in the lowland region is only about 200 feet high in places, as, for instance, between the Kogoluktuk, Shungnak, and Ambler rivers, north of Shungnak. At a distance it is almost impossible to distinguish the divides in this part of the region and travelers report that during the winter they have passed from one tributary to another without realizing the fact. With such a broad lowland region available it seems strange that the rivers have persisted across the trend of the lowland and have transected the Cosmos Hills.

In addition to these larger tributaries many streams that rise in the Cosmos Hills enter the Kobuk independently or join one of the larger branches. Some of these show peculiar features; for instance, some of the streams heading on the north side of these hills flow northward to the lowland or to a transverse stream, where they turn abruptly, cross the range, and thus enter the Kobuk. An example is Ruby Creek, which heads within 3 to 4 miles of the southern face of the Cosmos Hills but flows northward for 7 to 8 miles before joining Shungnak River; thence its waters are carried southwest about 20 miles before reaching the Kobuk. This condition prevails in spite of the fact that near its head, toward the south, there is a pass not over 400 feet above the Kobuk which has evidently been occupied by a former drainage way. Examples of this sort might be multiplied, but the one cited may serve to bring out the fact that the present



THE KOBUK VALLEY IN THE VICINITY OF LAKE SELBY.

drainage was in a large measure determined by the earlier topography. It is believed that these passes, transverse streams, and like features are best explained as due to drainage modifications induced by glaciation in the Endicott Mountains and contiguous territory in comparatively recent time.

Especially full description of the region north of the Kobuk in the eastern part of the Squirrel River–Reed River province has been given, as this region is best known. Farther west there are many large tributaries that rise in the hills to the north, but their basins are practically unexplored. Squirrel River has been visited, but only its lower part. This part of the valley is a broadly open gravel-filled lowland, in which the stream meanders in irregular fashion. Benches on the valley sides, the highest 400 feet above the stream, form prominent features, and the nearly impassable sloughs, marshes, and flats between the river and the hills are particularly notable. Many of the small tributaries of Squirrel River in their headwater parts flow in rock-cut gorges, but in their lower courses they flow in the gravel deposits of the main valley.

Passes from the Kobuk to the Noatak probably occur at the heads of many of the larger streams. A prospector with pack horses is reported to have gone to the Noatak by way of a pass north of Squirrel River, and it is probable that several low passes lead from the western part of this basin into the lower part of the Noatak Valley. At the head of Hunt River there is reported to be another pass which probably leads to Cutler River, a tributary of the Noatak. Stoney and his parties went to the Noatak by way of Ambler River; natives met by the expedition of 1911 on the Noatak reported having come by way of the Kogoluktuk and an easy pass into the Ipmiluik, a stream entering the Noatak 12 miles south of the camp of August 2; prospectors report having gone to the Noatak by this route and also by way of the Mauneluk, the next large tributary of the Kobuk to the east. It is probable that no good passes to the Noatak will be found farther east until Reed River is reached.

South of the Kobuk the hills are not so high and rugged as those to the north. The same terraced country stretches from the river to the foot of the hills and the slope to the crest of the ridges is nearly as steep. The spurs do not show as well-marked alignment as on the northern side and they have a less truncated appearance. Benches that lie considerably above the river are more noticeable on the southern than on the northern hills.

No definite name has been applied to the southern range as a whole. The western part has been called the Waring Mountains, the central part the Sheklukshuk Range, and the eastern end was considered by Stoney to be part of a northeast-southwest range, called by him the Lockwood Mountains. The latter name has here been applied to the range south of the Kobuk, and the mountains still farther south, which are entirely separate, have been called the Zane Hills. In many respects the drainage of these hills is peculiar. There are normal streams that rise on the northern face of these hills and flow northward to the Kobuk, but there are in addition some streams that rise on the southern face and, after flowing for a distance southward, turn abruptly, transect the range, and thus join the main stream. Pah River is the best-known example. As the form and relations of this river are well illustrated by the topographic map, further description may be omitted, except to point out that there is practically no divide between this stream and the Koyukuk drainage on the south and that the divide between it and Selawik River on the west is less than a thousand feet high.

Very little is known of the drainage and relief south of the Kobuk in the western part of the Squirrel River-Reed River province. From the views obtained on the Kobuk, and from the reports of Stoney and Cantwell and their maps, it seems probable that the range of hills is narrow and the streams are therefore relatively short. None of the peaks seen west of Shungnak were more than 2,000 feet high, and it is doubtful if more elevated points occur. East of Shungnak, however, some of the higher hills rise to 4,000 feet, but these are exceptional, the average elevation being probably not over 2,500 feet. Here and there a gap not occupied by a stream interrupts the continuity of the Lockwood Hills, notably at a place about 10 miles east of the mouth of Selby River, where a narrow gorge, whose bottom at the highest point is not over 500 feet above the Kobuk, and whose precipitous walls are over 1,000 feet high, cuts completely across the range.

Passes across the range south of the Kobuk can be found almost everywhere. The passes in the western part of the range lead into the Selawik basin; those in the eastern part lead into the basin of the Koyukuk. Stoney[1] reports having gone from Fort Cosmos to the Selawik by way of a pass not over 400 feet above the Kobuk. The Survey expedition of 1910 traveled with horses along the crest of the Lockwood Hills from a point west of Pah River to a point nearly south of Beaver River, so that even in its higher parts this range is not difficult to cross, and with the numerous transverse gaps a route from the Kobuk to the Koyukuk can be found that nowhere rises more than 400 to 500 feet above the Kobuk. The most traveled route between the Kobuk and the lower part of the Koyukuk is by way of the Pah. The name Pah signifies "door" and refers to the fact that this is the gateway into the Yukon basin.

[1] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 41.

THE HEADWATER MOUNTAIN PROVINCE.

As has already been stated, the upper part of the Kobuk Valley above Reed River is here included in the headwater mountain province. In the part of its course near the mouth of Reed River the Kobuk is one-eighth of a mile wide, but it decreases in width toward its headwaters in the high hills between the Alatna and the Noatak. Its depth also differs greatly from place to place. Near the mouth of Beaver River a sounding of over 14 feet was obtained, but natives report that above Kichaiakaka Creek the river splits up into many small streams, all of which are too shallow even for canoe navigation. Probably some of these streams rise in small glaciers, but the region has not been explored and little is known about it. Most of the valleys have forms such as are usually produced by glaciation, and there is reason to believe that in the past many if not most of the larger valleys were occupied by ice. This fact has been emphasized by Mendenhall in describing part of this region, for he states that much of the topography and stream alignments are of the confused types that result from ice work.

Several lakes form notable features in this province. The largest of these is Walker Lake, which is about 14 miles long and from 1 to 2 miles wide, and is hemmed in by rugged mountains except at its south end. Near by is Nutuvukti Lake, much smaller than Walker Lake but similarly situated. These lakes are probably of the same general origin as Selby Lake, in the more western part of the valley, already described and illustrated, and the several other mapped lakes in the neighborhood. Of an entirely different character is Norutak Lake, south of the Kobuk. It occupies a broad widely open lowland that is reported to extend uninterruptedly between the Kobuk and the tributaries of the Koyukuk.

The following description by Mendenhall[1] of the country around the head of Walker Lake furnishes a general idea of the topography of the mountain province as a whole:

> The lake is bordered on both sides by precipitous mountains which rise to heights of 3,000 or 4,000 feet. Southeast of it, toward the mouth of Reed River, the country becomes broken, the hills, which are from 1,000 to 4,000 feet in height being separated by broad passes, which are often not much above the general level of the streams.

As these mountains form the divide between Kobuk, Noatak, and Alatna rivers, there will be occasion to describe some of the specific features noted in the other basins later. (See pp. 32–33, 36–38.) For the present it will suffice to point out that the peaks and ridges are lofty and rugged, with great differences in elevation, and are undergoing erosion so rapidly that they preserve in few places any evidence of an earlier topography. Bare rock crests and talus-

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 25.

covered lower slopes dominate and are the characteristic features of the landscape.

THE NOATAK BASIN.

The region adjacent to the Noatak may be divided into six more or less topographically distinct parts. These, from the mouth upstream, are the coastal lowland, the Igichuk Hills, the Mission lowland, the second highland, the Aniuk lowland, and the headwater mountains. As was said of the Kobuk basin, it is probable that more complete knowledge of the geography would necessitate modification of these subdivisions, for they refer only to the region near the river and not to the entire basin. For instance, probably all the mountains form one main topographic unit in which the various lowlands have been carved. Inasmuch, however, as the six provinces enumerated above are the most striking features to the ordinary traveler, they will be adopted in the following description.

THE COASTAL LOWLAND.

The coastal lowland adjacent to the Noatak, as its name implies, has low relief, at no place rising more than a few hundred feet above the sea. It has the form and general characters of a coastal plain and not those of a normal delta. In fact, the delta portion of the Noatak above water, if the term delta is applied only to the part where the river splits up into distributaries, is not more than about 2 miles long. In this respect the Noatak differs in a marked manner from the Kobuk. Lakes and marshes, it is true, occur in great numbers on either side of the river for 10 miles above the mouth, but gravel benches 50 feet or more in height extend as far south as the large mapped island just above the first distributary to the west and are not periodically overflowed.

The plain is composed mainly of sands and gravels, probably of marine origin, which were deposited under water and then later uplifted and partly dissected. The slopes from the sea toward the next upstream province are rather gentle and in places no sharp line of demarcation between the two can be drawn. Near the river the upland is fairly well drained, but farther away the thawing of the surface in the summer makes an almost untraversable morass.

The main river is about a mile wide and has a gentle current. It is not much obstructed by islands or sand bars. At its mouth it is so shallow that boats must follow the channel. No soundings were made by the Survey party, but McLenegan's map shows a depth of 12 to 15 feet as far upstream as the big bend to the west near the camp of August 26. Few tributaries enter the Noatak in this part of its course and all of these are mere wet-weather streams, so that its valley is very narrow.

IGICHUK HILLS.

The topographic feature called here the Igichuk Hills, is a highland area from 5 to 15 miles wide trending in general east-west, the higher points of which rise to elevations of 1,500 to 2,000 feet. On the east these hills join those south of the Squirrel River basin of the Kobuk, which in turn are part of the general highland area called by Stoney the Baird Mountains. To the west the Igichuk Hills disappear as topographic features north of Cape Krusenstern. The most remarkable feature of this range is that the Noatak cuts through it in a narrow gorge. This lower gorge is 400 to 600 feet deep and is so recent a feature that practically no flood plains have been developed and ragged limestone points jut into the river in fantastic pinnacles. Benches along the hill slopes, the highest standing at an elevation of 1,000 feet, have been formed by water-worn gravel and sand. Above that elevation, however, the surface is mainly bare rock, affording numerous easily identifiable landmarks. Plate IV, *A*, gives a typical view of the Igichuk Hills from the knob 2 miles northeast of the camp of August 26, looking northwest. The Noatak, just above the point where it enters the lower gorge, may be seen to the left as a small white area. The gorge is between the low knobs in the middle ground and the higher hill at the left of the picture.

This range of hills is so narrow and low that it affords no considerable run-off, and consequently streams tributary to the Noatak heading in it are short and small. The largest are Agashashok and Igichuk rivers. The former, however, drains not only the northern face of the Igichuk Hills, but also part of the region to the north and will therefore be described later. Igichuk River enters the Noatak from the east, a short distance below the camp of August 26. Owing to the sluggishness of the current of the Noatak at this point the Igichuk has built a small delta. The stream is only 15 to 20 miles long and its basin includes not over 100 square miles.

MISSION LOWLAND.

The Mission lowland is a broad gravel-filled lowland bounded on the south by the Igichuk Hills and on the east by the highlands called by Stoney the Baird Mountains. The southwestern part of the province stretches westward uninterruptedly to the Arctic Ocean. Northeast of this broad pass there are low hills, which are higher toward the north and east and gradually converge toward the river, giving rise to the second highland province. The lowland is about 50 miles long from north to south and has an average width of about 20 miles. The greater part of the region is only 200 to 600 feet above sea level and has very low relief.

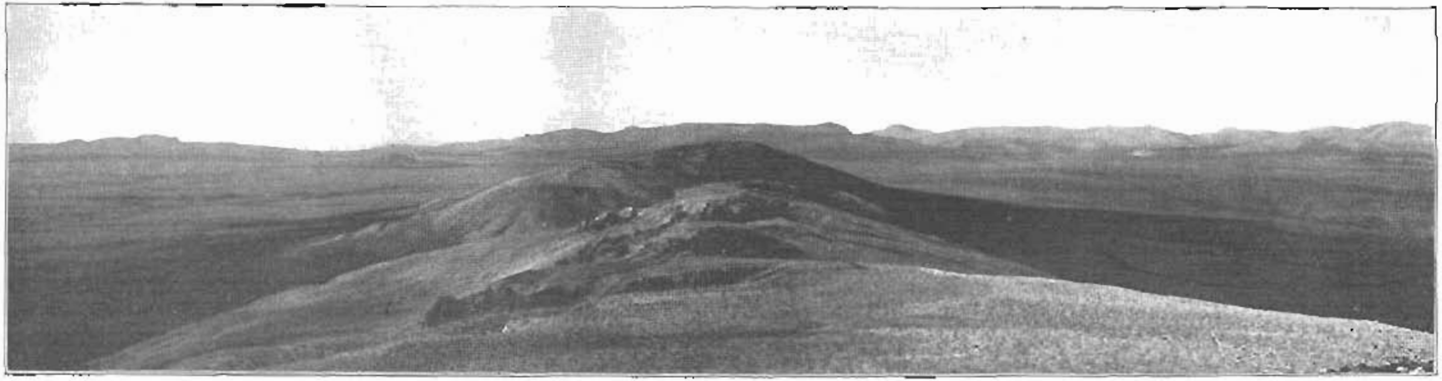
In the northern and central parts of this lowland the main river occupies a strip of the valley floor about 2 miles wide, within which it is a network of anastomosing or braided streams, most of them shallow and difficult to follow. Although the gradient of the river is low, the volume of water is so great that the current is strong and progress upstream can be made only by tracking. The banks are low, rising only 5 to 15 feet above the water at normal stages of the river. In the southern part of this lowland, below the camp of August 22, the river is not split up but flows in a single channel for a long distance along the northern flank of the Igichuk Hills. In this part of its course the stream is deep and on the south side is bordered by gravel bluffs from 50 to 150 feet above the river. A sounding near the camp of August 23 gave a maximum depth of about 30 feet and the width of the river at that place was 900 feet, but 2 miles upstream its width was 2,200 feet.

The country back from the river is a plain covered with so many lakes of all sizes and shapes that it has been possible to represent them on the map only in conventional or diagrammatic manner. These lakes have probably been formed by diverse processes, and, although many are old, flood-plain lakes, most of them had some other origin. Here and there rounded hills one-half mile in diameter at the base rise 100 to 300 feet above the general surface of this plain. They are symmetrical in shape and, although irregularly distributed over the plain, suggest, when viewed from a distance, giant haystacks. None of these was examined at close range, but they are apparently gravel mounds similar to those near the mouth of the Colville, described and illustrated by Schrader.[1]

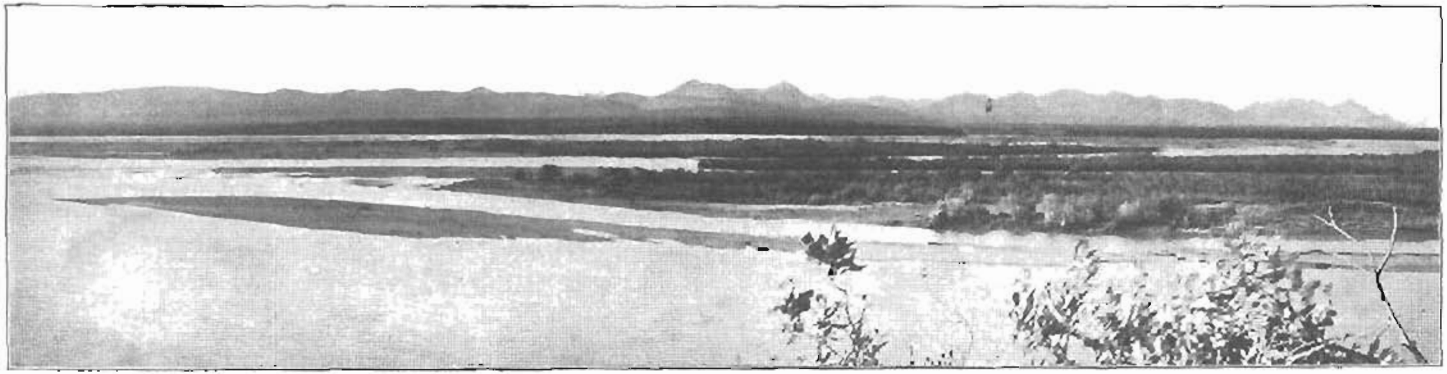
Side streams that rise in the highlands bounding the Mission lowland flow on steep gradients until they reach the plain, where they lose velocity and meander across the flat in valleys so slightly incised and so featureless that they are not recognizable at a distance. It is uncertain where most of these streams join the Noatak, for many enter sloughs. Even those that do join near the route traveled are likely to be mistaken for sloughs. The largest tributary in this province is the Agashashok, which empties into the Noatak from the east at the extreme southeastern part of this Province. It heads far back in the Baird Mountains and probably also receives a large amount of drainage from the west face of these hills. In the lower part of its course it flows parallel to the Noatak until that river, swinging against the Igichuk Hills, cuts out the lowland and permits the tributary stream to enter. Numerous other streams rising on the western slopes of the Baird Mountains are tributary to the Noatak. None of these, however, is large, and all are unnamed. From the northern slope of the Igichuk Hills only a few short streams flow into the Noatak.

The Mulgrave Hills, which bound the lowland on the west and their continuation to the north and east, are the source of several large

[1] Schrader, F. C., Reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 94 and Pl. XVI, *B*.

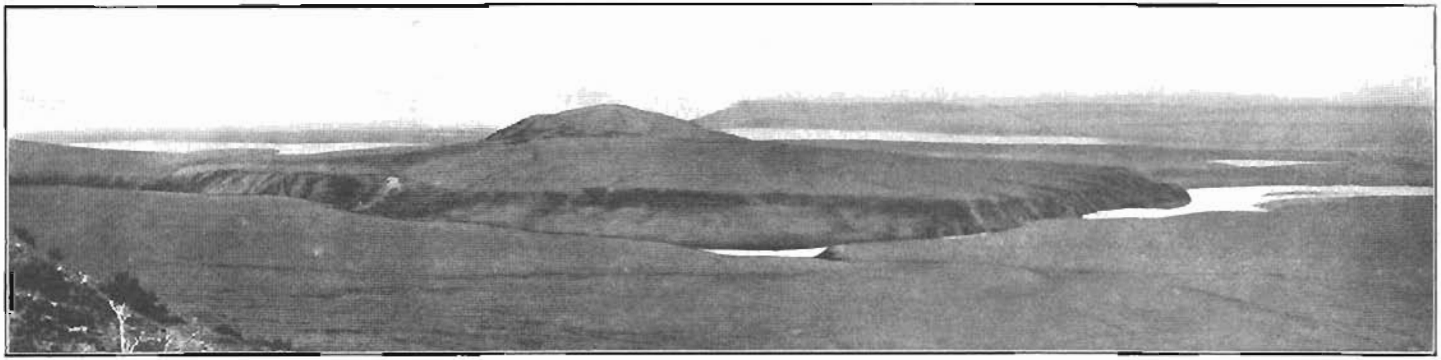


A. THE IGICHUK HILLS, NOATAK VALLEY.



B. NORTHERN PART OF MISSION LOWLAND.

A. HILLS WEST OF NIMIUKTUK RIVER.



B. TOPOGRAPHY IN THE VICINITY OF THE CANYON OF THE NOATAK.

streams. Of these the largest are Kelly River, which enters the Noatak about 8 miles in an air line above the camp of August 19, and the Kugururok, which comes into the main stream a short distance above the camp of August 18. Both these streams rise in the unexplored divide between the Noatak and the Arctic Ocean north of Point Hope, and the heads of both are reported to afford low passes into the northern drainage. The valley floors, even within the hills, appear to be very broad and steep walled, and these rivers probably extend northward for a considerable distance. Near the Noatak the streams are much split up and it is difficult to form a just idea of their volume.

Plate IV, *B*, is a view in the northern part of the lowland province, taken from a point on the south side of the river a short distance above the camp of August 19. Although the lowland is not so wide here as it is farther south, the view illustrates the braided character of the stream and the featureless plain bounded by mountains 2,000 to 3,000 feet high and 10 to 15 miles distant. At the extreme right of the view the gap in the hills marks the valley of Kelly River.

THE SECOND HIGHLAND.

The second highland province is formed by the convergence of the hills east and west of the Mission lowland. It extends from the canyon of the Noatak above the camp of August 18 to Nimiuktuk River at the camp of August 11, a distance of about 60 miles in an air line. In this part of its course the Noatak is from one-quarter to one-eighth of a mile wide. Although the river has numerous rather abrupt large bends it has no well-marked meanders and is in a relatively youthful stage. Here and there, as, for instance, 5 or 10 miles below the camp of August 11, it splits up into a number of braided streams, but through most of the province it flows in a single channel. Gravel terraces that stand 50 to 100 feet above the stream form prominent features, and higher terraces, not so noticeable, also occur. The Noatak has eroded a rather narrow steep-sided trench in these gravel deposits. Bedrock outcrops at many places on both sides of the valley, but although in some such places the current is swift there are no dangerous falls or rapids.

The hills that flank the stream rise with steep slopes to elevations of 2,000 to 3,000 feet above the river and as a rule have a rather subdued topography. Plate V, *A*, a view toward the west taken from the triangulation station near the camp of August 11, gives a general idea of the eastern part of the second highland area, which is fairly typical of the province as a whole. Most of the lakes in the foreground of this picture lie 50 to 150 feet above the river and are not on the present flood plain.

Perhaps the most striking feature of this province is the canyon that practically marks the beginning of this part of the valley. Plate

V, *B*, a view taken from the low hills about 2 miles south of the camp of August 14, shows the general topography of the canyon region. The Noatak, flowing from right to left in the picture, turns abruptly from the broadly open lowland north of the camp of August 14 and swings south and west through the narrow rock-walled gorge in the middle ground. One large lake and numerous smaller ones occupy the old more direct valley north of the canyon. Other views shown in this report (see Pl. XI, p. 70) give glimpses within the canyon. The walls rise precipitously 600 to 800 feet above the river and afford scarcely foothold on either side. The water rushes so swiftly through the canyon that a transverse wave reaching halfway across the river is set up as the stream impinges on the bluffs, first on one side and then on the other. In this constricted part of the river the water is deep. During periods of heavy rain the stream above the canyon rises rapidly but falls as quickly. McLenegan[1] notes that a short distance upstream the water surface fell 8 feet in a single day and states that this rapid fluctuation was one of the most noteworthy features. There will be occasion later (see pp. 93–94) to describe in more detail certain of the features in the neighborhood of the canyon which throw light upon its origin and also to describe the rocks exposed in the walls (pp. 70, 110).

Numerous side streams heading far back in the mountains to the north enter the Noatak above the canyon. It was not possible to determine definitely the position of the divide, but it appeared to be nearer the river to the south than to the north. The largest of the tributaries is the Nimiuktuk, or, as it is sometimes called, Indian River. For more than 5 miles above its mouth this stream is split up into a network of channels, which are separated from one another by low sandy islands. The western wall of the valley is marked by prominent hills, but the eastern part for at least 10 miles above the mouth of the river is a low rolling country not more than 400 to 600 feet above the stream. The depth of the valley floor below the present flood plain, however, is not very great, as outcrops of bedrock appear on both sides of the river for a mile or two above the mouth of the stream.

ANIUK LOWLAND.

East of the camp of August 11 the hills forming the second highland area recede from the river, and the last of the lowlands, here called the Aniuk lowland, commences. This is a gravel-filled depression about 75 miles long and 10 to 30 miles wide. In this part of its course the river is from one-eighth to one-sixteenth of a mile in width. There are many large angular bends in the general course

[1] McLenegan, S. B., Exploration of the Noatak River, Alaska: Report of the cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, p. 72, 1887.

of the stream as well as numerous much smaller meanders. The average width of the meanders is 1 to 2 miles, whereas the larger bends measured in the same way have in places a width of as much as 10 miles. The current has an average velocity of 2 to 3 miles an hour. On the whole the stream offers no serious obstacles to navigation by small boats except during periods of very low water, when the numerous bowlders in the river bed cause dangerous rapids.

Plate VI, *A*, a view toward the south and east taken near the camp of August 7, shows a typical part of the lowland. The most prominent features in this picture are the broad, nearly level upland and the meandering river. The river has incised its bed below the general level of the upland and is more or less hemmed in between steeply sloping gravel walls that rise to heights ranging from 50 to 200 feet. Flood plains alternate with cut banks and some abandoned courses of the river are preserved as lakes. Many of the lakes seen in the view, however, lie on gravel benches 50 feet or more above the river and have had a more complex history. The upland, as is evident from the view, is an almost featureless plain, except where low rocky hills, like those shown in the center of the picture, here and there rise above the gravels. Although the upland slopes downward from the hills that bound the lowland on the north and south as well as downward along the course of the stream, it gives a general impression of being essentially flat.

Numerous small streams rise in the low country near the Noatak. The larger streams, however, rise in the distant mountains and flow across the lowland in rather narrow trenches. The largest tributary from the south, Cutler River, joins the Noatak near the middle of this basin. The Cutler was called by Lieut. Stoney the Caribou, but this name was not published until after the other had been adopted. It carries nearly one-half the volume carried by the main river above that point and drains a large region between the Noatak and Kobuk. A large tributary, the Aniuk, enters the Noatak from the north. This stream heads in the distant rugged hills that limit the lowland to the north and probably receives most of the southward drainage from those hills. Many of the tributary valleys of the Aniuk show broadly open U-shaped cross sections in the mountains and were probably once occupied by glaciers. A broad, low pass leads from the Noatak by way of the lowland into the Colville basin, which drains into the Arctic Ocean east of Point Barrow. This pass was probably traversed by Howard, of the Stoney expedition, on his trip to the Arctic Ocean. (See p. 14.) The farthest point reached by McLenegan was about 10 miles east of the mouth of the Aniuk. Aniuk River was particularly notable because of the large amount of clear water it added to the Noatak.

THE HEADWATER MOUNTAINS

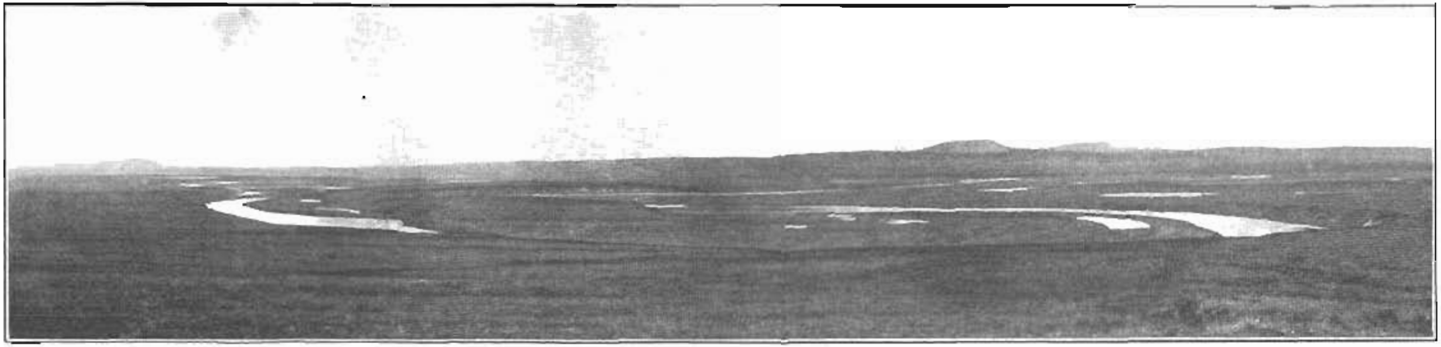
The mountainous headwater province, which extends roughly for about 75 miles east and west, is formed of the mountains that stand at the headwaters of Kobuk and Alatna rivers. (See pp. 25–26.) The floor of the main valley gradually narrows from a lowland 2 miles wide, in which the river meanders in a slightly incised trench, toward the headwaters, where it is entirely occupied by the stream. Gravel deposits here and there, the highest about 1,000 feet above the river, cover the steep rock scarps that are elsewhere bare and prominent. The rocky walls rise abruptly from the valley floor and have the truncated appearance usually produced by glaciation.

In the higher hills there are small glaciers, probably the remnants of larger ones. None of those seen was more than a mile or two long and none of them extended below an elevation of 5,000 feet. In the parts of the range that were not explored even larger glaciers may be found. None of the side streams, however, showed marked turbidity, such as is exhibited by streams that receive a large part of their water from glaciers.

Many valleys heading in the divide between the Kobuk and Noatak are reported to extend long distances and to afford passes by glaciated cols from one basin to the other. Plate VI, *B*, a view up Ipmiluik River, which joins the Noatak a short distance above the camp of August 1, shows a typical side valley and the general features of the highland province. The steep slopes, the bare ragged crest lines, and the broad main valley floor, with benches near the hills, are all represented. Natives report that the Ipmiluik Valley affords an easy route into the Kogoluktuk Valley of the Kobuk basin.

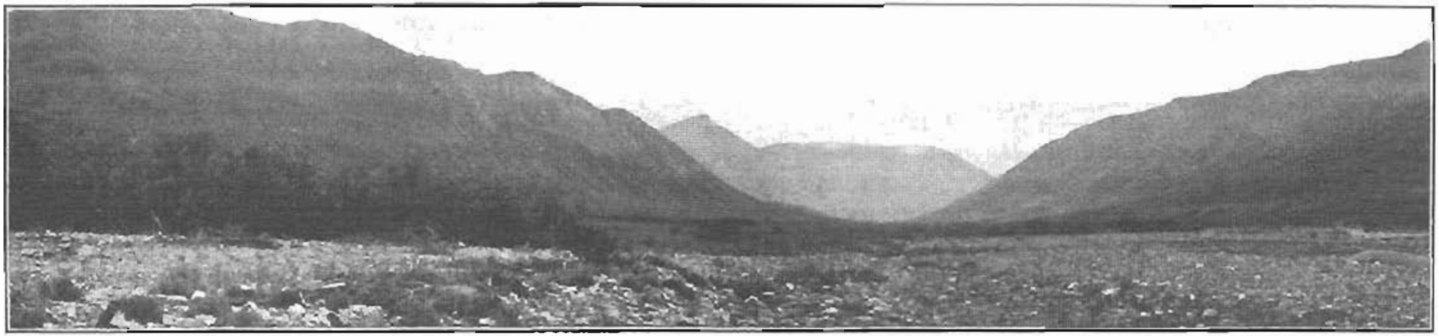
In the headwater mountain region there are passes into the Alatna by way of the route used by the Survey and also by way of Lucky Six Creek and Gull Pass. The pass used by the expedition of 1911 is about 1,000 feet above the Noatak and 8½ miles in an air line from that stream; the total distance from the head of canoe navigation on the Noatak to boating water on the Alatna is about 11½ miles, so that this route is especially good for a canoe portage. Gull Pass is about 1,000 feet higher, is much longer, and is far more difficult. It was not surveyed, but the general topography of this route was seen from both the east and the west.

Opposite the mouth of Lucky Six Creek there is also a pass into Reed River, of the Kobuk drainage, and another pass to the same stream by way of the southern fork of the Noatak is reported. Both of these are steep and difficult, but prospectors say horses can be taken over them. A pass into Colville drainage, at the head of one of the branches of Midas Creek, was also examined. The divide is about 8 miles distant from and 2,000 feet above the camp of August 2. This route is feasible for a canoe portage, and the distance between

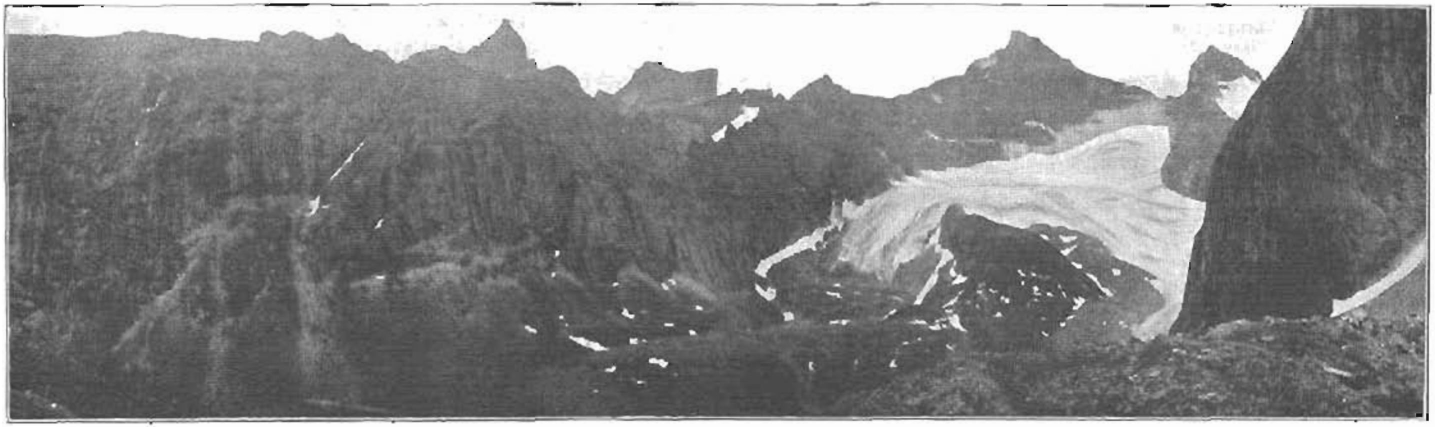


A. ANIUK LOWLAND FROM CAMP OF AUGUST 7.

B. NOATAK AND IPMILUIK VALLEYS.



A. UPPER PART OF ALATNA RIVER VALLEY



B. PEAKS AND GLACIERS IN CENTRAL PART OF ALATNA RIVER BASIN.

water deep enough to float canoes on the two streams is about 13 miles. This is possibly the Riley Pass traversed by Stoney on his first trip to the Colville, but his map and descriptions do not make this clear.

ALATNA RIVER BASIN.

KOYUKUK RIVER TO HELPMEJACK CREEK.

The Alatna River valley has a general northwest to southeast trend. It is about 140 miles in length and is rather narrow, as the side-stream valleys are short. The basin comprises two rather distinct topographic provinces. The southern one, carved in relatively weak rocks, has subdued topographic features; the other, carved in resistant rocks, is characterized by rugged mountains.

In the southern province the valley floor is a wide gravel-filled lowland in which the stream is incised but slightly and flows in sinuous meanders that try the patience of the traveler upstream. From this widely open, partly filled valley floor gentle slopes lead to the surrounding upland, which in few places rises more than 2,000 feet above the river. In this part of its course, although the stream is too swift to allow rapid progress to be made against it by rowing, its gradient is less than 5 feet to the mile. Here and there rocks outcrop on the two sides of the river, but the ledges form no obstruction to boats. Shallow-draft river steamboats have ascended this river as far as Helpmejack Creek, but only during periods of exceptionally high water. In 1911 a small river steamboat was able to get only about 40 miles before it was stopped by shallow water, although that season was not particularly unfavorable.

The largest tributary of the Alatna in this part of its basin is Siruk Creek, which enters from the west. This stream drains the broadly open lowland that probably extends from the Alatna to the Hogatza and thence by way of the Norutak Lake valley to the Kobuk. This lowland is reported to be the main winter trail from the lower Alatna Valley to the Kobuk. Other smaller streams also are received by the main river, but few of them are more than 5 to 10 miles long and in their lower courses are seldom distinguishable from sloughs of the Alatna.

HELPMEJACK CREEK TO HEAD.

Main stream.—The second topographic province extends from near Helpmejack Creek northward as far as the region was explored. In this province the river occupies a floor ranging in width from 1½ miles in the southern part to only a few feet in the headward portion, the maximum width of the stream itself being less than one-eighth mile. As far as Nahtuk Creek the river runs in a very sinuous course in a rather straight valley. Distances measured between a series of points along the course of stream in this stretch are at least three times as great as the distances in a straight line between the two end points of the series. Above Nahtuk Creek the course of the river becomes straighter, the current swifter, and the water shallower.

From Helpmejack Creek nearly to Twin Mountain Creek the floor of the valley has gravel deposits, which form marked terraces where the river has cut its bed a hundred feet or more into them. In this part bedrock outcrops here and there but forms no serious obstruction to small boats. Good gravelly and sandy footing may usually be found in normal stages of the river near the edge of the water. The bed and shore of the river from Twin Mountain Creek to the Nahtuk is formed of quicksand which makes traveling on shore extremely difficult. Fortunately, as a result of this condition, the river has a flatter gradient and consequently a slower current, so that fair progress upstream may be made by rowing or with a favorable wind by sailing. Above Nahtuk Creek firm sand and gravel, rather coarser on the whole than the material farther downstream, furnishes good traveling near the river. Still farther upstream the river splits into numerous small streams, some of which are too small to float even a light canoe. Between these places, however, there is but a single stream furnishing ample water.

Above the mouth of the Unakserak the volume of the Alatna is so small that it may be crossed almost anywhere on the riffles without going more than thigh deep. The slope increases so much that in the 15 miles between the camps of July 20 and July 23 the fall is 700 feet, or an average of nearly 50 feet to the mile. In this part the river flows in an almost uninterrupted succession of riffles. The river, now diminished to a stream only a few feet in width, makes many abrupt bends, abutting against rocky outcrops on either side of the floor. Gravel terraces and rock-cut benches here and there rise above the stream. On the whole the valley floor has a nearly straight trend and is much wider than the stream channel.

A general view of the upper part of the Alatna Valley, looking northwest from the camp of July 23, is given in Plate VII, *A*, which shows Alatna River to the right, the low gravel terrace into which the stream is cutting, the valley floor—which is very wide in proportion to the size of the stream—the characteristic slope of the valley walls, and the rather straight and parallel direction of the junction between the walls and the valley floor.

Side streams.—The side streams tributary to the Alatna are all relatively short and have no considerable discharge. Practically none of these streams was explored to its headwaters, so that their length can only be inferred by their relation to known basins and by reports of prospectors.

Iniakuk River, with its tributary Malemute Creek, is the most southern of the streams entering the Alatna from the east. It is in a measure parallel with the Alatna, but its eastern tributaries head in the range west of John River. It is reported that relatively easy portages lead by way of these tributaries to Malemute and Sixtymile rivers of the John River basin. There is also a low pass by way of one of the western tributaries to Alatna River above Lake Takahula. There will be occasion to refer again to this pass, which is picturesquely known to the natives as Akabloouk, or "daylight through the hills," in describing the glacial features of the region. On its western branch there is a lake several miles long.

Above the Iniakuk only a few small streams enter the Alatna until the Nahtuk is reached. This also comes in from the east, and its eastern tributaries are reported to head in the same hills as the western branches of the Iniakuk. Between the two there is reported to be an easy pass. About 4 miles above the Nahtuk is the Pingaluk, a small stream draining a triangular area between the Nahtuk and the next upstream creek, the Kutuk.

The Kutuk is said to be longer than either the Nahtuk or the Pingaluk. It is the river that, according to the text, Stoney ascended on his trip to Chandler Lake. According to his map, however, the Unakserak, which is the next stream north, is represented as the one he followed. Owing to this discrepancy, the fact that he traveled 35 miles to the head of the Kutuk does not definitely demonstrate the geography. Natives report that the Kutuk heads against Colville drainage, but it is believed that the portage by this route is too long to be practicable for transporting boats from one stream to the other.

