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A GEOLOGIC RECONNAISSANCE

IN

SOUTHEASTERN SEWARD PENINSULA AND THE NORTON BAY-NULATO REGION

ALASKA

BY

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

For several years after the organization of the Alaskan surveys in 1898 most of the appropriation was devoted to exploration. These exploratory surveys, although they had no high degree of accuracy, served to block out the larger features of the topography and geology, and the resulting reports and maps proved of great value to the pioneer prospector and miner. With the advance of the mining industry came a constantly increasing demand for maps which were based on a higher degree of refinement both with reference to geologic observation and to mensuration. To meet this demand areal surveys were begun first on a scale of 4 miles to the inch and later, where the mining interests warranted it, on a scale of 1 mile to the inch. The rapid industrial advancement in many parts of Alaska led to the expansion of surveys of this character almost to the exclusion of the purely exploratory work.

The progress made in reconnaissance and detailed surveys has seemed to warrant again diverting a part of the funds to exploring some of the little known regions. One of the largest of the unsurveyed areas in the more accessible parts of Alaska is roughly blocked out by lower Yukon and lower Koyukuk Rivers on the east and Norton Bay and Seward Peninsula on the west. This field was selected for survey because it was thought that the metamorphic rocks of the Seward Peninsula might occur within it, which would give presumption of the presence of auriferous deposits. The results of the investigation of this area are presented in this report.

In addition to exploring the region east of Norton Bay the party also extended the topographic and geologic mapping into the southeastern part of the Seward Peninsula, thus extending the surveys of Peters and Mendenhall, made in 1900. In this part of the field the results were sufficiently definite to warrant their publication in a map on a scale of 4 miles to the inch. The remainder of the survey, based as it was on foot traverses, which afforded little opportunity for areal mapping, seemed hardly sufficiently accurate to warrant the publication of maps on a larger scale than 16 miles to the inch.

Messrs. Smith and Eakin deserve great credit for the large amount of information gleaned during their very hasty exploration. The results form a notable contribution to the geology and geography of a region that was previously almost unknown. Though the economic results so far as most of the region is concerned are largely negative, they are, nevertheless, of no inconsiderable value. The geologic maps will indicate large areas which do not seem worthy of attention on the part of the prospector.

Besides covering the Norton Bay and lower Yukon region in an exploratory way, the report and its maps furnish the details about the southeastern part of the Seward Peninsula necessary to complete the reconnaissance work in that province. The publication of this report marks the close of the reconnaissance work in the Seward Peninsula which was begun a decade ago.

A GEOLOGIC RECONNAISSANCE IN SOUTHEASTERN SEWARD PENINSULA AND THE NORTON BAY-NULATO REGION, ALASKA.

By Philip S. Smith and H. M. Eakin.

INTRODUCTION.

West of Koyukuk and Yukon rivers a large area has long remained geologically unexplored. In a portion of this region an exploration party from the United States Geological Survey worked during the season of 1909, and the results of the studies there carried on and extended as far as Council, in Seward Peninsula, are set forth in this report. The party consisted of the writers, A. G. Winegarden, packer, and a cook. Supplies for a month were shipped to Nulato, the point from which the expedition set out, and the camp equipment and supplies were transported in the field by a pack train of four horses. Other supplies, sufficient to last the rest of the season, were sent to Nome and then transported, through the courtesy of the Wild Goose Company, to the mouth of the Koyuk and there cached to await the arrival of the party.

After many delays the party arrived in Nulato on the afternoon of June 24 and immediately began to get the outfit into condition for the trail. On the morning of June 26 active field work was begun. The route, as indicated by the location of the camps on the maps (Pls. I and V, in pocket), was westward to Ungalik River, thence northward to the Koyuk, which was reached on July 16. Here a halt was made until supplies from the cache could be obtained and the outfit put into shape for the next trip. On July 19 the party started northeastward along the divide between the Inglutalik and the Koyukuk drainage basins. This survey was carried eastward to the divide between Kateel and Inglutalik rivers. Return to the Koyuk was made along the divide between the drainage basins of the Buckland and the East Fork of the Koyuk, and a tie was made on the previous geological work of Moffit in northeastern Seward Peninsula. At the close of the trip the Koyuk was crossed near the mouth of East Fork, and the party arrived at the Koyuk cache on August 8. A severe storm and the work of replenishing supplies and making necessary repairs delayed setting out again until August 12, when the party got under way and made a meandering traverse of the areas between Koyuk River and Norton Sound that had not been visited by Mendenhall in his expedition of 1900. Moving along the divide between the Koyuk and the Norton Sound drainage basins, the party swung around the head of the Tubutulik, thence crossed the divide into the Fish River drainage basin, and, following along the foothills, came to the Omilak mine. From the mine the course was southeastward to the Kwiniuk and thence along the coast to Walla Walla. Supplies had been sent to this point from the mouth of the Koyuk, so that the horses had been able to travel light. From Walla Walla meandering traverses were made westward to Cheenik, which was reached September 17. By this time the top of the ridges were snow covered, and a start was made the next day for Council by way of the Kachauik-Fish River divide. Council was reached and the fieldwork for the season was stopped on September 21.

Locations were kept by continuous foot traverses run by each of the geologists independently and elevations were frequently noted by aneroid barometers. The barometric observations, however, were unchecked and served principally to give relative elevations. The foot traverses were paced, directions being obtained by means of Brunton compasses. The results of the different traverses were platted in the office by making adjustments between known points which had been determined instrumentally either by the Coast and Geodetic Survey or by Peters on the reconnaissance trip of Mendenhall in 1900. So closely did the various traverses check on known points that it is believed that, after the adjustments were made and the map prepared, few, if any, points were more than a mile out of their correct positions. That this apparently rough method of pacing is capable of giving good results is shown by the fact that the difference between the position of Camp A15, near the Bonanza mine, on the Ungalik, as determined by the two geologists, after having made a linear traverse of over 130 miles, was less than 5 miles. This result was obtained on the erroneous premise that both were pacing 2,000 paces to the mile. When, however, an individual rating had been obtained by comparing the scaled and paced distance to the mouth of the Koyuk and this correction had been applied to the location of Camp A15, it was found that the difference between the two traverses was considerably less than 1 mile.

Hearty acknowledgments are due to Mr. A. G. Winegarden, of Gardiner, Mont., who acted as packer throughout the various trips, for his unceasing activity in furthering the aims of the expedition and his willingness to perform more than his share of the camp work in the face of rather discouraging conditions. Thanks are also expressed for the friendly assistance of Mr. C. H. Munro, of the Wild

Goose Company, and to Messrs. Thomas Moon and John Lindburg, prospectors, in distributing supplies at appointed places and thus facilitating the movements of the party.

The writers desire also to express their appreciation of the work of the earlier geologists and engineers who have visited portions of the region or contiguous areas, and from whose published reports and manuscripts they have borrowed to supplement their own observations. Among those to whom the writers are most indebted for scientific information are Messrs. J. L. McPherson, W. C. Mendenhall, F. C. Schrader, F. H. Moffit, and A. H. Brooks; for the determination of the fossils collected they are indebted to the paleontologists of the United States Geological Survey.

GEOGRAPHY.

LOCATION OF AREA.

The area in which new geographic and geologic information has been obtained may be inferred from the description of the itinerary of the expedition of 1909. It has seemed feasible, however, to so extend the area actually visited as to include contiguous regions which throw light upon parts of the region visited in 1909 or in which the results of 1909 serve to confirm or explain problems raised by other investigators. The area treated in this report is therefore in the main rectangular and may be roughly described as bounded by parellels 64° and 66° north latitude and by meridians 156° and 164° west longitude. Described in terms of places and natural objects, the southern margin is near the settlement of Unalaklik, on the east coast of Norton Sound, and the eastern end of the northern margin is a short distance north of the big bend of Koyukuk and Kateel rivers and the western end is a short distance north of the town of Candle on Kiwalik River in the northeastern corner of Seward Peninsula. On the east the region is bounded by a north and south line passing a little east of the junction of the Melozitna and Yukon rivers; on the west the best known point to which to refer the margin is the town of Council on Niukluk River. The area can be best comprehended by reference to the general map of northwestern Alaska (fig. 1), and to the more detailed maps, Plates I and V. For several reasons it has been decided to show the eastern part of this region separately from the western. This has been done mainly because better information has permitted mapping of the western portion on a scale of approximately 4 miles to the inch, whereas the eastern portion is shown on Plate V on a scale of approximately 16 miles to the inch. A division of this sort separates the great sandstone shale area of the east from the more highly metamorphic areas of the west. In this report the eastern area, the one represented by

Plate V, will be referred to as the Nulato-Norton Bay region, and the western part (Pls. I, VI) will be called southeastern Seward Peninsula.

HISTORY OF EXPLORATION.