From the west, a short distance below the mouth of the Kutuk, a stream heading in glaciers was explored. Although of small size, this stream heads in the highest hills of the region, from which probably the Kobuk and Noatak rivers also receive some drainage. A pass was reported to lead by way of this valley into the Kobuk and Noatak valleys. A thorough search showed that this report, like much other hearsay testimony, was untrue. Although it is probable, as has already been pointed out, that the Noatak and Kobuk lie on the other side, this divide is so nearly unscalable that almost any other route would be preferable. Plate VII, *B*, shows the head portion of this valley, and indicates not only the unfeasible character of this route but also the general type of relief.

From the west several other unnamed streams enter the Alatna. None of these require special mention here, as their general features are indicated on the map (Pl. I). Gull Creek, which joins the Alatna a short distance above the camp of July 20, however, is important, as it is reported to afford the first feasible portage into the Noatak. The pass at the head of one of the branches leads into Lucky Six Creek, of the Noatak. This route is a rather difficult one, and is not so well adapted for portaging boats as the pass used by the Survey. It is reported to be about 1,000 feet higher than the more northern pass, and descent on the west side is steep. Prospectors say that it was named Gull Pass, for the first white man that crossed it.

The small gulch from the north joining the Alatna at the camp of July 20 is so small that it would not be worth mentioning, except for the fact that it leads to Colville River and is apparently a much-traveled route. The air-line distance to the Alatna-Colville divide from the camp of July 20 is less than 5 miles and the country is not at all difficult to traverse. Many indications near this place show that for a long time it has been the custom for natives to build their boats here for the trip down the Alatna.

The upper and better pass from the Alatna to the Noatak is by the gulch near the camp of July 23. This is occupied by little more than a wet-weather stream, heading in a broadly opened saddle which has an elevation of only 1,000 feet above the Alatna, and is not more than 3 miles in an air line from that stream. Three small lakes occupy the col, the smaller eastern one draining into the Alatna and the other two into the Noatak.

Farther upstream no large tributaries are received by the Alatna. About 12 miles above the camp of July 23 the river, which is little more than a mountain creek, forks, one part draining the country to the west and the other that to the north and northeast. Passes by way of either of these forks probably lead to the Colville, and some are undoubtedly low and may afford easy sledding routes; for boat portages, however, they would be too long, as it is practically impossible to ascend Alatna River, even during periods of high water, much above the camp of July 23.

The highlands.—Attention has so far been directed mainly to the lower parts of the basin—that is, to the valley floors of both the main and the side streams. With these the traveler is most in contact; but the valley walls, the ridges between streams, and the other parts that here have been called the highlands, in addition to presenting the greatest scenic interest, also occupy by far the larger part of the region and therefore also warrant description. The most accurate and complete information concerning these features is shown by the topographic map (Pl. I). As this map shows all the details, it may be supplemented by a general statement of the larger features of the highland topography.

The slopes leading from the valley floors are steep in all parts of the basin. In the smaller valleys these slopes in the mai nrepresent the normal erosion of a recently carved stream valley. In the larger valleys many of the slopes are oversteepened by glaciation. Plate VII, *A*, a view in the upper Alatna Valley already described, shows the slopes characteristic of the larger valleys and represents conditions that are by no means exceptional. Scaling the distances and elevations from the map shows that many of the valley walls slope at an angle of 30° or more. On streams such as the one shown in Plate VII, *B*, where glacial oversteepening has been effective, the slopes in places are practically vertical.

On the lower slopes the accumulation of detritus that has fallen from the cliffs above or has been deposited by the agencies formerly operative produces waste forms in accordance with the particular process by which they were formed. Higher up, the mantle of débris becomes thinner, until on the steeper slopes exposures of bedrock dominate. In such places frost action and allied weathering processes are abnormally active and constant disintegration of the exposures is taking place, the material clattering down the steep slopes until it finds lodgment on the gentler ones below.

The ridge tops that form the culmination of the valley walls rise to elevations of 4,000 to 8,000 feet. When viewed from a distance there is a general accordance of summit level somewhat similar to the features described by Schrader in the John River basin to the east, but when examined in more detail at closer range the crests differ considerably in elevation and seem to be undergoing such rapid degradation that they nowhere preserve any considerable area of an earlier topography. For this reason some hesitancy is felt in accepting the interpretation of the origin of this feature postulated by Schrader[1] for the accordance of summit level in the Endicott Mountains to the east. Although doubt is expressed as to the interpretation, there is no question that all the peaks rise within about 2,000 feet of the 5,500 feet assumed by Schrader as the elevation of his "Endicott Plateau" from which the Endicott Mountains are supposed to have been carved.

As the general trend of the bedrock structures is dominantly east and west many of the ridges also show the same direction. There is not, however, a decided difference in resistance to erosion between the various kinds of rock, so that the trend is not strongly marked. The granites, however, seem to be more resistant than the other rocks, and the ridges where they occur are loftier than those formed of schists and limestones. It is believed that this is mainly due to the greater resistance, but it may also be due in part to the originally higher uplift of the areas in which the granites occur. The most rugged forms also occur in the granite areas. This fact also is capable of antithetical explanations—first, that the granite on account of its physical character erodes into these forms, and, second, that because it makes the highest hills it was the place of the most intense glaciation in the past and has therefore been most deeply eroded by this agency.

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[1] Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 44.

crossed. Freezing continued until in February the ice had a thickness of 5⅓ feet. On May 19, 1886, the ice along the banks of the Kobuk began to crack, and by June 6 the river was free of ice. Joseph Grinnell,[1] who spent the fall of 1898 and the spring of 1899 in the central part of the Kobuk Valley, reports that on October 15 the river was full of ice and that by October 21 the ice was a foot thick. In the following spring the ice began to break on May 24, and by May 31 the river was free. No definite data were secured concerning the time of the freezing or breaking up of the Noatak, but Mendenhall [2] states that it is reported to free itself ordinarily early in June.

Although the rivers break early in June, it is difficult to reach the region from the United States much before the first of July. Ice in the lakes at the head of the Yukon basin prevents the through passenger boats from running until the middle of June. The last boat down the Koyukuk usually leaves the head of that river by the first week of September. Approach to the region by Bering Sea and the Arctic Ocean can not be made even as early as by way of the Koyukuk, for Kotzebue Sound usually does not open before the first week or so of July. Stoney stated that in 1885 the ice remained in Hotham Inlet as late as July 8. Grinnell [3] notes that in 1898 it was impossible to land at Cape Blossom before July 13 on account of the ice in Kotzebue Sound, but in 1899 a channel through Hotham Inlet to the mission was open on July 1, and a boat that wintered near Chamisso Island was able to reach Kotzebue on July 8.

PRECIPITATION.

At Allakaket a record of the precipitation since 1908 has been kept by Weather Bureau observers and affords the only instrumental data on the region.

Precipitation, in inches, at Allakaket, 1908 to 1911.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908	1.00	0.67	0.81	0.34	0.44	0.38	1.92	0.80	....	0.98	0.78	1.85	9.07+
1909	.11	.12	.63	.46	.41	2.81	1.35	.92	0.52	.44	.63	1.44	9.84
1910	1.62	.15	.52	.53	.50	1.63	2.62	1.55	.82	.50	.16	.28	10.88
1911	.65	2.05	.38	....	....	.29	2.24	1.59	1.41	.22	.38	1.04	10.25+
Average	.84	.75	.58	.44+	.45+	1.28	2.03	1.21	.92+	.53	.49	1.15	10.67+

The total for the year and the average for the different months have been computed in the same way as for the temperatures in the table on page 38. The average for the entire period has been determined by totaling the monthly averages. From this table it will be

[1] Grinnell, Joseph, Gold hunting in Alaska, Chicago, 1901, pp. 79-84.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 54.

[3] Grinnell, Joseph, op. cit., p. 13.

seen that at the mouth of the Alatna there is a precipitation of 9 to 11 inches a year. In spite of this apparent aridity, so much of the precipitation comes in the summer that the tourist gains the impression of a much wetter climate than is actually the case. It should be stated, however, that the records of the Weather Bureau station at Allakaket can not be applied to the entire region indiscriminately. Not only do the records cover too short a period, but it is a generally recognized fact that highland areas receive more precipitation than lower country. In the vicinity of Nome, where gages have been installed both in the highlands and on the coast, the precipitation has been from 50 to 250 per cent more in the higher than in the lower region.

Some idea of the precipitation may also be gained by noninstrumental observations by travelers. An attempt was made to determine from McLenegan's account of his trip the kind of weather he experienced from July 2 to August 11, 1885. Although the statements are not full enough for an accurate determination, it appears that of the 40 days he was in the Noatak basin 15 were partly rainy. During the 25 days that Lieut. Allen [1] was in the Koyukuk region in the same year, a summary of his observations gives the following facts:

Meteorologic notes of Lieut. Allen's expedition in the Koyukuk region, 1885.

	Nuklukyet to Koyukuk River.	Koyukuk River to Yukon River.
Total days	7	18
Clear days	1	0
Fair days	0	5
Cloudy days	6	13
Rainy days	3	6

In 1901 Schrader, on his expedition up John River, reported 11 partly rainy days in the 39 days he was in the region between the mouth of the Alatna and the Koyukuk-Arctic Ocean divide.

Smith reported that, in 1910, of the 72 days he spent in the region between the Koyukuk and the Kobuk and in the valley of the Kobuk 44 were partly rainy. From June 26 to September 1, 1911, a total of 64 days, 37 were partly rainy. It should be noted, however, that much of the rain came in slight showers, which did not last long. This was particularly true in the lower part of the Alatna Valley, where thunderstorms lasting an hour or so occurred almost every afternoon.

The following table gives the records of the snowfall observed at Allakaket during the years 1908 to 1911, so far as they have been furnished by the Weather Bureau:

[1] Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk rivers in the Territory of Alaska in the year 1885, 1887, p. 171.

Snowfall (in inches) at Allakaket, 1908 to 1911.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908	......	......	......	......	......	......	......	......	......	14.0	14.2	31.7
1909	2.2	2.8	9.8	7.8	......	0	0	0	0.8	7.5	11.2	25.0
1910	28.0	2.5	8.0	8.2	1.5	0	0	0	1.5	8.0	3.9	5.5
1911	*9.5*	*28.0*	*6.5*	*16.5*	*0*	*0*	*0*	*0*	*0*	*3.5*	*4.8*	*16.6*

The snowfall, expressed in terms of its equivalent water, was included in the table of precipitation given on page 40; and therefore the figures given above should not be added to those stated in the other table. A comparison of the snowfall with the total precipitation for each month indicates that the snow is abnormally dry, for it takes from 14 to 16 inches to make an inch of water, whereas the common ratio is about 10 inches of snow to 1 of water. This fact is probably explained by the low temperature, which reduces melting and thus prevents the snow packing closely.

From the record at Allakaket it is evident that the annual snowfall is about 6 feet. This, like the rainfall, is probably less than in the more mountainous parts, although prospectors report that in the Alatna Valley above the Kutuk there is usually so little snow that sledding is at times difficult. Early in June most of the snow on the lowlands has disappeared, but the snow in the protected valleys in the mountains lasts much later and has an important effect in sustaining the flow of the streams. Here and there, where the overflows during the winter have formed considerable thicknesses of ice on the valley floors, the snow and ice may last almost throughout the year. Masses of this sort were noted on July 22 in the upper Alatna Valley at an elevation of 2,000 feet and bade fair to remain throughout the season.

POPULATION AND SETTLEMENTS.

WHITES.

There are only five settlements within the Noatak-Kobuk region. These are Kotzebue, on the coast; Allakaket, on the Koyukuk; the Noatak mission, on Noatak River; and Shungnak and Kiana, in the Kobuk basin.

The most important place is Kotzebue, on the long promontory that separates Hotham Inlet from Kotzebue Sound. This place is the seaport for the entire district, and is normally the home of a missionary and family, three or four white traders, a few boatmen and mechanics, and a number of native families. After the break-up of the ice in the spring, however, missionaries, school-teachers, prospectors, and traders, together with a great number of natives from all the neighboring rivers, congregate for trading and fishing, in preparation for the coming winter, so that during July a thousand people are camped for 2 or 3 miles along the beach or in the town. Mail service from Nome is maintained by boat every 10 days during the summer and by dog sledge once a month during the winter. Travelers from Nome may reach Kotzebue by the gasoline schooner which serves as the mail boat. The trip takes about three days, as stops are made at way points, and the charges in 1911 were $25 for each passenger and $20 a ton for freight.

As has already been stated, Kotzebue is shut off by ice from direct communication with the outside world from the middle of September to the first of July. Even during the open season large vessels from the States can not approach nearer the town than Cape Blossom, an unprotected bluff about 12 miles to the south, because the channel is so narrow, crooked, and shallow that it is not navigable for boats drawing over 6 feet. In consequence of the difficulty of approach, therefore, most goods have to be reshipped, and this adds to the cost of the freight. Supplies of good quality and in amounts to meet the demand, however, can be obtained at the stores in Kotzebue at prices but little in excess of the cost of the same in Seattle plus the freight charges.

The second most important settlement in the region is on the Koyukuk at Allakaket and at Marsans. Although bearing two names, these places are practically one; Allakaket is the site of the mission of St. John in the Wilderness, directly opposite the mouth of the Alatna, and Marsans is the trading post a mile downstream on the west bank of the Koyukuk. Bergman, which used to be an important town in the early days of the Koyukuk gold excitement, has now been abandoned.

The mission is the home of a missionary, who is also the observer for the Weather Bureau and the Government school-teacher, and around it has gathered a native settlement. The number of natives varies during the season, and few of them have built permanent houses but live instead in tents. At Marsans there is only the storekeeper and his family and a few natives. As this post had been but recently installed, a complete stock of goods was not on hand. Prices, however, are reported to be reasonable and the quality of the articles good. Communication is by boat during the short summer and by an overland dog sledge route that reaches the Yukon near the mouth of the Tanana during the winter. The post office is at Bettles, but mail is also delivered en route. The nearest telegraph station is at the Government post at Fort Gibbon. The first boat of the season seldom reaches Allakaket much before July 1, and the last steamer down the river leaves not later than the second week of September.

The Noatak mission is the third largest settlement in the region. It is located on the west bank of the river, about 50 miles in an air line north of Kotzebue. The river at this place swings against a bluff 50 feet in height, and the settlement has been located on the upland. Practically the only white people at the mission are the missionary, his wife, and three children, but a native population of a score of families has congregated there, and many of them have built permanent log cabins. The buildings of both the whites and the natives are substantial and well made. A new schoolhouse was planned and was probably completed before the winter of 1911.

On the Kobuk are two small settlements, Shungnak and Kiana. Shungnak, which is near the site of Stoney's headquarters at Fort Cosmos, is a small settlement, consisting of a Friends' mission, schoolhouse, store, and the usual native huts. Formerly it was the headquarters of the United States commissioner and recorder for the Noatak-Kobuk precinct, but that office has been removed to Kiana. The store carries only a small stock of supplies for local needs and would not be able to supply a large district. Several prospectors live within 3 to 15 miles of the town on the various creeks, but there are not more than a dozen white people in an area of several thousand square miles.

Kiana is a small settlement at the junction of Squirrel River and the Kobuk. It started practically with the discovery of gold in the vicinity in the fall of 1909, although a native village had been located there previously. At the time the town was visited in August, 1910, it consisted of about a score of log cabins, a store, and restaurant, and had a native population comprising many families. It is understood, however, that during the winter of 1910–11 two more stores were opened, the recorder's office was established, and several more houses were built.

In addition to these larger settlements, prospectors' cabins are scattered here and there, most of them being unoccupied. The topographic map (Pl. I) shows the location of all the known cabins, but there are probably others, so hidden or so remote from the route traveled that they escaped notice. Many of the cabins are in good repair and might afford shelter for travelers. The deserted cabins, however, have been so thoroughly emptied that usually no supplies or even cooking utensils can be found in them. The only isolated cabins that were occupied at the time of the visit by the Survey geologist, except those near the settlements, were on Kutuk and Malemute rivers, both in the Alatna River basin.

An estimate of the total white population of the Noatak-Kobuk region was made incidental to the more direct objects of the expeditions, and although little accuracy may be claimed it is fairly certain that less than 250 white people reside within the basins of these streams.

NATIVES.

Each of the larger settlements of whites has on its outskirts an encampment of natives and these are at present the largest native villages. Kotzebue is the largest town, and here natives from places on the coast as far as Cape Espenberg and Point Hope and from Buckland, Selawik, Kobuk, and Noatak rivers meet to trade and fish, returning to their homes in the fall. At Allakaket natives from the Koyukuk and its branches congregate with those from the Kobuk and the Colville.

At present there are almost no native settlements remote from the villages of the whites. Here and there are isolated huts or hunting lodges used by one or more families, but these are not common. Formerly, however, there were large native settlements in the more remote parts. Stoney notes that on the Kutuk in the Alatna River basin there was a settlement called Nimiuk (meaning cottonwood) about 20 miles above the mouth.[1] Another settlement of the same name was described by the same writer on the upper part of the Noatak, probably near the camp of August 2 of the expedition of 1911. This was reported to consist of four huts occupied by about 30 natives and was the highest village on the Noatak. McLenegan does not mention passing any occupied native villages in his trip up this river, but states that "the greater portion of the inhabitants reside near the extreme headwaters of the river, to which place they repair on the approach of winter * * *. During the summer months they wander up and down the river, spending much of the time in fishing and providing for the needs of the coming winter."[2]

At the camp of August 7 several abandoned huts, most of which had caved in, and boat frames and coverings showed that the site had once been the home of a considerable native settlement. It was evident, however, that the place had not been occupied for many years except by passing natives. None of the coast natives remembered any permanent settlement at this place, although its location was well known because of the peculiar loop of the river near there, which they called Okuk, meaning tongue. Farther downstream at several places sites of old native settlements were seen, especially near the camp of August 18 and at the camp of August 23. Below the camp of August 19 natives were met almost every day traveling in their skin boats homeward to the mission.

In the Kobuk Valley there are reports and indications of numerous old settlements of natives, but at the present time outside of the native villages at Shungnak (or Long Beach, as the native town

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[1] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 44.

[2] McLenegan, S. B., Exploration of the Noatak River, Alaska; Report of cruise of the revenue-marine steamer *Corwin* in the Arctic Ocean in the year 1885, Washington, 1887, p. 75.

is called) and at Kiana there are only two that deserve mention, Oksik and Kalla. The former is situated a short distance below Squirrel River, near the place where the Kobuk divides into the northern and middle channels. It is reported to be the largest town in the lower part of the river, but at the time it was seen by the writer most of the inhabitants were at Kotzebue. Kalla is about 7 miles above Shungnak and is the place where most of the salmon fishing in the upper river is done. The natives from Shungnak congregate there in August, but during the rest of the season it is practically deserted.

Of the old villages that are now abandoned, the settlement at the mouth of Pah River was probably one of the most important. Near Stoney's old camp a considerable settlement used to exist, but the place, called Riley Camp, is now practically deserted except for one or two families. Stoney mentions a village in the headwater region of the Ambler, but nothing could be learned of its existence at the present time. Scattered camps here and there along the river were noted, but few of them indicated long occupancy by more than one or two families.

In all the writer's experiences with the natives he has been received with the greatest cordiality, respect, and interest. The older men did their utmost to impart their knowledge of the country and were skillful in describing and depicting the region in which they had traveled. Their ability to read topographic maps and their delight in recognizing on our map regions that they had visited is extraordinary. Physically the men are well developed and active; the younger ones are interested in sports and games, of which they have quite a number. The women are not so active and age early; this, however, does not prevent their carrying babies on their backs and at the same time "mushing" the dogs when tracking, pulling oars when in the boat, or cooking, fishing, and doing other work when in camp. Mentally both sexes are alert and attentive, although their lack of knowledge of English gives them on casual acquaintance an appearance of stupidity.

The summer is a particularly unfavorable time to make an estimate of the number of natives, as many are then away from home. In 1901 Schrader estimated that there were less than 200 natives in the Koyukuk basin and of that number only a small part should be assigned to the region covered by this report. Petrof,[1] in the census of 1880, gives the population of the Noatagamute (people of the Noatak) villages inland on the Noatak River as 400, but McLenegan[2] "places the number at 225, which it is thought fully covers the total population."

[1] Petrof, I., Tenth Census, vol. 8, p. 2.

[2] McLenegan, S. B., op. cit., pp. 75–76.

The results obtained by the census of 1910 have not yet been published in such form as to show the number of natives in the different villages and drainage basins. According to the figures available, the population of Kotzebue was 193, of Noatak village 121, and of Shungnak 210. Natives probably constitute at least three-quarters of this number, and it is doubtful if more than a hundred others live within the limits of the three basins treated in this report. The census states that for the whole of Alaska the density of population is one person to each 10 square miles of territory. If this figure is correct, it is probable that in northwestern Alaska the ratio is not much over one person to 40 square miles of territory.

ANIMALS AND VEGETATION.

ALATNA RIVER BASIN.

In the southern part of the Alatna basin few signs of game were seen. The absence is probably due to the fact that the natives have long hunted in this part and have gradually killed off the animals or driven them into less accessible regions. In the fall, however, the sloughs and ponds near the river are said to be fairly alive with ducks and geese. Farther upstream game is more abundant and varied. Around Lake Takahula ptarmigan were so numerous that they might be relied on for food. At other places still farther upstream ptarmigan were plentiful and were sufficiently large by the middle of July to be eaten. All were rather wild and should be hunted with a shotgun rather than with a rifle. Toward the head of the river larger game became more abundant. Sheep were found in the valley of the small tributary from the west below the Kutuk, and prospectors report that sheep are also plentiful in the hills at the head of the Kutuk and Nahtuk. Other bands of sheep were seen in the hills around the Noatak-Alatna divide and also east of Alatna River near the camp of July 22. In July the females were not in good flesh, but at that time the males are reported to be in their prime. Not many bears were seen, but evidence of their presence was common. They are reported to be mainly black; the only ones seen were of this color. Mendenhall[1] states that moose are known to the natives as far north as Chandler Lake in the Colville drainage basin, but no moose nor even signs of them were seen in the Alatna basin.

Fish are fairly abundant in the main stream and its tributaries. Salmon are reported to be caught in considerable numbers in the lower Alatna, but farther upstream grayling and whitefish are more abundant. These fish are caught and dried by the natives and form an important part of their winter's food supply. Pike were shot

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 56.

along the border of Lake Takahula as they were lying in the marsh grass. Suckers were caught at several places but did not appear to be very abundant. In Helpmejack Creek grayling were so numerous that they could be caught nearly as rapidly as the fly was dropped into the water. It is also interesting to note that fish were very abundant in the lakes on the Alatna-Noatak divide at the camp of July 25. It seems impossible that they could have reached the lakes by swimming, as the streams in their upper part are extremely steep and contain almost no water. It is believed that fish are sufficiently abundant throughout most of the region so that they could be relied on to furnish food for travelers and prospectors for a considerable time.

The vegetation of the Alatna Valley is typically sub-Arctic and Arctic in its character. In the lowlands trees and bushes are plentiful, but in the higher regions vegetation gradually disappears upslope, until on the peaks and the crests of the ridges even grasses are practically absent. Spruce is found along the valley as far as the camp of July 22, and its general distribution is graphically shown by figure 1. In the southern part of the basin the trees average 10 to 12 inches in diameter and extend up the slopes to an elevation of 2,000 to 2,500 feet, but the diameter of the trees and the elevation of the upper border of the forested zone gradually decrease northward until at the camp of July 20 the diameter of the trees is only 6 to 8 inches and even scattered trees do not extend more than 500 to 600 feet above the river. The northern limit of trees is so sharply defined as to make a decidedly abrupt break which seems to have been controlled by some other factors than temperature and elevation.

The general appearance of the vegetation north of the region in which spruce grows is fairly well indicated by Plate VII, *A*, a view looking north from the camp of July 23. Even willow and alder are scarce, and camp sites must be carefully chosen in order to get sufficient fuel for cooking. The same general kind of vegetation appears farther downstream in the small tributary valleys and above the belt of trees on the slopes of the main valley walls. In these treeless areas numerous brilliantly colored flowers add much to the landscape; for instance, near the camp of July 18 the eastern hillside for an area of nearly 2 square miles was so ablaze with fireweed that the color attracted attention for many miles. Blueberries and cranberries are also abundant in these open areas and form important additions to the available local food supply.

Grass for stock is sufficiently abundant for traveling pack animals, but the amount is not enough to permit the permanent pasturage of any considerable number. Schrader,[1] however, states that a horse is

[1] Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 20.

reported to have lived at large and secured his own forage during the winter of 1902–3 on the north fork of Koyukuk River and Maddren[1] says that in 1908 several horses wintered on the middle fork of the

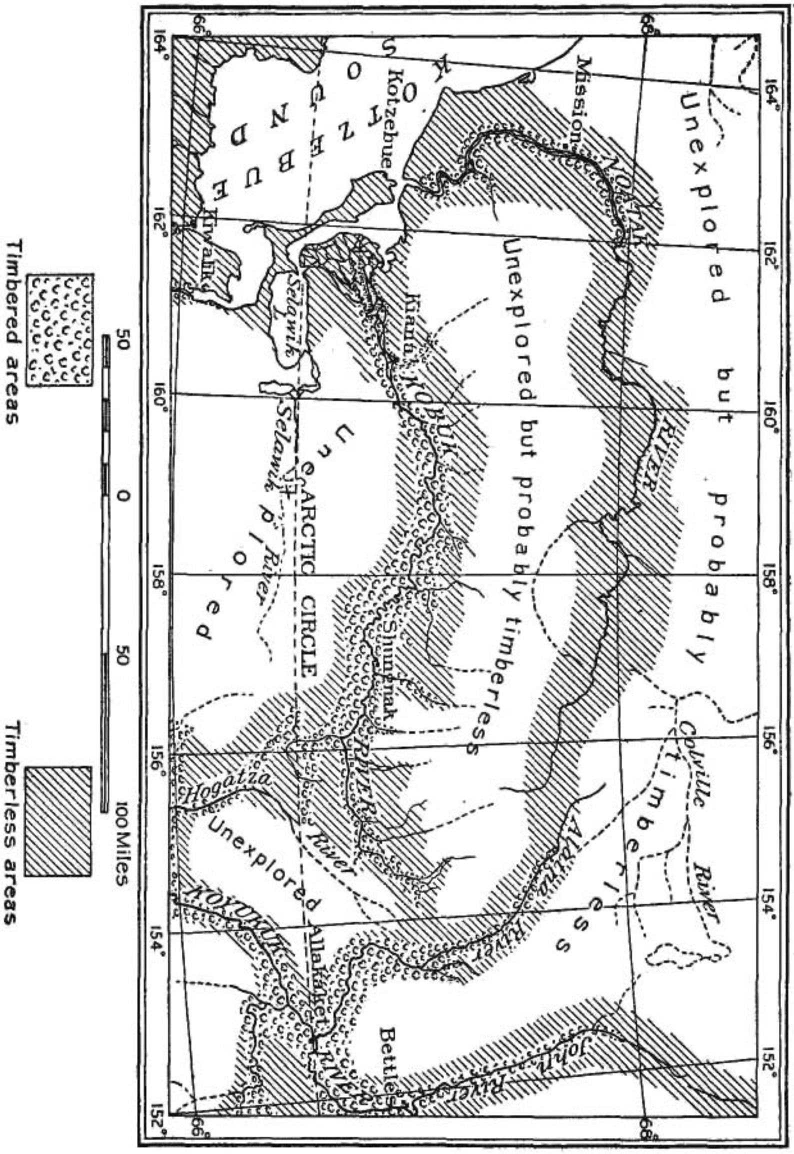


FIGURE 1.—Map showing distribution of timber in Noatak-Kobuk region.

Koyukuk and were in good condition in the spring. Owing to the early frosts and the watery condition of most of the grass, feed for stock must be rather carefully sought. The grasses growing on the

[1] Maddren, A. G., oral communication.

lower hill slopes and the horsetail grass (equisetum), which is found in well-drained fertile soils on bars or at the edges of open spaces, are relished by horses and seem to be the best. Redtop grass is particularly abundant around old cabins and settlements, but although it grows luxuriantly it does not seem to have the amount of nourishment that the tougher, smaller, less abundant grasses possess.

NOATAK RIVER BASIN.

Game in the Noatak region is on the whole more abundant than it is in the Alatna Valley. Sheep are so numerous in the headwater mountains that natives from places as far away as the Kobuk make annual trips to them for their winter's supply of meat. Near the camp of August 1 four natives from the Kobuk were met on such a hunting trip, and many sheep horns discarded by other hunting expeditions were found along the banks of Twelvemile Creek. Ipmiluik, the name of the river that joins the Noatak near the camp of August 1, means sheep, and refers to the fact that this is the route followed on the journey from the Kobuk after sheep. On the hill opposite the mouth of Twelvemile Creek, near the head of the Noatak, sheep trails are so numerous that the zigzag lines can be seen for several miles. Sheep were also obtained on the hill on the south side of the river opposite the mouth of Midas Creek. Some indications of bear were seen, but none of these animals were encountered. Wolverine was seen in the valley of the creek leading to the Alatna-Noatak portage. Fox, mink, and squirrel were also seen.

In the Aniuk lowland caribou are fairly numerous, and natives from the lower part of the Noatak as well as from the Kobuk make annual hunting trips to this part of the region. Early in August the bucks are in prime condition and have been so little hunted that with care they can be approached without alarming them. Fox, marten, and wolves were numerous, judging from the tracks on the sandy and muddy shores. Two cross-foxes were seen from the boat at a distance of only 25 to 50 feet. Birds did not seem to be very numerous, but the piles of ptarmigan bones around the many hawks' nests that were examined indicated that there were many more than we had suspected.

In the second highland and farther downstream caribou and sheep are practically absent near the river; bears, however, are much more numerous, and their trails can be found on almost every sand bar. No bears were seen, but from the size of the footprints it is judged that they are mostly the brown variety. In the mission lowland both land and water birds are much more numerous. Ptarmigan in flocks of 10 to 50 were found in the low country, and ducks, geese, and cranes were commencing to flock for their migration and could be seen on the lakes and sloughs by the latter part of August. Near the camp of August 23 birds were particularly plentiful.

A flock of 35 crane was counted, and flocks of 50 or more geese were by no means uncommon. In the river a short distance above this camp and for a considerable distance below seal in great numbers lay in the shallow water, looking at a distance like masses of sand.

The fish noted in the Noatak were in general the same as those in the Alatna. Salmon form an important part of the local food supply, and a few were seen on the drying frames at the native camp. They were not very numerous, and it is believed that many of the natives go to Kotzebue to catch their fish, as the farther the fish have traveled in fresh water the poorer they are said to be. McLenegan[1] noted that near the eastern margin of the second highlands there was a fishing village that was occupied only during the salmon run. The members of the expedition of 1911 were able to shoot so much fresh meat that they spent no time in fishing in any of the Noatak streams. It is believed, however, that these streams, like most of those in northern Alaska, have grayling and trout in sufficient number to be of considerable value to prospectors and travelers.

The greater part of the Noatak basin is timberless, and this will make the development of the region difficult. The most eastern spruce in the Noatak Valley, as shown in figure 1, is between the camps of August 13 and 14. At this place trees 8 to 12 inches in diameter appear along the well-drained banks of the river as a narrow fringe. Farther downstream spruce may be found almost everywhere in the immediate vicinity of the river to a point a short distance below the camp of August 26, at the mouth, where it is again absent. Over much of the swampy lowland back from the streams and on the hill slopes timber is absent, even in the western part of the valley. The large size and sturdy growth of the trees, even near the borders of the unforested areas, is striking. Fully as large and vigorous trees were seen within 15 miles of the extreme eastern limit of timber as anywhere else in the region, although the place was fully as high, as much exposed, and had a soil not differing radically from that of the neighboring tracts. That the frozen condition of the soil is not a dominating influence is shown by Plate XII, *B*, where a good stand of spruce may be seen growing almost immediately on top of clear ice.

Although spruce or other large trees are absent, some bushes large enough for fuel grow even in the headwater portions of the valley. Willow, alder, and poplar (cottonwood and balm of Gilead) were seen in the valley above the camp of August 2, and farther downstream they become more abundant and larger. In places the poplars are 6 inches in diameter and 20 feet high. These bushes are used by the natives on the upper river for frameworks for their huts. After the frame has been woven and twisted together sods, old boat coverings, and other materials are placed on top and chinked with earth and moss so as to form a serviceable shelter. In places fish nets are made from

[1] McLenegan, S. B., op. cit., p. 68.

twisted fibers of willow, which is used by certain of the inland natives for all purposes for which twine would ordinarily be employed.

Feed for stock is not abundant and frost comes so early that the season during which animals can obtain sufficient forage is very short. It is believed, however, that the supply is adequate for a few animals, such as a Survey pack train traveling rather rapidly through the country—but not sufficient to sustain the strength of the animals for a long period. Reindeer moss is particularly abundant in the better-drained lowland areas, especially those near Aniuk and Cutler rivers, and on the hill slopes a short distance back from the coast. These hill slopes have been used as the feeding ground for the herd of reindeer introduced by the Government, which ranges between the mouth of the Noatak and Cape Krusenstern.

Berries are generally plentiful in the lowland areas and form an important part of the local food supply of both natives and whites. Blueberries, cranberries, currants, and salmon berries are most abundant and owing to the cold climate can be picked in the fall and kept through the winter without deterioration.

KOBUK RIVER BASIN.

Throughout the greater part of the surveyed area near the Kobuk game is not plentiful. Caribou have been reported in the region, but none were seen by any of the Survey parties. There is, however, a herd of reindeer in the vicinity of the Sheklukshuk Hills, and it is possible that some of the stray deer have been mistaken for caribou. Bears are practically the only large wild animals. Those seen were black, but brown bears are said to be fairly numerous in the more remote parts of the basin. Sheep may probably be found in the headwater mountains, though the fact that the Kobuk natives make trips to the head of the Noatak for their supply of this meat indicates that these animals are not abundant nearer home. Moose are reported to have been found in the Kobuk Valley in the early days, but no signs of them were seen by Mendenhall or by the expedition of 1910. Small animals, such as foxes, marten, mink, and lynx, used to be fairly common but are yearly becoming scarcer. Muskrats are very numerous in the delta portion of the river.

Ptarmigan, spruce hens, ducks, and geese are the birds most commonly hunted by prospectors, and it is said that they are still sufficiently numerous to be relied on for food. The land birds are found mainly in the Squirrel River to Reed River province, but the water fowl are most abundant in the delta. Other birds are common throughout the region. A fairly complete list of the birds observed in this region has been prepared by Joseph Grinnell.[1]

[1] Grinnell, Joseph, Birds of the Kotzebue Sound region, Alaska: Cooper Ornithological Club, California, vol. 1, No. 1, 1900.

Fish are abundant in almost all the streams. Salmon is the most important as a food supply. These fish are particularly abundant as far up as Lake Selby, and during the fishing season drying frames may be seen at many places along the river. In the central part of the Kobuk basin the main native fishing camp is at Kalla, near the mouth of Kollyoksok Creek, a short distance above Shungnak. In addition to salmon a large white fish, known to the natives as "she," is also obtained in the Kobuk and in some of the larger lakes and is much prized for food. Grayling can be found in almost all the side streams and mountain brooks. Trout, probably the salmon trout, weighing as much as 3 or 4 pounds, were caught near Shungnak and are reported from many of the neighboring streams. Mendenhall[1] states that "numbers of pike are caught, especially in the delta of the Kobuk and in the sloughs of this and other streams, where there is but little current and water plants flourish."

Timber is found mainly along the larger streams, and, as indicated in figure 1, does not extend up the mountain slopes to elevations of more than 2,000 feet in the eastern part of the basin, the upper limit gradually decreasing in altitude toward the west. On the flats in the central part of the basin trees are usually absent, except in scattered clumps here and there where the upland is not too swampy. In the lower part of the delta trees are absent. Spruce and birch are the only trees that grow to sufficient size for lumber, and only the spruce is large enough for cabin logs. Stoney[2] notes that the largest spruce tree seen by him in the entire Kobuk Valley was near Cosmos Creek. It measured 80 inches in circumference at the base and 68 inches at a height of 6 feet above the ground and was 80 feet tall. This was an unusually large tree, however, and the average spruce does not exceed a foot in diameter. The birches grow on the low hillsides, except the prostrate variety, which occurs high on the valley sides. Willows and alders are abundant throughout the basin, except high on the ridges, and may be relied on as sources of fuel where trees are absent.

Grasses for stock are found on the lower hill slopes and on the lowlands. Mendenhall[3] notes rye grass, blue grass or red top, and a variety of bunch grass as the more usual species. The grasses flourish, particularly in the neighborhood of old settlements and camps, and quickly spring up in burned-over areas, but none of them seem to stand frost well, for all appear to wither and lose their nutriment as soon as freezing nights begin. Even when the grass is unwithered it is very watery, and the stock used on the expedition of 1910 grew constantly weaker, although there was an abundance of what appeared to be good grass.

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 55.

[2] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 83.

[3] Mendenhall, W. C., op. cit., p. 57.

During the expedition of 1901 collections of the flora were made when the exigencies of other work permitted, and a list of the specimens identified by F. V. Coville was published in the report of that expedition.[1]

DESCRIPTIVE GEOLOGY.

DIVISIONS OF THE ROCKS.

From the description of the various expeditions that have visited the region (see pp. 11–18) it is evident that a large part of the area shown on Plates I and II is unexplored, and much of the country that has been visited was traversed so rapidly that only the larger features were determined. As a consequence much remains to be accomplished before the geology can be adequately and correctly described. Certain facts, however, concerning the geology have been determined, and it is proposed to set these forth, together with the inferred correlations and interrelations to which they give rise. It should be noted, however, that where data have been collected under conditions so diverse different parts of the mapping naturally have different degrees of accuracy. More dependence therefore should be placed on the delineation of those areas actually investigated than on that of areas where the mapping rests solely on long-range views or on a study of float material.

Two main divisions have been made of the rocks from which the geology of the region has been inferred, namely, sedimentary and igneous rocks. Each of these classes has been further subdivided, and each of these smaller units has been distinguished on the geologic map (Pl. II) by a separate pattern or color. The sedimentary rocks have been divided into 13 groups, formations, or other stratigraphic units, as follows: Unconsolidated deposits, consisting of recent stream gravels; recent beach deposits; bench and outwash deposits; Tertiary deposits; the Mesozoic rocks, separated into the Bergman, Koyukuk, and Anaktuvuk groups; the Paleozoic rocks, subdivided into the Lisburne limestone, Noatak sandstone, Devonian limestone, Silurian limestone, undifferentiated Paleozoic limestones, and undifferentiated Paleozoic metamorphic schists. The last two divisions of Paleozoic rocks may possibly include some rocks of pre-Paleozoic age.

The igneous rocks have been subdivided into four main groups, which have been called late lavas or basaltic effusives, granitic intrusives, early intrusives and effusives, and greenstones.

The following table presents the main features of the stratigraphy of the region and shows the sequence and character of the different divisions, which are more fully treated in the succeeding pages:

[1] Mendenhall, W. C., op. cit., pp. 58–65.

Stratigraphy of Noatak-Kobuk region.