Prospectors and trappers have without doubt wandered over the region described in this report, but there is little or no record of their journeys and the facts that they learned have been lost. Other classes of travelers seldom ventured far from the main avenues of intercommunication; consequently, until within the last 10 or 15 years there have been few published references to any part of the

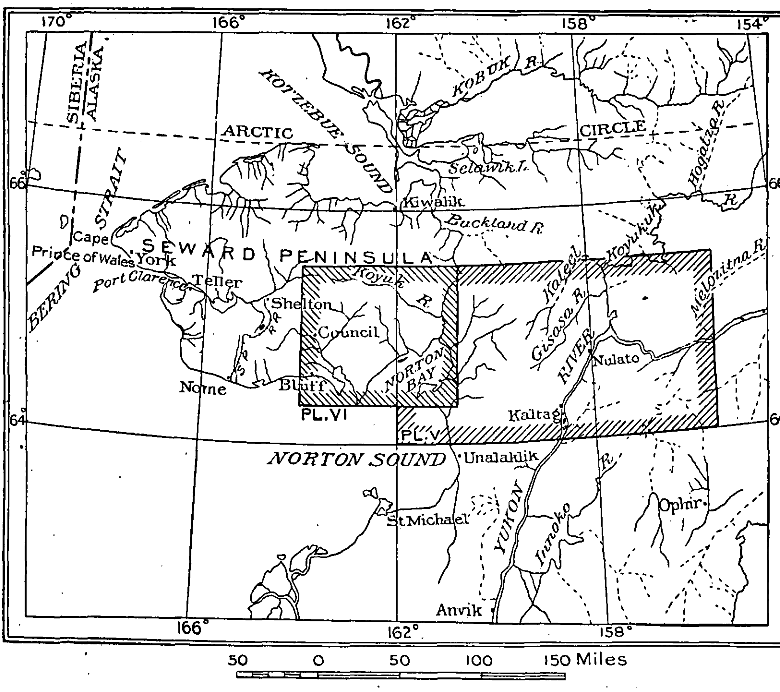

FIGURE 1.—Sketch map of northwestern Alaska, showing location of region considered.

region except the coast line, the Yukon and Koyukuk rivers, and the Kaltag portage. It is not intended at this place to give an account of all the exploring expeditions that have visited the waters surrounding Seward Peninsula, Norton Sound, and Bering Sea, and the reader who desires a more complete historical sketch is referred to the papers of Brooks[a] and Dall.[b]

The oldest settlement in this part of Alaska was at St. Michael, where, according to Dall,[c] Michael Tebenkoff, an officer in the Rus-

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

[b] Dall, W. H., Alaska and its resources, Boston, 1870, 627 pp. and map.

[c] Idem, p. 9.

sian-American Trading Company, established a post in 1833. From this point trading was carried on with the surrounding country. Soon other posts were established. Thus in 1838,[a] Malakoff, a creole, explored the Yukon as far north as the present town of Nulato and established a small settlement at the mouth of Nulato River. He left this post undefended during the winter of 1838–39 and it was destroyed by Indians. Soon afterward, in 1840, a trading post and fort were established on Norton Bay near the mouth of Unalaklik River and called by the name of the stream. This town, according to the 1900 census, had a population of 241.

In spite of the destruction of the first settlement at the mouth of Nulato River the Russian-American Trading Company, appreciating the importance of this place as a point giving ready access to the Koyukuk basin, sent Dérabin in 1841 to rebuild the fort. This was done, and in 1842 Lieutenant Zagoskin of the Russian navy visited the place. His visit is of interest because he made several short journeys into adjacent areas and published the results of his observations.[b] Although his accounts are fragmentary and imperfect, they show that he visited portions of Yukon River as far upstream as the mouth of the Melozitna, explored Koyukuk River as far as the mouth of the Kateel, and made a side trip up the Kateel to assure himself that the native reports of an easy route into the Buckland drainage basin were correct. Unfortunately the maps published with his report are not based so much upon his direct personal observations as upon reports heard by him, and consequently many of the features are indicated only in a most general manner.

In 1851 the trading post and fort at Nulato were burned and some of the inhabitants were massacred by Indians from the Koyukuk. When the town was rebuilt it was moved a mile or more up the river to its present location on a low gravel bench between Nulato Slough and Nulato River.

About 1850 the great activity among many of the different nations, notably the English, in searching for the Franklin expedition resulted in several ships wintering in the waters of Kotzebue Sound. From these ships several exploring parties visited neighboring areas and added geographical data. Of these expeditions few prepared maps of sufficiently large scale to portray any but the most general features of the region explored. Among the overland trips were the exploration of Selawik Lake and vicinity by Surgeon Simpson of H. M. S. *Plover*, the trip from Chamisso Island by way of Buckland and Koyuk rivers to St. Michael by Lieutenant Pim of the same

[a] Dall, W. H., Alaska and its resources, 1870, p. 48.

[b] Zagoskin, L. A., Travels on foot and description of the Russian possessions in America from 1842 to 1844: Ermans Archiv für wissenschaftl. Kunde von Russland, vols. 6 and 7.

ship, and the exploration of Buckland River by Captain Kellett and officers of H. M. S. *Herald*. Accounts of the voyages of the *Herald*[a] show that the last-named expedition went up the Buckland for 30 miles (probably measured along the circuitous course of the river) in a whaleboat and then about 30 miles farther in lighter boats. The Pim journey is also described in the same publication, but the narrative is more a recital of hardships than of geographic or geologic data and is not accompanied by a map.[b]

A later impetus to exploration was given when in 1863 the Western Union Telegraph Company undertook to build a telegraph line through Alaska to connect the settled parts of America and Europe. In 1865 Kennicott, who was in charge of the scientific work of this company, crossed the Kaltag portage and surveyed the route to Nulato. During the same year J. T. Dyer and R. D. Potter, according to Dall,[c] made a very hazardous and successful exploration of the country between Norton Bay and the mouth of the Koyukuk River on the Yukon. Unfortunately no map of this trip was published, and the data collected, although undoubtedly used by Dall,[d] have never been available. In 1865, also, another party under the leadership of Baron von Bendeleben explored the route for the line from Norton Bay to Port Clarence, but the results like those of the other parties have never been published.

The death of Kennicott in 1866 caused the leadership of the scientific corps to pass to W. H. Dall. It was the work accomplished while in charge of the telegraph exploration and during the year succeeding the abandonment of the enterprise that enabled Mr. Dall to write the most authoritative general book on Alaska that had appeared up to the time of the discovery of valuable gold deposits. All branches of geography and geology received some attention from this investigator and many of his observations will be quoted in more detail in subsequent portions of this report.

A period of ten or fifteen years elapsed during which few notes of value were collected and published concerning the Nulato-Council region. In 1885 Lieutenant Allen made his famous trip, during which a portion of the Koyukuk was mapped and also the portage from Kaltag to Unalaklik. About this time explorations by the Revenue-Cutter Service were begun. The explorations of this branch of the government service which directly concerned the Nulato-Council region were by Purcell in the vicinity of Selawik Lake and by Zane along the Koyukuk to Nulato.

[a] Seeman, Berthold, Navigation of H. M. S. *Herald* during the years 1845–1851, vol. 2, London, 1853, pp. 119–120.
[b] Op. cit., pp. 130–148.
[c] Dall, W. H., Alaska and its resources, p. 357.
[d] Op. cit., map.

In 1889 Prof. I. C. Russell[a] ascended the Yukon, and his report of this trip furnished many facts, both of geologic and geographic significance.

With the discovery of gold in the Klondike an influx of prospectors and others into Alaska followed, and soon afterwards the United States Geological Survey was able actively to undertake geographic and geologic investigations of the district. One of the earliest of these surveys was conducted by Spurr,[b] mainly in the basin of the Kuskokwim. The geologic and topographic map published with his report covers the area between the Koyukuk and the Koyuk and from the mouth of the Kateel southward, and is consequently the first geologic map of the eastern half of the area studied in 1909. Most of the information concerning the Nulato-Council region was compiled or gathered from reports of prospectors, and very little geographic significance, outside of the distribution of the different geologic groups, was added.

Schrader[c] in 1899 came down the Koyukuk and the maps published in the report of his trip, which were made by T. G. Gerdine, afford a much more detailed representation of the region than had hitherto been available. No traverses of the country away from the river were made, so that details regarding the region between the Yukon and Norton Bay were not acquired. At the close of the field work in the Koyukuk region Schrader went to Nome and with Brooks made the first examination by Survey geologists of Seward Peninsula.

In 1900 two main parties were dispatched to Seward Peninsula. One in charge of A. H. Brooks investigated the region as far east as Council; the other in charge of W. J. Peters, with W. C. Mendenhall as geologist, investigated the southern part of the peninsula as far east as the Koyuk. The field studies of the Peters party cover the western part of the area visited by the expedition of 1909 and will be referred to in detail in succeeding pages of this report. In the main, however, the results may be summarized as follows: A delineation of the major features of the topography by maps, the publication of data on various geographic subjects such as climate, vegetation, and fauna, and the statement both verbal and graphic of the areal, historical, and economic geology.[d] The studies of Mendenhall were carried on mainly from the streams; the three larger ones, the Fish, the Tubutulik, and the Koyuk, he ascended in canoes.

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[a] Russell, I. C., Notes on the surface geology of Alaska: Bull. Geol. Soc. America, vol. I, pp. 99–162.

[b] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1909, pp. 31–264.

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

[d] Mendenhall, W. C., A reconnaissance in the Norton Bay Region, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, pp. 183–222.