System.	Series.	Group or formation.	Lithologic character.
Quaternary.	Recent.	Stream deposits.	Sands, silts, and gravels, practically in process of formation.
		Beach deposits.	Sands, silts, and gravels, practically in process of formation.
	Pleistocene.	Bench and outwash deposits.	Sands and gravels of early glacial, fluviatile, and marine origin.
Tertiary.		Late lavas, or basaltic effusives (late Tertiary to Recent).	Basaltic lava flows and volcanic ash.
	Eocene.	Conglomerate.	Conglomerate with subordinate sandstones and shales.
............(?)............			
Cretaceous.	Upper Cretaceous.	Bergman group.	Conglomerate at base, becoming sandstones above.
	Lower Cretaceous or Upper Jurassic.	Granitic intrusives.	Granite and diorite stocks and dikes.
		Koyukuk group (probably contemporaneous with Anaktuvuk group).	Limestones, sandstones, shales, and associated volcanic tuffs, and breccias.
Jurassic (?).		Anaktuvuk group.	Sandstones with subordinate shales and conglomerates.
		Early intrusives and effusives.	Basic intrusives and flows and tuffs. Some gabbro.
Carboniferous.	Mississippian.	Lisburne limestone.	Thick limestone with subordinate shale members.
		Noatak sandstone.	Chiefly sandstone with subordinate quartzite, shale, and thin limestones.
Devonian.	Upper Devonian.	Limestone.	Grayish limestone, noncrystalline.
Silurian.		Limestone.	Highly magnesian limestone.
Undifferentiated Paleozoic (possibly including some pre-Paleozoic).		Greenstones.	Intrusive dikes and sills of diabasic composition.
		Undifferentiated limestones.	Limestones and dolomites, showing great variety of lithologic facies.
		Undifferentiated metamorphic schists.	Schists, slates, limestones, and associated igneous rocks.

SEDIMENTARY ROCKS.

PALEOZOIC AND PRE-PALEOZOIC (?) ROCKS.

UNDIFFERENTIATED METAMORPHIC SCHISTS.

The oldest rocks recognized are a group of metamorphic schists of complex origin and intricate structure. Although it is possible that younger rocks may be included by infolding and infaulting or by local dynamic metamorphism in regions of close folding, it is believed that the schists as a whole are different from any of the other rocks that will be described later.

DISTRIBUTION.

The undifferentiated metamorphic rocks are most extensively exposed in Seward Peninsula, north of the Kobuk, in the central parts of the Alatna and John River basins, and in the headwaters of

Alatna and Noatak rivers. They probably also form a large part of the unexplored highlands between the Noatak and Kobuk and between Alatna and John rivers. In the unexplored areas east of Buckland River and south of latitude 67° N. there are probably none of these rocks. Little is known of the region north of the Noatak, so that it is rather unsafe to predict the kind of rocks that occur in the unexplored tracts, but from the best evidence at hand it seems improbable that extensive exposures of these rocks occur north of latitude 68°.

The rocks therefore generally lie in a belt not over 70 miles wide, trending east and west in the eastern part of the Noatak-Kobuk region and then swinging rather abruptly until in Seward Peninsula the trend is nearly north and south. This belt is closely parallel to the marked structural trends that are better known in southern Alaska. It may be noted here that, although the metamorphic rocks have the surface distribution indicated, they may also occur deeply buried throughout the mapped area. Conversely, in those places where pronounced folding or faulting has raised certain of the overlying rocks high above the present plane of erosion, these older schists may outcrop at the surface.

LITHOLOGIC CHARACTER.

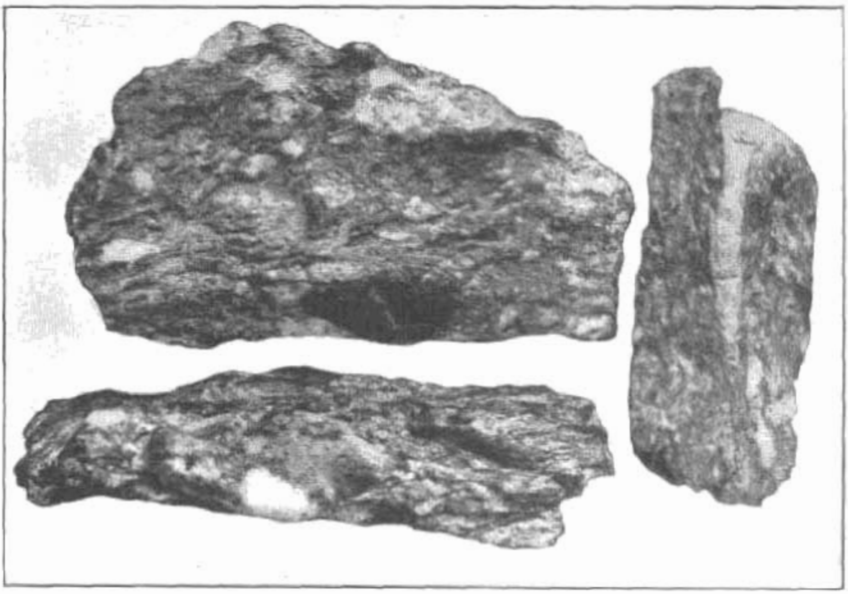
The undifferentiated metamorphic rocks cover a large territory and exhibit a correspondingly wide range of lithologic character, but are a unit in that all of them are much sheared and foliated and are schistose. Dominantly they are of a gray or grayish-green color, though black and brown beds are here and there found where carbonaceous material or iron oxides are abundant. The schists are not strongly resistant to weathering, but as they occur in the axes of greatest deformation they usually form rugged hills which have had their steepness emphasized by relatively recent glacial sculpturing.

Numerous subdivisions of the undifferentiated metamorphic schists will undoubtedly be made when the rocks are studied in greater detail. Differences in chemical composition have been observed and afford a basis for separation that would probably have stratigraphic value. The data at hand are not sufficient to afford a means of discriminating the various facies, but a statement of the several types may be made.

Considered as to size of grain, the rocks may be divided into schists and conglomerates. The schists predominate and may be still further divided from the most prominent mineral into quartzose schists, calcareous schists, carbonaceous schists, and chloritic schists.

The quartzose schists have been reported everywhere within the area of the metamorphic schists. As the name implies, these rocks consist dominantly of quartz. Plate VIII, *A*, shows a typical expo-

A. TYPICAL OUTCROP OF SCHIST, ALATNA RIVER.



B. SCHISTOSE CONGLOMERATE FROM DAHL CREEK, KOBUK RIVER.

sure of the quartzose schists in the central part of the Alatna Valley and might be duplicated from any region where these rocks occur. The quartzose schists are usually rather fine grained, much cleaved, and show a considerable development of foliate minerals, notably chlorite and muscovite. Biotite, however, is usually absent, except in the vicinity of granitic intrusives. The schists rarely show any original bedding structures, but two or more secondary cleavages are by no means uncommon. Under the microscope feldspar fragments may be recognized in certain sections, but they are of small size and constitute only a small proportion of the rock. Gradations between the quartzose and other phases of the schist have been seen and in such places the quartzose schists take on more and more the characters of the other facies.

The calcareous schists are similar to the quartzose schists in general metamorphic character, but contain abundant calcite and notably less quartz. These schists range from rocks of rather fine grain, in which the presence of calcite can be detected in the field only by the use of acid, to yellowish rather coarsely crystalline rocks composed mainly of calcite, with scattering flakes of chlorite and mica. The latter phase appears to have been recrystallized under static conditions; its original structures are not preserved, and it generally shows not more than one secondary structure. These rocks appear interlaminated with the quartzose schists and the other types. In some places, however, the field relations are such as to suggest that they have been derived through the dynamic metamorphism of limestones that were originally present in this group. Few calcareous schists were noted in the basins of John or Alatna rivers, but they are common in the Kobuk basin and in Seward Peninsula.

Carbonaceous schists and quartzites have been reported throughout the area of metamorphic rocks. They are dominantly quartzose, but on the whole seem to have been somewhat less sheared than the other metamorphic rocks. In many of the specimens the carbonaceous material occurs in the form of graphite, but in others it is in such a fine dustlike condition that its specific character has not been determined. Many of the carbonaceous schists and slates closely resemble certain of the Seward Peninsula rocks, notably the Hurrah slate [1] of the Solomon-Casadepaga region and the Kuzitrin formation,[2] dominant in the central part of the peninsula. In most places there are a great number of quartz veins and lenses in the carbonaceous slates and quartzites ranging from microscopic filaments to masses 2 or 3 feet in width and traceable for several hundred feet along the strike.

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles: Bull. U. S. Geol. Survey No. 433, 1908, pp. 59-62.

[2] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1906, pp. 69-70.

The chloritic schists are not so distinct as the others enumerated and are probably closely allied to the quartzose schists. They contain relatively less quartz and proportionately more chlorite, and in extreme examples chlorite is practically the only mineral recognized macroscopically. Under the microscope, however, quartz, zoisite, a little calcite, and some feldspar may be recognized.

Feldspathic schists, so common in parts of Seward Peninsula, have not been found in any large quantity in the Noatak-Kobuk region, though here and there small exposures of this type of rock have been observed. Garnetiferous schists have also been found but sparingly. Mr. L. M. Prindle, who spent a winter in the central part of the Kobuk basin, says that the rocks in the mountains north of the Ambler-Kogoluktuk lowland are in places highly garnetiferous.

The conglomerate phase of the undifferentiated metamorphic rocks has been observed at only two places—one along the south face of the Cosmos Hills near Shungnak, in the Kobuk basin, and the other nearly north of this place, between the camps of August 3 and August 4, on the Noatak. The conglomerate in the Kobuk locality occupies a strip about 2 miles wide, trending in an east-west direction, and dips southward. Although the relations to the other metamorphic rocks are not perfectly clear, the dip indicates that the conglomerate overlies the schists and slates to the north. Further evidence in support of this view is afforded by the fact that recognizable pebbles of black slate and of chloritic schist, together with numerous quartz pebbles, make up the conglomerate. These pebbles prove by their presence that schists, slates, and quartz veins were in existence and had been eroded before the deposition of the conglomerate, and they suggest an unconformable relation between these rocks and the conglomerate.

Other conglomerates of younger age will be noted later, but it should be distinctly understood that the one described above is thoroughly sheared and schistose throughout its extent and can in no way be explained by the lesser amount of deformation to which the later conglomerate has been subjected. This may be clearly seen by reference to Plate VIII, *B*, which shows three specimens of the metamorphic conglomerate. Not only have the pebbles composed of the softer rocks been deformed but even the quartz pebbles (shown best by the light-colored portion of the specimen farthest to the right) have been so pulled out and elongated that they are now many times their original length. It should be noted, however, that the pebbles shown on this plate by no means represent the maximum distortion, for by excessive elongation the pebble form becomes more and more obliterated, so that finally it can not be recognized. Therefore, many of the patches of quartz of no definite shape or distribution seen in the specimen may have been once distinct pebbles but are now stretched and shattered beyond recognition.

The schistose conglomerate from the Noatak was not seen in place but was found only as float. The localized distribution of this material, the lack of thorough water rounding, and the size and freshness of the specimens, all suggest that the float had not been transported far. Lithologically the rock is identical with that found in the Kobuk basin, but it contains somewhat less vein quartz and is rather finer grained.

STRUCTURE.

The lack of detailed studies of the extremely complex stratigraphy of the undifferentiated metamorphic rocks prevents determination of their structure. The distribution effected by the most recent diastrophic movement has already been described, but the structure that preceded this stage still remains undetermined. That there were two or more periods of diastrophism before the one that produced the present major structure seems clearly indicated, but the direction and extent of these movements is unknown. During the latest pronounced period of deformation the rocks were thrown into a series of east-west folds and broken by faults in the eastern part of the field, whereas north-south folds and faults were formed in the western part. Dislocations having an enormous throw must be postulated to account for the observed distribution of the rocks, and abnormal relations through overturning may be found in practically all parts of the field. The relation to the other rocks is therefore in places obscure or antithetical and isolated structural observations are often misleading. As a result of the extremely complex structure estimates of thickness are little better than guesses, but tens of thousands of feet of strata must be included in the undifferentiated schists.

Although it is impossible to express the major structure from the facts available, the smaller structures are prominent and may be seen in all exposures if carefully sought. As stated, the prominent structure everywhere observable is cleavage. So strongly marked is this feature that rarely if ever is the original structure of the rock determinable. In many exposures not only one but several structures due to deformation are visible. Thus it is no uncommon thing to see examples of folding and shearing of earlier cleavage planes by later deformation. This feature is recognizable even in Plate VIII, *A*, and is much more evident in the actual exposure.

Faults of small displacement may be recognized almost anywhere, and most of them appear to be of the thrust type. Larger faults probably occur, but the absence of easily recognizable guide horizons and the probability of unconformities between the schists and the younger rocks make precise determination of the amount of displacement impossible without considerably more detailed study. Slickensiding along the fault planes is common, but a large part of the dislocation was probably taken up by small movements along the cleavage planes and therefore the amount is undetermined.

These features, as stated before, are recognizable in all the members of the undifferentiated schists, but they are most prominent in the quartzose schists and least so in the calcareous schists and in the dark carbonaceous slates and quartzites. This difference may perhaps be due to difference in the age, but it may also be due to the fact that the calcareous schists are least resistant and therefore easily readjust themselves to stresses, whereas the carbonaceous quartzites and slates are more resistant and therefore withstood deformation best, and the quartzose schists, intermediate between the two, were easily deformed but were resistant enough to preserve more traces of their earlier condition.

AGE AND INTERRELATIONS.

As the undifferentiated metamorphic schists comprise a great thickness and variety of rocks, they probably have a considerable range in age. No fossils have been found in these rocks and therefore their age must be determined by analogies and inferences. Unfortunately, most of the rocks that are closely associated with the schists are also unfossiliferous, so that many of the correlations rest on analogies with areas far away, and in a region having a structure so complex as that of the Noatak-Kobuk region these analogies are liable to lead to considerable error. In Seward Peninsula the supposed equivalent schists underlie rocks of known Ordovician age and probably underlie Cambrian rocks unconformably, if judged by the difference in physical character. On John River Schrader's section shows the Totsen "series," that is the equivalent of the undifferentiated metamorphic rocks farther west, overlying limestones (the Skajit formation) containing indistinct fossils that are stated to be not older than Silurian nor younger than Carboniferous. Brooks, however, says:[1]

> The contact between these rocks and the Skajit was not exposed, but Schrader appears to have regarded the Totsen as the younger, though his statements on this point [2] are not entirely in accord. The evidence presented might almost equally well be interpreted as indicating that the Totsen underlies the Skajit.

On Alatna River the schists underlie unconformably a similar limestone and therefore are older than the Skajit formation. On Dahl Creek in the Kobuk basin the schists underlie a limestone that presumably is late Paleozoic, as fossils similar to those in the Devonian and Carboniferous limestones of Seward Peninsula are found in the float that probably came from the limestone. On the Noatak the evidence of age of the schists rests on the correlation of the limestones similar to those exposed on Alatna River. The schists are certainly older than the limestones, but nowhere are the higher rocks fossiliferous.

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[1] Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 215.

[2] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 55-62.

There will be occasion to refer later to the age of these limestones and to point out that probably they are of Paleozoic age. For the present, however, no more definite statement of the age of the schists can be made than that they probably were formed not later than the early Paleozoic and possibly as much earlier as the pre-Paleozoic. This determination is necessarily vague, but it suggests the correlation of these undifferentiated metamorphic rocks with the schistose rocks in the lower part of the Nome group or with the Kigluaik group and Kuzitrin formation of Seward Peninsula, with portions of the Birch Creek schist of the central part of the Yukon basin, and with the "Rapids," "Lake," and amphibolite schists of the Chandalar-Koyukuk region, not to mention other areas more remote.

UNDIFFERENTIATED PALEOZOIC LIMESTONES.

DISTRIBUTION.

The undifferentiated Paleozoic limestones are widely distributed throughout the Noatak-Kobuk region. Plate II shows graphically the places where these rocks have been recognized. From this map it may be seen that there are four more or less distinct large areas of these rocks together with many smaller ones. The four main areas are in the central part of John and Alatna River basins, in the headwaters of the Noatak, in the Igichuk Hills of the lower part of the Noatak basin, and in Seward Peninsula. The smaller areas are most numerous in the Cosmos Hills north of Shungnak and in the hills near the pass between the Kobuk and the Alatna. It is not intended by thus separating the areas of undifferentiated limestones to imply that subsequent investigation may not demonstrate that they are continuous or that some of them are the equivalent of certain differentiated formations or groups. In each of the areas the undifferentiated Paleozoic limestones show certain distinct features which make it desirable to treat the lithologic character, structure, and age of these rocks in each area separately and this plan will be adopted in the following pages.

LITHOLOGIC CHARACTER.

The Paleozoic limestone on John River[1] is described by Schrader as a—

> heavy-bedded crystalline limestone and mica schist. Weathered surfaces parallel with the bedding and planes of movement and crushing present a silvery sheen due to the presence of mica, while some layers grade wholly into a mica schist. On a fresh fracture surface the limestone is found to be highly crystalline, generally fine or medium grained, and of impure white or bluish-gray color, the latter apparently denoting the more dolomitic phases of the rock. It weathers to a dirty gray or light brown, sometimes tinged with red.

On Alatna River very similar limestones occur between the camp of July 10 and the mouth of the Pingaluk. In places the limestone is

[1] Schrader, F. C., op. cit., p. 56.

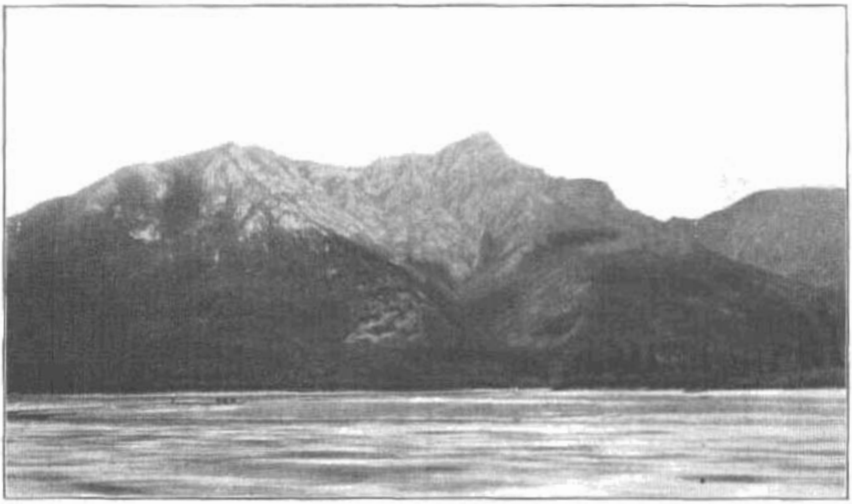
dark and has bluish-white bands; in others it is grayish and has been somewhat silicified; and in still others it is brownish and weathers to a sugary sand. No dolomitic horizons were recognized. Mica is recognizable in all of these phases and in places is so abundant that the rock might be characterized as a calcareous schist. Locally the limestone has been cut by greenstones and tremolite and other contact-metamorphic minerals have been formed.

Plate IX, *A*, a view of the hill east of Alatna River near the camp of July 10, illustrates the characteristic topography of the bare white hills to which the limestones give rise.

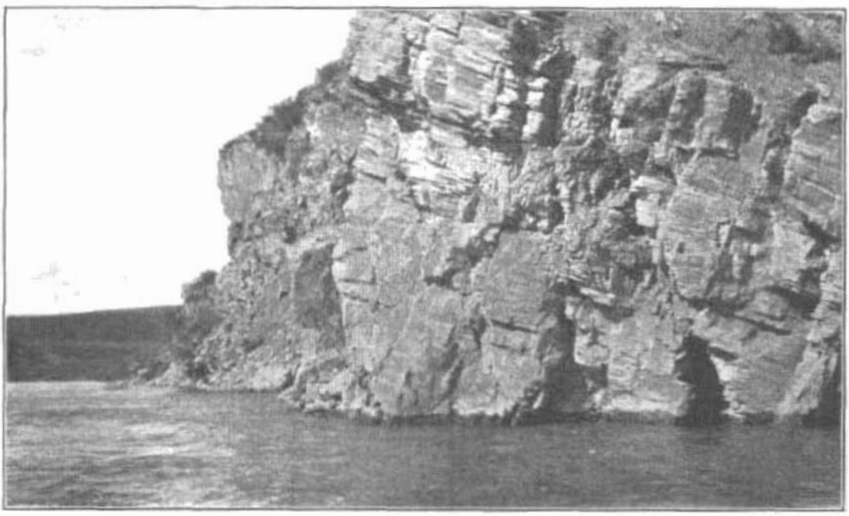
North of the Kutuk on Alatna River another band of limestones, about 2 miles wide, trends east and west. On weathered exposure the limestone appears quite brown but on fresh fracture is dark gray and rather less crystalline and schistose than the limestone to the south. This seems to be the eastern continuation of the limestone that occurs in the headward part of the Noatak. In the latter basin, however, the rock is somewhat more schistose and is usually darker on fresh fracture. Plate IX, *B*, which shows a near view of this limestone a short distance below the camp of August 4, illustrates the general physical character of the rock. Bedding is but poorly preserved, the dominant structure being cleavage. Here and there, however, the bedding may be recognized, as may be seen in Plate XIV, *A* (p. 122), a view of an outcrop a short distance below the camp of August 1, which will be described in somewhat greater detail later. The hammer handle is parallel with the bedding; the more prominent structure nearly at right angles to this direction is cleavage developed by the recrystallization of the limestone. Some scattered sulphides occur in the limestone in well-formed crystals. These on weathering stain the rock brown and give rise to most of the local variations in its color.

East of the camp of July 28, near the base of the limestone, there is a reddish limestone somewhat less schistose and more sandy on weathered surfaces than elsewhere. In the gravels of the large stream from the south, a short distance above the camp of July 31, many pieces of float were found having indistinct cylindrical tubes of white color in a dark, nearly black limestone, suggesting nearly obliterated corals.

The rocks of the Igichuk Hills have been provisionally classed with the undifferentiated Paleozoic limestones on account of lack of specific data and the absence of features characteristic of certain of the known limestones. These rocks are considerably deformed, and in places present schistose phases with original structures practically unrecognizable. Dolomites are practically absent and the rocks are recrystallized limestones of blue-gray to white color. Some sparsely disseminated sulphides are occasionally found and in places on weathering out have given the surface of the limestone a honey-



A. TOPOGRAPHY OF LIMESTONE AREA IN CENTRAL PART OF ALATNA RIVER VALLEY.



B. EXPOSURE OF LIMESTONE ON UPPER NOATAK RIVER.

A. FOLDED SANDSTONE CUT BY GASH VEINS, NOATAK RIVER.

B. DEFORMED PALEOZOIC ROCKS, NOATAK RIVER.

combed appearance. Little or no silicification was observed in the rocks and there were no minerals of contact-metamorphic origin. The general appearance of these rocks is fairly well shown by Plate IV, *A* (p. 28).

In Seward Peninsula the undifferentiated Paleozoic limestones have been most carefully studied by Moffit and from his report[1] the following description is abstracted:

> Northeast of the Asses Ears is an area of about 35 square miles [the largest limestone area shown in the extreme southwestern portion of Pl. II], made up chiefly of white marbles much sheeted and sometimes schistose, which appear as smooth, rounded domes, bare of moss, and therefore affording good footing to the traveler. Long radiating needles of tremolite are not uncommon, but otherwise the limestone is generally almost pure. * * *
>
> Black graphitic varieties [of limestone] are not uncommon, especially in the Inmachuk and Goodhope River region.

The smaller areas of undifferentiated Paleozoic limestones in the Kobuk and Alatna basins require no special description, as they are formed of rocks essentially similar to those already described. On the whole, judging from the descriptions of Mendenhall, the limestones appear to be in somewhat narrower belts and to be more interlaminated with schists. It is by no means certain, however, that this interlamination represents depositional differences, as it may be due either to infolding or to regional metamorphism. Although most of the bands of limestone are thinner than those already described the indefinitely located limestone area on Reed River is only part of a considerable exposure of this rock, the boundaries of which could not be determined because of their distance from the observer.

STRUCTURE.

Enough has already been said to show that all the undifferentiated Paleozoic limestones have been considerably deformed and the dominant structure is secondary. Cleavage rather than bedding is the structure observed and only in areas where the structure is exceptionally well preserved is the original bedding recognizable. For this reason, in attempting to determine the general stratigraphy, the areal distribution must be considered far more important than the observations made on minute structural features. Furthermore, observation from a distance usually does not disclose the true condition, and structure that appears simple at a distance becomes more and more complex the closer it is investigated. This fact has already been shown by certain of the foregoing illustrations and is emphasized by others introduced later (Pl. X, *B*, for instance).

The major structure of the undifferentiated limestones corresponds to the general east-west trend in the eastern part of the field and the

[1] Moffit, F. H., Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 22.

north-south trend in Seward Peninsula, already noted under the head of the "Undifferentiated metamorphic schists." The limestones, however, show by their continuity and areal distribution that they have not been subjected to the same amount of diastrophism as the schists; in general, they seem to occur as infolded or infaulted synclines and are unconformable on the undifferentiated schists. This structure is rather clearly indicated in the two belts of limestone in the central part of Alatna River valley. At the southern margin of this area the strike of the schists is nearly north and south and the dip is steep and variable to the east and west, whereas the limestones trend nearly east and west and dip steeply north. At the northern border the structure is not satisfactorily exposed, although the dip seems in general to be northward, as though the schists to the north overlie the limestone. Here and there, however, southward dips were observed and an overturned structure is suggested. Still farther north the narrow belt of limestone dips north on the southern side of the area and south farther upstream, indicating a syncline, a structure which is confirmed by the fact that in several places farther north the limestone caps the hills and the schists form the lower slopes.

The structure of the limestone belt in the upper part of the Noatak region is exceedingly complex and has not been satisfactorily determined. The general dip is apparently northward, but with folding so intricate as that shown in Plate X, *B*, which represents an exposure between the camps of July 31 and August 1, the true structure can be demonstrated only by detailed studies. Furthermore, the rocks in the hills north of Midas Creek (camp of August 2) dip south at high angles, whereas the limestones on the Noatak a short distance above that creek dip north, so that the inferred fault that exists between the two places makes satisfactory proof of the structure impossible, and the rocks farther west are covered by a mantle of alluvium.

The observations made in the Igichuk Hills are not sufficiently extensive to determine the major structure of the limestone in that area. The rocks are intensely deformed and the dips are so nearly vertical and their directions change so unsystematically from place to place that the only generalization possible is that the rocks are nearly on edge and probably form a much shattered and faulted synclinorium.

The structural features of the limestones of Seward Peninsula present some anomalies that can be explained only by further field investigation. Moffit[1] states that some of the massive limestones appear to have been thrust up through the overlying schists, possibly during granitic intrusions. The writer has not seen this feature and feels some hesitation in accepting Moffit's conclusion because of the

[1] Moffit, F. H., op. cit., p. 23.

mechanical difficulties involved and the lack of definite proof of the stratigraphic relation of the schists and limestones.

Small structural features recognized in the undifferentiated limestones are faulting, brecciation, recrystallization, and cleavage. The last two have already been sufficiently described. Brecciation is common and gives rise to a peculiar mottled appearance, caused by the fragments of noncrystallized original black limestone being embedded in later infiltrated white crystalline calcite. Much of the brecciation appears to have been effected by shattering unaccompanied by any considerable movement. Faulting on a small scale may be seen in many of the outcrops. The data for determining the amount of dislocation that has taken place are usually obscure except for faults of small throw. Along many of the larger faults the limestone has so flowed under pressure and then recrystallized that the evidence of movement is in large measure masked.

AGE AND INTERRELATIONS.

The Paleozoic limestone on John River contains indistinct fossils, which Prof. Charles Schuchert identified as "having the ventral valve of a brachiopod of the order of Meristina and Meristella and also resembling a transverse Seminula. This kind of shell indicates that the rock can not be older than Upper Silurian and not younger than Lower Carboniferous."[1] Owing to an error in assigning the Carboniferous limestone or Lisburne limestone in the John-Anaktuvuk section to the Devonian, and to the fact that the so-called Skajit formation was more disturbed and metamorphosed than the Lisburne, Schrader provisionally referred the Skajit to the "Upper Silurian" (Silurian). The difference in amount of metamorphism is not conclusive evidence, for the deformation seems to become progressively less toward the north. Schrader in his published report made no distinction between the rocks underlying the Lisburne limestone and those supposed to overly the Skajit formation. Studies in the Alatna River basin indicate that the equivalent of the Skajit formation overlies the schist, and from a reexamination of Schrader's notes it was found that the rocks underlying the Lisburne limestone are less schistose than those supposed to overlie the Skajit. It is therefore a problem whether or not the Skajit and the Lisburne should be correlated. The only fact opposed to such a correlation is the absence below the Skajit on John and Alatna rivers of the sandstone and shale series which underlies the Lisburne limestone on the John and Anaktuvuk. This absence may be accounted for by faulting, by nondeposition, or by the metamorphism of the sandstones and shales into the undifferentiated metamorphic schists. In view, however, of the absence of specific proof and the fact that other

[1] Schrader, F. C., op. cit., p. 57.

limestones are known in the stratigraphic column in northwestern Alaska it has seemed unwise at present to do more than suggest the possible equivalence of the Lisburne and Skajit formations.

The Skajit formation and the most extensive limestone on Alatna River are so nearly similar that no doubt is felt that the two are the same. Furthermore, there seems to be little room to doubt that the thinner band to the north on Alatna River is also the same limestone, having the same relation to the underlying schists. When traced westward, however, into the Noatak basin this same belt shows certain features that throw a little more light on the interrelations. It has already been noted that indistinct coral-like tubes, partly obliterated, that are found in creek gravels near the camp of July 30 are similar in general character to those found in the Carboniferous or Devonian limestones of parts of Seward Peninsula.[1] Furthermore, near the camp of August 1 (see Pl. X, *B*), these limestones overlie a series of sandstones that are indistinguishable from and are correlated with the Carboniferous sandstones to be described later. It is true that in this place the structure is exceedingly complex, and schistose rocks, sandstones, and limestones occur together in a confused manner. The sandstones, however, are perfectly distinct and do not seem to merge with the schists. They appear to be equivalent to the sandstones described by Schrader as immediately adjacent to the Lisburne limestone, and to the sandstones that will be described later as underlying the Carboniferous limestone in the western part of the Noatak basin.

Though the possible correlation of these limestones with those of Carboniferous age is thus emphasized, the fact must not be lost sight of that the evidence at hand is capable of other interpretations, and the uncertainty of the correlation suggested is so keenly felt that it has been deemed expedient to indicate the doubt by distinguishing on the map the known Lisburne limestone from these other rocks.

The age of the limestones of the Igichuk Hills is uncertain. No fossils have been found in them and their physical features do not distinguish them from several other thick limestone members in northern Alaska. Their outcrops where examined were so surrounded by deposits of recent alluvium that little of the general relations could be determined. Near the lower gorge of the Noatak, where Carboniferous rocks were exposed, there were some dolomites that suggested by their physical characters correlation with the Silurian dolomite of Seward Peninsula. Their close relation, however, with the Carboniferous rocks and the fact that dolomitic beds of considerable thickness occur in places in this series in Seward

[1] Smith, P. S., and Eakin, H. M., op. cit., p. 48.

Peninsula renders this correlation doubtful. The limestone of the Igichuk Hills certainly appears to lie unconformably above schistose rocks which are similar in general aspect to those occurring on Alatna River and in the headwaters of the Noatak and which, from their lithologic character and topographic expression, appear to be equivalent to them.

In discussing the age of certain rocks of northeastern Seward Peninsula, Moffit [1] states that "the massive limestones mentioned above should probably be correlated with the Harris Creek and Baldy Mountain limestones." Kindle [2] subsequently determined that the limestones of Baldy Mountain and Harris Creek are Carboniferous, but owing to uncertainties of correlation and the different interpretations of the structure the suggested correlation should not be accepted without further investigation, for limestones of Ordovician, Silurian, and Carboniferous age occur in close proximity.

Of the limestones forming the small scattered areas in various parts of the Noatak-Kobuk region the only suggestion as to age is afforded by the limestones at the head of Dahl Creek, near Shungnak in the Kobuk basin. In the float in the central part of this valley, not far from an outcrop of a downfaulted block of limestone, indistinct corals were found in a limestone bowlder. These were too poorly preserved to permit specific determination, but were of precisely the same appearance as fossils collected in 1909 from the limestones along the eastern flanks of the Darby Range in southeastern Seward Peninsula, which were identified as Devonian or Carboniferous.[3] Another similarity between these limestones and those of Seward Peninsula is the strong petroliferous odor they emit when freshly broken. The limestones having these particular characteristics were dark, nearly black, with interlaminated bluish-white bands, the whole somewhat crystalline.

To sum up the question as to the age of the undifferentiated limestones, it is evident that, as is implied in their name, they may include several limestones of different ages. Although the evidence is not conclusive, there are reasons for believing that some are equivalent to the late Paleozoic limestones. It seems fairly certain that the limestones as a whole are younger than the undifferentiated metamorphic schists as a whole. Although by no means proved, it is believed that all of the undifferentiated limestones are of Paleozoic age.

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[1] Moffit, F. H., op. cit., p. 24.

[2] Kindle, E. M., Faunal succession in Port Clarence limestone, Alaska: Am. Jour. Sci., 4th ser., vol. 32, 1911, pp. 335-349.

[3] Smith, P. S., and Eakin, H. M., Geology of southeastern Seward Peninsula and the Nulato-Norton Bay region: Bull. U. S. Geol. Survey No. 449, 1911, p. 48.

SILURIAN SYSTEM.

The only rocks of known Silurian age were found by Kindle in the vicinity of Cape Deceit, a promontory near the town of Deering. The following account is taken from his description of this locality:

> On the north coast of Seward Peninsula the writer has found at Cape Deceit a fauna which appears to be the same as the fauna at White Mountain [in the south-central part of the peninsula]. It is represented by a coral which is probably a species of Amplexus and a lamellibranch apparently identical with the Megalodon occurring at White Mountain. The limestone at Cape Deceit has the highly magnesian composition characterizing the limestone at White Mountain.[1]

The limestone at White Mountain is described by Kindle in the same paper as being several hundred feet thick, of white to light-gray color, much broken by joints with very indistinct bedding planes, highly magnesian, and as containing a late Silurian fauna comparable with the Guelph in the States.

The fact that in every place where this formation has been found—in southeastern Alaska, on Porcupine River, in the Rampart region, and in Seward Peninsula—the rocks are dolomitic is believed to be significant. Although dolomites are known to occur in many other series, the fact that this part of the Silurian is everywhere dolomitic suggests that certain of the limestones in the Noatak-Kobuk region that have not yet been differentiated should be closely examined for this feature. Some of the dolomitic beds already noted in the region southeast of the canyon and in the lower gorge of the Noatak may possibly belong to the Silurian.

Unfortunately, the Silurian exposures at Cape Deceit are so isolated by the sea and by recent deposits of alluvium that they afford no clue as to their relations with the other rocks of the region. The fact that they are not schistose suggests that they are not so old as the undifferentiated metamorphic schists to the south, but even this conclusion rests on several unproved assumptions.

DEVONIAN SYSTEM.

Undoubted Devonian fossils have been found only in float bowlders in John River basin a short distance north of Hunt Fork. The location of the rocks from which they were derived is therefore uncertain, though Schrader evidently believed that they were derived from the rocks exposed in the neighborhood. Owing to the fact that the particular outcrops from which the fossils came is not known, it has been impossible to indicate the Devonian strata on the geologic map (Pl. II), and they probably have been included in the Carboniferous rocks to be described later.

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[1] Kindle, E. M., The faunal succession in the Port Clarence limestone, Alaska: Am. Jour. Sci., 4th ser., vol. 32, 1911, pp. 347–348.

A reexamination of the original field notes fails to disclose a sufficiently explicit description of the rocks in the vicinity, and specimens brought back by Schrader afford the only means of determining the lithology and age of these rocks. From these specimens it may be seen that the rock is a sandy gray to dark-brown, medium fine grained, noncrystalline limestone, little if any cleaved, weathering to a lighter brown on exposed surface. The fossils are usually darker than the inclosing rock and show little or no evidence of deformation. These fossils were examined by Schuchert and Kindle, who report that they include *Spirifer disjunctus*, a typical Upper Devonian form.

In the Noatak region some doubtfully Devonian fossils have been obtained from rocks that were indistinguishable from the Carboniferous sandstones, shales, and limestones, and in this report these rocks have been included in the Carboniferous to be described later. That no marked break occurs between Upper Devonian and the lower Carboniferous (Mississippian) rocks in this part of Alaska is indicated by the facts that the truly Devonian rocks on John River were not distinguished by Schrader from the Carboniferous rocks, that the questionable Devonian rocks in the Noatak were not differentiated by the writer, and that Collier states that similar rocks in the Cape Lisburne region are apparently conformably overlain by lower Carboniferous rocks. It will therefore not be feasible to differentiate and map the two systems until more precise studies and more extensive collections have been made.

CARBONIFEROUS SYSTEM.

NOATAK SANDSTONE.

DISTRIBUTION AND LITHOLOGY.

Two main divisions of the Carboniferous rocks have been made, based mainly on differences in lithologic character. One division is composed mainly of sandstones, with subordinate amounts of quartzite, shale, and thin-bedded limestone; the other consists almost entirely of limestones. The former is called the Noatak sandstone, and the latter the Lisburne limestone, the geographic name given by Schrader.

The Noatak sandstone was seen and studied most extensively in the central and western parts of the Noatak basin, from the canyon as far east as the camp of August 9. Other areas correlated with this typical portion of the sandstone are the hills in which Midas Creek rises, north of the camp of August 2, and the northern part of the Fickett series mapped by Schrader on John River.

Views of characteristic phases of the Noatak sandstone and the topography to which these rocks give rise are shown in Plates V, *A*

(p. 29); XI, *A* and *B*; and XIV, *B* (p. 122). They illustrate the general field appearance of the rocks included in this formation.

In the most typical exposures seen from a point near the camp of August 11 to the canyon the rocks are dominantly sandstones, medium fine grained and rather massive, but containing layers of shale that accentuate the bedding. On exposed surfaces the rocks are usually rusty brown to brownish green, but on fresh fracture they are dark gray or greenish. The component minerals are usually not distinguishable macroscopically with the exception of quartz and flakes of mica. When treated with acid many of the sandstones effervesce slightly, showing the presence of calcite. Under the microscope the sandstone is seen to be composed mainly of quartz and some sericite, with limonitic and carbonaceous material filling the interstices.

Some slightly conglomeratic beds are associated with the sandstones and certain of these show flattened masses of indurated shale or quartzite which are of pebble-like form, but which may represent contemporaneous accumulations of mud. Mica has been developed parallel with the surface of these nodules, but the material within is unsheared. Many of these accumulations closely simulate fossils and can be distinguished from them only by careful examination.

Some thin beds of limestone, few over a foot thick, are interbedded with the sandstones. These limestone beds show considerable variation in color, some being dark gray whereas others have weathered to a light yellow. All the limestones are semicrystalline, but exhibit only slight signs of movement. Fossils are fairly numerous in some of these beds and are entirely undeformed. In places the rocks are cut by small local calcite veins and have been intruded by basic intrusive rocks. The limestone beds become more prominent and thicker toward the top of the formation. Limestones may be recognized above the intrusive sill in the upper central part of Plate XI, *B*, and outside of the more closely appressed portion of the fold in Plate XI, *A*.

Shales and slaty beds are interlaminated with the other members of this formation. Generally they exhibit both bedding and cleavage, but not much metamorphism. The slates contain little clayey material but seem to be formed mainly of fine-grained quartz and some calcite. As a rule the rock is too fine grained to permit its component minerals to be distinguished. Under the microscope it is seen to be composed mainly of quartz, kaolin, or sericite, and a greenish, nearly amorphous, finely divided mineral, together with magnetite, some sulphides, and limonitic material.