During 1901 Schrader made a trip to northern Alaska and visited portions of the Koyukuk drainage basin.[a] In the same year Mendenhall[b] explored the Kobuk River, and although this region lies considerably to the north of the Nulato-Council area the information secured throws considerable light on the problems of the latter. In the reconnaissance by Schrader, a geologic map was published showing the different formations along the Koyukuk northwestward from latitude 66° north, and this map and the notes on the lower part of the river already referred to on page 15 afford a continuous section from the Yukon northward.

Of the other survey expeditions that have visited contiguous areas the party under Collier in 1902 and the Atwood party of 1907 are the only ones that require specific reference here. The main object of these expeditions was to study the coal resources of portions of Alaska. A publication has appeared setting forth the results of the investigations by Collier,[c] but Atwood's report has not yet been published, though many of the manuscript notes have been kindly furnished to the present writers.[d]

In 1906 a traverse from the mouth of the Koyukuk to the shores of Norton Sound and thence to Council was made by a party sent out by the War Department. The object of the survey was to determine the feasibility of a land route from the navigable waters of the Tanana to the vicinity of Council City. The maps accompanying the report of this survey were the first to give accurate information concerning a strip of country 5 to 10 miles wide extending from the mouth of Koyukuk to the mouth of the Koyuk, and are replete with facts of geographic interest. J. L. McPherson was in charge of the field work and prepared the text of the report.[e] Specimens of the various formations crossed were collected and submitted to the United States Geological Survey for study. On this account it was not necessary to cover the area surveyed by McPherson's party again when the Nulato-Council region was visited in 1909. Reference to this report will be made in more detail in subsequent pages of this paper.

In 1908 A. G. Maddren made an exploratory survey of Innoko River and contiguous areas. His report on this trip, with the accompanying maps, affords considerable information concerning the

[a] Schrader, F. C., Reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, 139 pp.

[b] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1901, 68 pp.

[c] Collier, A. J., Coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903, 71 pp.

[d] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: Bull. U. S. Geol. Survey No. 467, in preparation.

[e] McPherson, J. L., Reconnaissance and survey for a land route from Fairbanks to Council City, Alaska: Sen. Doc. No. 214, 59th Cong., 2d sess., 1907, 22 pp., 7 maps, 6 plates.

country south of the Yukon. Practically all the features shown on Plate V south of the Yukon were taken directly from his maps.[a]

GENERAL TOPOGRAPHY.

Throughout the Nulato-Council region the relief is relatively low. Few hills over 3,000 feet occur and the larger part of the upland area is only about 2,000 feet above sea level. Although there are no high ranges, steep slopes lead from the flat river bottoms to the highlands. In the Nulato-Norton Bay region there are numerous parallel northeast-southwest ridges, the highest of which forms the divide between the Inglutalik-Ungalik and the Kateel-Gisasa river basins. The hills to the north of the East Fork of Koyuk River are low and rolling, without pronounced direction. Farther west, in Seward Peninsula, there are three ranges forming prominent landmarks; these are the hills between Buckland and Kiwalik Rivers, and the Darby and the Bendeleben Mountains. The higher points of the first range rise to elevations of about 2,500 feet; in the Bendeleben Mountains the highest point is a little over 3,700 feet, and in the Darby Range the highest peak is about 3,000 feet. In the two last-named ranges precipitous slopes more than 2,000 feet high give a very rugged topography.

Outside of these three higher areas the uplands are rolling, with elevations from 1,000 to 2,000 feet above sea level, unforested, well drained, and covered with angular fragments of frost-riven waste. Pinnacles of the underlying rocks form fantastic knobs here and there.

The drainage of the region studied flows into the Yukon, into Norton Bay, into Norton Sound, or into Kotzebue Sound. The streams belonging to the Yukon drainage and to the eastern part of Norton Bay show pronounced parallelism with the geological structure, and long, narrow valleys are the result. The gradients of the main valleys are low, but those of the small side streams rise rapidly headward. In places the streams flow through narrow rock-walled canyons of slight depth, but in others flat flood plains and gravel deposits occur. In the headward portions of the basins complex relations of the streams on opposite sides of the divide are noted, and it is by no means possible at long range to foretell the direction of the drainage. In Seward Peninsula, where the geologic structure is more complex, the effect on the streams is not well marked and irregular courses are the rule. In this part of the area the longer streams, such as the Koyuk, the Kiwalik, and the Tubutulik, flow more or less parallel

[a] Maddren, A. G., The Innoko gold-placer district, Alaska: Bull. U. S. Geol. Survey No. 410, 1910, pls. I and II.

with the mountains, but Fish River and its larger tributaries flow at right angles to the Bendeleben Range.

Almost all the valleys show signs of having been eroded entirely by stream action. In the headwaters of the rivers rising in the Bendeleben and the Darby Ranges, however, there are glacial cirques and valleys. Here the present streams form irregular threads on the broadly open floors of valleys with very steep sides. At the mouths of the streams flowing into Norton Bay many of the streams, instead of showing erosion features, have filled the former valleys, which have been depressed, with sand and gravel. Examples of this kind of topography are found at the mouth of the Kwik, the Tubutulik, and the Kwiniuk Rivers, where numerous lakes and sloughs form an untraversable network during the summer.

The coast line presents numerous examples of different types of shore topography. From the Reindeer Hills to the Koyuk a coastal plain, recently emerged, affords a relatively straight shore with such slight depths of water off the coast that approach for large vessels is impossible. Of course, under such conditions, harbors do not exist. On the western side of Norton Bay the sinking of the land and the attack of the waves have resulted in a rugged coast with cliffs and harbors. This part of the coast is formed by the Darby Range, which rises in abrupt slopes from the sea and forms a long southward pointing peninsula. West of this range the deep reentrant of Golofnin Sound and Bay, which probably represents the submerged portion of an old valley similar to that of Fish River, affords a good harbor. Still farther west rocky headlands with intervening beaches produce a diversity of forms. On the depressed portions of the coast there are sand spits, such as the long point extending east from near the mouth of the Kwiniuk.

DRAINAGE BASINS INCLUDED.

All the streams flowing through the Nulato-Council region may be considered as belonging to one of three main basins, namely, the Yukon, the Norton Sound, and the Kotzebue Sound. Of these the first two include by far the greater number of streams. Roughly computed about 50 per cent of the area shown on the maps, Plates I and V, is drained by the Yukon and its tributaries, 45 per cent by tributaries to Norton Sound, and 5 per cent by streams flowing into Kotzebue Sound. In the description of these different basins no attempt will be made to enumerate all the streams belonging to each, for that sort of information may be better gathered from the maps (Pls. I and V), but rather to present the particular features not easily legible on topographic maps of such scales as those adopted for publication.

YUKON BASIN.

The portion of the Yukon considered in this report extends from slightly east of the mouth of the Melozitna on the northeast to near the mouth of Kaiyuh Slough on the southwest. In this distance the main tributaries are the Koyukuk, the Nulato, the Kaltag, and the Khotol. Regarding these various streams, with the exception of the first two, no new data of geographic interest were received during 1909, and as the facts already known about the Kaltag and the Khotol are indicated on the map accompanying these reports, no further description of them will be attempted.

Kateel and Gisasa rivers formed the portions of the Koyukuk drainage that were visited and mapped, but only the upper 30 to 50 miles of each stream were seen in any detail. McPherson, who crossed the Gisasa near latitude 65° North, describes the valley as follows:[a]

> The Gisasa River is a stream from 70 to 150 feet wide, with gravelly bottom. Along the river banks on the north side of the valley is a heavy growth of spruce. Along the south side of the valley timber grows in scattered bunches, the intervening ground being to a considerable extent marshy and niggerhead tundra.

From the survey of 1909 it was found that the Gisasa Basin was a peculiar, narrow one, lying between the Nulato on the southeast and the Kateel on the northwest. The river from mouth to head near Camp A9 must be nearly 70 miles in a direct line. In this distance few or no tributaries much more than 10 miles in length are received. The basin is thus probably less than a score of miles wide in its widest part, and in the headward 50 miles it is generally much less.

As will be shown in a later portion of this report the direction and the general physical features of the Gisasa Valley are due to the geologic structure of the region, which trends northeast-southwest. Although in portions of its course the river flows on a flat gravel plain essentially at the level of the stream, in other parts it has rock walls through which the stream has cut narrow canyons. These canyons are not continuous, but appear at irregular intervals along the valley. None of the canyons are deep, only a few of the rock walls, if any of them, reaching a height of 50 feet. Above the steeply incised walls a more open valley is usually found, which indicates rather recent minor deformation of an anterior topography.

The Kateel Basin was seen in less detail by the writers, but its general features are essentially similar to those of the Gisasa, except that its valley is wider and it has longer tributaries. From the survey of McPherson it was determined that Arvesta and Caribou creeks are tributaries of the Kateel. The former, where it was crossed, near latitude 65° north, is from 50 to 70 feet wide and from 1 to 3 feet deep. The latter is much smaller and runs at an elevation

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[a] McPherson, J. L., op. cit., p. 17.

about 500 feet higher. Prospectors who crossed the region somewhat north of McPherson's route state that the volume of the Kateel is much smaller than that of the Gisasa.

A general idea of the Kateel Basin was afforded by a view from Traverse Peak, though the weather was unfavorable for a thoroughly satisfactory observation of the topography. From this point it was evident that the northeasterly trend observed in the Gisasa Valley was still dominant. The divide along the western margin of the basin ran nearly north and south, so there is a considerable area tributary to this river. Low passes lead from the Kateel into the Ungalik, or into the Inglutalik, and probably into the Buckland. The pass from the Kateel to the Buckland was not actually seen, but enough of the drainage arrangement was evident to show that some of the western tributaries joining the Kateel below its junction with Arvesta Creek head in the low hills east of the Buckland, so that an easy route undoubtedly exists between the two rivers.

The Nulato River Basin is long and narrow, being formed by two large streams occupying strike valleys that coalesce a few miles from the Yukon and below this point are transverse to the structure. The main branch is about 50 miles long in a straight line. Its valley has a broad gravel-filled floor on which the stream meanders in irregular pattern. It will be seen from the map of this valley that, although lying parallel with the Yukon and not more than 20 or at most 25 miles away from that stream, it drains northeastward, whereas the Yukon in that part of its course flows southwestward. This results in a more than right-angled turn near the mouth of the Nulato, and suggests that the physiographic development of the streams has been complex. Smooth slopes rise steeply from the valley floor to the relatively even uplands. On the southeastern side high hills scored by narrow gulches preserve the snowfall late in the summer. The volume of water carried by the main branch is therefore more constant throughout the season than is the case of those streams dependent upon the rainfall. Passes easily traversable by horses lead from the Nulato Basin to that of the Gisasa, of the Shaktolik, and probably also of the Unalaklik.

NORTON SOUND DRAINAGE.

TRIBUTARIES OF NORTON SOUND EAST OF KOYUK RIVER.

East of Koyuk River the main streams belonging to the Norton Sound drainage from south to north are the Unalaklik, the Shaktolik, the Ungalik, and the Inglutalik. All of these rivers show pronounced angular bends on a large scale, most of which are to be accounted for by the geologic structure of the region. This condition is best illustrated by the three northern streams, whose basins are almost completely mapped. It will be seen from the map that for the first 5 or 10 miles[a] in a straight line from the coast the rivers flow in winding courses at a right angle to the shore. Upstream from this point the course abruptly changes, and for the next 10 to 30 miles the rivers have a nearly north-south trend. Still farther upstream the direction again changes, and the streams flow from the northeast or even from the east-northeast.

Taken as a whole, the three rivers have narrow, rather contracted basins in the middle or north-south part of their courses, because few tributaries enter from the east and west; in the upper part, however, because the main streams are flowing more or less across the geologic structure, the side streams are long and the area tributary to the main streams is therefore more extensive. Rock-walled canyons, separated from each other by gravel-filled basins, bear witness to recent crustal movements throughout the area.

Unalaklik River was not visited by the survey party in 1909, but portions of it are well known, because the portage from the Yukon to St. Michael follows the lower part of this stream. A long branch joining from the north heads against the Shaktolik River, and it is probable that an easy pass across the hills to Nulato River exists. The northeast-southwest trend of the drainage and the intricacy of stream arrangements make it difficult to interpret the topography at long range. It is possible, therefore, that the Shaktolik may extend farther around the head of Nulato River than was evident at a distance, so that there may be more than one divide between Nulato and Unalaklik rivers.

North of the Unalaklik is a rather small stream, the Iguik, which drains the triangular area between the Unalaklik and the Shaktolik. Its drainage basin is at most only a few hundred square miles in area.

Although previously mapped as a rather unimportant river, the Shaktolik drains a considerable territory between the Ungalik on the north and the Unalaklik on the south. Its course is so irregular that it can with difficulty be recognized at any considerable distance. The Shaktolik was first seen in detail near camp A10. At this place its course was nearly due north, giving the impression that it flowed northward into the Ungalik. Near camp A13, however, it joined with a branch from the south and formed a good-sized stream. From the small increase in the size of the northern branch between camp A10 and its junction east of camp A13 it seems certain that only a few tributaries enter between these two places.

Near camp A10 the river is incised in a narrow rock-walled canyon about 30 feet deep. Above the canyon walls the topography opens out into a broad older valley which had reached maturity before the uplift took place by which the present cycle was started. The floor

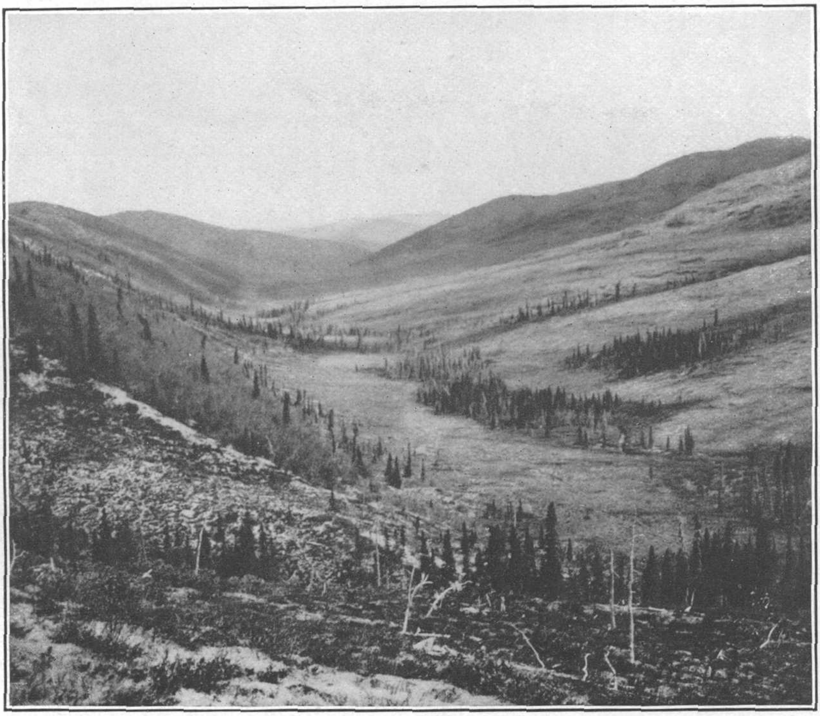
[a] The figures given represent measurements in an air-line and not along the circuitous courses of the streams.

of this older valley is in large measure rock cut with a relatively small amount of gravel covering. Well-rounded material, however, is practically universally present and affords indisputable proof of the presence of stream erosin at this higher level. Near camp A13 the canyon-like character is wanting. Four or 5 miles below camp A14 incised meanders, with radii of from one-half mile to 1 mile, occur. Here the walls are, for the most part, gravel, with the bedrock not exposed. It is believed that the differences in the amount of filling and incision noted along this stream are due to the undulatory character of the most recent uplift.

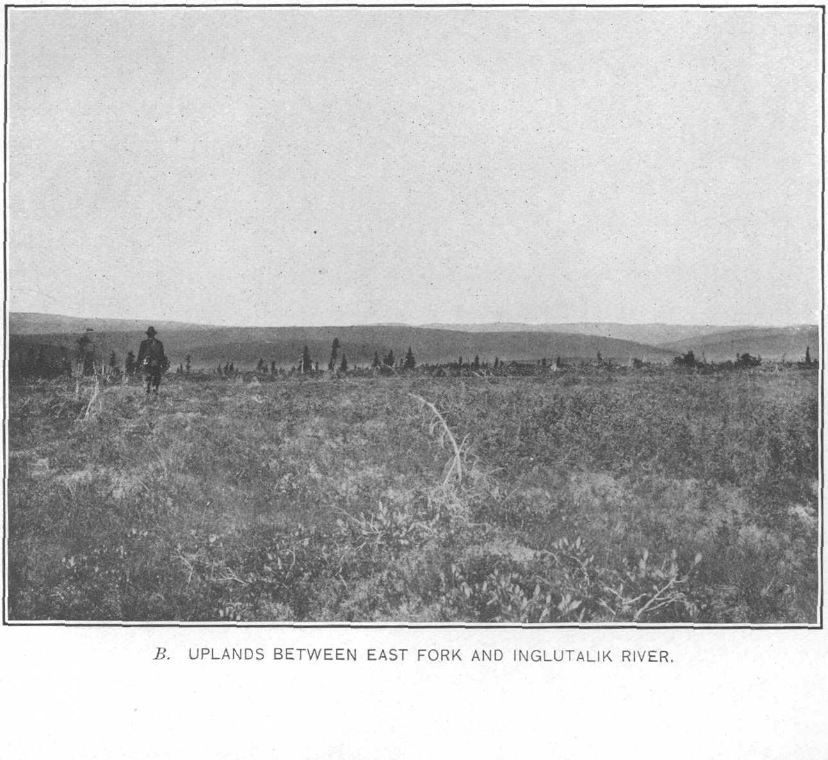
No accurate determinations were made of the volume of the Shaktolik, but from float measurements near camp A12 it was found that the discharge was between 150 and 200 second-feet. The tributary from the north joining east of camp A13 was of about equal volume, and below camp A14 the amount of water had increased to such an extent that the stream could be crossed only with difficulty. In this connection it should be noted that 1909 was an exceptionally dry season, so that a greater volume is to be expected during a year of normal precipitation.