Quartzites are especially common in the exposures in the vicinity of the Noatak Canyon. Most of them are dark, nearly black, but brown and red iron-stained members are not uncommon. The greater induration of the quartzites appears to be due to the pronounced folding to which the rocks have been subjected and also to the igneous

A. FOLDED PALEOZOIC ROCKS IN CANYON OF THE NOATAK.

B. PALEOZOIC ROCKS INTRUDED BY GABBRO, CANYON OF THE NOATAK.

intrusions in the vicinity. As a result of the igneous action much of their dark coloring matter has here and there been destroyed and they weather white, so that at a distance they are difficult to distinguish from certain of the limestones. This contact phase may in places be traced several hundred feet from the igneous rock. The red and brown colors noted above have been produced mainly by the weathering of sulphides that occur in the quartzites.

The rocks of the Midas Creek region that are provisionally correlated with the Noatak sandstone are typically sandy slates showing little or no schistosity, but having a well-marked lamination, which is in places transverse to the bedding. In addition to the quartz and scattered mica flakes observable in hand specimens, these rocks, when examined under the microscope, show a content of bleached biotite, chlorite, albite, zircon, and iron ores. The apparently greater shearing to which they have been subjected may be accounted for by their closer proximity to the region of pronounced dynamic metamorphism.

The rocks on John River that are correlated with the Noatak sandstone were described by Schrader, under the name Fickett series, as consisting of—

> dark shale, schistose shale, and apparently some dark limestone, which is succeeded by quartzite, grit, and conglomerate * * *. The quartzite, grit, and conglomerate are hard and flinty, the grains and pebbles being thoroughly united by a siliceous cement. The best exposure of these rocks that was seen is that at Fork Peak [just north of latitude 68°], * * * from which point for about 15 miles northeastward to beyond the Anaktuvuk portage they present a steep face to the northwest * * *. Here the dip is gently south or southeast. Apparently these same conglomerates and grits were also encountered in the lower reaches of a deeply cut gulch about 20 miles south of Fork Peak, west of the mouth of Hunt Fork. Toward the top of Fork Peak the grit and quartzite give way to dark schistose slate and dark-gray micaceous sandstone.[1]

According to Schrader's notes and descriptions, this same division includes metamorphic rocks which in the present report have not been correlated with the Noatak sandstone, but have been classed with the undifferentiated metamorphic schists. According to Schrader, these rocks overlie the more northern ones which have been correlated with the Noatak sandstone. Such an interpretation, however, presents so many difficulties that until further evidence is adduced it is believed more reasonable to accept the interpretation that the schistose beds are older than the less-deformed beds here correlated with the Noatak sandstone.

STRUCTURE.

In general the folding of the Noatak sandstone has not been so intense as that of the other rocks already described. Schrader reported open folding in this formation on John River. In the eastern

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 68-69.

part of the Noatak also the folding is not extreme, but vertical and overturned dips were observed at many places farther west. The folds and faults shown in Plates X, *B*, and XI, indicate that the structure is by no means simple. In spite of the complexity of local details the larger structure appears to trend in the main east and west. In a broad way the Noatak sandstone disappears under higher rocks toward the north and has been removed by erosion, it having been more uplifted, toward the south. Although this appears to be the general structure, it should be remembered that the actual structure is made up of subordinate folds and faults, which when viewed in detail present many diversities from this simple, locally inexact, generalization.

The Noatak sandstone has been subjected to pronounced regional dynamic metamorphism, and in addition to the larger structures cleavage has been produced in almost all its members except the more massive quartzite beds. This structure is particularly prominent in the finer-grained beds and in many places the original bedding is so masked that it may escape detection. Plate XIV, *B* (p. 122), shows an exposure of the slaty phase of the Noatak sandstone between the camps of August 12 and 13 on the north side of the Noatak. The bedding is shown by the color banding parallel with the hammer handle. This banding is evidently due not only to differences in color, but also to different chemical composition, texture, material, and size of grain. Transverse to the bedding and in Plate XIV, *B*, having a considerably lower dip is a well-marked cleavage, which is so strongly developed that the rocks weather into slabs parallel to its direction rather than to that of the bedding.

Although cleavage is everywhere noticeable, schistosity was not observed in the typical area of Noatak sandstone. In the area of rocks correlated with the Noatak sandstone on John River, however, Schrader mentions schistosity in certain members. It is possible that the rocks so described belong rather to the supposed underlying undifferentiated metamorphic schists than to the Noatak sandstone, and that they have been infolded or infaulted.

AGE AND INTERRELATIONS.

Fossils have been found at several places in the area of typical Noatak sandstone. The most definite collections from rocks in place were made at locality 11AS46, on the south side of the Noatak, about 8½ miles east of the camp of August 9, and at localities 11AS51 and 11AS53, on the north side of the river, about a mile east of the camp of August 11. Mr. Girty, who examined the fossils from these places, states that the three collections belong together, and he furnishes the following lists of fossil determinations:[1]

[1] Girty, G. H., unpublished letter.

Locality 11AS46:
- Menophyllum sp.
- Stenopora sp.
- Batostomella? sp.
- Schuchertella? sp.
- Chonetes aff. illinoisensis.
- Productus aff. indianensis.
- Productus aff. undatus.
- Productus aff. longispinus.
- Productella hirsutiformis?
- Camarotœchia sp.
- Spirifer aff. striatus.
- Spirifer aff. centronatus.
- Cliothyridina aff. sublamellosa.
- Leptodesma aff. spergense.
- Aviculipecten sp.
- Bembexia? sp.
- Orthoceras sp.
- Paraparchites sp.

Locality 11AS51:
- Zaphrentis sp.
- Lingula? sp.
- Schizophoria aff. swallowi.
- Chonetes aff. illinoisensis.
- Productus aff. indianensis.

Locality 11AS51—continued.
- Productus aff. longispinus.
- Productus sp.
- Pugnax? n. sp.
- Dielasma aff. formosum.
- Spirifer aff. paucicostatus.
- Spirifer aff. striatus.
- Spiriferina aff. subelliptica.
- Ambocœlia aff. levicula.
- Cliothyridina aff. hirsuta.
- Athyris? sp.
- Aviculipecten sp.
- Murchisonia sp.
- Pleurotomaria sp. 2.
- Euomphalus sp.
- Naticopsis n. sp.
- Naticopsis aff. carleyana.
- Paraparchites sp.
- Phillipsia sp.

Locality 11AS53:
- Zaphrentis? sp.
- Chonetes aff. illinoisensis.
- Spirifer sp.
- Ambocœlia sp.

In discussing the significance of these determinations Mr. Girty says: "The geologic age I take to be upper Mississippian of the American section or the Mountain limestone or the *Productus giganteus* zone of the European section." On the first stream from the north, west of the camp of August 7, locality 11AS43, float bowlders of limestone were found in great numbers in the stream gravels. Many of these contained fossils which Mr. Girty determined as follows:

Locality 11AS43:
- Favosites? sp.
- Cladopora? sp.
- Cyathophyllum? sp.
- Stromatoporoid coral?

Locality 11AS43—Continued.
- Zaphrentis.
- Crinoid stem.
- Camarotœchia? sp.

A short distance downstream from this place, on the south side of the Noatak the following fossils as determined by Mr. Girty were found in the float:

Locality 11AS45:
- Zaphrentis sp.
- Cladopora? sp.
- Camarotœchia? sp.

From a bowlder of limestone in the canyon of the Noatak at locality 11AS67 a single fossil was found which Mr. Girty states is Zaphrentis sp.

Concerning these three collections Mr. Girty says:

> The doubtful Carboniferous collections comprise lots 43 and 45 and possibly 67 * * *. The preservation of the specimens in these collections is very unfavorable and the forms themselves are not diagnostic. The faunas are unlike anything at present known in the Alaskan Carboniferous, and they appear to me to represent a pre-Carboniferous facies. Dr. Kindle, however, who kindly examined them at my request, writes me that he sees no good reason for calling them even provisionally Devonian. The reasons given for this opinion are the abundance of crinoid stems, some of which are said to have a peculiarly flattened form, and the fact that one of the corals (a rather slender small-celled branching form, which I have cited as Cladopora? sp., but which may possibly be of bryozoan nature) is a different species from a similar form in the lot which he is accepting as possibly Devonian.
>
> It is evident, therefore, that a satisfactory determination of the age of this fauna must be deferred until it is possible to obtain more diagnostic and more satisfactorily preserved material.

In the John River region Schrader found no fossils in place, but numerous stream pebbles in the regions where the rocks now referred to the Noatak sandstone outcrop yielded lower Carboniferous (Mississippian) forms, as determined by Prof. Charles Schuchert. The lithology of the pebbles was similar to that of the rocks in place, but it is possible that some of the fossils may have come from the Lisburne limestone farther upstream to the north. The following identifications were made by Prof. Schuchert:

Locality 493:
- Lithostrotion (of the group in which the corallites are not in close embrace).

Locality 495:
- Spirifer striatus Martin.
- Productus scabriculus Martin.
- Spirifer near S. neglectus Hall.

Locality 513:
- Productus scabriculus Martin.

Locality 520:
- Productus semireticulatus Martin.

Locality 521:
- Spirifer striatus Martin.
- Productus, a very small underdetermined species.
- Cystodictya nearest to C. lineata.

Locality 522:
- Spirifer striatus Martin.
- Fenestella.

Locality 525:
- Spirifer striatus Martin.
- Spiriferina cristata Schlotheim?

Locality 534:
- Streblotrypa near nicklesi Vine.
- Fenestella, several species, one of which is near F. cestriensis Ulrich.
- Cystodictya.
- Pinnatopora.
- Rhombopora.

The above eight localities represent one formation in the upper part of the Lower Carboniferous. This fauna is unlike that of the Mississippi Valley in that it does not have the characterizing fossils, as the screwlike bryozoan Archimedes and the blastoid genus Pentremites.

Localities 497 and 529 have a Syringopora much like *S. multattenuata* of the Upper Carboniferous. This genus, however, has little stratigraphic value, but the development of the species present is indicative of Carboniferous.

Localities 511, 518, and 454 are represented by a crinoidal limestone apparently the same as at localities 525 and 521 and probably from the horizon of the latter.

Localities 463 and 464 represent another horizon, since the lithology is quite different from any of the other localities. The only fossils present are large crinoidal columns like those of the Lower Carboniferous.

Locality 461 also has large crinoid columns and may represent the Lower Carboniferous.

The above localities probably all represent the same Lower Carboniferous formation as that of the specimens from localities 493, 495, 513, 520, 521, 522, 525, and 534.

Locality 519 has Fenestella, Cystodictya?, and crinoid columns. The material is unsatisfactory, and all I can do is to state that it indicates either Devonian or Carboniferous.[1]

From the above facts it is concluded that the Noatak sandstone is of lower Carboniferous (Mississippian) age. Possibly certain of the lower beds may have been formed in the extreme upper part of the Upper Devonian, but from Kindle's statement (p. 74) there is considerable reason for believing that all the rocks are Mississippian.

LISBURNE LIMESTONE.

DISTRIBUTION AND LITHOLOGY.

The name "Lisburne" was first applied by Schrader to the limestones at Cape Lisburne and was extended to include similar limestones found by him at the head of John and Anaktuvuk rivers. Later studies of the type locality were made by Collier[2] and still more recently by Kindle,[3] but this area is outside the region treated in this report. As a result of the work of the expedition of 1911 certain limestones in the western part of the Noatak region have been assigned to this formation. The position of the different areas is indicated on the geologic map (Pl. II), and the Noatak and John-Anaktuvuk localities will be described in the following pages.

On John River the Lisburne limestone forms a belt about 15 miles wide. According to Schrader:[4]

> The rocks of the Lisburne formation may be characterized for the most part as medium-bedded semicrystalline limestones of impure white or gray color. They weather gray, light rusty brown, or chocolate. They form the mountains that rise to a height of 2,500 to 3,000 feet above the floor of the Anaktuvuk Valley. Near the summit occur two beds of intercalated shale, each apparently several hundred feet thick and containing some thin layers of dark gray limestone * * *. Judging from exposures observed in the region of the Anaktuvuk, the thickness of the limestone formation is probably a little over 3,000 feet.

In the Noatak region three areas are correlated with the Lisburne—one southeast of the canyon, one in the hills west of Kugururok River, and one in the lower gorge of the Noatak. The first is about 5 miles southeast of the camp of August 14, in a region of considerable faulting and igneous intrusion, where the relations are complex. The rocks exposed here are highly siliceous cherty limestones, considerably brecciated and recemented by chert. They are light brown

[1] Schrader, F. C., op. cit., p. 70.

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

[3] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 28, 1909, pp. 520-528.

[4] Schrader, F. C., op. cit., p. 63.

on exposed surfaces, but on fresh fracture are in places much darker. Indistinct fossils, mainly crinoid stems replaced by silica, may here and there be found on the weathered surfaces. Farther north these limestones are apparently overlain by a band of nearly black semicrystalline limestone with numerous white patches formed by the remains of corals. The rocks are exposed in small outcrops on steep north-facing scarps.

West of the Kugururok, limestones form the hills bounding the Mission lowland to the north. At a distance most of the hills are a brilliant white, but west of Kelly River a steep ravine exposes reddish limestones underlying the white. The rocks were not examined in place, but float from these hills showed the light-colored limestone to be semicrystalline and to have numerous thin dark, nearly black bands interlaminated with bluish-gray to white beds. Pebbles of the reddish limestone were similar to those found farther east, near the camp of August 4, and to the reddish sandy limestone that occurs near the base of the undifferentiated limestones around the head of the Noatak, north of the camp of July 28. On microscopic examination the red color was found to be due to a considerable amount of hematite in the rock. This coloring material is not evenly distributed but is concentrated irregularly here and there. It may have been leached from a calcareous sediment rich in iron. This reddish-brown limestone is also considerably exposed in the hills at the head of Cosmos Creek north of Shungnak, in the Kobuk region, and is there included in the undifferentiated limestones.

In the lower gorge of the Noatak, about half a mile below the camp of August 25, there is a silicified limestone bearing some indistinct fossils on its weathered surface. Bowlders of a dark, nearly black limestone containing numerous well-preserved fossils in such position that they evidently had not traveled far were found near the upstream end of this exposure. A little farther downstream is an outcrop of a brecciated dolomite, which is not distinguished from the other limestones. Indistinct unidentifiable organic remains were found in this dolomite. Still farther downstream, near the western limit of the exposures, is a dark, nearly black semicrystalline limestone with thin light-colored partings, which are so numerous that over 30 were counted in a thickness of an inch of limestone. This phase is nondolomitic.

STRUCTURE.

The rocks correlated with the Lisburne limestone show no structure discordant with that of the Noatak sandstone, already described. In all exposures the rocks are considerably folded and show secondary structures induced by the regional metamorphism. In the locality near the canyon and in the area west of the Kugururok the general trend of the lines of major structure is east-west to northwest-southeast, and the dip is dominantly toward the north. In the exposures near the lower gorge the strike appears to be about N. 20° W. and the dip steep and variable from west to east.

Smaller structural features, such as jointing and cleavage, are often seen and have caused the rocks to weather in slabby form. The intersection of the folding by the jointing in places gives rise to a "pencil structure," by forming fragments 6 to 8 inches long and half an inch thick. Brecciation also occurs in certain members of this formation, especially the dolomite, the cement being considerably more crystalline than the older fragments.

AGE AND INTERRELATIONS.

Fossils from the limestones southeast of the canyon have been examined by Messrs. Girty and Kindle. The former furnishes the following list of fossils from the more southern beds:

Locality 11AS65:
- Bryozoan?
- Productus? sp.

Locality 11AS65—Continued.
- Spirifer aff. rockymontanus.
- Composita aff. subtilita.

Concerning this collection Mr. Girty states that it contains little that is distinctive, so that nothing definite can be said regarding it, although it is rather suggestive of the Pennsylvanian.

Mr. Kindle examined the fossils from the more northern locality and writes:[1]

> The material consists entirely of fragmentary corals embedded in a dark dolomitic limestone. The best preserved and most abundant of these is a species of Cladopora, which is comparable with *C. labiosa*. Both the fossils and the rock matrix resemble rather strongly some of the specimens that have been obtained by me and by others from Black Mountain, in Seward Peninsula. The evidence is insufficient to make any positive correlation, but I would suggest that the material might be assigned provisionally to the Devonian, unless there is some distinctive stratigraphic evidence against such an assignment. The fossils probably represent either Devonian or Mississippian, probably the former.

Float fossils found near this place in the Noatak canyon and also on a gravel bar near the camp of August 19, probably derived from the limestones of the hills to the north, have been examined by Mr. Girty, who identifies the specimen from the former locality (11AS61) as *Lithostrotion portlocki?* and that from the latter (11AS73) as *Lithostrotion irregulare?* Mr. Girty states in a letter accompanying these determinations:

> These I believe to belong at about the same horizon as the foregoing [Nos. 46, 51, and 53, from the Noatak sandstone], showing merely different aspects of the same fauna. These coral lots (Nos. 61 and 73) have the facies that we know in the Lisburne limestone, which I believe to be composed of equivalent beds.

[1] Kindle, E. M., unpublished letter.

The richest fauna was obtained from the dark, nearly black limestone float at the northern part of the lower gorge of the Noatak. The following fossils were determined by Mr. Girty:

Locality 11AS77:
- Fenestella, several sp.
- Pinnatopora sp.
- Batostomella? sp.
- Cystodictya sp.
- Rhipidomella aff. pulchella.
- Derbya sp.
- Chonetes aff. illinoisensis.
- Productus aff. undatus.
- Productus aff. indianensis.
- Productus aff. semireticulatus.
- Productus aff. longispinus.
- Productus aff. 2 sp.
- Dielasma sp.
- Spirifer aff. striatus.
- Spirifer aff. paucicostatus.
- Martinia aff. glabra.
- Reticularia sp.
- Cliothyridina aff. hirsuta.
- Nucula sp.
- Leda sp.
- Palæoneilo aff. sera.
- Edmondia sp.

Locality 11AS77—Continued.
- Leptodesma aff. spergenense.
- Aviculipecten sp.
- Sphenotus aff. contractus.
- Sphenotus aff. unioniformis.
- Sphenotus sp.
- Sanguinolites sp.
- Schizodus sp.
- Schizodus? sp.
- Cypricardinia? sp.
- Pleurotomaria sp.
- Platyceras sp.
- Naticopsis sp.
- Euomphalus aff. spergenensis.
- Sphærodoma aff. littonana.
- Bulimorpha sp.
- Loxonema sp.
- Trochus? sp.
- Orthoceras sp.
- Eumorphoceras? sp.
- Paraparchites sp.
- Glyptopleura sp.
- Primitia sp.

According to Mr. Girty these fossils belong to the same group of rocks as those found in the Noatak sandstone and already described (11AS-46, 11AS51, and 11AS53). As stated above, however, he is of opinion that these rocks lie at about the same horizon as the Lisburne limestone, but they show different aspects of the same fauna. In one the fossils are mainly corals, whereas in the other they are principally mollusks.

Although the paleontologic evidence from the only rocks of this formation that were found in place is not so conclusive as is desired, there seems to be no valid objection to considering all of these limestones as one formation of Mississippian age. According to Mr. Girty's determination, based on the fossils from localities 11AS46, 11AS51, and 11AS53, the Noatak sandstone and this limestone formation are of practically the same age.

Further detailed studies will undoubtedly separate this formation into different members, but the present statements serve to bring out the early Carboniferous age of these rocks and to suggest their correlation with the Bettles "series" of the Koyukuk and Chandalar regions (described by Schrader) with certain limestones of Seward Peninsula and with similar limestones in the Yukon-Tanana region.

MESOZOIC ERA.

DIVISIONS OF THE ROCKS.

Three areas of Mesozoic rocks are shown on the geologic map (Pl. II). The largest of these areas forms the southeastern part of the region shown on the map and embraces most of the basin of the main Koyukuk River. Two smaller areas of Mesozoic rocks are shown in the extreme northern part of the mapped area. These areas are probably only a small part of the actual exposures of these rocks, for the region is practically unexplored. So far as known the rocks in all three of these areas are of Cretaceous age. Owing, however, to differences in age and lithologic character they have been divided into three groups: On the south side of the Endicott Mountains two groups, the Koyukuk and Bergman, have been distinguished and have been differentiated from the Cretaceous rocks north of the range. This separation does not imply that a part of the group north of the mountains may not be the equivalent of certain of the rocks to the south. In addition to the Mesozoic rocks found and mapped Triassic float was noted in the central part of the Noatak basin.

TRIASSIC SYSTEM.

OCCURRENCE.

Triassic rocks have been recognized in the region treated in this report only as float in the central part of the Noatak basin, in the gravels of the first stream from the south below the camp of August 7. The material is practically indistinguishable in lithologic character from the dark Carboniferous limestones in the vicinity. At the time the rock was found its significance was not appreciated and a thorough examination of the neighborhood was not made. Triassic fossils were obtained from a piece of float of nearly black chert within dark thin-bedded limestone. The silicification had taken place subsequent to the consolidation of the rock and had replaced much of the original material, which was probably limestone. The fragment was very hard, so that it may have been carried for a long distance, but in the field the impression was that the rock had not traveled far. Float limestone, questionably of Devonian but certainly of Paleozoic age, was also found in the same stream gravels, so that little or nothing of significance concerning the areal distribution of the Triassic rocks from which the float was derived could be determined without extensive investigation.

AGE AND CORRELATION.

The age of the fossiliferous cherty limestone float was determined by Mr. Stanton, who states:

7244. No. 11AS44; Noatak River at first stream from south, west of the camp of August 8, approximately latitude 68° N., longitude 159° W.:
Pseudomonotis subcircularis (Gabb).

Upper Triassic. The collection contains only a single species, but it is represented by a number of well-preserved specimens and is a widely distributed and very characteristic form found thus far only in the Upper Triassic.

This is the same horizon as that represented at Cape Thompson, 175 miles to the west, where Kindle[1] found dark cherts and thin-bedded cherty Upper Triassic limestones overlying Carboniferous rocks and interbedded with soft black shales and argillites containing black, green, and dull-red cherts. It should be noted that there was a considerable interval between the known Carboniferous and Upper Triassic. So far as now known this period in northwestern Alaska was unattended by deposition and its history is consequently obscure.

Although Triassic rocks have been reported only at the above two localities in northwestern Alaska the same characteristic fossils have been found at many places elsewhere in Alaska. They have been found along the Alaska-Yukon boundary, in the central part of southeastern Alaska, in the Copper River region, and in southwestern Alaska. The rocks are therefore widespread, and it is highly probable that with further study some of the areas in northwestern Alaska composed dominantly of older rocks may prove to have infolded and infaulted representatives of this younger system.

LOWER CRETACEOUS OR UPPER JURASSIC SERIES.

KOYUKUK GROUP.

Distribution.—The Lower Cretaceous or Upper Jurassic rocks represented on the geologic map (Pl. II) have been found in the central part of the Koyukuk basin and on the northern face of the Endicott Mountains. These rocks in the Koyukuk basin have been called by Schrader[2] the Koyukuk series, a name that has been applied also to the lithologically similar rocks of the Zane Hills.

Lithologic character.—Schrader describes the typical formation as an impure pinkish to reddish-colored limestone, which is associated with igneous amygdaloids and andesitic tuffs.[3] In his later report he noted that in addition to these rocks he found dark shale, slates, and some sandstones or arkose. The area studied by Schrader was near

[1] Kindle, E. M., Section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 28, 1909, pp. 526-528.

[2] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 476-477; A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 77.

[3] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 477.

the northeastern boundary of these rocks, where the dip was in general northeast. He reported that the limestone member is 800 feet thick.

In the Zane Hills, where similar rocks were examined by the Survey party in 1910, limestones were entirely absent and the group consisted of agglomeratic and arkosic beds associated with basic intrusives and effusives cut by acidic intrusives. This area was near the western margin of this group, where the strikes are dominantly northwest to southeast and the dips are westward. Characteristically the rocks are dark colored, generally greenish, but here and there dark red. As they are arkosic rocks, it is very difficult in the field to differentiate their sedimentary and igneous phases, so that the two have been mapped together. Some conglomeratic beds were recognized, but the pebbles were mainly of dark igneous rocks, none formed of schists or granites having been recognized. Ferromagnesian minerals are common and appear as glittering crystal faces on freshly broken specimens. Generally, however, the rocks are too fine grained to permit macroscopic determination of their component minerals.

The rocks are thoroughly indurated and compact, even on exposed surfaces, where they are firm and solid or but little disintegrated. So well are the various components consolidated that the rock breaks across the grains rather than around them. No great differences in resistance to erosion were noted between the different members, and consequently no notable features have been produced by erosion. Steep cliffs have been formed at many places, but they do not persist for long distances nor mark easily identifiable horizons, being rather the expression of various erosive activities working on essentially homogeneous material.

Fragments of vein quartz were not recognized in the Koyukuk group and later formed veins were not seen in the Zane Hills, though they are noted by Allen and Schrader in similar rocks farther east. No mineralization was seen and the group is believed to be practically barren.

Structure.—The major structure of the Koyukuk group where it is exposed is anticlinal. The trend of the axis is broadly northwest-southeast; the dips are to the east on the eastern margin and to the west on the other side. However, there has been much minor deformation, so that the structure is by no means simple. Faults of considerable magnitude have been observed and more profound movements must be postulated in order to explain the observed facts of distribution. As a result of these movements slickensiding has been produced and in a few places schistosity has been developed. It is believed that this schistosity, however, is distinctly local and is entirely separated from the schistosity noted in connection with the undifferentiated metamorphic rocks. (See pp. 55–60.)

The deformation to which the group has been subjected has produced cleavage and jointing. Schrader[1] notes that "A profuse jointing trends N. 25° W. and dips steeply northeast, and a well-marked cleavage strikes northeast and dips 75° SE." In the Zane Hills no such persistency in direction was observed, though the structures were evident. Owing to the complex structure the thickness of the group was not determined, but it is evidently great.

Near the granitic contacts the Koyukuk group is in many places considerably indurated and new minor structural features have been produced. It must not be inferred, however, that the rocks have been recrystallized, for they have not; though the induration is greater and the texture is more compact few new minerals have been developed.

Age.—The age of the Koyukuk group has been determined by means of fossils collected by Schrader from the pink limestone on the west bank of the Koyukuk near Waite Island and from another locality a few miles farther downstream to the southwest. Both collections were determined by Stanton,[1] who reports that they contain *Aucella crassicollis* Keyserling, a fossil characteristic of the Lower Cretaceous in Russia, though other species of Aucella are found in the Upper Jurassic. No other fossils have been found in this group of rocks and it is therefore evident that the age of the portions other than the limestone is extremely doubtful.

The age limits of this group can not be fixed definitely, but certain facts indicate that although some parts of it may have a more extended range the group as a whole was formed during Lower Cretaceous time. The facts that elsewhere in Alaska there was a considerable diastrophic break between the Upper and Lower Cretaceous, that Upper Cretaceous is represented in the region and lies unconformably above the Koyukuk, that this group is cut by granites similar to the granites represented by pebbles in the Upper Cretaceous beds, all point to the conclusion that these beds do not extend above the Lower Cretaceous. On the other hand, although none of the older Mesozoic rocks are known to be represented in the region, the difference in lithology suggests that the Koyukuk group does not belong to either the Jurassic or Triassic.

ANAKTUVUK GROUP.

Lithologic character.—The Anaktuvuk group of Lower Cretaceous or Upper Jurassic rocks has been examined only by Schrader, from whose report[2] the following statements are practically quoted.

The group consists of impure sandstone or arkose and a little conglomerate. The sandstone is usually heavy bedded, beds 6 to 8

[1] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 77.
[2] Idem, p. 75.

feet in thickness being common, and is generally fine to medium grained, but in some localities becomes so coarse as to be almost a grit. In color it ranges from dark or bluish gray to dirty green. The coarser grained rock commonly presents a speckled appearance and seems to be composed of grains of variously colored flint. Although distinctly sedimentary in origin, it contains also some detritus of igneous rocks, such as fragments of feldspar and ferromagnesian minerals. The igneous rocks from which these sediments were derived were not observed in the vicinity of the Anaktuvuk. Conglomerate is apparently rare, having been observed at only one place. Here it is typically rather fine, few pebbles being more than three-fourths inch in diameter. The pebbles are noted for their angularity and consist mainly of white quartz and dark slate-colored flint. The cementation is firm, but is not so strong as that of the Paleozoic rocks to the south.

Rocks reported by Howard on the Colville have been provisionally correlated with the Anaktuvuk group. Practically nothing is known about these rocks except for reports of prospectors that the sandstones contain coal beds and the statement by Howard[1] that at this place outcroppings of coal were observed. Inasmuch as coal is not known in the typical Anaktuvuk localities considerable doubt is felt as to the validity of this correlation.

No accurate measurement of the thickness of the Anaktuvuk group was made by Schrader, but he estimates it to be at least 2,000 feet.

Structure.—The general strike of the Anaktuvuk rocks is east and west and the major structure is monoclinal. The rocks in general dip gently northward at varying angles but present subordinate low anticlines and synclines. The structure was probably produced by the same mountain-building forces that were exerted in the range to the south. Beside east-west flexures the rocks exhibit a subordinate or minor system of cross folds or warpings, whose axes trend north and south, giving rise here and there to low domes.

The group is freely traversed by two systems of jointing. The dominant or major system trends nearly northwest and dips almost vertically to the southwest. The minor system traverses the rocks at nearly right angles to the major and trends northeastward, dipping southeastward at an angle of about 80°. Both systems seem roughly to correspond in trend with the similar structure in the Paleozoic rocks in the Endicott Mountains.

Age.—The age of the Anaktuvuk group was determined by Stanton as probably Lower Cretaceous by means of fossils collected by Schrader about 8 miles north of the margin of the Endicott Mountains and at several points still farther north. Of these fossils the most characteristic are *Aucella crassicollis* Keyserling and closely related

[1] Stoney, G. M., Naval explorations in Alaska, Annapolis, 1900, p. 69.

forms which indicate Lower Cretaceous age, though it is possible that they may come from the uppermost Jurassic. Schrader, however, points out that no fossils were obtained near the base of the group and consequently the lower age limit is not proved. The general uniformity of lithologic character throughout the group suggests that there is no decided break in the sequence of the beds and that as regards period of formation the group is probably a unit.

On paleontologic grounds the Anaktuvuk group may be directly correlated with the Koyukuk group, which occurs on the south side of the mountains. Lithologically, however, the two are entirely dissimilar, for although contemporaneous igneous rocks are numerous in the southern area they are entirely absent in the region north of the range.

UPPER CRETACEOUS SERIES.

BERGMAN GROUP.

Distribution.—Upper Cretaceous rocks occur extensively in the Koyukuk basin and also south of the Kobuk. These rocks were first recognized by Schrader in 1899,[1] but were not adequately described until after Mendenhall's and Schrader's expeditions in 1901. Mendenhall's results were published about two years earlier than Schrader's, but the field work on which the reports were based was practically contemporaneous. The name Bergman is derived from a formerly important trading post on the Koyukuk below Alatna River.

Lithologic character.—Dominantly, the Bergman group is a series of dark greenish-gray arkosic conglomerates and sandstones. The base of the section exposed on Alatna River, on the lower part of John River, and on the upper part of the Kobuk is a conglomerate made up of pebbles of the older rocks, namely schists, limestones, vein quartz, and igneous rocks, such as greenstones and granites. The beds are thoroughly indurated and are usually more resistant than the higher sandstones. As a result, they form conspicuous pinnacled ridges, particularly in the range north of the Kobuk from Beaver River westward to the Mauneluk. It is because of similarity in topographic expression in this particular that the hills south of the Kobuk from Ambler River westward are correlated with the areas of Upper Cretaceous rocks. This division corresponds closely in all physical features with the Ungalik conglomerate, of probable Upper Cretaceous age, described in the extreme eastern part of Seward Peninsula and the adjacent Norton Bay region.[2]

Toward the top of the lower division sandstones become more numerous, and at its top the group is composed almost entirely of

[1] Schrader, F. C., op. cit., p. 77.

[2] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911, pp. 55–57.

sandstones which are practically indistinguishable from the sandstones of the Shaktolik group of the more southern part of the Koyukuk basin.[1] The rock is medium fine grained, of rather uniform texture, and generally of a greenish-gray color. It is thoroughly indurated and offers fair resistance to weathering, not so great resistance, however, as most of the rocks already described. As a result, the sandstone portion of the Bergman group generally forms somewhat rounded, coarsely dissected hills of medium elevation.

The rock contains abundant fragments of rather angular ferromagnesian minerals and feldspars, whose glittering faces and partial crystal outline resemble the phenocrysts of an igneous rock. Generally, the beds are rather massive, showing no pronounced stratification. At many places, however, beds of dark shale interlaminated with the sandstones serve to bring out the structure. No extensive exposures of the shales were observed by the expeditions of 1910 or 1911, but Mendenhall[2] notes belts of shale many hundred feet thick. He also notes red and green shales in the Kobuk basin near Lake Nutavukti, but such shales have not been recognized in other parts of the region.

Fragments of what appears to be wood and lignitic beds have been found here and there in the sandstone member. A bed of lignite occurs in the hills immediately east of Pah River, and another near Tramway Bar on the North Fork of the Koyukuk, but both beds are apparently thin and of poor quality. Owing to the absence of determinative fossils some areas in the central part of the Kobuk basin mapped provisionally as Tertiary may prove to be Upper Cretaceous, in which case workable lignite beds may on closer examination be found in the Bergman group.

Structure.—The Bergman group as a whole is considerably folded and faulted, and the average inclination of the beds is probably about 45°. Along the northern margin of the area occupied by these rocks the strike is approximately east-west and the dip south, but even in localities so near the northern margin as the Lockwood Hills the dip is in places northward. The group has therefore been thrown into a number of appressed but not overturned folds. This deformation was accompanied by faulting but, so far as determined, by no profound dislocation, and the faults appear to have been of the normal or gravitative type. The Bergman group appears to have been less severely deformed than the Koyukuk group in the same region, and this appearance was also noted by Schrader,[3] who states: "On the whole the series does not seem to have received from the

[1] Smith, P. S., and Eakin, H. M., op. cit., pp. 57–60.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 39.

[3] Schrader, F. C., op. cit., p. 78.

geologically late crustal movement the widespread tilt exhibited by both the Anaktuvuk series on the north of the range and the Koyukuk series on the south."

Owing to the deformation and to the rapid manner in which the geologic work was carried on, no accurate estimate was made of the thickness of the Bergman group. Schrader states that it is at least 2,000 feet thick, and later measurements show a thickness of at least 10,000 feet, with neither the top nor the bottom exposed.

In addition to the major structure noted, the group shows many minor characteristic structural features. Cross-bedding is here and there common. A peculiar concentric weathering, giving rise to shallow bowls, some of them as much as 3 feet in diameter, is especially notable. On the bedding planes grooves and ropy structures, which are usually interpreted as mud-flow markings but whose origin is not well understood, are common. All these structures are duplicated in the Shaktolik group, in the southern part of the Koyukuk basin. The numerous concretions noted in that group, however, were not observed in the Bergman group.

Jointing is common. Between Alatna and John rivers Schrader[1] noted a pronounced jointing which trends northwest and dips 80° NE. and a minor jointing which trends north and dips 80° E. The direction of the system of jointing, however, is not constant but changes, probably in conformity with the folding and faulting to which the rocks have been subjected.

Age.—Although search for fossils has been made wherever the Bergman group was seen no identifiable specimens have been found. The age of this group was therefore determined by the supposed correlation or interrelation of these rocks with those of known age. Schrader[2] states that the Bergman overlies the Koyukuk group (Lower Cretaceous) and does not appear so much deformed, but believes that the two may probably be of nearly the same age. Mendenhall[3] states that the induration of the Bergman is greater than that of the known Tertiary beds and therefore assumes a pre-Miocene and probably a Mesozoic age.

The close lithologic similarity of the Bergman group to the Shaktolik group of known Upper Cretaceous age has already been noted, and the resemblance is regarded as highly important. The fact that the Bergman group rests directly on the Paleozoic rocks along the northern border of the area suggests that it is not Lower Cretaceous and indicates either that the Lower Cretaceous was deposited and removed before the Bergman was deposited or that the Koyukuk group never extended so far. The latter assumption suggests two

[1] Schrader, F. C., op. cit., p. 78.
[2] Idem, pp. 77–78.
[3] Mendenhall, W. C., op. cit., pp. 40–41.

possibilities—either the cycle of deposition was interrupted or the upper group was laid down while the land was sinking and was practically conformable with the lower group. The facts that elsewhere in Alaska a period of pronounced deformation ensued between the Lower and Upper Cretaceous, that the Koyukuk is more deformed than the Bergman, and that the two groups show a decided difference in lithologic character indicate that there was a considerable hiatus between the two. Such a break would be indicated by assigning one to the Lower and the other to the Upper Cretaceous.

The age of the upper part of the Bergman group is extremely uncertain. It is by no means proved that sedimentation here did not proceed uninterruptedly from late Cretaceous to early Tertiary time. The great thickness of nonfossiliferous rocks undoubtedly represents a long period of deposition. The thick conglomerate at the base of the Bergman appears to mark a constantly encroaching shore line, so the lower beds may be considerably older than the same lithologic member farther inland. This interpretation seems to fit the general facts of distribution, and the Tertiary deposits in the central part of the Kobuk basin (see pp. 87–89) may therefore mark the later part of this general period of sedimentation. If further investigation should prove this to be true, the upper part of the Bergman group is Eocene, but, as this relation has not been proved, it has seemed advisable to differentiate the known Eocene deposits on the map and to consider the larger part of the Bergman group shown on Plate II as of Upper Cretaceous age.

CENOZOIC ERA.

TERTIARY SYSTEM.

LITHOLOGIC DESCRIPTION.

Tertiary rocks have been recognized in the Noatak-Kobuk region only in the central part of the Kobuk basin. They were examined most critically in 1901 by Mendenhall, from whose report the following description [1] is taken.

The most eastern exposures occur along the lower part of Ambler River and in the hills between that stream and the Redstone on the west, Shungnak River on the east, and the Kobuk on the south. The rocks consist of conglomerates, soft cross-bedded sandstones, and shales. In many places the shales are carbonaceous and contain obscure remains of plant stems. Some phases of the conglomerate are made up wholly of poorly assorted material derived directly from the adjacent mica schists. Most of the pebbles are white vein quartz, somewhat rounded, and are embedded in a matrix consisting mainly

[1] Mendenhall, W. C., op. cit., pp. 41–42.

of muscovite and foils of chlorite. These beds have a distinct brown color by which at a distance they may be distinguished from the other rocks.

About 25 miles west of the locality on Ambler River and just below the mouth of Hunt River there is an outcrop of a hard quartz conglomerate containing coal fragments, and prospectors report that similar beds form bluffs for several miles along the lower course of Hunt River. In the banks of the Kobuk 30 miles still farther west are the most extensive exposures of these rocks. For 8 to 10 miles below the mouth of Reed River a succession of conglomerate layers, with pebbles of quartz, mica schist, limestone, and serpentine embedded in a micaceous matrix alternating with less resistant beds, is in places exposed in both banks of the Kobuk. The individual conglomerate beds vary from 10 to 200 feet in thickness, but are of rather uniform character. The softer beds between are sandstones, shales, fire clays, and coals. The coals in these rocks are described on pages 151–152.

STRUCTURE.