Ungalik River shows the same characters as the other streams tributary to Norton Bay from the east. Its basin shows the three distinct parts previously referred to, namely, an open east and west course through the coastal plain province, a narrow north and south portion parallel to the geological structure of the region, and a northeast and east-northeast course in the headward portion. In this upper part the basin shows the same feature previously noted on the Shaktolik, namely, that the tributaries from the south are longer than those from the north, so that the basin, if the main stream be considered as its axis, is decidedly unsymmetrical. This lack of symmetry seems to be due to three causes, namely, structural control, climatic conditions, and tilting. Asymmetrical valleys are common in Alaska, and have previously been described by different authors. An epitome of the various causes with reference to a specific region has been published by Goodrich.[a] It was pointed out by this geologist that the effect of insolation differs according to the condition of the stream as to load; thus, if the stream is overloaded, the tendency will be for the waste to push the stream toward the side receiving the least sun, whereas, if the stream is not carrying all the material it can the reverse tendency will dominate, and the stream will migrate toward the side receiving the most sun. Plate II, *A*, shows one of the tributaries of the Shaktolik below camp A12, which is migrating toward the north because the stream is underloaded and the south-facing slope receives more warmth than the

[a] Goodrich, H. B., Cause of asymmetry of streams: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 285-289.



A. ASYMMETRIC VALLEY, SHAKTOLIK BASIN.



B. UPLANDS BETWEEN EAST FORK AND INGLUTALIK RIVER.

other. In a consideration of the development of the drainage it should be borne in mind that types due to one cause alone are practically absent and that complexity of origin, rather than simplicity, is normal.

From Ungalik River passes may be found into the Inglutalik to the north or to the Kateel on the east, or into the Shaktolik on the south. None of these passes are over 3,000 feet above the sea, and many could be found at elevations below 2,500 feet. The saddle by which McPherson crossed from the Kateel to the Ungalik was only a little over 2,000 feet.

As regards size, the Ungalik is not so large as the Shaktolik. Two miles below camp A16 the stream could be crossed in less than 2 feet of water, and farther upstream it was still shallower except for occasional deep holes. Lower downstream, however, in the coastal plain portion of its course, it becomes deeper and sluggish, and instead of a hard gravelly bottom it has a soft mud bottom that makes crossing difficult without a boat.

Inglutalik River derives its name from the Eskimo words meaning "river of bones," in reference to the number of mastodon and other bones found in the terrace of gravels along its course. It is at least 60 miles long and appears to have a greater volume of water than either the Shaktolik or the Ungalik. Below camp A18, in the coastal plain province, the river can not be forded; at camp A18 is the first riffle, and on it good crossing in about 2 feet of water is afforded. Poling boats have been taken as far as camp B9, and during seasons of normal precipitation could undoubtedly be worked still further upstream.

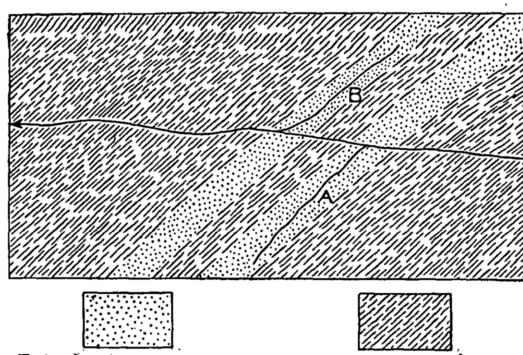


FIGURE 2.—Arrangement of drainage due to geologic structure.

In the upper part of the Inglutalik Basin the drainage is very complex, and many readjustments have taken place, so that at a distance of 5 or 6 miles it is impossible to tell whether the river drains toward the north or the south. Backhand or barbed drainage is common. It should be noted, however, that this feature is not always to be accounted for by capturing, but in many instances is due to the geological structure. Figure 2 indicates in diagrammatic manner how a normally developed subsequent stream (A) may have a barbed junction with the main stream without capturing having taken place. In this same figure stream B is also a normally developed subsequent stream, but as the soft bed on which it has developed forms an acute angle with the course of the main stream the tributary enters without the barbed junction.

Low passes easily traversed by horses lead from the Inglutalik into the Kateel basin to the northeast; into the Ungalik on the south; into the Koyuk on the west; and into the Buckland on the north. It is reported, although it was not confirmed by personal observation, that part of the Selawik drainage also heads against the Inglutalik. There are no known facts which would make such a condition unlikely, but the region in question is so entirely unexplored that conjectures as to the drainage are hardly warranted. The only information on this subject is Zagoskin's trip up the Kateel to near the big bend, in 65° 30′ north latitude. According to this traveler a low pass leads from near this point northwest to the Buckland. It should be realized, however, that Zagoskin did not attempt the passage; that there may have been a misunderstanding as to the river on the western side of the divide, and that it is possible his informants were not correct in their geography. From the present status of knowledge it seems more likely that a pass northwest of the big bend of the Kateel would lead into a north-flowing branch of the Selawik than to a west-flowing branch of the Buckland.

KOYUK RIVER.

Koyuk River enters the northern reentrant of Norton Bay and is a river over 80 miles long. For the first 15 miles from the mouth it has a nearly southerly course, but above this point it flows more or less directly from the west toward the east. For 60 miles or so its tortuous meanders make measurements along the river many times the air-line distance. Mendenhall and Peters in 1900 traversed the river as far west as the head of canoe navigation a few miles above Knowles Creek, and the details of their map have been taken for the course of this stream. In 1903 [a] Moffit and Witherspoon, mapping the northeastern part of Seward Peninsula, added many facts concerning the Koyuk basin north of the main stream and concerning the river itself beyond the point reached by Mendenhall and Peters in 1900.

From the observations of the earlier geologists and topographers, supplemented by the field work of 1909, it appears that the Koyuk basin is unsymmetrical. Of the various tributaries, East Fork undoubtedly drains the largest territory. Its basin is about 30 miles long, heading against portions of Buckland and Inglutalik river basins. Many low passes lead from the East Fork basin into the

[a] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula: Bull. U. S. Geol. Survey No. 247, 1905, pls. II and III.

Buckland. Probably the lowest pass is by way of the branch on which camp B12 was located. The elevation of this camp was approximately 300 feet above the junction of East Fork and the Koyuk, and as there is a strong upstream current, due to the tides, as far as the mouth of Peace River, it is safe to assume that the mouth of East Fork is practically at sea level. North of camp B12 there is a broad abandoned valley in which there are several lakes. Some of these drain northward and some southward. The elevation of these lakes is not more than 100 feet above the camp, so it is certain that there is a route across Seward Peninsula from Norton Sound to Kotzebue Sound, nowhere more than 400 feet above sea level.

TRIBUTARIES OF NORTON SOUND WEST OF KOYUK RIVER.

West of Koyuk River the main tributaries of Norton Sound from east to west are Kwik, Tubutulik, Kwiniuk, and Fish rivers. All of these streams are mainly within the area occupied by metamorphic rocks of complex structure and consequently do not show by their courses the striking structural control noted in the rivers farther east. Because of the greater amount of information available concerning the region west of the Koyuk, the map of southeastern Seward Peninsula (Pl. I) shows the distribution and character of these rivers in greater detail than was possible on the smaller scale map adopted for the Nulato-Norton Bay region (Pl. V).

Kwik River is a small stream about 20 miles long flowing in the main on a very flat slope in a circuitous course in a gravel-filled basin. It heads in the divide between Norton Bay and the east-west portion of the Koyuk. Passes lead across this divide at low elevations. The lowest pass is by way of the branch on which camp C4 was located. At this point a broad, open saddle at an elevation of only a little more than 600 feet affords an easy route from one basin to the other. The most characteristic feature of this basin is the flat lowland through the lower three-quarters of the area and the short, rather steep gradients of the streams above the point where they enter the flats.

Tubutulik River had previously been traversed by Mendenhall and Peters, so that few notes concerning the stream arrangements were collected in 1909. In the main this basin is parallel with the igneous intrusions of the Darby Range, but above Lost Creek, where the granites disappear, the course for several miles is more nearly east and west. Above this point its general direction is north and south. In this part of its course is a lowland, locally known as Death Valley, which is elliptical in outline and about 7 miles long by 5 miles wide. North of Death Valley the headwater streams rise in the high eastern extension of the Bendeleben Mountains and flow on steep gradients into the Death Valley Basin. The lower 5 to 10 miles of the Tubutulik basin is formed by swampy lowlands similar to those at the mouth of the Kwik. In fact, the area between the lower portions of these streams is practically undivided, and it would be almost impossible to determine just what portion of the flat was tributary to one stream and what to the other.

Measured in a straight line from its head to its mouth, the Tubutulik is about 40 miles long, but its numerous meanders make the distance along the river much greater. Several low passes lie between the Tubutulik and the Kwik on the east, the Koyuk on the north, and the tributaries of the Fish on the west. The ridge between the Tubutulik and the Kwik nowhere exceeds 1,000 feet, so that at the heads of the tributaries are many places where passages at elevations of 600 to 800 feet may be found. Between the Tubutulik and the Koyuk there are two low saddles where the elevation does not exceed 1,000 feet. The most important of these saddles is the one east of Death Valley, where the trail from Nome to Candle crosses the divide. At this place the elevation is only a little more than 800 feet above sea level. The low saddle is north of the north fork of the Tubutulik and leads into Timber Creek, a tributary of the Koyuk. This pass is broadly open and has several small lakes scattered on the flat divide. Between Tubutulik and Fish rivers there are two or three low passes, but the one taken advantage of by the telephone lines is perhaps the lowest. North of this one, however, near camp C8, there is a saddle at an elevation of about 1,000 feet, by which horses can easily cross from the Tubutulik into the Fish River basin.