According to Mendenhall the Tertiary rocks of the Kobuk basin are everywhere thrown into folds. Faults, however, were not observed. The structure is decidedly complex and is distinctly local, but time was not available for examining the exposures, so that the structural details can not be stated. Owing to the fact that the structure was not completely worked out the thickness of the Tertiary rocks was not determined.

AGE AND INTERRELATIONS.

The age of the Tertiary beds of the Kobuk region was first determined by Dall,[1] whose decision was based on specimens and descriptions furnished by Cantwell, without fossils. However, apparently from the fact that these beds were similar to and on the strike of fossiliferous beds of supposed Tertiary age to the southeast, near Nulato, Dall says: "There can be little, if any, doubt that they belong to the same series." Subsequently, during the explorations by Mendenhall, fossils were obtained from the sandstones near the mouth of Reed River. These were examined by Knowlton,[2] who reported:

> This collection consists of five small specimens, the matrix being grayish, fine-grained, very hard sandstone. The plant remains are not retained with great fidelity, but fortunately all are determinable. Four species are represented, as follows: *Ginkgo* sp., probably *G. adiantoides* (Unger) Heer, *Taxodium distichum miocenum*, Heer, *Taxodium tinajorum* Heer, *Populus arctica* Heer. With so few species as a basis

[1] Dall, W. H., and Harris, G. D., Correlation papers, Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 248–249.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 42.

for comparison it is not possible to speak very dogmatically as to their probable age, but, all things considered, I should incline to refer them to the so-called Arctic Miocene, which is now generally regarded as belonging really to the Upper Eocene.

The Eocene age of the fossils seems fairly well established, but the question previously raised (see p. 87), whether or not there was unbroken deposition from the Upper Cretaceous into the Eocene, so that the two merge uninterruptedly, should be considered. The similar areal distribution of the two series, their similar lithology, and the apparently identical diastrophic history to which both have been subjected, all point to the conclusion that there was no stratigraphic break between the Mesozoic and the Tertiary. According to this interpretation the Eocene beds of the Kobuk basin mark deposits formed close inshore or in part on the land at a late period in a cycle of constantly encroaching marine invasion which commenced in the Upper Cretaceous and was terminated by mountain building at the close of the Eocene. In other words, the conglomerate deposited close to the old land during this cycle of submergence is regarded as forming an unbroken lithologic unit which ranges in age from Eocene to Upper Cretaceous.

QUATERNARY SYSTEM.

DIVISIONS OF THE DEPOSITS.

A great many deposits of Quaternary age have been recognized in the Noatak-Kobuk region. These beds have been formed under many different conditions during a considerable period of time; and may be divided into three distinct types, namely, marine, stream, and glacial deposits. Some of these deposits belong to one or the other of the above types, but in the main the various processes have so interacted that the result has been deposits having features characteristic of several agencies. Although an attempt will be made to distinguish the various agencies involved in the formation of the different deposits, the subdivisions used in mapping and in the following descriptions are based on time of formation rather than on mode of genesis. Only two divisions have therefore been made of the Quaternary deposits shown on the geologic map (Pl. II), namely, the recent deposits and the older bench or high-level gravel deposits. In many places it has been impossible to draw a hard and fast line between the two divisions, not only because of the lack of specific information but to a great extent because the scale of the map is not large enough to permit the facts to be represented without enormous exaggeration. To emphasize the limitations imposed by the scale it may be pointed out that a deposit 100 yards wide in the field would be represented on the map by a line about 0.007 of an inch thick. Consequently the Quaternary deposits, especially the recent gravels, have been omitted from all the smaller streams.

OLDER DEPOSITS.

DISTRIBUTION.

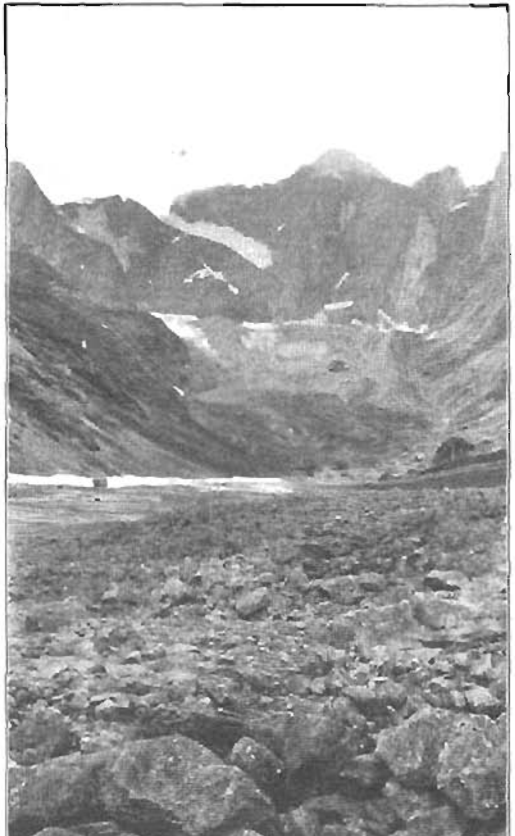
The older gravels occupy much more extensive areas than the recent deposits described on pages 104–106. They spread over much of the region and give the dominant features to the topography near the main rivers. Their origin is complex, and although they have been studied at many places, not enough is known of the entire region to allow an adequate treatment of their distribution and interrelation.

In the Noatak region these older gravel deposits are most abundant between the coast and the Igichuk Hills, in the Mission lowland, and in the Aniuk lowland, but small remnants here and there on the hillsides above the present streams in many parts of the basin point to a much wider distribution of these deposits in the past. In the Kobuk basin extensive deposits occur near the mouth of the river, and from Squirrel River eastward to a point beyond Reed River. Here, also, a much wider distribution is indicated for these deposits in the past. In the part of the Koyukuk basin treated in this report there are enormous areas of old gravel deposits. Along the main river the largest areas of these deposits occur southwest of the Zane Hills, south of the Alashuk and south and east of the mouth of the Alatna. On the tributaries of the Koyukuk large areas occur in the basin of the Hogatza, in the lower part of the Alatna, and in the vicinity of Siruk Creek, possibly joining with the Hogatza flats, and in the lower part of John River. On all the streams, however, there are higher smaller deposits that are apparently portions of more extensive deposits which have been partly removed by erosion. All these areas of older Quaternary deposits are indicated on the geologic map (Pl. II), which best illustrates their distribution.

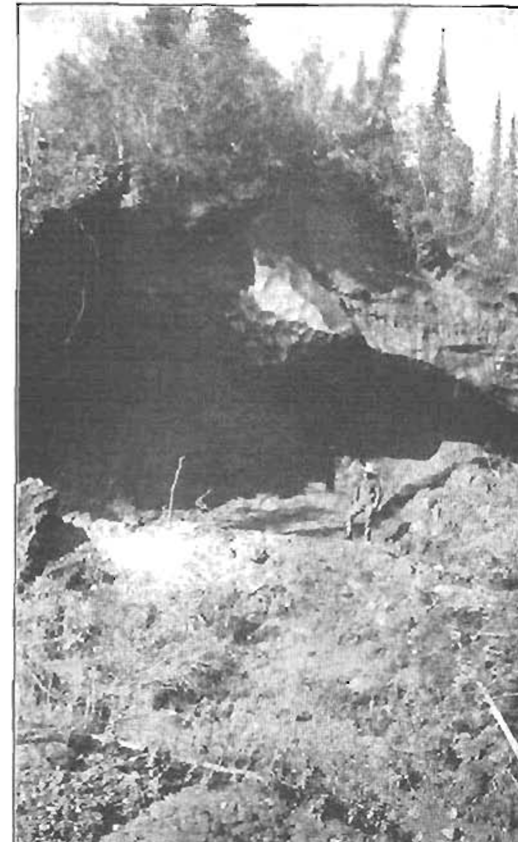
PHYSICAL FEATURES.

Noatak basin.—Certain of the older deposits were evidently formed by a single process, but most of them were produced by various activities, so that it is difficult to classify the several deposits by genesis, and therefore a regional classification has been adopted. According to this plan the deposits of each of the larger streams will be described separately, though reference will be made to other areas where similar or related deposits occur and their genesis, so far as known, will be stated.

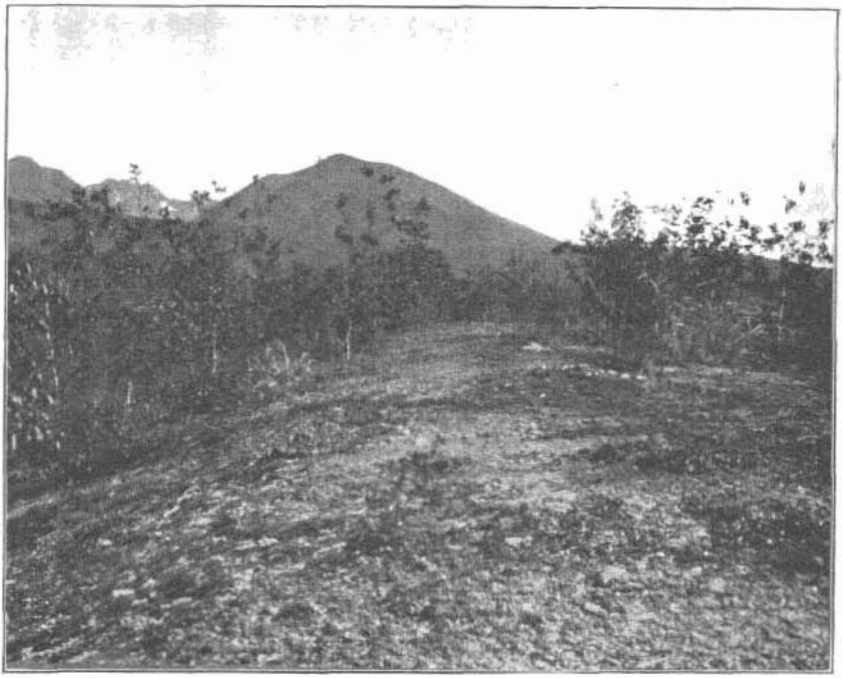
The Noatak basin formerly contained extensive valley glaciers. The limits reached by the ice have not been determined, for with the waning of glaciation great glaciofluviatile outwash deposits mantled most of the lowlands, effectively concealing many of the older deposits and the previous topography. It is believed, however, that the



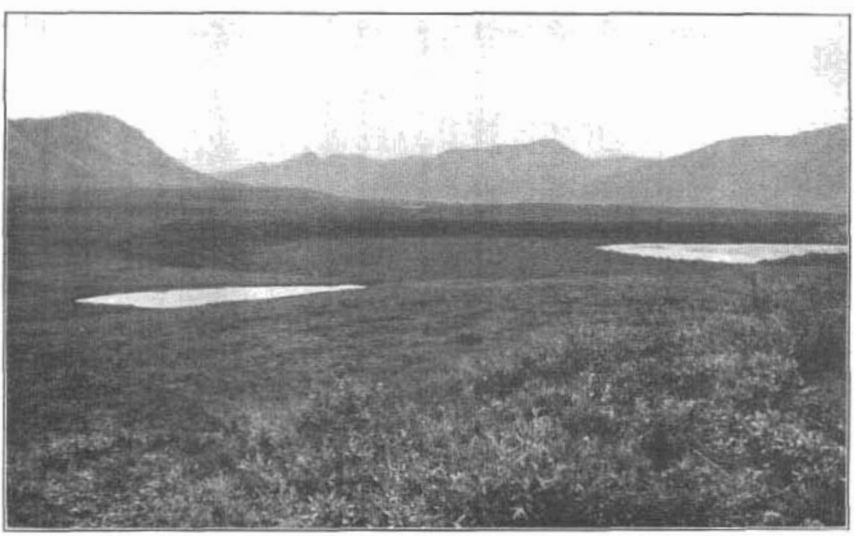
A. GLACIER AND GLACIAL DEPOSITS, ALATNA RIVER.



B. ICE CLIFFS IN BANKS OF THE NOATAK.



A. MORAINE NEAR OUTLET OF LAKE SELBY, KOBUK RIVER.



B. LAKES ON OUTWASH PLAIN, UPPER NOATAK RIVER create. Ice beds of this sort were seen at short intervals all along the Noatak from the camp of August 4 to the mouth, except where the hills are close to the river.

The general aspect of the topography to which these older deposits give rise in the Noatak basin is fairly well shown in Plates IV, V, and VI, but Plate XIII, *B*, taken from the terrace back of the camp of August 1, in the eastern part of the Noatak Valley, shows certain features in somewhat more detail. In this view the Noatak appears at the right with the bare stream-gravel flood plain in process of formation. An earlier flood-plain deposit in which the river is intrenched lies 6 to 10 feet above the level seasonally overflowed by the river and forms the central part of the view. This plain has been cut in an older outwash deposit whose surface rises 100 to 150 feet above the river. The slopes leading to this higher level are as steep as the angle of repose of the material. Lakes of irregular form, which differ greatly in size, lie here and there on the upland. One of these lakes, seen toward the left of the view given in Plate XIII, *B*, stands in a position which indicates that it probably lost some of its former extent by the cutting of the now abandoned flood plain already noted. Above this rather prominent terrace at least four other benches may be seen on the hillsides to the left, the highest being at least 500 feet above the river.

It is evident from this view that various stages of valley filling and reexcavation are recognizable. In this rapid exploratory trip the different levels could not be correlated and the elevation of the highest deposits could be determined only at long intervals and often at unfavorable localities. It has seemed desirable, however, to record certain observations on the upper limit of recognized gravel deposits in the Noatak basin. These observations were made at Twelvemile Creek, at Midas Creek, at the canyon, and on the northwestern slopes of the Igichuk Hills. On the hill southeast of Twelvemile Creek water-rounded bowlders of granite, which had evidently been transported far, as none of this rock outcrops in the vicinity, were found in great numbers up to an elevation of 1,200 feet above the river or 3,600 feet above the sea, and for 200 feet higher the slope remained constant, as if the gravels might extend to that height. Northeast of the camp of August 2, near Midas Creek, a low bench 120 feet above the Noatak lies about a mile distant from the river. In the next mile are several higher terraces, irregularly distributed, but having rather flat tops. Each of the benches toward the northeast is slightly higher than the preceding one, but the gravels are not very thick, for a knob of schist with a thin layer of gravels on top is exposed at an elevation of 500 feet above camp. The last definite water-worn gravel recognized was a granite bowlder at an elevation of 850 feet above camp or over 3,000 feet above the sea. At the canyon of the Noatak well-worn water-deposited material was recognized up to an elevation of nearly glaciers originating in the headwater mountains did not extend as far as the camp of August 11, at the east border of the second highland province, and the glaciers formed in the hills north of the Mission lowland do not appear to have extended to the sea within the explored area. With the more complete disappearance of glaciers, except in the protected mountain recesses, the Noatak began to excavate and reassort the material. Of the older buried deposits little is known except where they are exposed in the natural sections along the streams.

Most of the older outwash deposits seen are composed of fairly well stratified material but contain many irregular bowlders, the largest weighing a hundred tons or more. These bowlders were seen in various stages of emergence from the gravel deposits in which they occur, and were particularly evident at places where the older deposits had been transected by streams where they formed rapids in the river.

In some of these deposits bones of extinct animals were found. In water-rounded and stratified gravels on the north bank of the river below the camp of August 12 portions of the skull and limbs of a mammoth were found. In the gravels of the first stream below the camp of August 7 and on the stream about 6 miles above the camp of August 12, on the south side of the river, pieces of the tusk of a mammoth, evidently washed out of the higher level deposits, were found in the present creek gravels. The natives report that a good deal of fossil ivory is found in the deposits, and they keep a careful lookout for it when traveling along the river, as it has a cash value of about a dollar a pound. Fragments of various bones from the mammoth, all considerably waterworn, were seen near many of the abandoned native camps.

In the upper part of the outwash deposits at many places are beds of ice, more or less mixed with muck and silt, but in places almost pure. A typical ice bed 20 feet or more thick is shown in Plate XII, *B*, which represents a place between the camps of August 18 and August 19. At this place masses of ice are exposed in the banks of the Noatak up to an elevation of 150 feet above the river. Upon the ice lies a thin cover of silt and forest litter on which spruce trees and other vegetation are growing, as is shown in the view. Where exposed the ice melts rapidly, the water drains away, and the muck and débris collect as a sticky mud. Twigs and branches of willow and spruce are in places interbedded in peaty layers with the ice, indicating alternations of deposition and of land surfaces. No mammalian remains were found associated with the ice beds. Owing to the rapid melting caves and pinnacles are formed and where these occur in the river banks the material is constantly dropping into the stream, the large fragments that break off endangering small boats by the waves they

Arctic Ocean. Instead, however, of following this course the river has abandoned this gravel-filled lowland, has swung southward and then eastward, and traversed a range of hills from 1,500 to 2,000 feet high. Although the changes by which the stream took this course are not yet determined the simplest working hypothesis that will explain the known facts is that glacial ice, occupying a part at least of the Arctic Ocean basin, obstructed the former westward discharge of the Noatak and forced it to find outlets south and east of the ice front. These outlets were perhaps uncovered only after lakes had been formed between the Igichuk Hills and the glaciers and their water surface raised several hundred feet. After this drainage had been established and intrenched, the return of the river to its former course after the ice disappeared was prevented by the heavy glacial outwash deposits that had accumulated in the old valley. This explanation no doubt requires more corroborative evidence than is at hand, but it fits the known facts, and also might explain certain other features, for example, the peculiar form and position of the high gravel ridge separating Hotham Inlet from Kotzebue Sound and the reported glacial till beneath the gravel north of Cape Blossom,[1] both of which might mark lateral deposits from a tongue of ice blocking the former outlet of the Noatak and extending into Kotzebue Sound.

The origin and character of the older gravel deposits that extend from the recent marine gravels several hundred feet up the southern slopes of the Igichuk Hills have not been determined. They may be in part of marine or they may be of fluviatile or glaciofluviatile origin, or possibly of all three. No sections of these deposits have been examined, and therefore little is known about them. In general surficial character they appear to be closely similar to the coastal plain deposits in adjacent parts of Seward Peninsula, which are of marine and fluviatile origin.

Kobuk basin.—The older deposits in the Kobuk basin were formed under conditions broadly similar to those already described in the Noatak basin to the north. Although fluviatile sands and gravels were deposited earlier than the period of maximum glaciation, for the main drainage features had been established prior to that time, they have not been recognized in the region. During the period of maximum glaciation the ice centered in the highlands of the Baird Mountains on the north and flowed down the existing valleys, covering parts of the lowland and eroding and transporting most of the former valley fillings. The maximum extent of the glaciers has not been determined, as most traces of their presence have been buried under later deposits. Ice extended from the mountains through the Alatna-Kobuk pass into Helpmejack Creek, down Reed, Beaver, Selby, Mauneluk, Kogoluktuk, and Ambler rivers at least as far as the

[1] Hershey, O. H., The ancient Kobuk Glacier of Alaska: Jour. Geology, vol. 17, 1909, pp. 83-91.

main valley of the Kobuk. That the Ambler valley was occupied by ice is proved by the following statement by Mendenhall:[1]

About 2 miles above the mouth of the Ambler River, on its left bank, occurs a deposit of blue bowlder clay 25 feet in thickness. Blocks and pebbles of dark crystalline limestone, much greenstone, and relatively small amounts of conglomerate and sandstone are scattered through the clay, and these bowlders are sometimes subangular and finely striated. The rocks of the lower course of the Ambler are sandstones and conglomerates, so that the greater part of the coarser material in the clay has been transported at least some miles. Overlying the clay are deposits about 100 feet in thickness of irregularly stratified yellow sands and clays without coarse material. The lower portion of this deposit at least is to be regarded as a true ground moraine, thus proving the extension of the Ambler Valley glacier to beyond this point.

In the Kogoluktuk Valley distinct morainic topography was recognizable to a point within 3 or 4 miles of the Kobuk. Opposite the place where the Mauneluk emerges from the hills stands a well-marked frontal moraine, several hundred feet high, through which the stream has intrenched its course. Below Lake Selby (Pl. III) a partly obliterated moraine forms a barrier behind which is the small lake 3 miles north of the Kobuk; but the best-marked moraine is a mile or so farther north. A portion of this moraine, shown in Plate XIII, *A*, which illustrates the narrow ridgelike character of this deposit, rises to an elevation of at least 200 feet above the surrounding country and forms a natural highway. Knobs and kettle holes occur in it here and there, and the topographic details are remarkably preserved. Through this moraine the river rushes in a narrow, steeply incised gorge whose floor is strewn with large angular blocks of rock too big to be transported by the stream.

Mendenhall[2] states that the outlet of Walker Lake—

probably marks approximately the southern limit of the glacier at its principal stages of advance, and the materials discharged at its front, sorted and worn by the waters flowing from it, built up the valley and remained as a dam after the retreat of the ice tongue. Along the eastern shore and near the southern end of the lake exists a mass of angular material, probably representing a moraine built up by an ice stream from Walker Lake or the upper Kowak [Kobuk].

Just above the mouth of Reed River, at the junction of its valley with that of the Kowak [Kobuk] is a low hill made up of the Bergman conglomerates, and leading out from its foot toward the mouth of the Reed River is a long train of angular rubble composed of schistose rocks. Evidently this is the moraine of an ice stream, which occupied the valley of Reed River and headed back among the altered rocks of its upper course, for material of the type represented in the moraine does not outcrop in the vicinity.

Toward the pass from the Kobuk to the Alatna, Mendenhall[3] notes—

Distinctly striated pebbles occur along upper Kichaiakaka Creek, and the confused topographic forms of the gravel fillings of this valley and its continuation westward across the portage to the Kowak [Kobuk] immediately suggest ice action.

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 48.

[2] Idem, pp. 47–48.

[3] Idem, p. 46.

No definite proof of the amount of ice in the main Kobuk Valley has been obtained, but the effect of the action of the ice on the drainage indicates a body of considerable extent. No frontal moraines of the main Kobuk glacier have been recognized, though the recessional moraines of the tributary valleys, described above, are sharp and definite. Probably the ice, after flowing down the larger tributary valleys, expanded into lobes on entering the Kobuk lowland. Perhaps several lobes coalesced and formed a continuous glacier that occupied the eastern part of the valley. It seems, however, as if the ice in the Kobuk Valley must have been dominantly a stagnant mass rather than a vigorously eroding agent and that it obstructed drainage instead of eroding the surface.

Evidence of this obstruction is seen in that part of the basin between Ambler River and Reed River. The details of the history of this obstruction have not been worked out, but it appears that at one time the glacier occupying the valley of Lake Selby extended across the Kobuk Valley and abutted on the Lockwood Hills, forming a lake upstream—that is, east of this barrier. As the lake rose its surface at last reached the elevation of the lowest sag across the Lockwood Hills and spilled over. The channel thus formed was eroded rapidly until it became a narrow gorge, cut down to an elevation of about 800 feet above sea level. This now appears as the transverse gap in the hills about 17 miles east of the mouth of Pah River. The narrowness of the gorge and the character and relations of the deposits point to the conclusion that the erosive agency was water rather than ice. The evidence of the high level of the lake is shown by gravel terraces and irregular deposits up to an elevation of 1,000 feet above the Kobuk, or 1,400 feet above the sea.

With the unblocking of westward drainage by the retreat of the Lake Selby glacier it appears that a lower gap was uncovered in the place now marked by Pah River. Farther downstream the large Ambler glacier still obstructed westward drainage, and it is by no means improbable that the Kogoluktuk and Mauneluk glaciers also may have formed barriers to free westward discharge. This stage is marked by large gravel terraces 200 to 300 feet above the Kobuk. With farther retreat of glaciation the Ambler obstruction was removed and free westward drainage was permitted. It is difficult, however, to explain why the transverse southward drainage by way of the Pah was abandoned and the present northward drainage established. The full explanation would undoubtedly involve a number of connected incidents, such as the unblocking of the western discharge, the diminution in the amount of water, the glaciation in the Zane Hills to the south, the reversal of course through capture, and possibly also tilting.

Deposits were formed not only in places where obstructions caused diversion of drainage, but even where a free discharge was permitted, at localities where glacially eroded materials were deposited beyond the front of the ice. It is impossible to indicate the extent of the modifications of the topography produced by this enormous outwash of material. Without doubt much of the Kobuk lowland and the lowland north of the Cosmos Hills is formed of this group of deposits, though definite criteria are now unrecognizable, as the gravels have been partly transported by running water.

With the disappearance of glaciation the new drainage lines that had become established were continued and the temporary lines, due only to the ice occupation, were abandoned. As a result channels marking short-lived discharges, now unoccupied by streams, are represented by passes, such as that between Wesley and Ruby creeks or the divide at the head of Cosmos Creek. With the development of the new drainage lines the streams in some places were forced to excavate part of the glacial filling of their valleys; in other places glacial erosion had deepened the valleys, so that stream deposition took place; in still other places glacial modification was so slight that the streams flow almost on the preglacial surfaces.

Considerable space has been devoted to describing what is known or surmised about the conditions under which these deposits have been formed, for the questions involved are not only of academic interest but are of practical importance, as a full understanding of the processes and conditions under which these deposits were formed would undoubtedly contribute greatly to the successful search for placers and prevent much useless exploitation.

In the vicinity of Squirrel River and at a few points farther down the Kobuk, as well as near the camp of August 25 on the Noatak, deposits of well-sorted and rounded gravels, composed almost entirely of quartz pebbles, form notable terraces up to elevations of about 400 feet above the sea. These and the other deposits near the mouth of the Kobuk have not been studied closely enough to determine their mode of origin. It is probable that some of them are of marine or fluviomarine origin, the origin suggested for certain of the deposits at the mouth of the Noatak.

Koyukuk basin.—The older gravel deposits of the main Koyukuk Valley have not been examined critically and little is known about them, except that probably in large measure they are formed of the outwash from the various tributary streams during the maximum period of glaciation. So far as known, glacial ice did not reach the valley of the main river, but the evidence as to the foremost stand of the ice is obscured by the later deposits. Although little is known of the deposits in the main stream valley, those in the valleys of Hogatza, Alatna, and John rivers have been seen in some detail and the facts learned about each will be given in the following pages.

The larger part of the Hogatza drainage basin up to an elevation of about 1,000 feet is gravel filled. Only the western and northwestern part of this lowland has been examined and its eastern part may possibly connect with the low area that extends westward from the Alatna near Siruk Creek. The Zane Hills, which bound the basin to the west, were the source of small valley glaciers that formed moraines and outwash deposits which constitute the dominant topographic features of this part of the basin. The deposits show a wide range in character of material, but most of them appeared to be waterlaid.

The deposits along the northern margin of this lowland, where the gravels lap up on the south side of the Lockwood Hills, contain many bowlders, apparently derived from areas outside the present basin. No deposits formed by glaciers originating in the Lockwood Hills were recognized, and whatever ice existed in these hills was probably so small in amount that it was relatively ineffective as an agent of erosion and transportation. An outline of the conditions under which certain of the deposits in the northern part of the Hogatza basin were formed has already been given in the description of the former spillways of the ice-impounded waters of the Kobuk (p. 96). Here as there many details are still obscure and much investigation will be required to elucidate them satisfactorily.

The Alatna basin has undergone extensive glaciation of a valley type, as is shown by many of its topographic features, such as truncated spurs, oversteepened slopes, and the locally overdeepened valley floor. The whole form of the Alatna Valley shows that it was modeled by a larger and less wieldy agent than running water and then been partly filled in and partly reexcavated, so that the present streams show courses discordant with that of the valley. Only the deposits, however, will be described here, not the erosional forms produced by glaciation. No topographically recognizable moraines were noted in the valley, but resorted deposits, containing large angular bowlders, apparently ice transported, were found in many places. About 13 miles south of the junction of Helpmejack Creek and the Alatna there is a deposit of blue clay containing striated pebbles, which was probably formed of glacial rock flour. Ice-transported erratics and outwash deposits have been found up to heights of more than 2,000 feet above the main river. On the hill slopes west of the camp of July 12, below Lake Takahula, well-rounded granite and other far-transported float was found up to an elevation of 1,800 feet above the Alatna, or over 3,000 feet above the sea. On the northern divide of the valley heading in the glaciers west of the camp of July 16 are several foreign erratics. One of these was an angular block of granite, 10 feet in shortest dimension, perched on exposed schist bedrock in such relations that it must have been brought and deposited by a glacier heading in essentially the same region as the existing glaciers (Pls. VII, *B*, p. 33, and XII, *A*, p. 90), but at least five times as large.

Some ice from drainage basins now separated from the main Alatna River entered the valley during the period of maximum glaciation. As already noted, Mendenhall [1] pointed out that ice from the Kobuk discharged into the Alatna. He states:

> Along Helpmejack Creek and the middle Alatna drainage changes have taken place that are best explained by glacial action. The direct topographic continuation of the upper Helpmejack Creek Valley is eastward into the Alatna by the pass which leads to the latter stream in the vicinity of Rapid City, but Helpmejack Creek at present leaves this broad open way, turns to the south at right angles to its logical course, and reaches the Alatna at Beaver City. Such a course was probably originally a spillway for glacial waters and in it Helpmejack Creek became intrenched while the more northerly outlet was still occupied by ice. Upper Helpmejack Creek occupies a filled valley, but not a systematically filled one. The valley is occupied by incompetent meandering streams and numerous small ponds at varying elevations. Its ridges and terraces while of waterworn sands and gravel, so far as examined, are at no constant elevation and bear no obvious relation to each other. In short, the topography and stream alignments are of the confused type which results from icework and are in strong contrast to the more regular types which are due to normal stream growth.

Another pass to the east of the main Alatna River, near Lake Takahula, served also as a spillway for both ice and water. This place, which is known by the natives as Akabloouk, meaning "daylight through the hills," is a broadly open saddle at an elevation of about 400 feet above the Alatna. It was formerly occupied by drainage diverted to Malemute River, a tributary of the Alatna, when southward drainage was obstructed by the Helpmejack or Takahula glaciers.

Although the older gravels extend to considerable elevations in the Alatna Valley, those having the strongest topographic expression are from 50 to 200 feet above the river. These gravels are well stratified and water rounded, being similar in general features to those in the Kobuk and Noatak basins. Certain unusual features were noted, however, near the camp of July 8, where the gravels on the southwest side of the river, near the top of the bench 50 to 100 feet above the river, are thoroughly cemented into a conglomerate from 5 to 25 feet thick, which extends for a distance of over a mile. Large blocks of this conglomerate, which have been undermined by the removal of the unconsolidated gravels beneath it, have fallen down and form notable objects along this part of the river. In this same general region brown, heavily iron stained high-level gravels are much more common than elsewhere.

The following description is quoted from Schrader's report [2] on the Pleistocene deposits of the John River region. The term "till,"

[1] Mendenhall, W. C., op. cit., pp. 46-47.

[2] Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 84-86.

used in his description, is probably equivalent to the term "outwash deposit" used in this report, and it is doubtful whether the word "till" can be correctly applied to any of the deposits.

In the lower part of the intramontane section of John River, where the valley occasionally widens, it is sometimes floored by a till sheet from 50 to 100 feet thick, containing ponds and lakelets, some of which seem distinctly to be of glacial origin. Till is prominent also in the mouths of some of the side valleys, as Till Creek valley, which opens into that of John River on the east at about the sixty-eighth parallel. Here good exposures show the deposit to be typical till. It has a thickness of at least 100 feet and forms a broad terrace or sort of small, triangular plateau a mile or more in extent, occupying the mouth of the side valley. It slopes westward to where John River has been crowded to the bluffs on that side of the valley. On the east it overspreads and conceals the lower benching and bedrock topography. Till Creek, a torrential stream, flows in a small canyon whose steep banks are formed of the bowlder clay or ground moraine.

In the region of Fork Peak, near the head of John River, at the confluence of several of its tributaries, the valley is wide and open and is floored by a till sheet at least 150 feet in thickness. The surface declines to the southwest, denoting that the deposit has largely come from the northeast, a view which is supported by bedrock striæ farther down the valley. The till ascends the northwest slope of Fork Peak to an elevation of 2,500 feet and may continue much higher, but becomes obscured by younger talus and coarse débris of doubtful character, which, however, also exhibits an ill-defined terminal moraine topography. At the elevation of about 3,500 feet is a bench overlain by talus and drift, which, judging from topography, was probably largely deposited by a local hanging glacier.

The John Valley till sheet extends across the divide by way of Anaktuvuk Pass and is continuous with that of the Anaktuvuk Valley and the Arctic slope. At the pass the valley is 3 miles wide and open, and its surface is so flattened with infilled drift that the small streams descending from the mountains in this locality are deflected by the merest obstacle to either side of the divide, flowing sometimes northward by way of the Anaktuvuk to the Arctic and at others southward to John River and the Yukon.

At the pass occur lakelets of glacial origin. One of these, Cache Lake, just northeast of the divide, is 30 feet or more deep. Its surface lies about 100 feet below that of the adjacent ground moraine, giving for the till sheet here a thickness of at least 130 feet. Just south of the pass the till sheet formerly extended entirely across the valley, as is shown by the flat-topped outlying remnants of ground moraine in its middle. These rise to a height of more than 100 feet above the stream and accord in level with the ground-moraine terraces on either side.

On the whole, the till sheet in this northern part of the range seems rarely to extend up the side slopes to more than 500 or 600 feet above the floor of the valley * * *.

Naturally, the side valleys in this region were among the last to become free from glaciers, some of which probably remained long after the disappearance of the ice from the adjacent parts of main valleys. This is shown by the presence of relatively fresh terminal moraines in the side valleys. Four miles northwest of the middle of John River valley the small valley of Contact Creek is crossed by such a moraine. It is typical, being about 60 feet high and one-fourth of a mile in length, measured parallel with the valley. A similar but older feature occurs in John River valley near the middle of the range, about 12 miles in a direct line south of the sixty-eighth parallel. Here the valley flat is crossed by a terminal moraine about 60 feet high. * * * It still forms a continuous ridge or dam across the valley, except where the river has cut a notchlike passage 200 yards wide at the left. At the right the moraine seems to be continuous with the till sheet, which is 10 to 20 feet thick, and rests on the bedrock benching at a height of about 100 feet above the river. As seen in looking parallel with the valley the ridge presents an undulating profile and is sharp crested, owing to its upstream side being cut away by the river. Though it exhibits but little of the typical hummock-and-kettle topography of a terminal moraine, it is composed mainly of typical bowlder clay carrying striated pebbles and bowlders, some a foot or more in diameter. The materials noted are of the same constitution as those of the river gravels, there being no erratics. The principal surface or front of the moraine, which slopes southward, supports a growth of spruce, some of the trees having a basal thickness of 1½ feet.

A few miles above this moraine occurs the last lingering remnant of the John Valley Glacier. It consists of a lone, roughly circular mass of ice about 300 feet in diameter, rising from the middle of the gravel-covered valley flats to a height of 60 feet. * * * At the top the ice terminates in several distinct knoblike prominences projecting 10 to 20 feet above the main mass. One of these is cylindrical or pipe shaped. The others are crudely pyramidal. The ice is partially capped and flanked by a deposit of genuine till from one to several feet thick, to whose protection it doubtless in large measure owes its preservation. From three sides small streamlets of light-colored muddy water, arising from the melting of the ice and thickened with glacial rock flour from the till, flow down and deposit their load of fine, argillaceous sediment over the flats around the foot of the mass. This glacial mud is of very light color. It is sticky and differs decidedly from the present stream deposits of the valley. This ice mass is undoubtedly a remnant of the John Valley Glacier. Its presence at this late date, after apparently all the other glacial ice has disappeared from the surrounding region, together with the rounded topography of the adjacent mountains, already noted, suggests that this locality is probably near what was the belt of maximum precipitation, and consequently of maximum ice accumulation, that traversed the mountains during glacial time, and is therefore among the last to become free from ice.

Other areas.—The only other known extensive deposits of the older gravels are in Seward Peninsula and in the vicinity of Selawik Lake. The deposits of Seward Peninsula have been adequately described in several Survey reports and require no comment here further than the statement that glacial deposits have not been observed in the portion of the area represented on Plate II. The deposits are of fluviatile, marine, or extraglacial origin, or were formed by combination of processes.

The region in the vicinity of Eschscholtz Bay and Selawik Lake is not well known and the literature concerning it is less available, so it will be described here somewhat fully. The following quotations give the principal results of observations made by Quackenbush [1] on the older deposits. Along Eschscholtz Bay—

high bluffs face the water all around except at the wide Ahweengnuk delta and for a few miles to the westward of the mouth of Buckland River. * * * The bluff does not end, however, at Elephant Point, but bends to the south and continues around the western and part of the southern shores of Goose Bay. * * * At the base of Elephant Point the bluff is 15 feet, rising less than a mile to the west to the altitude of 120 feet and gradually descending to a height of 20 feet at the opposite end * * *. The bluffs on Goose Bay have apparently been entirely neglected by

[1] Quackenbush, L. S., Notes on Alaska Mammoth Expedition of 1907 and 1908: Bull. Am. Mus. Nat. Hist., vol. 26, 1909, pp. 87–130.

writers, although they are continuous with the historic bluff and contain most of the species of fossil mammals found at this latter place. From the base of Elephant Point the bluff rises southward to the maximum height of 75 feet and descending again forms a bank 25 feet high at the first bend of Lost River * * *.

A bluff stretches without a break from Choris Peninsula eastward along the north shore of Eschscholtz Bay and is continued up the Ahweengnuk Valley in the form of a terrace. For a distance of 7 miles the bluff is being cut by waves and its structure beginning at the rocky hill on the base of Choris Peninsula is as follows: First, yellowish, sandy silt without trace of stratification, half a mile long, 50 feet high, tapering down to 18 feet; second, flat terrace, 18 feet high and 1¾ miles long, composed of fine dark bluish-gray silt, containing a few small irregular layers of peat; this terrace extends across the base of Choris Peninsula and several miles north along the shore of Kotzebue Sound; third, fine light-colored sand and silt, stratified, three-quarters of a mile long, 35 feet to 70 feet high; fourth, fine grayish silt (like that at Elephant Point) 4 miles long, 30 to 40 feet high; fifth, a section 150 feet long exposing several alternating strata of sand, coarse gravel, sand, and fine gravel, overlain with a thick deposit of fine light-colored silt; the coarse gravel stratum and some of the others are sharply cross bedded. From this point east the beach is broad and high and the bluff is almost entirely overgrown with grasses, moss, and low willow bushes. The few bare slopes near the top and the material brought to the mouths of numerous spermophile burrows indicate that this part of the bluff, averaging about 35 feet high, is formed of a deposit of sand containing many small round pebbles and overlain with from 5 to 11 feet of yellowish silt. No fossils were found east of the cut sections. The terraced section of the bluff near Choris Peninsula is vertical and there is a soft clay flat in front of it. The remainder of the steep-cut portions is bordered by a low sandy beach. Some trifling patches of ice, which had been formed in fissures near the surface, were exposed in the fourth section.

Fossils were collected on the flats and beaches at the bases of all five sections of the cut bluff and two specimens were found on the talus in the third section. A mass of sticks cut by the teeth of beavers was seen embedded near the top of the bluff at the western end of the second section * * *.

High bluffs extend all around the outer curve and along the southern side of Selawik Lake. The bluff is cut in a few places on Selawik Lake for a distance of 15 miles from the outlet, but it appeared to be entirely overgrown with vegetation to the east and was not examined further. The deposit is mostly unstratified sand containing considerable gravel; in some parts silt lies on the top, in others the bluff is composed entirely of silt. A few small fragments of mammoth tusks and caribou bones were found on the gravelly beach, but no fossils were seen on the bluffs.