Southwest of the Tubutulik the Kwiniuk River drains an area of approximately 100 square miles. It has an extremely irregular course, its bends in the main being dominated by the general north-south geologic structure. It has many side streams joining it in back-hand manner. This is especially true in the portion around camp C14. About 2 miles south of this point there is a long tributary coming in from the west which makes a sharp bend and cuts across the prevailing structure to join the Kwiniuk; 2 miles north of camp C14 also there is a stream flowing almost due south until it enters the northeastward-flowing Kwiniuk. It is believed that some of these abnormal features may be explained by the obstruction of the drainage by deposits formed by valley glaciers from the Darby Range, which have prevented a former direct course to the sea.

The Kwiniuk basin is about 30 miles long and is on the whole rather narrow. In places rock walls constrict the river, but in other places there are gravel-filled basins of small extent in which the river splits into many separate channels. At the mouth, the river flows on the broad gravel deposits (which probably represent basin filling) that merge with the flats at the mouths of Tubutulik and Kwik rivers. In this part of its course the basin is characterized by an intricate network of sloughs and channels impossible to traverse in summer.

Fish River is the largest stream west of the Koyuk. Between it and the Kwiniuk many streams heading in the north-south Darby Range flow in short courses eastward into Norton Sound or westward into Golofnin Sound. Fish River, like the Koyuk, was ascended by Mendenhall and Peters in 1900, and the form of the main river has been taken directly from their map. It is an extremely tortuous stream in its lower and middle course, but in its headward part and for a short distance in the so-called Fish River gorge it is an actively degrading stream. In the lower part the river splits into numerous distributaries on the delta, and its flow is so sluggish that it is difficult to distinguish the main channel from blind sloughs. Steam river boats ascend the river as far as White Mountain, but above this point as far as Council, on the Niukluk, or as far as Mosquito Creek, on the main river, horse boats are used.

Above the junction of Niukluk and Fish rivers the valley of the main stream is constricted and the river flows through a gorge with rather steeply sloping walls for a distance of about 10 miles. Upstream from the gorge the valley opens out and the floor is a flat gravel-covered plain 15 miles wide parallel with the direction of the stream and 30 miles long transverse to this direction. This part of the basin is an unexplained physiographic feature. The plain is dotted with lakes and sloughs slightly sunk below the general level of the surface. Here and there, irregularly distributed, are low gravel mounds from 10 to 50 feet in height, that seem to mark former deposits so dissected that perhaps not one-hundredth of their original extent is preserved.

The main tributaries from the west are Niukluk and Pargon rivers. The former rises in the Bendeleben Mountains and the hills to the south about 20 miles west of the mapped area. The Pargon, sometimes incorrectly called the Parantulik, rises in the high east-west range which forms the eastern extension of the Bendeleben Mountains. It flows along the southern margin of the Fish River basin for nearly 20 miles before entering the main stream. From the east the main tributaries of Fish River are, from south to north, Etchepuk and Rathlatulik rivers and Mosquito Creek. All of these rise in the high Darby Range that forms the eastern border of the Fish River basin. In their headward portions they all flow in rather youthful valleys with fairly steep gradients, but as they cross the flats their slopes decrease, and they flow in sinuous courses slightly incised below the level of the plain.

KOTZEBUE SOUND DRAINAGE.

The only portion of the Buckland or other Kotzebue Sound drainage seen was between camps B5 and B13. In this region only the headward part of some of the streams belonging to the Buckland were observed near at hand, and therefore few additional data as to the larger features of the basin as a whole were obtained. It seems, however, that the area of this basin has been in large measure exaggerated. From the mouth of the Buckland to the divide between that river and the East Fork of the Koyuk in a straight line the distance is between 50 and 60 miles, and from the mouth to the divide near camp B5 is only a little over 60 miles.

Like many of the other basins which have been carved mainly on bedded sediments of Mesozoic age in this part of Alaska, the basin of the Buckland tributary streams shows pronounced structural control. This results in an irregular distribution of narrow valleys parallel to the geological structure of the region, with transverse gorges. In this kind of topography the recognition of the true direction of the drainage from a distance is almost impossible. The western branch of the Buckland, visible from Bear Creek (north of camp B13) flows in a broad, flat valley, the average gradient of the stream from mouth to head probably not exceeding 6 to 8 feet a mile. In the descriptions of Quackenbush [a] and of the earlier surveys by Captain Kellett and other officers of H. M. S. *Herald* and *Plover*, it is stated that the Buckland is navigable in light boats for about 60 miles as measured along the river's course, that is, as far as the forks of the stream about 20 miles north of the Koyuk-Buckland divide.

The low pass from Buckland to the east fork of Koyuk River has already been described. A pass from the Buckland into the Kiwalik basin by way of Bear Creek has been utilized by a road from the mining camp on Bear Creek to Candle. The divide between the Buckland and the Inglutalik is low, and, although usually covered with dense brush, it offers no considerable obstruction to crossing from one drainage basin into the other.

UPLANDS.

As has already been stated, the relief in the Nulato-Council region is relatively low. Few hills are more than 3,000 feet high, and the larger part of the upland is probably not more than 2,000 feet above sea level. There are, therefore, but small differences in elevation between the uplands and the lowlands and still less between different portions of the upland. This results in producing a sky line uninterrupted by any considerable inequalities.

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[a] Quackenbush, L. S., Notes on Alaskan mammoth expeditions of 1907–8: Bull. Am. Mus. Nat. Hist., vol. 26, 1909.

Smooth, rolling uplands are particularly characteristic of the East Fork-Inglutalik divide. In this part of the field the features are slightly dissected, rounded domes, with gentle slopes merging with the present valley walls by a series of benches. Plate II, *B* (p. 22), shows a typical portion of this upland and is characteristic in a broad way of the divides between most of the minor drainage basins. On such uplands traveling is good, as the surface is well drained and the frost-disintegrated fragments afford good footing. Not only are uplands of this type found in the regions where unmetamorphosed sedimentary rocks form the bed rock, but they are also characteristic of parts of the schist region—as, for instance, at the head of Kwik River.

Even the higher and more rugged divides here and there show a somewhat flat-topped character. Thus, on both sides of the Koyuk-Buckland lowland there are numerous flat-topped hills, some a mile or so in width, carved on materials very different both in composition and in apparent resistance to weathering. This feature is also seen in the hills north of Death Valley on the Tubutulik. On one of these hills north of camp C7 a profile similar to figure 3 was observed which

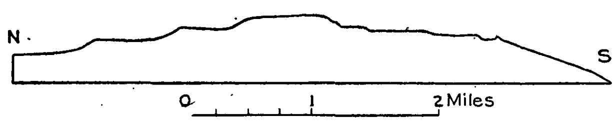


FIGURE 3.—Profile of hill north of camp C7, at head of Tubutulik River.

showed at least five flats from a quarter to half a mile wide. These have been produced on a complex structure of schists, thin limestones, and granites.

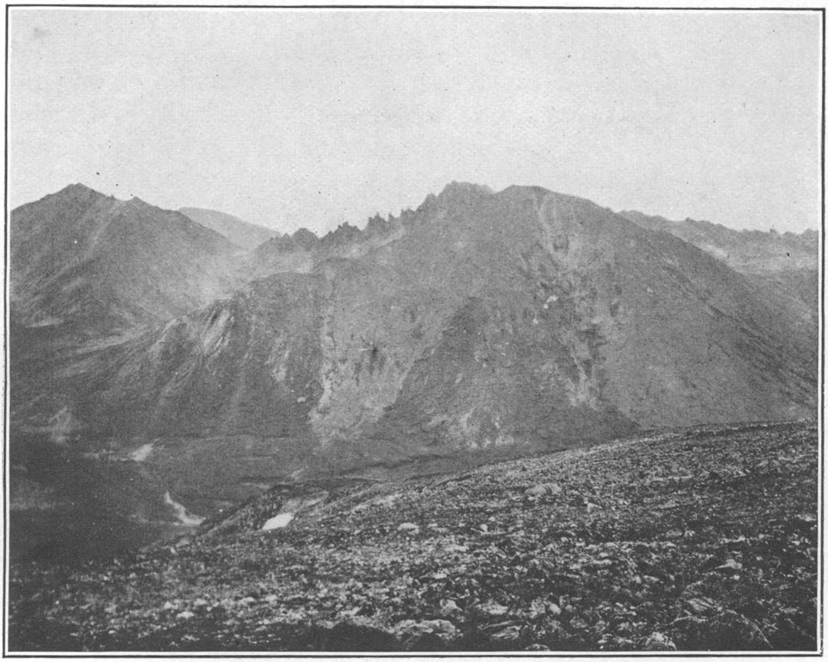
The two main mountainous regions are (1) the divide between the Yukon and the Norton Bay drainages, called by McPherson the Brooks divide, and (2) the Darby and Bendeleben mountains. In the former the general trend is north and south, with the highest points only little more than 3,000 feet in elevation and the average much less. Conical peaks rising 500 to 800 feet above their neighbors afford easily recognizable landmarks, visible for long distances. A few steep, rocky crags were seen, but all are easily scalable. In the Darby and the Bendeleben mountains the trend of the former is predominantly north and south and of the latter east and west, so that together they form a crescentic highland area. The crest line of this range is ragged and irregular, being in places close to the north and west side of the range and at others close to the south or east side. Here and there the crest line is so narrow that passage even on foot is hazardous, and blocks of waste disturbed in passing roll hundreds of feet down the slope before finding lodgment. This is true particularly of the Bendeleben Mountains, where glacial action of the alpine type has been effective in the past. In certain parts of the Darby Range also this same agency has produced similar uplands. Plate III, *A*, shows a portion of the Darby Range much dissected by glaciation and illustrates the narrow pinnacled character of the upland that results. Such divides are not due to valley glaciers having covered the upland, but are the result of headward erosion on opposite sides of the ridge.

Regarding the origin of the uplands, there has been no clear evidence found to indicate the effective causes. As will be explained in detail later, it is known that the deformation which took place after the deposition of the Cretaceous sediments was so great that any topography formed prior to this event must have been so changed as to have little or no effect on the present topography. The surface therefore has been formed between the Eocene and the present time. It is known that none of the mountains indicated by the dips of the strata formed by the folding are preserved at the present time in this region. The upland surface has therefore been produced by erosion, and the present hills owe their height rather to greater resistance to erosion than to original constructional uplift. Whether this erosion resulted in a nearly plain surface approximately at sea level, which has subsequently been uplifted and again dissected, or whether the erosion took place at considerable elevations above sea level and leveled without base leveling the tops of the hills, is a question that must await much fuller investigation. There are the following objections to the interpretation that the present upland surface represents a formerly nearly base-leveled surface subsequently uplifted—the absence of any water formed deposits on the surface of the upland; the lack of deep-rock weathering; the number of flats separated from each other by sharp scarps similar in all characters to the uppermost one, which require similar explanations; the absence of drainage arrangement that would correspond to the hypothetical earlier surface; the indications that present-day processes are responsible for leveling without base leveling. On the other hand, the main objection to the idea that the upland does not mark an old erosion surface nearly at base level is the lack of known processes capable of producing a nearly plain surface on rocks of different resistances to erosion. It seems wise therefore to suspend judgment as to the origin of the uplands, as further information is required before their genetic classification can be effected.

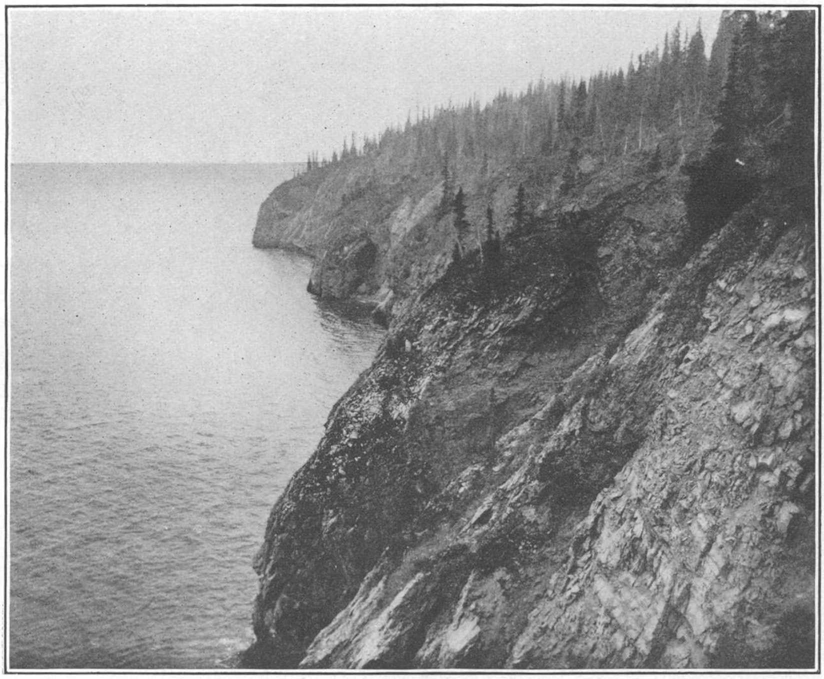
COASTAL FEATURES.

Soundings made by the Coast and Geodetic Survey [a] and others have shown that nowhere in Norton Bay and Sound within the areas represented on Plates I and V is there a depth of water exceeding

[a] See chart 9380 of the Coast and Geodetic Survey, edition of 1908.



A. CHARACTERISTIC MOUNTAIN TOPOGRAPHY, DARBY RANGE.



B. EAST COAST OF DARBY PENINSULA.

100 feet, and over much of this water area the depth averages about 50 feet. In general the 5-fathom line lies several miles from the coast, so that vessels find no harbors and have to discharge cargoes on lighters. A few exceptions to this rule occur, most notably along the east side of the Darby Peninsula and at Golofnin Sound. At the former locality the coast is rocky and landing places for vessels of sea-going size are wanting. Plate III, *B*, shows a typical portion of the eastern coast with the waves beating directly on the cliffs and with a beach so slightly developed that it is impossible for a man to walk around the shore. With such topography it is evident that shelter for vessels is wanting.

Golofnin Bay, on the other hand, presents a fairly good harbor for vessels drawing less than 20 feet, as it is sheltered by high hills from the strong winds. The channel, however, is crooked and the bay is constantly filling up with the detritus brought down by Fish River. Ocean-going vessels from Seattle call at this place irregularly during the season and discharge cargoes near the mission on lighters. Without recourse to dredging, however, this harbor would be of slight value in the general economic development of the region. It is, moreover, some distance from the productive gold areas and so is not much used, although during the boom days of the Council region it gave promise of being important and even now it is the gateway by which most of the supplies for Council and vicinity enter the country.

Kotzebue Sound on the northern shores of Seward Peninsula is also a relatively shallow sea, few if any places having a depth of 100 feet. One of the latest incidents in the geology of the region was a slight depression of the land, so that the submerged lower courses of some of the larger streams afford shelter for light-draft vessels. The shallowness of the basin as a whole and the crooked and constantly changing channels leading to these harbors make navigation difficult.

Tides in Norton Sound are relatively slight in their range but increase toward the bay heads. No accurate measurements of the tides have been made in this part of the region, and as the wind has a considerable effect on the change of water surface it is impossible to make any short-period observations of value. It is probable, however, from determinations made at Nome, that the tides seldom have a range of more than 2 feet along the east side of Darby Peninsula. Judged by the way in which the Koyuk was backed up by the tide near camp A20 the tidal range near the head of Norton Bay probably exceeds 3 feet.

As has been already noted, lagoons are found along portions of Norton Sound. These owe their formation mainly to shore currents blocking the mouths of streams. Sand reefs, such as occur near Solomon and at many other places in western Seward Peninsula, are absent in the area studied. Many of the lagoons are filled with drift timber, a good deal of which has doubtless been brought down by the Yukon and cast upon the shore by the currents.