On the south side of Hotham Inlet there are some cut bluffs 100 feet in height composed of silts, but containing near the top an ill-defined stratum of water-worn gravel and bowlders up to 6 feet in diameter, which are embedded in the fine sediment and must have been deposited by floating ice. The gravel consists of quartz, conglomerates, gneissoid rocks, and shows no signs of glaciation; one rounded lump of black bituminous coal was collected in the talus. In the southwestern angle of the inlet a vertical section shows that this portion of the bluff is sharply divided into very thin horizontal strata from top to bottom. A steep continuous bluff of yellowish silt extends along the west side of Hotham Inlet for at least 15 miles to the north; it varies from 50 to 100 feet in height and occasionally shows some signs of stratification. Several pieces of mammoth tusks and some small unrecognizable fragments of bone were found on the gravel beaches or in the water along Hotham Inlet, but only one specimen—the metatarsal of a horse—can be definitely stated to have come from these barren deposits; it was found on the talus on the west side of the inlet about on the latitude of the Arctic Circle.

AGE AND INTERRELATIONS.

The earliest known data on the age of certain of these deposits were furnished by Kotzebue,[1] who found fossils at Elephant Point. These fossils were examined and described by Eschscholtz, who regarded them as Pleistocene. Subsequently this place was visited and described by many others, notably by Beachey in 1826, Dall in 1885, Maddren in 1904, and Quackenbush in 1907. None of these writers appear to question the Pleistocene age of the beds.

Certain clays and ice beds on the Kobuk, reported by Cantwell, were correlated by Dall[2] with the deposits at Elephant Point and were named by him the Kowak clays and assigned to the Pliocene or Pleistocene(?). Dall states that these deposits do not extend to Noatak River, but the descriptions of that stream given in this report (see pp. 91–92) show that they do.

Gradually, as more of the region was explored and data were accumulated, fossil mammoth and other remains were found at many places. From the foregoing description of the older deposits it is evident that most of them were formed during or after the period of maximum glaciation, but it is not yet possible to determine their age more specifically, for the time relation of maximum glaciation in this part of Alaska to that in the United States is not certain. It is probably true that in a broad way the period of greatest glaciation was synchronous in the two regions, but that it was precisely coincident, even in a geologic sense, is by no means demonstrated. In addition to the deposits formed while the ice was at its greatest extent there are others that were formed subsequently, and certain of these later deposits are so new that they undoubtedly belong to the Recent epoch. The older gravels therefore include deposits ranging in age from Pleistocene to Recent.

It is not unreasonable to suppose that certain earlier beds may subsequently be recognized in the areas now mapped as formed of the unconsolidated deposits. For instance, the coastal plain deposits near Nome, which are in many ways analogous to the high-level gravels skirting Kotzebue Sound, contain fossils which Dall[3] has identified as pre-Pleistocene, and it would therefore not be at all surprising if further investigation should disclose late Tertiary sediments in this region. That the extent of such sediments is probably slight, however, seems certain, and the bulk of the deposits here described are believed to be of Pleistocene to Recent age.

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[1] Kotzebue, Lieut. Otto von, Voyage of discovery into the South Sea and Bering Straits, London, 1821, 3 vols.

[2] Dall, W. H., and Harris, G. D., Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 265–268.

[3] Dall, W. H., Climatic conditions at Nome, Alaska, during the Pliocene: Am. Jour. Sci., 4th ser., vol. 23, 1907, pp. 457–458.

RECENT DEPOSITS.

MARINE GRAVELS.

The recent marine gravels occur along the coast and are confined practically to deposits in process of formation. They vary greatly in lithology and physical features from place to place. In deposits near rocky headlands large bowlders, formed of the rocks in the neighborhood, predominate. In deposits farther away the material is finer grained; the softer minerals having been removed, the more resistant materials remain. Here and there muds and silts have been deposited and sands and gravels are absent. Some deposits near the mouths of streams consist of mixtures of fluviatile and marine sediments. Practically all the recent marine deposits are not permanently frozen. The deposits, so far as known, are not consolidated but consist of uncemented silt, sand, gravel, or bowlders.

No sections of typical marine gravels along this part of the Arctic coast have been examined, so that little is known of their features other than those seen on the surface. Furthermore, as has been already pointed out, only the recent marine gravels are included in the section, the deep marine deposits or those occurring at a considerable elevation above sea level having been omitted. Consequently the recent marine gravels may be considered as forming a narrow fringe along the coast and having rather slight thickness.

STREAM DEPOSITS.

The stream deposits are of greatly diverse types, their character depending on the history and relations of the streams by which they were formed. Some of the smaller streams have eroded their valleys and laid down deposits under the same local conditions that now prevail in their drainage basins. The deposits in such a valley are formed of the rocks outcropping in the basin, and their features are characteristic of deposits formed by ordinary single-cycle streams. A stream of this type, however, is rather the exception than the rule, for most of the streams have had a more complex history. The valleys of some of these streams of more complex history show an interruption in the orderly succession of events, whereby decrease in gradient has caused the building up of the valley floor. In other places increased slope has renewed degradation. In still other places several activities have combined, and the present stream is eroding former stream-deposited gravels. In such places the gravels, instead of being formed of rocks of local origin, may have come from outside the present drainage basin of the stream, and instead of having the features of ordinary river gravels may, through this double concentration, have become more rounded and better sorted.

Not only may the present streams be rehandling former stream gravels, but they may also be traversing unconsolidated deposits formed by other agencies. For instance, the greater part of the floor of the present Kobuk and Noatak rivers is carved in deposits of glacial and glaciofluviatile origin, already described (see pp. 90–97), and as a consequence the present stream deposits resemble in large part the older deposits. This is particularly notable on the Noatak, where large bowlders washed out of the earlier deposits form numerous rapids in the stream, line the banks at low water, and are being built into deposits that are distinctly abnormal for a single-cycle stream.

At several places mountain glaciers give rise to streams that are forming deposits characterized by features due to their double mode of origin, consisting of normal stream deposits mixed here and there with large, irregular ice-transported blocks. The fine material in such deposits also differs from that of the usual stream deposits in that it is mainly a product of glacial erosion rather than of normal weathering.

In many places the stream gravels so merge with the deposits of marine origin that it is impossible to separate the two. This is especially true in the delta of the Kobuk and at the mouths of other streams. This interrelation is further complicated by the fact that at several places ancient bench deposits, such as occur near the mouth of the Noatak, are being subjected to the action of marine and fluviatile agencies, so that the resulting deposits show the results of three processes.

Examples to show the great diversity of the stream gravels in the region might be multiplied, but the foregoing indicate some of the more common types. All these deposits show certain more or less universal features. All the material is unconsolidated and has been subjected to more or less sorting prior to deposition. Practically all the shallow recent stream gravels are not permanently frozen, a fact that is of considerable economic importance, for the physical condition of the gravels with respect to cementation by permanent frost exercises a considerable control on the development of mining. The data concerning the presence or absence of permanent frost are not sufficiently complete to permit a final statement as to the distribution of frozen and unfrozen deposits, for artificial sections are almost entirely absent and in natural sections the surface exposed to the heat and air is thawed, even in deposits that are permanently frozen.

GLACIAL DEPOSITS.

Recent glacial deposits occur only in the vicinity of the existing glaciers and are therefore limited to the mountain regions. They have been seen only at the headwaters of Alatna and Noatak rivers, Farther up Alatna River, west of the camp of July 12, in the limestone near the top of the 3,200-foot hill, are sheared sills or dikes of greenstone schist having many of the features noted in the preceding locality. Specimens from this place, however, show in addition to the recrystallized albite a considerable amount of hornblende, which was not recognized in the other rock, though originally it may have been present and have been subsequently altered to chlorite. Small amounts of magnetite also occur in the rock, but other minerals are practically absent.

Igneous rocks that have been subjected to pronounced deformation and attendant metamorphism have been recognized in the Kobuk region in the vicinity of Shungnak and at Squirrel River. In the Shungnak region greenish igneous schists were recognized in the hill east of the Kogoluktuk and at several places in the ridge between Wesley and Cosmos creeks a mile or so south of Iron Mountain. At the latter place the igneous schist appears to cut the underlying slates and forms a sill between that rock and the overlying limestone. So far as observed it does not cut the limestone nor does that rock show any contact effects. Metamorphism of the rocks as a whole, however, has proceeded to such lengths that the absence of contact metamorphism is not conclusive. These older igneous rocks have schistose structure, are greenish in color, and consist mainly of greenish chlorite and plagioclase feldspar, the latter as a rule completely recrystallized.

In the same general region are serpentine rocks, often mistaken for jade, that appear to be analogous to the greenstones. One exposure of these rocks in place was examined at the head of Dahl Creek. Specimens of this greenish compact fine-grained dike rock were found to consist of magnetite and pyrite inclusions in a microcrystalline groundmass of serpentine. The rock is but little sheared, and for this reason considerable doubt is felt in assigning it to the greenstone group. From reports of prospectors and others this type is presumably much more extensive in the Jade Hills, west of Ambler River, than it is in the vicinity of Shungnak, but that locality has not been critically examined and little is known of the distribution and extent of this type at that place. The greenstones in the Squirrel River region are essentially similar to the more common type previously described. All of them are considerably sheared and have a distinctly schistose structure. Albite and chlorite are the most abundant mineral constituents and both are later than the original minerals of the rock.

The greenstones of northeastern Seward Peninsula have not been studied in detail. Moffit states that—

dikes and sills of greenstone, such as are seen in the western part of the peninsula northwest of Nome, were not observed in the region. If such are present in the area immediately south of Kotzebue Sound they are probably so greatly altered that many of their original peculiarities have been lost and they are not now readily distinguishable from the including schistose sedimentary rocks. Altered greenstones are present, but so far as observed by the writer they do not have the form of sills or dikes and appear rather as great irregular masses or stocks.[1]

AGE.

The criteria for the determination of the age of the greenstones as a whole are not such as to permit a precise and definite assignment. It has been proved that these rocks cut the undifferentiated metamorphic schists and certain of the undifferentiated Paleozoic limestones and have been subjected to strong dynamic metamorphism. None of these events, however, can be assigned a definite age. The undifferentiated schists (see pp. 60–61) were probably early Paleozoic or possibly pre-Paleozoic. The limestones that are intruded are apparently the same as those on John River, which, as stated on page 65, are probably not older than Silurian nor younger than lower Carboniferous; near Shungnak, however, the greenstones apparently do not cut the undifferentiated Paleozoic limestones. The major period of metamorphism does not seem to have affected the known Carboniferous rocks and in Seward Peninsula appears to have been earlier than the Ordovician.

There are many conflicting lines of evidence, therefore, which lead to diverse conclusions. From general considerations and from analogy with near-by better known areas it seems probable that the greenstones and associated rocks are of Paleozoic age and are probably older than the Carboniferous. How much older is not known and can not even be postulated until further detailed work is done and more of the unknown area is explored.

EARLY EFFUSIVES AND INTRUSIVES.

DISTRIBUTION AND GENERAL CHARACTERISTICS.

There are three principal areas of the rocks here called the early effusives and intrusives—the extreme eastern part of Seward Peninsula, the vicinity of the canyon of the Noatak, and the Zane Hills in the Koyukuk basin. The first two areas, so far as known, have been indicated on the map, but the basic rocks of the Zane Hills have not been distinguished on the map from the sedimentary rocks of supposed Lower Cretaceous age called the Koyukuk group.

The group of rocks in Seward Peninsula has been described by Moffit[2] as follows:

Andesites are abundant in the Kiwalik-Buckland divide and are probably the surface representatives of an igneous magma corresponding in composition to the deep-seated diorites and monzonites. As already stated, they occupy, where observed by

[1] Moffit, F. H., The Fairhaven gold placers: Bull. U. S. Geol. Survey No. 247, 1905, p. 27.
[2] Idem, pp. 30–31.

the writer, a position intermediate between the basic rocks of the western side of the ridge and the central acid ones and form a large part of the watershed. They are of a dark-gray or greenish color and on an exposed surface have a spotted appearance due to the alteration of the feldspar phenocrysts. Both hornblende and pyroxene varieties were seen, the latter containing considerable olivine in addition to pyroxene and showing the secondary mineral iddingsite. Alteration of pyroxene to hornblende was also observed. The feldspar is a basic variety, labradorite or sometimes anorthite, giving as alteration products chlorite and epidote.

Andesite breccias were found at various localities.

In the vicinity of the Noatak Canyon rocks in a measure similar to the andesitic rocks of Seward Peninsula were examined. In general, however, the rocks at the canyon differ from the andesites in that they are mainly of intrusive character, effusive phases being practically absent. Topographically these igneous rocks near the canyon form numerous sharp pinnacles of irregular distribution. In the main they are stocklike masses with dikes and sills here and there radiating out from the periphery. Some amygdaloidal phases were seen and though not parts of surface flows these were in the upper part of dikes near the surface. The filling of the amygdaloids was mainly calcite.

The rocks are medium fine grained and weather to a rusty brown color on exposed surfaces. In hand specimens the only minerals easily recognized are feldspar and pyroxene. Under the microscope the feldspar is seen to be mainly labradorite of an acidic phase. The dark minerals are mainly augite with subordinate amounts of biotite, commonly altered to chlorite, and some magnetite. Sulphides are also sparingly present. The structure is hypidiomorphic granular. From the above characters it follows that the rock is a fine-grained gabbro.

A view of a faulted dike in the Noatak Canyon is shown in Plate XI, *B*. The gabbro forms the right-hand portion of this view and the dark band with the light-colored contact phase in the middle portion. The rocks cut are sandstones, quartzites, and thin limestones belonging to the Noatak sandstone. A few miles west of this place the same rocks exhibit structures characteristic of ellipsoidal basalts in the round bowlder-like appearance of the exposed surfaces. Metamorphism is invariably rather strongly marked near the gabbro-sandstone contact for a distance of several feet. This effect is shown by the bleaching of the otherwise dark-colored sedimentary rocks and the greater induration.

The gabbro shows a pronounced jointing and in places a slickensiding produced by faulting, but nowhere was the rock at all schistose.

The eastern locality of early effusives and intrusives has already been described under the Koyukuk group (p. 81). It is unnecessary to repeat the details further than to point out again that amygdaloids, tuffs, and volcanic agglomerates occur in the Zane Hills so intricately associated with the arkosic sandstones and conglomerates and other sedimentary rocks that they can only be differentiated after much more detailed study than has at present been attempted. All these rocks are of an andesitic or dioritic composition and texture.

AGE.

The most definite evidence as to the upper age limit of the early effusives and intrusives is afforded in the eastern part of Seward Peninsula south of the area covered in this report and shown on the map (Pl. II). Here similar rocks form bowlders in the conglomerate at the base of the Upper Cretaceous section of that region. This definitely places the upper age limit of the igneous rocks as earlier than that period of sedimentation. In the same region granites which are known to cut the andesites and associated rocks intrude fossiliferous Devonian and Carboniferous limestones. Although it has not been proved beyond question that the andesites also cut the Carboniferous rocks, such an interpretation seems warranted by the general relations and structures of the two groups.

In the Noatak region sedimentary rocks younger than the Carboniferous do not occur near the gabbro intrusives, so that the upper age limit of the latter is not directly determinable. The Carboniferous quartzites, sandstones, and shales are intruded and therefore the igneous rocks are later.

In the Koyukuk region the basic igneous rocks of the Zane Hills form pebbles in the Upper Cretaceous conglomerate and sandstones. It has been pointed out (p. 82) that the Lower Cretaceous or Upper Jurassic age of the Koyukuk group as mapped rests on fossils found in certain limestones associated with igneous tuffs and other rocks. If this correlation is correct and the igneous rocks are actually interbedded with the Lower Cretaceous or Upper Jurassic sediments the age of the igneous rocks is definitely settled. However, as the age determination does not rest on incontrovertible facts, there is reason to doubt the validity of the conclusion.

As is noted later (p. 114), the granites, which are probably referable to this same major period of intrusion, cut the early effusives and intrusives. It is therefore open to question whether the supposed Lower Cretaceous sediments associated with the igneous rocks have been correctly correlated or whether they may not in reality belong somewhat lower in the time scale. Whatever may be the correct answer to this query, it seems evident from the facts at hand that the early effusives and intrusives are of Mesozoic age, were probably formed in the middle rather than in the early part of that era, and are certainly older than the Upper Cretaceous.

GRANITIC ROCKS.

DISTRIBUTION AND LITHOLOGIC CHARACTERS.

The rocks here grouped together as granitic rocks occupy in the main three areas—Seward Peninsula, the Zane Hills, and the highlands between the Noatak and Kobuk. In all these regions this group is composed of acidic intrusive rocks of medium fine grain and rather uniform composition. The rocks occur mainly as batholithic masses from which there are numerous small apophyses which intrude the country rock.

In Seward Peninsula there are many places where the granitic rocks are exposed within the mapped area, namely, in the hills forming the Buckland and Kiwalik divide, southwest of Candle; in the central part of the Kugruk basin; and in the divide between the Inmachuk and Cottonwood Creek. All of these localities have been described by Moffit, and the following extracts taken from his report [1] serve to give only one or two typical examples. Near Kugruk River—

the rock is of a light-gray color and has an even grain of medium coarseness. While not differing greatly in appearance from the true granites, it has a somewhat unlike mineral composition, resulting from the presence of a considerable amount of plagioclase feldspar in addition to the orthoclase, the two being present in about equal quantities or with the plagioclase slightly predominating. In thin section the microscope shows plagioclase, orthoclase, hornblende, quartz, and biotite; titanite, apatite, and magnetite are always present. On the basis of the amounts of plagioclase and orthoclase this rock is classed with the monzonites.

The microscopic study of the siliceous schistose rocks of Kiwalik Mountain and the neighboring hills, also of Potato Creek, has led to the conclusion that they also are highly altered granites. The hand specimens show a light-colored, saccharoidal, schistose rock, often slightly stained with iron oxide. In the outer portion of the area the disturbing forces appear to have had greater effect than near the central part, although the entire mass is highly altered. Under the microscope the rock is seen to contain more quartz than feldspar, with minor quantities of muscovite, biotite, apatite, and zircon in grains or rarely in crystals; secondary calcite is rather frequent.

In the Buckland-Kiwalik divide the granitic rocks include—

a number of different varieties—granites, monzonites, and quartz diorites. Hornblende is the prevailing dark mineral of the granites, but at times biotite takes its place. By a decrease in the amount of quartz the granites approach syenites in composition, such phases being characterized by the abundance and large size of orthoclase crystals, which usually show Carlsbad twinning and have roughly parallel arrangement, with the small intervening spaces filled with hornblende, biotite, and a small amount of quartz. Titanite is abundant.

In the Zane Hills the granitic rocks are similar to those examined in Seward Peninsula. They are formed mainly of quartz, orthoclase, and biotite. Microcline, microperthite, and undetermined plagioclase feldspars occur in varying amounts. Hornblende is also a usual constituent. Magnetite and apatite form only a small bulk of the

[1] Moffit, F. H., op. cit., pp. 27-29.

rock, but are nearly everywhere present. Aplitic phases in the small dikes from the larger granite masses were noted at a number of places. None of the granites appeared to have been sheared since consolidation, though some indications of movement during the crystallization of the magma were seen.

In the divide between the Noatak and Kobuk granites undoubtedly occur in large masses. This is inferred from the granite pebbles and bowlders in the unconsolidated deposits that have been derived from this region. The rocks in place have been seen only in the mapped area west of the camp of July 16 on the Alatna. The general appearance of the granite and its topographic expression are shown in Plate VII, *B*. Unfortunately the specimens from this place were lost in transit, so they could not be examined microscopically. Granite from the same general region, however, was found as float on the hillside of the Alatna Valley, high above Lake Takahula, and on the hill east of Twelvemile Creek in the Noatak basin. The specimens from both these places show considerable quartz, with some orthoclase and microcline feldspar and smaller amounts of oligoclase or oligoclase-albite, some mica, mainly muscovite but with a little biotite, usually more or less chloritized, and varying but very small quantities of epidote and garnet.

It is uncertain whether granitic rocks occur north of the Noatak in the hills north of the camp of August 7. The float in this part of the basin is so much mixed that it was impossible to distinguish the source of particular pieces. In this part of the basin float of a coarsely crystalline hypidiomorphic granular rock that is not known to occur in any part of the explored region was found. It consisted entirely of bytownite feldspar and augite, with small amounts of olivine. From this composition it may most appropriately be called an olivine gabbro. The absence of quartz makes doubtful the assignment of the rock to the granitic group previously described, and further explorations will be necessary to prove whether the olivine gabbro should belong to the granitic group or to the early basic effusives and intrusives.

Another rock of unknown distribution and relations which may belong to the group of granitic rocks was found as float in some of the streams in the vicinity of Shungnak. This rock was coarsely crystalline, basic, granular, and made up largely of chromite, with smaller amounts of iron silicates and feldspar. Bowlders up to a foot or more in diameter were fairly numerous in Dahl Creek. If this float really belongs to the group of granitic rocks, it will be necessary eventually to split up the group into an acidic phase, characterized by the normal granites, and a basic phase, to which these basic and ultrabasic rocks now known only as float belong.

AGE AND INTERRELATIONS.

The determination of the age of the granitic rocks has already been partly treated in discussing the age of the early basic effusives and intrusives. In that section it was stated that the granitic rocks cut the other igneous rocks in the Kiwalik-Buckland divide and in the Zane Hills and formed pebbles in the conglomerate at the base of the known Upper Cretaceous section. The latter condition is also found to be true of the conglomerate at the base of the same group on the Alatna. It seems fairly certain that the upper age limit that can be assigned to the granitic rocks as a whole is pre-Upper Cretaceous. The lower age limit may be determined on the basis of the assumed age of the early basic rocks. This, however, has been shown to be open to question. There is no doubt, however, that granites in all essential respects similar to those under consideration have been found in the Darby Range of Seward Peninsula, cutting fossiliferous Devonian or Carboniferous limestones.[1] It follows, therefore, that the granitic rocks were formed probably in the Mesozoic and certainly between the known Devonian or Carboniferous and the known Upper Cretaceous sediments.

As already suggested in a previous paragraph, the most widespread period of volcanism in Alaska appears to have been in the Jurassic, and it seems more than likely that these granites were intruded during that general period.

It should be pointed out, however, that a comparatively long period must have elapsed between the early effusives and the granitic intrusives, for the two are formed under such different conditions that there must have been thorough consolidation and considerable burial of the lavas before the granites were injected. It is therefore necessary to take into consideration this interval in assigning a definite age to the igneous activities by which these two groups were produced.

LATE LAVAS OR BASALTIC EFFUSIVES.

DISTRIBUTION.

Late lavas occur chiefly in two areas in the Noatak-Kobuk region, namely, in Seward Peninsula and in the Koyukuk basin.

In Seward Peninsula the most extensive areas are in the extreme southwestern part of the mapped area along the valleys of Inmachuk, Kugruk, and Kiwalik rivers; at several places along the coast, notably west of Cape Deceit; and in the lower country flanking the Kiwalik-Buckland divide. The recent basalts in the latter locality have not been mapped, as their differentiation from the early basic effusives and intrusives has not been effected. It is known that the group is also represented in the Buckland basin, but the region has

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911, pp. 64-70.

not been critically examined and little is known of the occurrence except that the rocks form rapids 30 miles above the mouth of the stream and prospectors report float basalt in other parts of the basin.

In the Koyukuk basin recent basalts have been seen at three places, but probably further exploration would result in the discovery of other areas occupied by these rocks. The three areas are on Kanuti River, about 30 to 40 miles in an air line east of the mouth of that stream; along the flanks of the Zane Hills, west of the mouth of the Hogatza; and on the northern flanks of the Zane Hills in the pass from the Pah to the Selawik, between these hills and the Lockwood Range to the north.

LITHOLOGIC CHARACTER.

The recent basalts in northeastern Seward Peninsula have been best described by Moffit and the following abstracts[1] have been taken from his published report:

In color the lavas are dark gray, green, or nearly black; they are usually very cellular or even spongy in appearance but at times compact and without the amygdaloidal cavities. Outcrops of the older lavas in place are not plentiful, and the edges of the sheets, where cut through by the streams, are marked by tumbled heaps of blocks resulting from the jointed columnar structure of the lava. In a few places they form flat-topped hills or mesas from 20 to 50 feet high, very conspicuous when viewed from a distance and evidently the remains of a partly eroded sheet. Agglomerates and breccias were observed at several points. A study of the numerous specimens collected shows them to be made up of diabases and basalts, both rich in olivine. In the basalts especially olivine phenocrysts are abundant and very noticeable, even in the hand specimen. Iddingsite is not infrequent as an alteration product of the olivines. * * *

In this region the outpouring of liquid rock took place in not very distant time, for the ropy surface and irregular margin are still preserved, just as at the time when the molten stream ceased to flow. Caverns or tunnels, produced by the cooling of the surface and subsequent outflow of the still liquid rock beneath, are numerous. They show a height of 20 to 25 feet and a width in some instances as great as 200 or 300 feet, but rarely have the roofs preserved to the present time, since the weight was too great for an arch of such width. Flattened lenticular steam cavities, 2 to 3 feet in greatest diameter, are sometimes exposed, and the upper surface of the sheet is marked here and there by smooth, irregular elevations produced by the escape of steam and the welling of the lava from below.

Important modifications of the drainage were brought about by the extrusion of the lava, which occupied the depressions and flowed down the valleys in broad rivers of molten rock. At times the cooling of the advancing front wall dammed back the flow and forced it over the low, rounded divides between the watercourses into the next valley beyond, or formed a lake which finally overflowed the obstruction and resumed its original course, only to repeat the process a little farther on.

In this way islands of bare ground were left between the great finger-like protrusions along the edge of the sheet. At the same time a shifting of the watercourses was brought about, for when not of sufficient volume to fill it the lava occupied the lowest part of the valley and the waters sought a new channel parallel to the old one, along the edge of the hardened flow. A number of lakes and ponds also owe their existence to the damming of streams by lava.

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[1] Moffit, F. H., op. cit., pp. 31-32.

Mendenhall[1] describes the Kanuti River locality, in the Koyukuk basin, as follows:

> Along the middle Kanuti River * * * horizontally bedded vesicular olivine basalts form bluffs 50 to 75 feet high on the north bank of the river, and similar bluffs south of the valley are probably due to the same formation.

On the southeastern flank of the Zane Hills occur numerous exposures of dark amygdaloidal basalt, which form a low ridge north of the Koyukuk. Under the microscope the rock is seen to consist of small phenocrysts of augite and plagioclase feldspar in a fine-grained groundmass of the same material. Magnetite occurs as an accessory and chlorite as a secondary mineral, resulting from the alteration of the augite. The rock as a rule has a much less glassy appearance than the basalts of Seward Peninsula. On exposed surface it weathers to a rusty brown color, but few exposures were seen in which this oxidized layer was as much as one-sixteenth of an inch thick.

In the vicinity of the pass between Pah and Selawik rivers, a reddish-brown lava forms low level-topped mesas of considerable extent. The flows were rather thin, for down some of the small ravines a vertical distance of 100 feet or so were found outcrops of the underlying Cretaceous sandstones and conglomerates. So far as observed the lava was entirely undisturbed. Under the microscope a specimen from this place showed phenocrysts of orthoclase one-eighth of an inch in length in a groundmass of orthoclase, albite, and biotite with accessory magnetite and secondary iron oxides. The red color of the rock is due to the finely divided and widely disseminated iron oxides. This rock has all the features of certain of the lavas from the lower part of the Koyuk basin reported by Smith and Eakin[2] in 1909. The extent of the lava flow at this locality was not determined, but it undoubtedly occupies a much greater area than that shown on the geologic map (Pl. II). Probably some of the topographic features of the Pah-Hogatza basin will subsequently be shown to have been produced by the barrier formed by the outpouring of this lava, and certain of the high-level gravels may have been formed as a result of drainage modifications it undoubtedly induced.

AGE.

The effusions of recent basalt took place probably in the later stages of the Tertiary and extended down almost to the present time. In the Noatak-Kobuk region the only direct evidence as to the earliest date to be assigned to these lavas is the fact that they overlie Upper

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[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 42.

[2] Smith, P. S., and Eakin, H. M., op. cit., p. 73.

Cretaceous rocks unconformably. However, as there was a pronounced period of diastrophism that occurred later than the Eocene and as the lavas were not affected by it, it is evident that they were formed subsequent to that event.

The extrusion of lava continued down to a very recent time, as is shown by the freshness of the rocks and the unmodified character of the topography to which they give rise. As already noted, the ropy surface, unfilled gas cavities, and lava-dammed lakes indicate that certain of the flows are very recent. Furthermore, it has been shown by Collier[1] that in near-by portions of Seward Peninsula the recent basalts overlie gravels which are cemented by indurated clays. Mendenhall[2] found similar conditions in the Koyuk basin, where horizontal recent basalts lie on 5 feet of gravel, which in turn rests unconformably on schists.

All these flows are not portions of a once continuous sheet or of a single extrusion. This is proved not only by the different character of the rocks and the different amount of weathering they have undergone, but also by the fact that at the locality noted in the preceding paragraph Collier found pebbles of an earlier lava in the gravels overlain by the recent basalts. The latter fact shows that there had been an early lava flow, succeeded by a period of erosion in which the gravels were formed prior to the eruption of the covering lavas.

From the foregoing statements it may be inferred that all of the recent basalts were not contemporaneous. Although they probably range in age from late Tertiary to Recent, when considered in a broad way it is believed that they all mark essentially one period of volcanism. Therefore, although many years undoubtedly elapsed between different flows, even in the same district, there are sufficient reasons for assembling the lavas together and regarding them all in a stratigraphic sense as practically a unit.

VEINS.

Although the occurrence of veins is of much importance in the search for valuable mineral deposits, it has not been possible to indicate their distribution on the geologic map (Pl. II) on account of the limitations of the scale. Consequently in the following pages a description is given of the general types of veins recognized and the kinds of rocks in which they occur, and the account of the places where veins carrying ore minerals have been exploited is left to the last section of this report, which treats of the economic geology (pp. 125–157).

[1] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 31.

[2] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: Special Publication U. S. Geol. Survey, 1901, p. 206.

OLDER QUARTZ VEINS.

The veins of the region may be divided roughly on the basis of their most abundant constituents into two main types, namely, quartz and calcite veins. The former are the most abundant and are economically the most important. The quartz veins are further divisible into many smaller groups on the basis of age or mineral composition. It is not known how many periods of quartz vein formation there were, but at least two appear to be fairly distinct and identifiable—one prior to the profound pre-Mississippian deformation and the other after that period of diastrophism. In the present report the veins formed during the first period are called the older quartz veins, whereas the others are called the younger quartz veins.

From the above definition of the two groups it is evident that the older quartz veins are found only in the undifferentiated Paleozoic metamorphic schists and the undifferentiated Paleozoic limestones. As already pointed out, most of these limestones are believed to be later than the schists, and in the field it is found that the older quartz veins are almost if not entirely confined to the schists. This fact is significant as indicating the general distribution of these veins, for the areas of schist are shown on the geologic map (Pl. II). In all the areas mapped as undifferentiated metamorphic schists, from John River to Seward Peninsula inclusive, representatives of this group of veins were recognized.

As the older quartz veins have gone through the same deformational processes to which the older rocks have been subjected, their field appearance shows evidence of this history. They usually occur as stringers, lenses, and irregular masses of quartz of slight horizontal or longitudinal extent. Plate VIII, *A* (p. 56), previously described, shows some of these veins in the schists on Alatna River. Unfortunately they are not very distinct in the illustration, but they can be recognized as the light-colored, hard bunches around which the cleavage wraps, a little to the right of the hammer. The veins are discontinuous and, although in places zones or areas having numerous veins are seen, the individual members can not be traced for any distance. This feature is important in determining whether the veins can be successfully exploited as lodes.

The filling of the older veins is almost entirely quartz. Some sulphides or their oxidation products are seen in a few of the veins, but they form an insignificant amount of rock. It is probable, judging from assays made of similar veins in Seward Peninsula, that native gold is also found in the older quartz veins. This fact has not been demonstrated in the Noatak-Kobuk region, but it is believed that this group of veins is the source from which a large amount of the placer gold has been derived.

YOUNGER QUARTZ VEINS.

The younger quartz veins occur widely throughout the Noatak-Kobuk region. Although this group includes all the veins later than the major period of metamorphism, and so may occur in any of the rocks in the region, they, like the older quartz veins, are largely confined to the undifferentiated Paleozoic schists and limestones. Unlike the former group, however, they have been found in the Noatak sandstone and Lisburne limestone. Few if any veins occur in rocks younger than the Paleozoic, so that the distribution is confined to the areas occupied by rocks older than the Mesozoic.

Like the preceding group, there are strong reasons for believing that all the younger quartz veins are not of the same age. Data to permit the separation of the different members of this group, however, are not yet at hand. Many of the younger quartz veins appear as fillings of crevices or gashes in the highly deformed sandstones along the Noatak. A particularly clear illustration of the appearance of these veins is shown in Plate X, *A* (p. 63), which shows a sandstone outcrop a short distance above the camp of August 13. At this place quartz veins have been formed in the axis of a closely appressed and ruptured fold, transverse to the bedding. The veins are all of slight extent and the filling has the appearance of being derived by infiltration from the adjacent rock. The veins contain practically no mineral other than quartz, and it is believed that gold and other economically valuable minerals are not to be sought in this type of vein.

There are, however, certain of the younger quartz veins, apparently from a deep-seated source, that may contain valuable minerals. Such veins appear to be most common in the black slates and quartzites of the undifferentiated metamorphic schists. They range in size from almost microscopic dimensions to masses 2 to 3 feet in width traceable for considerable distances along the strike. Veins of this sort were particularly examined at the head of Dahl Creek, north of Shungnak. At this place the hillside is covered with a heavy quartz float derived from veins in the vicinity, many of the pieces weighing more than 100 pounds. Although quartz was practically the only mineral recognizable in the rock, many specimens from this place in the possession of prospectors showed considerable free gold in well-formed crystalline aggregates.

Although the younger quartz veins are numerous in the harder, more resistant Paleozoic rocks, it is relatively uncommon to find them extending far into the limestones. It is believed that the reason for this condition is not that the higher rocks had not been formed, but rather that extensive fissures could not be maintained in a rock that flows under pressure so easily as a limestone. In other words, the more brittle rocks fractured and produced open spaces when subjected to deformation, whereas the limestones yielded somewhat as wax does under pressure. This feature makes it uncertain whether a particular limestone was formed later than certain of the veins in near-by areas or not, and therefore in a large measure causes doubt as to the correlation of different members.

Before leaving the subject of the younger quartz veins it is necessary to point out that, although they were formed subsequent to the main period of dynamic metamorphism, many of them were subjected to pronounced mountain-building forces. As a result, although the veins are not so sheared and knotted as the older veins, they have been folded, faulted, and otherwise deformed from their original condition. They seldom occur, therefore, as continuous veins traceable for long distances with a constant dip and strike but are usually discontinuous, shattered, and irregular. This fact is important, for the development of mines on these veins will require a thorough and precise determination of the complex structural features of the veins to be exploited.

CALCITE VEINS.

Calcite veins are confined almost exclusively to the limestone areas and rarely extend more than a short distance into the schists. As a rule they are similar to the younger quartz veins of the gash type, and like them are believed to have derived their filling mainly from the rocks in the immediate vicinity of the fissures. Plate IX, *B* (p. 62), previously described, shows some of these calcite gash veins particularly well in the more massive member in the center of the view. At this outcrop, which is a short distance below camp August 4 on the Noatak, the longer axis of the elliptical cross section of the veins stands nearly vertical and the different veins are arranged en échelon.

Calcite is practically the only mineral in these veins. It occurs in many different forms, from separate crystals an inch or more in length, having perfect rhombohedral outlines and open spaces between the crystals on opposite walls, to fine-grained marble-like masses completely filling the vein. In a few veins a little quartz has been found associated with calcite, but it is generally in small amounts. Sulphides occur but sparingly in the calcite veins, though in some of the brecciated limestones there has been sulphide mineralization that is so associated with calcite that the rock superficially appears to be a calcite vein. Native gold is not known to occur in any of the calcite veins in the Noatak-Kobuk region. North of Nome in Seward Peninsula and in the vicinity of Chicken Creek in the Yukon-Tanana region gold has been found in calcite veins. It is not known whether the veins are similar in origin to those in the

Noatak-Kobuk region, but it is believed that as a whole the calcite veins of the gash type do not warrant exploitation as lodes and also did not afford any notable amount of gold for the production of placers.

ORIGIN OF THE VEIN MATERIAL.

The source of the vein material in the two types of veins known to carry valuable minerals, namely, the older and certain of the younger quartz veins, is as yet undetermined. So far no connection has been traced between any of these types of veins and the igneous intrusions. The absence of definite proof, however, does not preclude the possibility of such an interrelation. It is an important question to determine, for the distribution of the veins depends on the geologic history, which is therefore a matter that should be closely investigated in the field and the conclusions thoroughly tested.

The greenstones and associated schists show some sulphide mineralization of a disseminated type that may have been brought in during the intrusion of the rock from a deep-seated source. The amount of this mineralization, however, seems to be very slight. Sulphides are also found in intrusive rocks at the Noatak Canyon, but only in scattered grains, and the mineralizing effect does not seem to have extended far beyond the immediate contact. In the regions occupied by granite a little sulphide mineralization was observed. It was so small in amount, however, that save for a few scattered brown oxide stains on the rock it would have almost escaped detection. No sulphide mineralization in the recent basalts has been recorded.

It has already been suggested that the fillings of certain of the quartz and calcite veins which occur in irregular gashes have been formed during or at the close of the dynamic metamorphism of the region. In this type of vein it is believed that the filling has been derived from the contiguous rocks and has migrated into the open spaces where it has been deposited. If this interpretation is correct, it seems probable that these veins, though of widespread distribution, hold out little promise of being commercially valuable.

SUMMARY OF THE GEOLOGIC HISTORY.

From the preceding description of the various rocks and deposits that have been recognized, together with the notes on their structures and relative ages, the geologic history of the region may be inferred. However, as the reconstruction of these different stages in the history are not obvious to all, an attempt will be made in the following pages to give a consecutive statement of the various events that are believed to have occurred in the Noatak-Kobuk region. In this summary much of the evidence on which the succession has been determined has been omitted and should be sought in the general descriptive portion of the report. In order to avoid too much repetition some of the statements have been made more definite than the facts at hand warrant; for instance, the Bergman group is regarded as Upper Cretaceous, though, as explained on pages 86–87, this determination is not proved by fossils nor exact stratigraphy but is based on several assumptions. The following statements should, therefore, not be considered independently from the fuller evidence presented in the earlier portions of this report.

The earliest event recorded in the region was the deposition of certain of the undifferentiated schists as sediments probably similar in all essential respects to the sands and muds that are being deposited in the sea at the present time. Subsequently these deposits were consolidated, possibly undergoing various elevations and depressions so that occasional breaks in the depositional cycle may have occurred. Veins of the older quartz vein group were found in the rocks. A pronounced period of deformation then ensued, whereby the rocks were sheared and rendered schistose and secondary minerals formed. This mountain-built mass was then subjected to erosion, streams and other denuding agencies beginning to carry away material from the highlands and to deposit it again in the sea. After this process had continued for a considerable time the region was submerged and some of the undifferentiated limestones were deposited. Owing to uncertainty as to the age of these rocks, it is impossible to state the time of this depression and as there was probably more than one period of limestone formation the history of this part of the geologic sequence is obscure.

During the deposition of the earlier undifferentiated limestones there appear to have been igneous intrusions marked by the presence of the greenstones. These have been subjected to profound deformation and seem to be older than the main mass of the undifferentiated limestones and were formed apparently at the close of the early great period of mountain building. A period of greenstone intrusion has been recognized in many parts of Alaska—in Seward Peninsula, in the Koyukuk basin, in the Yukon-Tanana region, in the Copper River region, and in the Kaiyuh Hills. The evidence from these places does not afford conclusive proof as to the time of the intrusion, for in Seward Peninsula the greenstones cut limestones of questionable Devonian or Carboniferous age, in the Yukon region the greenstones are Devonian, and in the Copper River region and in southeastern Alaska the intrusion was Carboniferous or later.

In the Mississippian the region was again one of deposition and the Noatak sandstone and Lisburne limestone were laid down. The fossil contents of these two formations show that the rocks were

A. DOUBLE STRUCTURE IN LIMESTONES, NOATAK RIVER.

B. DOUBLE STRUCTURE IN SANDSTONES, NOATAK RIVER.

essentially contemporaneous, but the deposition continued for a long time, as is shown by the great thickness of strata composing these formations. The presence of Triassic float shows that deposition was more or less continuous into the Mesozoic. That there were interruptions is probable, for the Triassic is Upper Triassic and no Pennsylvanian nor Lower or Middle Triassic is known, so that the region may have been an area of erosion during that time.

After the consolidation of these sediments another period of mountain building ensued, in which these rocks, together with the earlier schists, were folded and faulted and probably lofty mountains were formed. Erosion again began to attack the region, to wear down the hills, to remove the materials and to form deposits in outside areas.

No records of the events in the middle Mesozoic are preserved unless portions of the Koyukuk group in the Zane Hills and the igneous rocks associated with the known Lower Cretaceous limestone were formed in this period. It has already been suggested that from analogy with other parts of Alaska such an assumption is reasonable, though unproved. Following the early basic effusives and intrusions there were widespread injections of granitic rocks.

In the Lower Cretaceous the only definite fact is that limestones were deposited. Fragmental volcanic ejecta and flows are apparently closely associated with these rocks. As may be judged from the geologic history of near-by portions of Alaska, pronounced deformation and further volcanic effusion closed this period. This resulted in a considerable part of the region becoming land subjected to erosion. The material removed from this land was deposited in the sea that probably existed south of the Kobuk. Gradually the region sank and the Upper Cretaceous deposits encroached farther and farther on the land, possibly extending continuously from the southern to the northern margin of the mapped area. Thousands of feet of strata were deposited during this period, which probably extended from the Upper Cretaceous into the Eocene.

With the close of this period of deposition the last great period of deformation ensued. The present major topographic features were produced, though the mountains were probably much more lofty, and the details were far different from those seen to-day. Probably it was during this period of mountain building that the already folded Mississippian rocks were still more deformed, and the secondary structures, such as those shown in Plate XIV, may have been produced. The absence, however, of evidence concerning the relations of the Cretaceous and Mississippian makes the time of formation of the cleavage indefinite, and it is possible that the latest structure shown in these views was produced during the post-Mississippian deformation noted above.

From that time on the region has been land and has been undergoing almost continued erosion. The only marked interruption to this process was the effusion of the recent basalts, which probably began late in the Tertiary and extended down almost to the present. These effusions appear to have been spasmodic and to have taken place in a number of separated areas. The lavas flowed into the lowlands of the existing topography and by their resistance in many places have preserved these surfaces from further erosion until the lavas themselves had been removed. It is for this reason that many of the characters of that old land surface may be determined by the scattered patches which in favorable localities have been preserved under the lavas.

While the lavas were being poured out in the lowlands, erosion was still active over much of the area, and the highlands were being more and more degraded. Movements of the earth's crust without doubt also took place, but these were broad regional uplifts or depressions rather than sharp mountain-producing flexures.

After erosion, deposition, and lava effusions had been in progress for some time, a change ensued whereby glaciers were formed in the mountains. Many of these glaciers were large and extended for considerable distances down the previously formed main valleys. So far as known, however, all of them were distinctly of the valley type, and they did not form huge ice caps mantling all the country, as did some of the now vanished ice sheets in the northern United States. To these ancient glaciers must be attributed the formation of many of the most prominent of the present-day erosional and depositional features.

Concerning the late geologic events, the following account of observations in southeastern Seward Peninsula[1] gives a general idea of the conditions observed in the Noatak-Kobuk region:

> All this time deposits of glaciofluviatile, fluviatile, and marine origin were being formed in the areas not occupied by the ice, where the conditions were favorable. Lava flows may also have occurred at this same time in the areas not occupied by the ice.
>
> With the close of glacial conditions oscillations of the crust similar to those preceding the period of glaciation again become evident. It is not intended to imply that these oscillations ceased during glacial time, but the evidence is so obscured that the movements were not recognized. The general result of these postglacial uplifts has been to raise the region somewhat above the relative position it occupied during the Pleistocene. Apparently, however, the sum of the recent upward movements has not yet equaled the sum of the earlier downward movements, so that the floors of many of the larger streams are still below sea level. The general recent uplift is shown in the rock-walled shallow canyons in which many of the streams flow.
>
> Although the later Tertiary to Recent movements have been described as resulting in certain general conditions, it should be distinctly understood that these move-

[1] Smith, P. S., and Eakin, H. M., op. cit., pp. 99-100.

ments were such that while depression was taking place in one part of the region, uplift may have taken place in another. Hence it appears that deposits at the same elevation above or below sea level are by no means synchronous and may be entirely unrelated in origin. Contemporaneity of the various deposits can only be determined by careful and detailed investigations of the region. Inasmuch as many of the problems of economic importance are connected with the correct correlation of the different deposits, it is necessary that such correlations should be searchingly investigated and not be based on superficial examination or upon apparent similarity of factors known to be variable.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

The larger part of the Noatak-Kobuk region is unexplored, and even in places that have been visited by prospectors and miners little is really known about the mineral resources. In spite of this fact gold placers, gold and copper lodes, and deposits of nonmetalliferous minerals, including coal, have been found and partly developed. These deposits occur in many parts of the region that have been studied by Survey geologists. It is proposed to set forth in these pages the facts learned about the different occurrences and the suggestions and inferences drawn from them as to the conditions under which the deposits were formed. It is believed that in this way the record will be of service not only in describing the present status of the mining industry but also in pointing out the places where further prospecting or exploration is likely to bring returns and in indicating areas that are dissimilar to the known productive regions. In this description the northern part of Seward Peninsula, included on the geologic map (Pl. II), will be omitted, for the mineral resources of that region have already been treated in a publication of the Survey by Moffit,[1] which should be consulted by those interested in that district.

GOLD PLACERS.

KOBUK BASIN.

GENERAL CONDITIONS.

Auriferous gravels have been reported in many parts of the Kobuk basin, but in only two regions has there been any notable production—the Shungnak region in the central part, and the Squirrel River region in the western or lower part. Mining in the Shungnak region has been carried on almost continuously since 1898, but in the Squirrel River region the discovery of placers was not made until the fall of 1909. There are geologic grounds for believing that much of the area between these two camps may subsequently prove to contain auriferous deposits. The economic conditions imposed by the geo-

[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905.

graphic position of the Kobuk region, however, have exercised and must always exercise a control that will prevent working deposits which in a milder climate and in more accessible regions could be successfully mined. Although it is probable that the present high costs may be in part decreased as the region becomes more opened up, the long distances that supplies must be carried, the frequent handling of freight required, and the short season available for water transportation and surface mining are unavoidable.

The general geologic conditions in both the Shungnak and Squirrel River regions are similar. In the former region glaciation was much more pronounced in the past and it undoubtedly affected placer accumulations to a more marked extent. The area of the more mineralized rocks is less in the Shungnak region, but the lower part of the Squirrel River region is more extensively covered with outwash deposits. At both localities the gold in the placers appears to be near its bedrock source and seems not to have been transported far. As a result the rich ground is more or less irregularly distributed and the tenor ranges within wide extremes.

SHUNGNAK REGION.

The main placer developments in the Shungnak region are on those streams heading in or flowing through the Cosmos Hills, namely, Dahl Creek; Riley Creek, a tributary of Kogoluktuk River; and Shungnak River. When visited in 1910 there were only 10 to 12 miners in the whole region, so that the production was small. Although no accurate statistics are available as to the production, it is doubtful whether $100,000 in gold has been taken from the placers in the 10 to 15 years that they have been worked.

DAHL CREEK.

Dahl Creek is a stream 8 miles long, the lower 3 miles or so of its course being through the Kobuk lowland, the middle 2 to 3 miles in a narrow rocky gorge, and the upper mile or two in a rather open valley. The placers that have been worked are located near the southern face of the Cosmos Hills and in the central part of the valley, where the junction of three small streams with Dahl Creek has made a small flat. During the time that the Survey party was in the region no work was in progress on any of these claims, but mining had been carried on earlier in the season at both places, and had been in progress for several years in the past.

The bedrock under the unconsolidated deposits here is black slate and schist with numerous small veins of quartz and in places some sulphide mineralization. The bedrock breaks into rectangular blocks of small size and the joint faces are commonly iron-stained. The dominant strike is across the creek, and thus the rocks make good riffles for catching the gold. The slope of the bedrock surface is rather low, so that some difficulty is experienced in disposing of the tailings from mining. Near the lower group of claims schistose conglomerate outcrops but does not form bedrock under the productive placers. Limestone occurs near the placer ground in the middle part of Dahl Creek, but although float from this rock is found in the gravels it does not come down as far as the creek and does not form any of the surface on which gravel accumulation took place. Igneous rocks of a dense texture and greenish, glassy color were noted upstream from the placers, but though these rocks have furnished many of the bowlders in the placers, they do not seem to have been connected with the mineralization and did not contribute valuable minerals to the placers.

Only the creek gravels have been mined on Dahl Creek. These average about 4 feet thick. In some places their thickness is only a foot or so, but in others it is as much as 8 feet. Holes sunk on some of the low benches on either side of the stream have shown unconsolidated deposits 15 feet thick. Practically none of the stream gravels are permanently frozen, but some of the low benches that have been prospected are reported to be in that condition.

The gravels in the productive placers are of the normal creek type, consisting of well-rounded pebbles with only a small amount of muck. Large, somewhat angular bowlders, most of which are of local derivation, are numerous in the gravels and cause a good deal of trouble in the mining operations. One of these large bowlders a short distance below the placers, near the southern face of the Cosmos Hills, measured 14 feet in length. It was made of the sheared conglomerate and had not been transported far. Many smaller bowlders occur directly in the pay gravels, however, and it has been necessary to blast them out of the way.

The pay gravels differ in no essential respect from the overburden. They are usually from 1 to 2 feet in thickness and practically all the gold lies in and on the bedrock. The distribution of the auriferous gravels is very irregular and it has been impossible to successfully trace any continuous pay streak. The gold occurs in pockets, which, when exhausted, give no clue as to their relation to other rich spots. Such a distribution seems to indicate that valuable minerals were either laid down more or less evenly and then dispersed by a change in the discharge of the creek or else that the gold was originally deposited by a stream having strong variations in transporting ability.

Owing to the irregular distribution of the gold the value per cubic yard is of almost no significance. When a rich spot is found several hundred dollars may be taken out in a few days, but at other times only a dollar or so a day can be made. Figures for the total production are also unsatisfactory, but they give a more accurate estimate of the value of the ground. The returns are not complete and probably exaggerate the amount of gold recovered, but they are an indication of the size and present importance of the creek. According to the returns of the miners, in no year has Dahl Creek produced more than $10,000, and probably half this amount is nearer a correct estimate for the average production during the past six years. If this assumption is correct, not over $30,000 has been taken from this creek since its discovery.

Only a small amount of Dahl Creek gold was studied, so that a full description is not available. The gold examined from the upstream group of placers was reddish to brass-yellow in color. The pieces were small and some were distinctly spongy and had fairly sharp outlines, as though they had not been transported far from their place of origin. Some wire gold was also seen but was notably rare. Nuggets of considerable size have also been found in this part of Dahl Creek. One of these was seen that had a gold content worth about $65. It was a fairly well-worn piece and had a considerable amount of greasy-looking milky quartz attached. In 1911 a large flat piece of gold worth over $600 was found near this place. Assays are reported to have shown the gold to be worth about $16.20 an ounce.

Among the concentrates from Dahl Creek placers magnetite is the most abundant mineral. There is also a small amount of chromite, some of the pieces being a foot or so in diameter. Garnets are almost entirely absent. The occurrence of native silver in the concentrates has been reported and pieces nearly an inch in diameter have been examined. The silver seems to be particularly free from admixture with other metallic minerals, such as copper or lead; a small amount of cadmium, however, was recognized by blowpipe examination. No evidence was secured as to the source from which the silver was derived.

Mining is carried on by pick-and-shovel methods and the gold is won by passing the gravels through sluice boxes of whipsawed lumber. Owing to the high transportation charges machinery would be expensive to install, and owing to the character of the gravels and their tenor few mechanical devices could be successfully operated. Short ditches provide the necessary head for sluicing, and there is almost always sufficient water to meet the demand.

From the physical features of the gold and the distribution and other characters of the auriferous alluvium it seems probable that the gold has been derived from places within the Dahl Creek basin, especially from the areas occupied by the black slates and schists. It is believed that the source of the mineralization is the quartz veins, which are so abundant in this formation.

Some prospect holes have been sunk near Dahl Creek close to the southern front of the Cosmos Hills or the northern margin of the Kobuk lowland. The returns have, however, been insufficient to warrant development and the holes have been allowed to cave, so that it was impossible to examine a section of the gravels. It was reported by prospectors that the bedrock surface slopes southward at a high angle below the lower cabins, so that shafts even 40 feet deep failed to reach bedrock. In this lower part of Dahl Creek the stream flows through the unconsolidated deposits of the Kobuk lowland. The absence of any shallow placers in this part of its course seems to indicate that the upper part of the gravels of the lowland area does not contain sufficient gold to form economic deposits where subjected to the sorting of such streams as Dahl Creek.

KOGOLUKTUK RIVER.

Sparsely disseminated colors of gold have been reported from many parts of the Kogoluktuk basin, but the only stream on which placers have been mined is Riley Creek. This is a tributary from the west, heading against the Dahl Creek divide and flowing first north, then east, to join the Kogoluktuk. Placer ground has been mined in a desultory way by parties of one to three men on the headwaters of this stream since 1908. Mining was in progress here when the region was visited by members of the Survey in the early part of August, 1910, but soon afterwards was abandoned for the season.

The placers occur in a region of black slates, limestones, and a few intrusive igneous rocks. The bedrock is similar to that of the placers on Dahl Creek, except that limestones are much more numerous. Evidences of deformation and dislocation are pronounced and the stratigraphic succession of the rocks has not been determined. Quartz veins in the black slates that form the bedrock under the ground that has been worked are particularly numerous and are believed to be closely associated with the formation of the productive placers.

In the placers typical stream gravels are practically absent. Sections show angular slide and slightly worn unconsolidated deposits of local origin in which are irregularly distributed bowlders from outside basins. Most of these foreign bowlders are of large size and are mainly of igneous rocks belonging to the greenstones and associated types. They are usually well worn and probably have been brought into their present position by the combined action of ice and water during the closing stages of the glaciation of the lowland north of the Cosmos Hills. Although these greenstone bowlders are found in the placers, they are in no way connected with the origin of the gold, and their distribution, except as marking former glacio-fluviatile conditions, is of no economic significance.

The gold occurs mainly in the crevices of the bedrock and in the angular unconsolidated material lying on top of the bedrock. In the part of the deposit that is mined large bowlders are less numerous than in the upper 2 or 3 feet, but there are many bowlders even in the pay streak. The whole character of the material in which the gold is found is more like that of residual placers than of ordinary creek placers.

The slight amount of transportation that the auriferous material has undergone is also indicated by the shape and quality of the gold. Practically all the pieces examined were sharp and angular and many had small particles of quartz attached. No large nuggets have been reported from these claims. Pieces worth up to 50 cents were seen, and a few worth as much as \$2 to \$3 were reported. The gold was bright and in an average sample the pieces were worth from one-tenth cent to 2 cents each. The individual particles are spongy and consequently appear to one used to the usual run of placer gold to be worth much more than is actually the case. The precise assay value of the gold was not learned, but it was understood to be about \$16.25 an ounce.

Accurate estimates of the total production are not available, but from the amount of ground that has been mined during the past three years and its reported tenor it is believed that not much more than a thousand dollars a year in gold has been won.

Mining costs are high and the Riley Creek placers are unfavorably situated for economic development. The two greatest obstacles to cheap mining are absence of a sufficient water supply and the presence of large bowlders. The latter trouble, however, is not so serious as the lack of water, for few of the bowlders are so large that they can not be rolled out of the way by hand or be gotten rid of by undermining. Practically the only water available is derived from the melting snow on the north-facing slope of the Dahl-Riley creek divide. Furrows parallel with the contour have been dug on the hill slope to collect the surface and shallow seepage water formed from the melting snow banks. From these furrows the water is led down the hillside and impounded behind a sod dam, whence it is led by a short ditch and hydraulic hose to the sluice boxes. So slow is the collection of water that under favorable conditions it takes about 3½ hours to collect enough for 1½ hours sluicing. No water, of course, can be wasted for groundsluicing. Even shoveling into the sluice boxes can only be carried on for four or five periods a day. During wet weather, of course, the reservoir fills up more rapidly and so relatively longer periods of sluicing are possible.

After the period of sluicing and while the dam is refilling the miners are busy cleaning away the large bowlders and getting everything in readiness for the next time that the water can be turned on. The large bowlders are not cleaned but are simply rolled onto the already worked out part of the claim. In order to use the water effectively, the sluice boxes are made only about half the ordinary width and were formerly set on a pitch of 1 inch in 12 inches. Subsequently, however, a pitch of 1 to 15 was adopted.

The Riley Creek placers that have been worked seem to derive their gold content from the rocks exposed in the immediate vicinity. They are so situated that they have no adequate water supply and bowlders are so numerous that the placer can be developed only at great expense. Farther downstream, where the water supply might more nearly meet the demands, the presence of thicker overlying deposits and large bowlders is to be expected. The absence of especially effective sorting in this part of the basin suggests that placers will be of distinctly local importance. The whole Kogoluktuk basin, so far as indicated by the conditions on Riley Creek, seems to promise only localized placers of irregular distribution, workable as pockets rather than as extensive deposits.

SHUNGNAK RIVER.

Placer mining on Shungnak River has been carried on for a mile or so below the narrow canyon by which this stream traverses the Cosmos Hills. Work has been in progress here during the open season almost uninterruptedly since 1898. Only two or three parties of three or four men each have attempted mining during any year, and in 1910 only one placer camp of one white man and two or three natives was in operation. The use of native labor is an interesting experiment and, although it is reported that white men can do more work, the wages paid the natives (about $4 a day and board) are so much lower that the difference in efficiency is compensated for.

Bedrock in the productive part of the river is mainly black slate and schist, but other sedimentary and igneous rocks occur at no considerable distance from the placers. Limestones occur near the head or northern end of the canyon, but are not closely associated with the deposits of auriferous alluvium. The igneous rocks near the placer mines are composed mainly of serpentine with scattered particles of magnetite and are of a dark-green color. These rocks have been sometimes mistaken for jade, and it is probably owing to this error that the whites have reported the name "Shungnak" to mean "jade" in the native language.

Most of the mining has been done near the southern face of the Cosmos Hills, where small flats permit turning the stream aside by wing dams. The gravels mined are usually shallow. The upper two feet or so is stripped off and the lower part only is put through the sluice boxes. The overburden is made up of typical river gravels with some large bowlders irregularly distributed throughout. It is not known whether the valley of Shungnak River through the Cosmos Hills was at one time occupied by ice, but it is certain that glacially eroded and transported bowlders have been brought in by glacio-fluviatile action and form part of the reworked material of the unconsolidated deposits.

The pay gravels are rather irregularly distributed and mining therefore has been in the nature of pocket hunting in those places where the water could be handled. The gravels are unfrozen and in a measure this is a disadvantage, as much water seeps into the pits. During high water the miners are sometimes driven out of the workings. The gold is found in the lower part of the unconsolidated deposits and in the crevices of bedrock, especially where it is black slate.

Most of the gold found in the placers of the Shungnak is in small pieces worth from one-half cent to 3 cents, but nuggets worth up to about $40 have been found, although they are by no means numerous. The gold is reddish, and although not rusty it is not bright and shiny but has a dead luster. Its assay value is reported to be $16.70 an ounce. The form of the gold is very characteristic and is distinct from that of the gold from any other part of the Shungnak region. The little pieces look like shot that have been flattened under the hammer, and this form is sometimes spoken of by the prospectors as "pumpkin seed" gold.

Magnetite is by far the most abundant mineral among the concentrates collected with the gold and is probably derived from the basic intrusive dikes which cut the metamorphic rocks. Garnet, or so-called "ruby," is almost entirely absent from the gravels. Small nuggets of copper and also of silver are sometimes found in the sluice boxes. Some of the silver nuggets are nearly an inch in diameter and contain but very small amounts of other metals as impurities. No clue as to the origin of the silver was obtained, but the copper nuggets were probably derived from the copper sulphide impregnated zone near the limestone-schist contact, an example of which will be described in more detail on pages 147–150.

Statistics of the production from the Shungnak River placers have not been kept and estimates prepared by interested parties are not reliable. It is improbable that the annual production amounts to more than a few thousand dollars in gold, and a liberal figure for the total production from this river would not be more than $50,000.

SQUIRREL RIVER REGION.

DEVELOPMENT.

The developments in the Squirrel River region have been small, and although gold prospects are said to have been found on eight to ten tributaries, when the region was visited in 1910 mining was in progress on only one of the streams, namely, Klery Creek. That this is the only place where productive placer exists is improbable, for conditions analogous to those on Klery Creek are reported at several other places in the Squirrel River basin. With further prospecting other valuable placers will undoubtedly be found. There is, however, the strong tendency of prospectors to hold ground on a proved creek and to prospect the adjacent areas only when driven to it by the exhaustion of the known ground or the inability to secure claims on the desired creek.

At the time the region was visited by the Survey geologist not over 50 men were at work, and about a third of this number were employed on one claim. Capital had not taken hold of the region and there were few opportunities to work for wages; consequently the camps were run on a partnership basis and few of the men were equipped with the supplies necessary to carry them for a year or so of unproductive labor, such as that involved in building drains for opening up a property. Wages were said to be $7.50 a day and board for ordinary miners, but as there was only one company employing men and as that company was able to obtain all the help it needed at $5 a day the above figures are more or less fictitious. Though the labor conditions will undoubtedly change if the camp proves successful persons should be warned against going to Squirrel River if they have nothing but wages to depend upon. In 1910 there was no chance of employment for more than a few men, and without supplies or funds any venture would be unsuccessful.

Furthermore, the usual wholesale staking of the region has tied up much of the available ground, so that unless the prospector goes some distance from the productive creeks his chance of obtaining a claim by original location is slight. One is compelled to go a considerable distance from the proved ground or else buy or obtain a lay on a recorded claim. Any of these choices entails additional expense, which the prospector should be prepared to meet. The unjustness of the system is well shown on Klery Creek, where 64 claims have been recorded above the Discovery claim and at least 20 below that point, and yet there is no work being done on more than ten of the claims and of these probably not more than four or five produced a thousand dollars during 1910. This statement is not intended to discourage prospecting but only to point out the small amount of work really in progress.

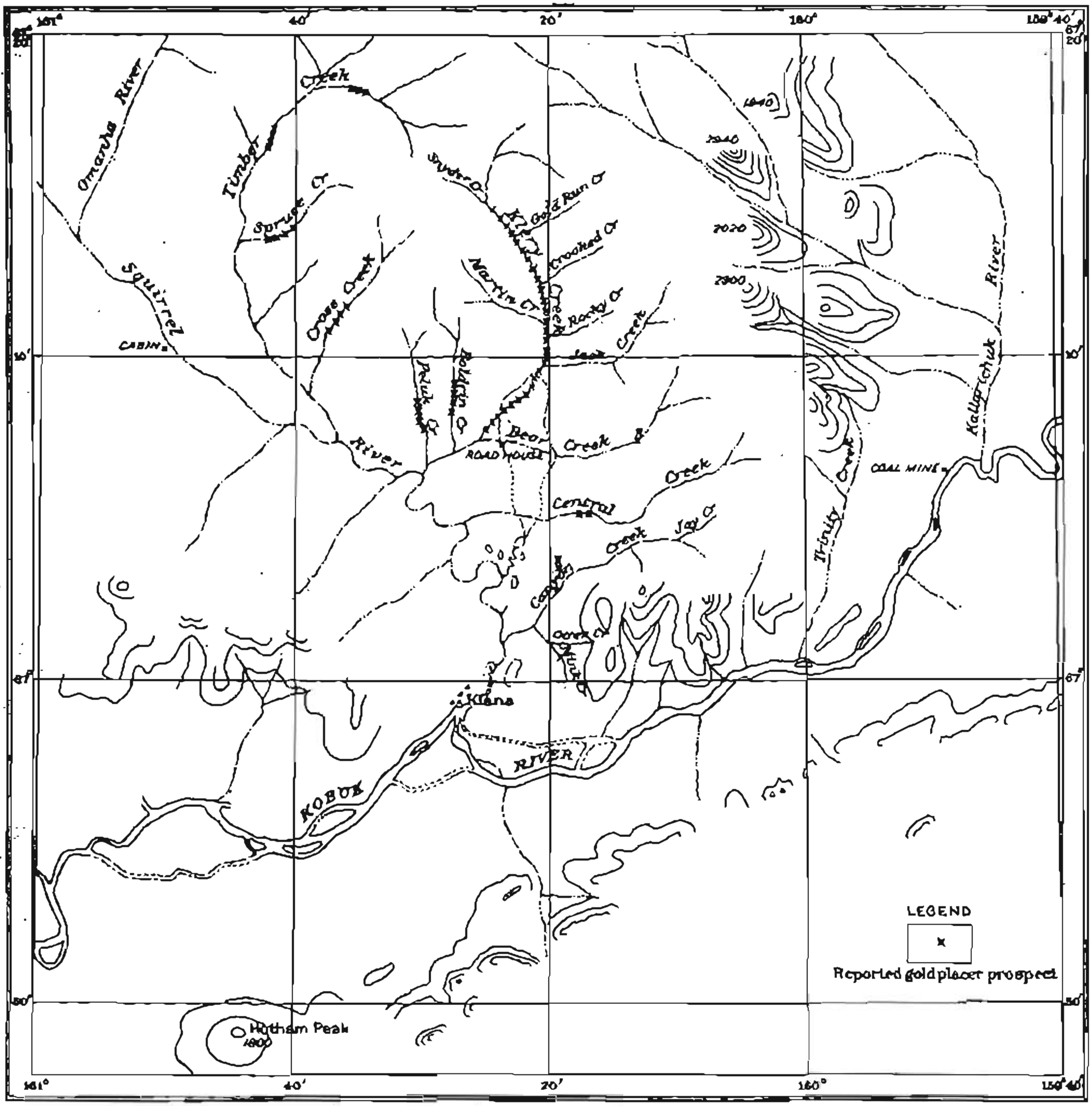
The sketch map shown in Plate XV, compiled mainly from reports of prospectors, shows the eastern part of the Squirrel River basin. Although it has not the same degree of accuracy as the other maps accompanying this report, it shows the general arrangement of the streams, the approximate distance and direction between places, and the areas where auriferous gravels have been discovered.

CREEK PLACERS.

Description of operations.—Klery Creek was the only stream on which mining was in progress in 1910, and as two or three claims on this stream were seen in detail a description of its placers will be given. It should be borne in mind that the general conditions at the placers where mining is being done are likely to be the same at similar places throughout the field, so that the facts learned by mining on one claim are helpful in the understanding of unprospected ground.

The most active work was in progress near the mouth of a small tributary, Jack Creek, a short distance above the Discovery claim. At this place there is a rock-cut gorge with a gravel-covered floor about 150 yards wide. On this floor the stream formerly followed the eastern side, but in order to allow mining the stream was turned to the other side by a roughly constructed dam. Owing to the exceptionally rainy season of 1910 the stream was abnormally high, and three times during the summer the dams were completely washed away by the floods, some of the sluice boxes with the gold in them being recovered only with difficulty. The upper 12 to 18 inches of gravel in the bed where the stream has been turned aside is removed by shoveling and the larger bowlders are either rolled behind the miners onto worked-out ground or are pulled out of the way by a team of horses. This stripping is done rapidly and is carried down to a point where the gravels show some "sediment" or fine mud that coats the well water rounded pebbles and fills the interstices. None of this surface material is put through the sluice boxes, as repeated experiment has shown that it contains practically no gold. Between the upper foot or foot and a half of gravel that is stripped off and bedrock is a foot to a foot and a half of gravel in which gold is obtained. These gravels are typical river wash, but have been less recently handled by the stream than those above them. The lower gravels, together with the upper 6 inches to 1 foot of disintegrated bedrock, are put through the sluice boxes and it is from them that the gold is won.

Bedrock on this claim is mostly schist, but on the lower end of the claim and continuing downstream on the next adjacent claim is a massive, much-fractured, and contorted bluish-white limestone standing at a high angle and cutting the creek transversely. The



5 0 5 10 Miles

1912

SKETCH MAP OF SOUTHEASTERN PART OF SQUIRREL RIVER BASIN.

schist shows many different phases on the working claim. In part it is a dark graphitic slaty schist with numerous small veins and stringers of quartz. The bands of this schist are not more than a few feet in thickness and are interlaminated with somewhat calcareous and quartzose schists, some of which are rusty yellow in color owing to the decomposition of some of their constituents. The iron mineral from which this limonite had been derived could not be determined, but it was probably in part pyrite. In at least one place on the claim a narrow band of limestone interlaminated with the schist was seen. From this description of the bedrock it is evident that lithologically the rocks are similar to those in the richer parts of the Nome region, in the Iron Creek basin, in the Kougarok, on Ophir and Melsing creeks near Council, in the Solomon and Casadepaga regions, and near Bluff. This resemblance is further strengthened by the relation of the schists to the heavy bluish-white limestones at all these places.

Several hundred ounces of gold from this claim were examined and the coarseness of the pieces was remarkable. Practically no fine gold was found and few if any pieces of the gold recovered were worth less than one-half cent. Several nuggets worth $25 to $50 have been found, and while the writer was on the ground one nugget weighing nearly 7 ounces and worth about $125 was picked up in the gravel. In form the gold from this claim is chunky or in nuggets, but a little wire gold was also seen, though no flaky or scaly gold was observed. The gold is dark, but almost never black, and shows few signs of recent movement. Although some of the corners have been rounded, it does not in general appear to have traveled far. In fact, many pieces are sharp and angular as though but recently unlocked from the parent ledge. Some of the nuggets have pieces of the country rock still adhering to them. The most abundant mineral attached to the gold is quartz of the same physical aspect as the quartz in the strings and lenses in the schist. Black graphitic slaty schist is also attached to the gold in some of the specimens, and the way in which the gold forms filaments in this rock shows indisputably that some of the placer gold has been derived from this kind of country rock.

Estimates of the productiveness of this ground are of small value, for the nuggety character of the gold makes the tenor range between wide limits. It is reported that over 190 ounces were cleaned up from about six box lengths shortly before the visit by the Survey geologist. At the time of the writer's visit a clean-up of 120 ounces was made from about 4½ box lengths. This is equal to a bedrock surface of about 500 square feet, so the production from this cut was nearly $4.50 per square foot of bedrock. As a working force of 15 men were able to strip and shovel into sluice boxes this amount of ground in a little over a day, it is evident that this work is immensely profitable. The width of the pay streak is not known, for when the claim was visited all the work had been done only on the eastern side and the western margin of the productive ground had not been reached.

Water for sluicing is obtained from Klery Creek by running a hydraulic hose several hundred feet upstream and bringing down the water thus obtained on as flat a grade as can be maintained. This supply, however, does not furnish an adequate head, so that some other method will have to be tried. But slight difficulty should be experienced in obtaining a satisfactory supply, as the volume is ample for the present demands. No accurate measurements of the volume of Klery Creek were made, but the fact that a crossing, even on a riffle, could not be made in less than 2½ feet of water, in a current of such speed that care had to be taken in keeping one's feet, shows that several thousand miner's inches are probably available during a season such as 1910. It should be noted, however, that that year was abnormally wet and estimates based on observations during that time are undoubtedly above the average.

Few assays have been made of gold from this claim, but on a sample submitted to the assayer of the Nome Bank & Trust Co. a fineness of 0.888½ was determined. This would give a value of $18.37 an ounce.

In the concentrates collected with the gold in the sluice boxes magnetite is the most abundant mineral. This forms a much larger proportion of the concentrates than it does around Nome. Together with the magnetite is also some ilmenite and a little pyrite and limonite. These iron minerals are probably derived mainly from the greenstones and greenstone schists, although the pyrite and its accompanying limonite may have come from veins in the schists or from the vicinity of the limestone-schist contact, a place commonly mineralized in other regions. Garnet or so-called ruby, common in the concentrates from Seward Peninsula, is relatively rare and forms but a small proportion of the black sand. This mineral is absent in the adjacent schists derived from igneous and sedimentary rocks. None of the rare heavy minerals so far have been recognized in the concentrates.

About 1¼ miles upstream from this claim is another claim where gold similar in physical character has been found. Work on this ground has been carried on by a crew of only four men and consisted mainly in dam building and bringing up a bedrock drain, so that only a small production had been made and the opportunity of examining a large amount of gold was not afforded. It seems certain, however, that the gold from this claim is of the same chunky character as on the lower claim, although the proportion of fine gold is larger and the nuggets, as a rule, weigh less. From the shape of the gold it is believed that it has been derived from near-by sources and has not traveled far.

Midway between these two claims the gold is of an entirely different character, although the general geology shows no marked change, except that the limestone is more remote and the canyon character of the valley is more pronounced. The gold from this claim is practically all in fine bright scales. No nuggets worth more than a few cents each have been recovered, though several hundred dollars' worth of gold has been won. The scales are all more or less of the same size, no flour gold being seen. All of the flakes are of a bright gold color with no tarnished nor black coating. No pieces with quartz or other foreign material attached were seen. This gold was of the type locally known to the miners as "bar" gold and showed by its physical characters that it has traveled much farther from the ledge from which it was derived than that found either upstream or downstream from this place.

Gold similar to this "bar" gold has also been found downstream from the first-described claim. It is identical in all essential respects with the one just described and has probably had a similar history. The fact that this gold has traveled farther from its parent ledge is indicated by its higher assay value. It is not possible to give the precise assay value, for the sample that was tested was mixed with nugget gold taken from one of the claims farther upstream. This mixed sample, however, showed a higher gold tenor than the nugget gold previously quoted as worth $18.37 an ounce, so the difference is probably to be assigned to the greater fineness of the "bar" gold.

Origin of the gold.—The distribution of the gold and the difference in the physical characters presented by this mineral from the several claims in this stretch of about 2 miles present problems of economic importance. It is believed that the coarse nuggety gold on the two claims has been derived from near-by areas of bedrock and has not traveled far from its source of formation. Possibly concentration had been effected in earlier stages of the valley development, and the gold was subsequently reconcentrated in the present streams, but the movement by this process must have been relatively slight. On the other hand, the fine flaky gold found downstream from the areas of coarse gold seems to represent the smaller, lighter particles which, because of their size, have been carried farther from their source. Such an interpretation is analogous to the well-known distribution of gold in a sluice box, where the larger, heavier particles are found toward the head end of the box and the smaller, lighter pieces near the foot or discharge end. According to this explanation there are several localities of mineralization cut by Klery Creek, each being more or less close to the areas of heavy gold, whereas in the intermediate regions the stream has not been so close to regions of as great mineralization and the gold has been derived from the areas upstream.

Too little is known about the region to determine beyond question whether the mineralization is confined to a single zone or whether there are a great number of these mineralized zones, but from the number of places where gold has been reported in the Squirrel River basin it seems probable that there are at least several and possibly many zones of mineralization. Further study of this important question is necessary, for it affects the future of the region. Not only is it important in determining the probable area in which gold placers may be expected, but the information is also valuable in determining the trends of the placer ground. From the experience in Seward Peninsula it is believed that the contact of the heavy limestone and the graphitic or quartzose schists is one of the most favorable localities for searching for placer deposits in this group of rocks. This experience seems to be borne out in part by the work on Squirrel River, for the richest claim so far discovered has been near this contact. That there are other places where mineralization has been pronounced can not be doubted, and the prospector should therefore not place undue emphasis on the above suggestion.

BENCH AND DEEP GRAVELS.

So far only the shallow creek gravels in the stream beds have been exploited. There are, however, bench and high-level gravels in this region, as well as the broad fillings of the main stream valleys, which are possible sources of mineral wealth. None of these older gravels have been prospected as yet, and therefore suggestions as to their probable value or character are tentative and subject to revision when more information is obtained. The lower benches already noted as occurring at several different elevations above the tributary streams, such as Klery Creek, seem to have had essentially the same method of formation as the known auriferous creek gravels. It is therefore believed that in the neighborhood of bedrock mineralization these benches will be productive of placer gold. Most of the benches of this character on Klery Creek had but small length or breadth, so that only discontinuous deposits resulted. Such benches, however, may afford rich pockets of auriferous gravel which would well repay exploitation. Many of the benches seem to be covered with muck and turf, which fact suggests that the gravels will be frozen and require thawing apparatus.

The higher gravels, which are of wide extent and cover not only the lower slopes of the Squirrel River basin but also extend both up and down the stream along the Kobuk, present problems that are much more difficult to interpret. The origin of these gravels can be solved only by a general survey of a large area in the lower part of the Kobuk Valley, supplemented by numerous good sections of the deposits by means of prospect shafts. The character and distribution of these high-level gravels strongly suggest that they have not been formed by normal fluviatile action. There is a possibility that they may mark marine deposition, but it seems more probable that they are the outwash deposits from ancient glaciers which at one time occupied the more eastern part of the Kobuk Valley. If this interpretation is correct, there is small probability that economically profitable placers will be found in these gravels. Although outwash deposits may contain gold, it is believed that normally the valuable minerals are so disseminated that, except under conditions of subsequent concentration, the valuable minerals can not be profitably extracted. These high-gravel plain deposits consist largely of rolled quartz pebbles. No striated fragments or other marks of direct glaciation were observed. The condition of these gravels with respect to frost is not known. As a rule, gravel deposits at any considerable elevation above the adjacent streams are so well drained that they are not permanently frozen. At several places where these gravels are exposed in the valley walls of the tributary streams there are indications that they are not frozen. These places, however, are not conclusive as to the conditions of the gravels in the intermediate area between two streams, where the gravels are not exposed to the light and air and where the groundwater level rises so that the gravels are not as well drained. From the character of the surface in some of these less well-drained areas it seems certain that permanently frozen ground will be encountered.

No prospecting of the deeper gravels that form part of the flood plain of the main Squirrel River has been done, so that no definite information as to the presence of placer ground is available. It is understood that prospectors have found colors of gold on many of the bars and in shallow holes which did not reach bedrock. The ground was frozen and the necessary machinery for exploring the deposits was not at hand, so that the deep ground was abandoned for the more easily worked shallow creek diggings. From the experience on Seward Peninsula it seems questionable whether important placer gold deposits will be discovered in these flats. It should be reiterated, however, that the data for basing a decision are inadequate, and the above suggestion is little better than a guess, warranted only by the desire to prevent the reckless expenditure of time and money on ill-considered projects.

NOATAK BASIN.

EXTENT OF PROSPECTING.

There are no placer mines in operation in the entire Noatak basin. During the rush to Alaska following the gold excitement of 1898 the basin was visited by prospectors. None of the early nor the later comers, however, discovered deposits of sufficient promise to tempt them to attempt development, and when the region was visited in 1911 even prospecting had practically ceased. Here and there in the lower 200 miles of the river abandoned cabins were seen which had been the homes of these gold seekers. A short distance below the Noatak Canyon was seen one of these cabins that had been abandoned but recently. A well-worn trail led to a near-by creek and there were evidences that placer prospecting had been in progress rather recently, but no information concerning the results of this work could be obtained.

Although it is doubtful whether more than a few hundred dollars' worth of gold has been mined in the entire basin it is believed that the region has not been adequately prospected. Numerous stories of rich finds indefinitely located are of course heard, but there are only two places where placer gold is known to have been found. These are in the headwaters of the river on Lucky Six Creek and near Midas Creek in the vicinity of the camp of August 2. The few facts regarding these two areas are given in the following pages.

LUCKY SIX REGION.

Lucky Six Creek is a stream joining the Noatak from the east about 12 miles in an air line south of the camp of July 23 at the mouth of the tributary of the Alatna heading in the pass to the Noatak traversed by the Survey expedition of 1911. Gold was discovered on this stream in 1898, and from time to time since then small parties of prospectors have visited the region. This place is so inaccessible, however, that the miners have spent only a few days there. Not only is the region inaccessible, but it is also difficult to prospect for lack of timber. It is reported that the planks used for making sluice boxes were whipsawed by hand on Reed River of the Kobuk basin nearly 30 miles away and were hauled by dogs and men to Lucky Six; there were no logs for cabins and consequently the prospectors lived in tents. Although now that more of the geography and resources of the region are known, it has been found that spruce can be obtained in the Alatna Valley not more than 12 miles in an air line from Lucky Six Creek, yet the labor of transporting the lumber even this distance and over a divide at least 1,000 feet high is a great tax on time and energy. Even wood for fuel is scarce and is mainly green alder and willow.

The Lucky Six basin was not surveyed, but the general geology was learned from a study of the stream to the north. This creek, known as Twelvemile Creek, is not more than 10 or 12 miles long. For half a mile or so above the mouth the stream meanders on the outwash gravel plain of the main Noatak. Farther up, the stream enters the hills and the river lies in a narrow precipitous gorge incised in bedrock and early glacial deposits. In this part the creek is not more than 50 feet wide, even during times of high water, but it is a roaring torrent with its bed full of huge bowlders that make crossing difficult. Still farther up, the gradient of the valley decreases, but in the headwater regions the slope again increases.

Geologically the Lucky Six region presents many problems. Various kinds of rocks occur in intricate relations. The larger part of the bedrock appears to have originally been a sediment that was subsequently metamorphosed. No masses of the granite were seen in place, though dikes were reported by prospectors and may exist in the more remote parts of the valley that were not explored. Limestones form a considerable part of the divide north of Twelvemile Creek and appear to have a general east-west trend. The direction of the structure in the schists, however, is not constant, though it, too, appears to strike east and west and to dip north.

Gravel and partly rounded morainic material extend to an elevation of 1,200 feet above the creek, or 3,600 feet above the sea, but it is not in this material that the gold values are reported to have been found. Instead, the gold is said to occur only in the cracks and crevices of the bedrock in the creek or in the very shallow present-day creek gravels. All the gold is said to be notable for its coarse size and the absence of fine flaky pieces. It is described as shaped like "pumpkin seeds," has a reddish color, and assays about $19.20 an ounce.[1]

During 1911, while the Survey party was in this region, three prospectors were met who intended to spend the winter in prospecting. They had started up Alatna River in a light-draft steamboat with supplies for two years, but about 40 miles above the mouth the boat had been stopped by low water. They therefore decided to make a rapid reconnaissance of the region and await the freeze-up before moving their supplies to the Noatak. Consequently the men, with supplies for a month, visited the headwater region and did a little surface prospecting. This work was of a decidedly superficial nature, but it is understood that the returns were not sufficient to induce the men to hold to their original plan of wintering at this place.

MIDAS CREEK REGION.

From the same prospectors noted in the preceding section, one of whom, William McCarmant, had been in the headwater region of the Noatak in 1904, it was learned that placer gold had been obtained on Midas Creek, a tributary from the north joining the Noatak near the camp of August 2. The gold was reported to have been found in small particles, all of which were rather well worn. During 1911 the Midas Creek region was again visited by these prospectors and

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[1] Lloyd, L., unpublished letter.

although their work was of a superficial character certain results of significance were obtained in connection with the geologic observations made by the Survey party. It seems that much disseminated gold in fine particles was found in the creek and ancient gravels of the Noatak, both north and south of the river, but that the gravels of the tributaries of Midas Creek that are derived entirely from the hills north of the camp of August 2 are not auriferous. From the geologic study of the rocks forming these hills it is believed that they are younger than the metamorphic schists and belong to the group called in this report the Noatak sandstone. The older rocks that are more likely to be mineralized apparently form the bedrock to the south and underlie those forming the hills in which Midas Creek rises. It is therefore believed that the gold reported to have come from Midas Creek was derived either from the older rocks forming the southern part of the basin or else that it may have come from the outwash gravels which have been transported for long distances. These ancient gravels have been recognized up to an elevation of 850 feet above the mouth of Midas Creek and they are believed to have been mainly of glaciofluviatile origin.

Some prospecting has also been done south of the Noatak opposite Midas Creek. Although it is reported that small colors of gold were found at many places, the abundance of large bowlders in the streams makes prospecting difficult without numerous appliances not easily procurable in this remote region. The bedrock south of the Noatak at this place appears to be similar to that generally present in the better-known placer regions of the Seward Peninsula. Where the undifferentiated limestones form the hills, however, the probability of finding productive placers seems slight.

KOYUKUK BASIN.

MAIN STREAM.

According to Schrader,[1] "Placer gold has been known in the Koyukuk basin since the early nineties, if not before. It was first discovered in the bars of the river, of which the most noted seem to have been Hughes and Florence bars, both far below the present placer diggings." At the present time, however, no mining of any of these deposits is in progress, and it is probable that the production of gold from this source has been small. Maddren[2] estimates that about $4,000 in gold was won from these two bars. Little is known of the origin or mode of occurrence of these placers. From prospectors' reports it appears that the gold was in very small pieces and had evidently been carried for a considerable distance. It is important

[1] Schrader, F. C., A reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 98.

[2] Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 297.

to note, however, that during 1911 placers were found on a tributary stream about 30 miles distant in the same general belt of rocks which outcrops near the river at these bars. This fact suggests that the gold may have been derived from the group of rocks that has been provisionally mapped as belonging to the Koyukuk group.

The main Koyukuk placer region lies outside of the area discussed in this report and therefore will not be described. For an account of the geology and resources of that important region, reference should be made to the other Survey publications, notably those by Schrader[1] and Maddren.[2]

TRIBUTARY STREAMS.

In the Hogatza basin colors of gold are reported to have been found by prospectors in some of the stream gravels. No productive areas, however, have been discovered and no prospecting is in progress.

On the headwaters of Indian River, a stream entering the Koyukuk near Florence bar, some placer mining has recently been begun. Little is known of the geology in this region. The bedrock is reported to be slate and granite and the gold occurs in shallow stream gravels. The bedrock is so disintegrated or decomposed that it can be easily shoveled into the sluice boxes and separated from the gold. Brooks[3] estimates that the production from this place in 1911 was worth approximately $14,000. Only a few claims on Felix and Snyder creeks have been developed, but prospects have been located on many of the near-by streams. The productive area is reached from Hughes on the Koyukuk by an overland trail about 25 miles long. Some 50 to 100 men were in the region during 1911, but only a few were actually engaged in mining.

The next upstream tributary on which placer has been found is the Alatna. Prospectors visited this stream in 1898 and at intervals later. A little placer gold was found in some of the gravels in that part of the valley where the southern belt of undifferentiated metamorphic schists occurs, but the indications were not sufficiently promising to induce further work and the region is now practically abandoned by prospectors.

On Mecklenberg Creek, a small tributary of Malemute River, which in turn flows into the Alatna and traverses this same general belt of undifferentiated metamorphic schists, a prospector reports having found colors of gold in the creek gravels. This locality was not visited and nothing of importance was learned of the occurrence, but no workable deposits have been developed. The gold is in small

[1] Schrader, F. C., op. cit.

[2] Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, pp. 284-315; The Koyukuk-Chandalar region, Alaska: Bull. U. S. Geol. Survey No. 532, 1913.

[3] Brooks, A. H., The mining industry in 1911: Bull. U. S. Geol. Survey No. 520, 1912, pp. 38-39.

particles, very few of them flaky, and is of a reddish color. No black or rusty gold was reported. In the concentrates magnetite is very abundant but garnets are only sparingly found.

Some prospecting in the Alatna basin has also been carried on in the belt of undifferentiated metamorphic schists north of the larger area of undifferentiated limestone, where the dark slates form the country rock. Two prospectors living on the Kutuk have found sufficient prospects on this stream to cause them to continue exploration, but no gravels of workable value have yet been discovered. Work at this place has been carried on only in the shallow gravels of the present stream. It is believed that the gold has been derived from quartz stringers and veins in the slate. Magnetite is abundant in the concentrates, but garnets are practically absent.

Very little prospecting has been done on John River. Schrader[1] states that "Colors were obtained here by the writer from gravels in the mouth of a small creek near the northern edge of the Totsen series" (the southern area of undifferentiated metamorphic schists). In a subsequent report Maddren[2] states:

> Crevice Creek, which lies in these rocks [schists] on the east side of the river [John River], and Fool Creek and its tributaries, on the west side, are the only localities where encouraging prospects have been found up to this time [1909]. About $1,800 worth of gold was mined on Crevice Creek in 1904 and good prospects were found on Midas Creek, a tributary of Fool Creek, in 1905, but these discoveries have not led to further development.

There seems little room to doubt that the valuable minerals in the known placers on both John and Alatna rivers have been derived from the undifferentiated metamorphic schists and their included veins. The only igneous intrusives or effusives near the placers are the greenstones.

GOLD LODES.

At the present time no lodes have been developed to a producing stage in the region, and there are very few places where even prospecting has amounted to much more than the annual assessment work stipulated by law. As usual, one of the troubles has been due to the prospectors overburdening themselves with more claims than they could handle, so that their efforts have not been concentrated on any particular place. Consequently, so far as affording information about the lodes is concerned, the prospecting has been largely valueless, and one examining the region is forced to rely mainly on natural exposures of the possible lode deposits. Indications of mineralization occur at many places, but the general inaccessibility of the region and the high valuation set on many of the prospects do not invite the investment of outside capital. Without abundant funds the developments are hampered, and many of those attempted are ill directed.

[1] Schrader, F. C., op. cit., p. 101.

[2] Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. U. S. Geol. Survey No. 442, 1910, p. 314.

KOBUK BASIN.

On the divide between Dahl and Riley creeks there are numerous veins in the black slates and schists. Most of these veins are small stringers, but some lenses 18 inches to 2 feet in width were noted. In one vein in particular on this divide specks of gold are reported in the quartz and a shallow prospect hole had been dug. The broken quartz from this hole had been panned, and numerous small particles of gold are said to have been obtained. On the northern slopes of this ridge, and continuing as far as the placers on Riley Creek, there is heavy quartz float all over the surface. In many pieces of the float fine gold is visible, and some pieces containing several dollars' worth of gold are reported to have been found. The auriferous quartz from this place is mostly of a dense texture and a greasy white color. Sulphides are almost entirely absent. In places the quartz is iron stained, but the discoloration is not present everywhere or in considerable amounts. The quartz in places shows indications of a comb structure, and does not seem to have been recrystallized or badly smashed. On account of these characters it is believed that the veins from which this quartz was derived belong to a series formed later than the maximum period of regional metamorphism. This interpretation is further supported by the greater continuity of these veins as compared with those in the oldest schists. It is believed that these quartz veins are intimately connected with the local placers on Riley Creek and that they are the sources from which the placer gold was derived.

An attempt to interest outside people in developing this gold quartz has so far proved unsuccessful. From the character of the exposures of quartz veins in the immediate vicinity it appears that the treatment of the vein material would require the handling and milling of a large amount of the country rock as well, and this would necessarily reduce the gold tenor. The question whether these veins can be worked is answerable only by careful and extensive sampling of the kind of material that must be mined and milled if the project is developed commercially. It is evident that picked specimens are absolutely worthless in arriving at the valuation; the samples of the vein material alone are likewise misleading.

There are many other places where veins similar to those at the the head of Dahl Creek have been seen, and it is by no means improbable that they, too, carry some free gold, although in the hurried examination it escaped detection. These veins are more numerous in the areas occupied by the black slates, especially near the base of the limestones. The distribution appears to be dependent on the physical features of the slates, but the deposition of gold may have been due to chemical reactions induced by the presence of carbonaceous material throughout these rocks.

From a recent newspaper clipping it is learned that a quartz vein has been located on Hunt River near the Jade Mountains. Picked specimens from this place are reported to have yielded over $100 a ton in gold. Nothing further, however, is known about this discovery.

ALATNA BASIN.

During the early rush into the Koyukuk some quartz veins were found in the belt of undifferentiated metamorphic schists in the central part of the Alatna basin. These were staked and held for several years, awaiting the expected boom. Practically no work was done to open up the leads, and when the place was visited in 1911 a few insignificant pits, driven on small iron-stained quartz stringers, were all that could be recognized of the early work, and the place has apparently long been deserted.

Schrader notes that in 1902–3, in the divide between the Alatna and Noatak, prospectors reported lode deposits carrying high gold and copper values. The veins were said to consist essentially of quartz with pyrite and chalcopyrite, but some specimens contained stibnite also. The location of the veins was very indefinite and they were not seen in 1911. The fact, however, that the highest assays made by the Survey of the specimens brought out by the prospectors carried less than $2 a ton in gold, as well as the fact that no work has been done recently in the region, shows that the tenor was not sufficient to warrant development under the high costs prevailing in the upper Alatna Valley.

NOATAK BASIN.

As in other regions, reports of lost prospectors finding enormously rich deposits are common. Unfortunately, however, these "finds" can not be located when subsequently sought and their value tends to increase the less that is known about them. An instance of this sort was the reported discovery of rich gold quartz in the vicinity of Mount Kelly, a hill about 40 miles north of the camp of August 19. On attempting to learn about this gold quartz it was found that the locality was extremely indefinite, varying from the Igichuk Hills near the mouth of the river to the region beyond the Noatak drainage. It is not intended by the above remarks to cast doubt on the fact that gold-bearing quartz may have been found in the Noatak basin, but only to point out that with such indefinite location it is not possible to discuss the significance of the reported discovery. From the little that is known about the geology in the vicinity of Mount Kelly north of the Noatak, it seems probable that extensive deposits of economic value are absent, for the region is probably formed of the higher Paleozoic sediments, which as a rule are but little mineralized. There is, of course, the possibility that the pronounced deformation that is known to have affected the region may have raised the higher beds, so that they have been removed by erosion and the older schists, which are usually more or less mineralized, may have been exposed.

Another occurrence of gold quartz has been reported from the hills south of the river, a short distance east of the canyon. A prospector, with pack horses from Squirrel River of the Kobuk basin, spent part of the fall and winter of 1910 in the hills north of Squirrel and Salmon rivers and returned with numerous specimens of quartz, some showing free gold. It was not possible to obtain a description of this trip at first hand and consequently most of the information is indefinite. That the prospector was satisfied with the indication of mineralization was shown by the report that he intended to return and carry on further exploration during the winter of 1911–12. Presumably the region has schists and metamorphic limestones as the country rock. These have usually proved auriferous.

COPPER LODES.

KOBUK BASIN.

Lodes carrying copper sulphides have been prospected at several places in the Noatak-Kobuk region, but the only systematic attempts to exploit the veins have been made in the Kobuk basin. At two places attempts have been made to prospect copper lodes, but at neither have the explorations been sufficient to determine the extent of other geologic relations of the ore. One of these prospects is located on the west side of Ruby Creek, about 5 miles from the junction of that stream with Shungnak River. The other lies west of the left fork of Ruby Creek, near the head of Cosmos Creek. A low limestone hill, locally known as Aurora Mountain, is the center around which the claims at the latter locality are grouped, and this name will therefore be used to designate that locality.

Copper-bearing leads on Ruby Creek have been known for many years and were critically examined in 1906 by experts in private employ to determine their commercial value. Conditions at that time prevented the purchase of the properties, and only a small amount of work has been done recently. Owing to the length of time that has elapsed since active work was in progress, many of the pits and open cuts have caved and filled to such an extent that they afford poor opportunity for examining the deposits and adjacent rocks. In this part of the Ruby Creek valley on the lower slopes there is a heavy covering of talus and vegetation, so that without pits and other sections many important facts are indeterminable.

Mineralization on Ruby Creek appears to be confined to a brecciated zone or zones in the limestones. Sulphides have been deposited in the open spaces thus formed and the ore-bearing solutions have penetrated the limestone along many cracks and crevices and have in part replaced it. There is some brecciated dolomite at the mine, and this also has been replaced and intersected by sulphides. The sulphides of economic importance are mainly bornite and chalcopyrite, but galena and iron pyrite were also noted. In the surficial part of the deposit both the blue and the green copper carbonates are common. Limonite, derived from the weathering of the pyrite, in several places forms a gossan, or "iron hat," several feet thick over the sulphide-impregnated limestone. It is reported that the weathered material when panned yields colors of gold. Average pans of the gossan from an open cut above the main workings are said to give from 1 to 3 cents in gold. Assays are reported to have yielded as much as 11 per cent of copper, but no details were obtained as to the manner in which the samples were taken.

The main developments on the northernmost property consists of an adit and two open cuts. The mouth of the adit is only a few feet above the high-water level of the creek. The tunnel has been driven about 40 feet through a much slickensided and fractured limestone, in places showing mineralization. Two short drifts, totaling only about 30 feet in length, followed especially strong indications of mineralization but evidently soon passed out of rich ore. The walls stand fairly well, but caving of the surface has so blocked the mouth of the adit that 12 to 18 inches of water stands on the track. A boiler was brought in from the Kobuk by way of the low pass at the head of Wesley Creek by a team of 70 dogs. When work was started, a home-made mine car was used to tram the broken rock away from the working face, but a new automatic dumping car has since been installed. Wooden rails are, however, still in use. Natives have been employed as muckers and for the simpler mining operations are said to have given satisfaction.

On the hill at an elevation of about 150 feet above the adit an open cut about 30 feet long and 10 feet or more wide had stripped the surface and had cut into the bedrock to a depth of 5 to 7 feet. Most of this pit was covered with caved surficial material, so that little could be seen. The mineralization seemed to be essentially the same as that exposed in the adit. Although the bedrock in the open cut is limestone it differs in some respects from that exposed in the tunnel, for none of the dolomitic phase was recognized and in places it seemed to be darker and suggested correlation with a higher horizon. However, there has been so much dislocation that the structure was not determinable and in the absence of fossils the above suggestion is to be regarded as little better than a guess.

At about the same elevation above Ruby Creek as the adit already described, and 200 to 300 yards southeast of the open cut on the hill, another open cut about 30 feet long has uncovered a zone of mineralization. The mode of occurrence is essentially the same as that at the two other places, but only the upper weathered portion has been exposed. Copper minerals are less abundant here, but there is more limonite. Sulphides were but sparingly seen; the iron occurred mainly as oxide and the copper mainly as carbonate. It is reported that samples of the ore from this cut have a higher accessory gold content than that from either of the other two places.

At a locality in Aurora Mountain, about 3 miles west of the Ruby Creek copper leads, the geologic structure is essentially synclinal; brecciated and deformed limestone forming the top of the hill lies above a series of dark slates and schists that form the lower slopes. Near the contact between the two rocks, but occurring almost invariably within the limestone, are indications of sulphide mineralization. The surface of the hill is so covered with frost-riven talus of limestone that except in artificial cuts the rocks are not exposed in place. Here and there copper carbonate float is found in considerable abundance.

Developments on Aurora Mountain consist mainly of holes dug through the overlying mantle of detritus in places where the copper float is particularly abundant. The only prospecting of this sort that has been carried to any considerable extent is on the northeastern slope of the hill about 300 feet above the contact of the limestone and schists. Exploration at this place at first consisted in sinking a shaft on the uphill side of a particularly conspicuous area of carbonate float. At the time this place was visited in 1910 the shaft was partly filled with water and its walls were so covered with ice that they could not be examined. It was reported that the shaft was about 22 feet deep and intersected a fairly promising copper lead about midway between the surface and the bottom. The bottom of the shaft is also said to have shown some good ore. Samples from the lower part of the shaft show bornite and chalcopyrite as well as carbonates.

Owing to the difficulty of mining the shaft was abandoned and a crosscut at about 250 feet lower elevation was commenced to connect with the deepened shaft. This adit was about 30 feet long, and it will be necessary to extend it over 250 feet to reach a point directly underneath the shaft. Throughout its length the adit is in barren brecciated limestone, in few places showing any mineralization. Slickensiding is evident at many places, but although the amount of throw was not determined it probably was not very great, as different rocks were not brought into juxtaposition. In spite of the brecciation and faulting the rock stands well, and it has been necessary to timber only the entrance to the adit, where it passes through the surface detritus.

Analyses by Thomas Price & Co.[1] of picked specimens of the bornite are reported to show 0.04 ounce of gold per ton, worth about 82 cents

[1] Lloyd, L., unpublished letter.

and 1.4 ounces of silver per ton, worth about 91 cents, in addition to the copper content. Assays by the same analysts of chalcopyrite from Aurora Mountain yielded 0.01 ounce of gold per ton, worth about 20 cents, and a trace of silver in addition to the copper. Neither at Ruby Creek nor at Aurora Mountain, however, does the sulphide mineralization seem to have produced auriferous placers. In Ruby Creek colors of gold have been found, but at Aurora Mountain no placer gold has been reported in the stream gravels.

Although the Ruby Creek and Aurora Mountain localities are the only ones where prospecting has been carried on, there is probably similar mineralization at many other places. In fact, mineralization near the contact of certain of the limestones and schists has been recognized all the way from Seward Peninsula to this region. So far prospecting has failed to show that any of these deposits either in Seward Peninsula or in the Kobuk region are workable.

Until the mode of origin and the general characters of ore bodies of this type are fully understood it seems unwise to do much dead work, such as running long crosscuts to intersect a possible ore body in depth. Even after a considerable body of ore has been disclosed a careful scrutiny of the costs of mining in this remote and rather inaccessible region should be made before expensive permanent mining machinery is installed. Although these facts should not discourage intelligent prospecting, they should serve as a warning that the search is likely to be expensive, as the cost of preliminary investigation will be high.

MISCELLANEOUS LOCALITIES.

Veins carrying copper and silver ores are reported by a prospector in the Noatak region. The silver ore is said to occur on the north side of the Kobuk-Noatak divide between the Reed and Maunneluk River portages. No description of the geology nor mode of occurrence was learned. The same prospector [1] reports that farther west, on the Noatak side of the pass from Kogoluktuk River, there is a considerable deposit of copper ore, and float of native copper is found in some of the streams. This place is probably in the headwaters of Ipmiluik River, a tributary of the Noatak near the camp of August 1. Assays are stated by Mr. Lloyd to have shown 9.81 per cent copper and 27.73 per cent lead; the samples, however, were not representative but selected specimens. This ore is said to carry also some gold and silver. An assay of ore from what is supposed to be a continuation of this same vein on the Kobuk side of the divide is reported to have yielded gold and silver to the value of $1.24 a ton. No work has been done at this place, and in fact it was only discovered and a few samples taken during a hurried trip from the Kobuk to Lucky Six Creek.

[1] Lloyd, L., unpublished letter.

In the Koyukuk region, in addition to the copper sulphides already noted in the veins on the Alatna, Schrader [1] states that—

the principal specimens [of copper-bearing rocks] seen by the writer during the recent work consisted of water-worn fragments found in the John River gravels and derived apparently from the quartz veins. They contained some copper pyrites and a little bornite * * *. What is supposed to be a vein of considerable size containing iron and apparently copper pyrites was observed in a steep limestone cliff of the Skajit formation overlooking the river, where no examination or collection could be made.

COAL DEPOSITS.

KOBUK BASIN.

Coal deposits in many parts of northwestern Alaska have been described. In the Noatak-Kobuk region, however, the only place outside of Seward Peninsula where coal has been mined is near the mouth of the Kallarichuk on the Kobuk. This place was described by Stoney [2] as follows:

On my second trip to the Putnam [Kobuk] I discovered a vein of bituminous coal outcropping on the north side of the river about 90 miles from the mouth. I tried a lot of it in the furnace of the steam launch with very satisfactory results, though it had long been exposed to the weather. The vein was between 2 and 3 feet thick and dipped at an angle of 30° from the river.

Cantwell also tried some of this same coal in his launch, but the results were not satisfactory. Mendenhall also examined these beds and reported that—

the coals occur in low bluffs along the river, interbedded with conglomerates and fire clays. Those sufficiently well exposed for examination are of poor quality and burn slowly, yielding abundant ash and the disagreeable gases which are characteristic of impure lignites. So far as determined none of the coals outcropping here are more than 2 or 3 feet in thickness, and the majority of the seams are much thinner. Half a dozen, with a thickness of 6 or 8 inches, were examined during the reconnaissance.

During the recent development of placer mining in the adjacent Squirrel River basin some of this coal has been mined and transported for local use. In fact, a few sacks have even been carried as far as Dahl Creek, near Shungnak, for the use of the prospectors. A sample of this coal was submitted to the Bureau of Mines for analysis, with the following result:

Analysis of coal from the Kobuk basin, Alaska.

[No. 793, Laboratory No. 11097, Nov. 3, 1910. A. C. Fieldner, chemist. Air-dry loss, 2.40.]

	As received.	Air dried.	Moisture free.	Percentage referred to coal less ash and moisture.
Moisture	10.50	8.30	....	....
Volatile matter	28.95	29.66	32.35	35.36
Fixed carbon	52.94	54.24	59.15	64.64
Ash	7.61	7.80	8.50	....
	100.00	100.00	100.00	100.00
Sulphur	0.41	0.42	0.46	0.50
Calories	5,852	5,996	6,538	7,145
British thermal units	10,534	10,792	11,534	12,861

[1] Schrader, F. C., op. cit., p. 104.

[2] Stoney, G. M., Naval explorations in Alaska, 1900, p. 80.

From the above analysis it is evident that the coal is a good grade of bituminous coal with a rather high efficiency. Of the Alaskan coals it most closely resembles Cretaceous coal from the vicinity of Circle and Nulato.

Some lignite was observed in the Cretaceous sandstones of the Lockwood Hills near Pah River, and coal float has also been reported on the lower part of the Ambler and on the Kogoluktuk. These localities are all in the belt of Upper Cretaceous and Eocene rocks, so that coal beds may be looked for in these rocks. So far as known, however, none of the coal beds in these rocks in this part of Alaska have proved to be of great value. The following statement [1] taken from a report of a region of similar rocks farther south, though summarizing the conclusions regarding the coal resources of that area, is equally applicable to the Noatak-Kobuk region.

> From the fact that so far there is no productive mining on any of the coal-bearing rocks outcropping along the Yukon within the mapped area, it seems improbable that workable beds in the same series of rocks will be developed in the immediate future in the more remote regions, where transportation facilities and markets are wanting. Although thicker beds may be found here and there, the additional cost of transportation for each mile that the deposit lies back from the river or from some other cheap avenue of communication increases much more rapidly than the thickness of the bed could be reasonably assumed to increase.

Of course in those places where there is a local demand for coal, such as in the vicinity of active mines, the value of a near-by deposit is so great that a search for coal in the adjacent areas of Upper Cretaceous and Eocene rocks is not only warranted but necessary.

MISCELLANEOUS LOCALITIES.

Schrader [2] states concerning the presence of coal on John River:

> Coal detritus in considerable quantity and of a character to suggest the probable occurrence of coal of economic value somewhere in the region north of this locality was seen in the John River gravels near the base of the Endicott Mountains. This coal may apparently with safety be called a good grade of bituminous. It breaks with conchoidal fracture and has a bright shiny or glossy black surface.

This coal probably comes from the Bergman group of rocks along the southern flanks of the mountains and has the same relations as the coal from the Kobuk previously described.

In the Colville basin coal has been reported at several places. The coal deposits seen by Schrader in the Upper Cretaceous to the north of the mountains lie outside the area covered by this report and their description will therefore be omitted. According to Lieut. Howard,[3] coal was found on the Colville nearly due north of the camp of August 1 of the expedition of 1911. This place was described as follows:

> During the forenoon we passed a hill about 500 feet in elevation, with outcrops of coal. On the sides of this hill beyond the coal were also found pieces of a substance

[1] Smith, P. S., and Eakin, H. M., Bull. U. S. Geol. Survey No. 449, p. 141.
[2] Schrader, F. C., op. cit., p. 107.
[3] Stoney, G. M., Naval explorations in Alaska, 1900, p. 69.

called wood by the natives. It was hard, brittle, light brown in color, very light in weight, and burned readily, giving out quantities of gas. This material was scattered about in all shapes, sizes, and quantities.

In the Colville basin, according to Schrader,[1] two prospectors found coal on the Killik and used it for their camp fires. Unfortunately the position of this stream and its coal deposits is not definitely known, though Schrader indicates that the Killik lies somewhat to the north of Chandler Lake.

Farther west, in the Cape Lisburne region, coal is known to occur in the lower Carboniferous (Mississippian) rocks, so that possibly similar deposits may occur in these rocks where exposed in the Noatak basin. No coal beds nor even coal float were seen, however, and it is probable that this part of the Mississippian series does not outcrop near the river.

Near the mouth of the Noatak, not far from the camp of August 25, a prospector reported finding a recent deposit of material that he has used as fuel. Specimens from this place show a dark-brown, compact material that burns readily in the flame of a match and gives out considerable smoke and oil but leaves practically no ash. David White, who examined the material, reports that the specimen is composed entirely of large fern spores and resembles the so-called "bogheads." This deposit was not seen in place and no facts as to its extent or relations were learned. If there is enough of it the deposit should have considerable value as a local fuel.

DEPOSITS OF OTHER MINERALS.

In addition to the foregoing deposits there are others of lesser extent or value or concerning which but little is known. Thus, stibnite is said to have been found in certain of the lodes that were noted on Alatna River.

LEAD.

Galena has been found in small quantities associated with the copper sulphides at both Ruby Creek and Aurora Mountain near Shungnak. A small amount of vein quartz and some brecciated and recrystallized dolomite with galena was seen near the high hill west of Wesley Creek in the same region. A shallow prospect hole has been sunk on this stringer, but so far the indications are not at all promising.

IRON.

At places in the Kobuk region magnetite in masses as much as a hundred pounds or so in weight has been found on the surface, especially near the limestone and schist contacts. Float of this sort is particularly abundant on the slopes of the sharp conical hill locally known as Iron Mountain, east of the pass between Cosmos Creek and the left fork of Ruby Creek. Specimens from this place show a

[1] Schrader, F. C., op. cit., p. 31.

nearly pure magnetite with here and there drusy cavities lined with small octahedral crystals of this mineral. As the magnetite has not been seen in place, speculation as to its origin is hardly warranted. There are no near-by igneous rocks, so it seems improbable that these bodies are due to contact-metamorphic effects. Owing to the occurrence of limonite and hematite bodies in similar limestones in the Solomon region of Seward Peninsula, a tentative suggestion is that the magnetite of the Shungnak region may have been formed by the metamorphism of similar iron oxides which were laid down either contemporaneously with the inclosing limestones or earlier than the great period of dynamic metamorphism. The magnetite shows no signs of having been sheared, so it must have been either entirely recrystallized or deposited subsequent to the period of regional deformation.

Whatever theory of origin of these ores proves to be the true explanation probably matters little, for the deposits so far as known have but slight economic value. The high operating costs, coupled with the absence of large ore bodies, will necessarily deter capital from undertaking their development.

ASBESTOS.

Some attempts have been made to mine asbestos near Shungnak. This mineral is found in more or less close association with the greenstone intrusives. Several holes have been made in ledges of this rock on the east side of Dahl Creek above the upper placer mines, and samples of the asbestos have been submitted to manufacturers. It is reported, however, that the asbestos, although of good color, has slight tenacity, so it is not suitable for making high-grade articles and therefore commands a low price. For ordinary purposes this asbestos is well suited, but the small amount paid for this grade is not sufficient to meet the transportation charges. Furthermore, the quantity so far discovered is small, and it would therefore be expensive to mine.

JADE.

In almost all the streams of the Shungnak region north of the Kobuk bowlders of a hard, green, slightly translucent rock are plentiful. These are commonly called jade, but this determination is probably incorrect. A complete examination has not been made, but most of the pieces are undoubtedly serpentine, others are green quartzite, and still others are probably nephrite. The last-named mineral is closely akin to jadeite but is an amphibole instead of a pyroxene. The two may usually be distinguished with the hand lens or by specific gravity tests, for jadeite is granular and has a specific gravity from 3.01 to 3.32, whereas nephrite is fibrous and has a specific gravity of less than 3. None of the nephrite seen was of gem quality. The imperfections were due to cleavage, which makes the rock split into thin layers, and to inclusions of other minerals, notably magnetite, which spoil the translucency and give the stone a spotted appearance.

Stoney collected specimens of the jadelike rock and submitted them to expert examination. The report describing the various samples is as follows: [1]

Analysis of jade from Kobuk basin.

[Analyst, F. W. Clarke.]

	A	B	C	D
Ignition	1.78	1.38	1.76	1.73
Silica	58.11	55.87	56.85	57.38
Alumina	.24	2.07	.88	.19
Ferric oxide	5.44	5.79	4.33	4.43
Ferrous oxide	.38	.38	1.45	1.25
Manganous oxide	Trace.	Trace.	Trace.	Trace.
Lime	12.01	12.43	13.09	12.14
Magnesia	21.97	21.62	21.56	22.71
	99.93	99.54	99.92	99.83

A. Greenish-gray, splintery, lamellar in structure.—This sample as seen in the slide and by ordinary light presents a uniformly colorless field of a homogeneous non-pleochroic mineral and is transversed by fine wavy rifts running all in the same direction. The inclosures are very minute; some are mere dustlike particles, others are distinctly recognizable as limonite. Between crossed nicols the entire field is covered with very indefinitely outlined areas, which are alternately light and dark as the stage is revolved. With a power of 230 diameters these areas are seen to be composed of wavy and uneven scales and bundles of fibers so interwoven and confused that no trustworthy measurements of extinction angles are obtainable. Many of the bundles seem to extinguish in directions approximately parallel with their length; but others show wide angles. * * *

B. Like A, but more granular.—This specimen in thin section and by ordinary light is also almost colorless, or very faintly greenish and without pleochroism. It shows only a few yellowish and opaque inclusions, which are evidently of a ferruginous nature. Between crossed nicols it exhibits the well-known nephritic structure—a dense aggregate of short fibers and scales, the fibers arranged in clusters, or radiating tuftlike bundles without definite boundaries, which merge into one another as the stage is revolved. In cases where these bundles are composed of fibers lying approximately parallel, angles of extinction were measured varying from 0° to 15°.

C. Paler, nearly white, closer grained.

D. Brownish, highly foliate.

Several attempts to develop the jade in the Jade Mountains west of Ambler River have been made, but so far unsuccessfully. The small and controlled market for this mineral and the inferior quality of the specimens so far found, together with the high mining costs inevitable in this rather inaccessible region, will probably prevent jade mining in these hills becoming profitable in the near future.

[1] Clarke, F. W., and Merrill, G. P., On nephrite and jadeite: Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 115–130.

CONCLUSIONS CONCERNING FUTURE MINING DEVELOPMENTS.

The foregoing account of the small amount of mining or even of prospecting in the region shows that the investigation has not been adequate and that conclusions at the present time regarding the economic resources of the region have an insufficient basis of fact and are to be regarded as little more than tentative suggestions. It seems worth while, however, to state certain observations and the deductions made from them in order that the available information and theory concerning this little-known region may be at the disposal of the prospector and investor.

From what has been said of the general geography it is evident that in a region so remote and so difficult of access and having a climate so severe, the costs of transportation, supplies, and labor are necessarily high and will not materially decrease in the near future. Fish and game may be sufficient for the need of the prospector for short periods, but there is no adequate local food supply. Even wood for fuel is absent throughout a large part of the region and timber for use in mining can be procured only in a rather small area.

Although the commercial conditions will in large measure determine the future development of the Noatak-Kobuk region, the present paper deals primarily with geologic facts, and emphasis has here been placed upon these.

The basis of the first mining development in the region will probably be gold-placer deposits rather than gold lodes or veins or deposits of other minerals. It is believed, therefore, that the regions most worthy of prospecting are those in which the undifferentiated metamorphic schists form the country rock. From the geologic map (Pl. II) it may be seen that these rocks are most widely distributed in the country between the Noatak and Kobuk and are almost absent north of the Noatak or south of the Kobuk. The intricate structure of the region and the small scale of the map preclude the representation of all the details, so that the map should be regarded as indicating only the larger geologic features rather than detailed facts having but local significance.

Another geologic fact of importance that requires much study is the history of the mineralized region. Much of the area of the Noatak-Kobuk region, occupied by the undifferentiated metamorphic schists, is a highland which in the past was covered with snow and ice and had many of its valleys occupied by glaciers. Under such conditions effective sorting was reduced to a minimum and previously formed detritus was in large measure removed. This material was so mixed with glacially eroded material that there was little or no gravitative sorting. On reaching the limits of glaciation the heterogeneous débris was deposited as the ice melted and was distributed by streams. In the region where deposition was taking place, however, concentration was not pronounced, for the dominant process was aggradation. As a consequence, although a large amount of material was being dumped by the ice and spread out by the streams, continued building up was taking place. It should also be noted that the ends of the glaciers were not stationary, but advanced and retreated almost continually, so whatever processes of concentration took place at the front were weakened by being dissipated over a considerable area.

It is therefore believed that in the distinctly glacial deposits extensive rich placers are but little to be expected or would have such an irregular distribution that they would be difficult to mine systematically. Here and there even in the glaciated areas, possibly some auriferous preglacial material may not have been eroded. Such auriferous deposits, however, would have a distinctly local distribution. Some areas of this sort may also be preserved in protected places under the mantle of outwash material. These may be of value but would be difficult to find and to mine.

With the close of the period of maximum glaciation and accompanying outwash the streams intrenched their courses in the earlier gravels and now flow at many places in rather narrow trenches a hundred or more feet below the surface of these deposits. In this process concentration of these glaciofluviatile deposits has been effected, but whether it has formed placers can be determined only by prospecting. From the assumed distribution and amount of gold in the outwash deposits it is probable that except under particularly favorable conditions this secondary concentration would not produce very rich placers. Places which should be examined by prospectors are those where this later sorting has affected deposits formed by a long-continued stand of the ice in one place or where reconcentration of material from early nonglacial deposits subsequently buried by outwash is actively in progress.

In spite of the difficulties that handicap immediate development and forbid large enterprises dependent on quick returns on their investment, it is believed that there is a large area of practically unknown country in the Noatak-Kobuk region that warrants investigation by observant prospectors equipped with easily transported, relatively inexpensive outfits.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

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The preparation and use of peat as a fuel, by C. A. Davis. In Bulletin 442, 1910, pp. 101–132.
*The distribution of mineral resources in Alaska, by A. H. Brooks. In Bulletin 345, pp. 18–29. 45 cents.
Mineral resources of Alaska, by A. H. Brooks. In Bulletin 394, 1909, pp. 172–207.
*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. 35 cents. (Abstract in *Bulletin 259, 1905, pp. 32–46. 15 cents.)
*Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.
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*Gold placers of Turnagain Arm, Cook Inlet, by F. H. Moffit. In Bulletin 259, 1905, pp. 90–99. 15 cents.

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