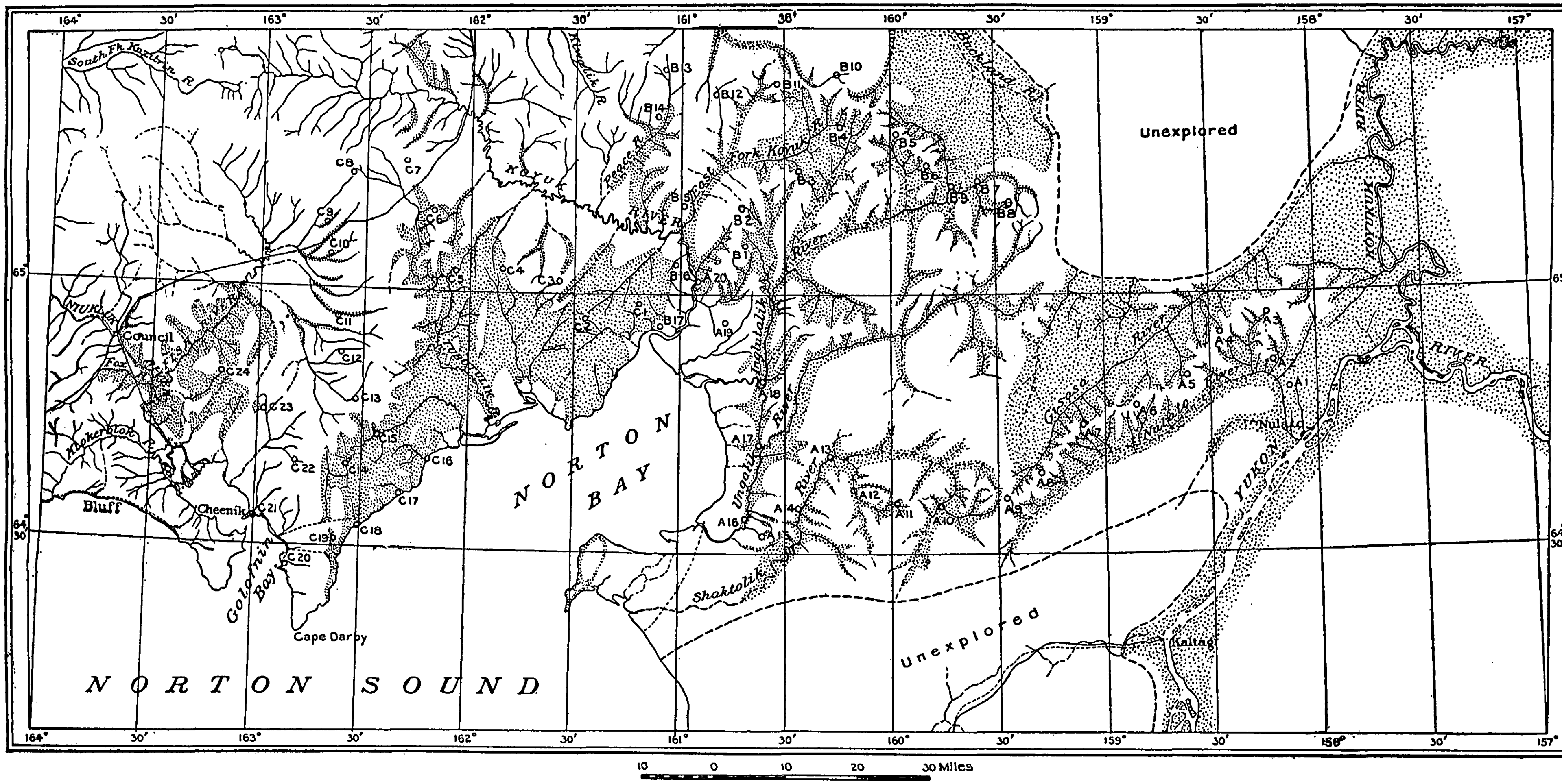
The currents are complex and have been determined mainly by the effect they have exerted on the land forms. Near the mouths of the Kwiniuk and the Tubutulik the long spits with their free ends pointing east give clear evidence that the currents there are flowing from west toward the east, but, south of camp C17 for 4 or 5 miles the apparent direction is southwest. At Carson Creek, however, the general direction seems to be northeast. On the east side of Norton Bay, near the mouth of the Inglutalik, the shore forms seem to have been made by currents flowing toward the north, whereas near Island Point the dominant current seems to divide, the southern part flowing southward and the northern part northeastward. From the south end of the Reindeer Hills the long south-pointing sand spit seems to show that the direction of currents there is in general southward.

VEGETATION AND GAME.

As the main object of the expedition of 1909 was to acquire information concerning the geology of the region traversed, little attention was paid to extraneous matters. A few notes on the general character of the vegetation and game may, however, be included.

Of the evergreen trees spruce is the only one of sufficient importance to be considered. The trees seen probably average 10 to 12 inches in diameter. Spruce extends as far west as Council, but beyond this point is practically wanting. In the eastern part of the area, near the Yukon, it grows at elevations close to 2,000 feet, but farther west, toward Norton Bay, at lower elevations, so that west of the Brooks divide it is seldom found above 1,000 feet. West of the Koyuk it rarely is found above 800 feet, and only in the valleys along the streams. In the western part of the Fish River drainage basin, spruce does not grow on any of the streams north of Mosquito Creek. Spruce is found along the eastern coast of Darby Peninsula up to elevations of about 800 feet, but west of the range it seldom grows at more than 500 feet above the sea. Plate IV shows the general distribution of timber in the region.

Birch, used by the natives for sled frames and similar gear, is found in many places in the Yukon basin, but it gradually disappears farther west until the last birch seen on the Koyuk was near Kenwood Creek and the last sizable trees in the Darby Peninsula were on the eastern slopes of Mount Kwiniuk and on the lower slopes of Mount Kwiktalik or Haystack Mountain. White birch is found in the Yukon basin, but does not occur notably to the west of this area. The Seward Peninsula birches are the yellow and the black birch. The low pros-



MAP SHOWING DISTRIBUTION OF TIMBER.

trate birch, which has little or no fuel value, is much more widely distributed and can be found throughout Seward Peninsula.

Willows are common along almost all the Seward Peninsula streams. The willows are of several different kinds, from prostrate varieties to trees 8 or 10 feet in height, the latter being the main source of fuel throughout the western portion of southeastern Seward Peninsula. Alders are most numerous along the eastern shore of the Darby peninsula, where they form a dense undergrowth of half recumbent interlocking branches, through which passage can be effected only by chopping a trail.

No statement of the vegetation would be characteristic without mention of the abundant berries, which grow mainly above the tree zone. Blueberries are particularly prolific, the low bushes forming in places a mat of vegetation. Salmon berries, much prized by natives and prospectors, grow under essentially the same conditions as blueberries and are especially abundant on rolling low uplands, such as those between the Buckland and East Fork of Koyuk River. Currants are found, but are not abundant.

Several kinds of grasses and forage for horses are found and are generally sufficiently plentiful, so that they do not have to be specially sought until late in the season. The pack horses used by the Survey party were particularly fond of the so-called "goose grass," a kind of equisetum that grows on well-drained areas near the banks of the streams where trees do not form a thick shade. By the first of September frosts so impair the vitality of the grasses that forage must be sought with care in the protected valley heads facing south, and it becomes necessary to place camp with considerable thought as to the feed supply.

Flowers are abundant and give brilliancy to the landscape in the spring and summer. Some fifty varieties were noted, but no collections were made, and therefore no specific determinations were possible. The general impression, however, was that flowers were abundant, but that they were limited to relatively few genera and families.

Birds and animals are fairly abundant throughout the region, although they are not so plentiful that game can be relied on for food. In the higher hills between the Yukon and Norton Sound numerous caribou signs showed that the mosquitoes had driven these animals into the highlands during the early part of the summer. Farther west caribou are almost entirely wanting, although probably a few may still be found in the unfrequented region north of the Koyuk. Domesticated reindeer, held either by government or private ownership, are herded near the mouth of the Shaktolik and south of Cheenik. These herds are moved from place to place, and sometimes the animals stray away and become wild.

Bears are comparatively numerous in the less frequented parts of the region. Well-trodden bear trails run along the Shaktolik for many miles, where the animals fish during the salmon season. Along the ridge between Kwik and Tubutulik rivers, also, bear signs are abundant, especially while the blueberries are ripe. In the upper part of the Kwiniuk basin near camp C14 the sand bars are covered with bear trails. From the reports of prospectors and trappers it is said that most of the bears are rather large and brown, few black bears being found. The only bear that was seen by the Survey party was a very light brown.

Caribou and bear are the only two large animals in the region but there are several small animals that are caught either for their fur or as food. A few rabbits are found in Seward Peninsula, but none were seen in the Nulato-Norton Bay region. Red foxes were seen, and cross foxes are reported. Some marten, muskrat, and other small skins are taken by trappers in the Yukon basin contiguous to Nulato, but the number of skins is yearly decreasing. Porcupine were seen in the Inglutalik and Tubutulik river basins. Ground squirrels common in the less-forested regions of Seward Peninsula are almost entirely absent throughout the greater part of the area east of the Koyuk River.

Of the birds, ptarmigan are perhaps the most abundant throughout the region as a whole, but they are seldom found near the coast and are yearly becoming fewer and fewer. Early in the season these birds are found hiding in the brush with their young, but later in the summer flocks of fifteen or so may be flushed in many of the blueberry patches. After the berries begin to fail and cold weather approaches, the ptarmigan move from the higher land and congregate on the sand bars of the streams. A little later they begin to gather into the large coveys so often seen after the snow has begun to fall.

Along the coast where ponds and lagoons occur ducks, geese, and other water fowl are plentiful. The southward migration of the geese in 1909 took place the last of August and the first of September, and during this time thousands of birds passed over Norton Bay. Cranes were seen, some living on the low swampy country of the coastal plain province and others apparently making their homes on the dry rolling uplands. Robins, crows, and many other birds living in more southern regions were also observed but not minutely noted. Owls, both barred and snowy, are common, and their regurgitations may be found on almost every knob that gives a lookout over the surrounding country. A few eagles and hawks were seen. Spruce or "fool" hens were especially noted in the Darby peninsula country south of the mouth of the Kwiniuk, but they are also found in many other parts of the region.

Fish are almost always plentiful and can be relied on by travelers for food. Grayling are the most common of the fish and are found in all streams of sufficient size. In length they range from a few inches to about 20 inches. They will take a fly hook at almost all times during the summer. Trout of several varieties live in the clear swift waters of the mountain streams and may be caught with a fly hook. Salmon usually run up the larger streams and are much used for food by trappers, prospectors, and natives for themselves and their dogs. Salmon were seen on the Inglutalik as far upstream as camp B9, on the Koyuk above East Fork, on the Kwiniuk above camp C14, and on the Niukluk far above Council. The season of 1909, however, was a particularly poor salmon season, and only a few fish were caught in any of the Norton Bay streams considered in this report.

Salt water forms of life are abundant in Norton Bay and are used for food and clothing. The tomcod, a small, bony fish, and the herring are caught by natives and whites. From the fur of the hair seal much of the clothing of the natives is made, and the skin of the oogruk, a thick-skinned seal, furnishes almost all of the homemade footwear (the mukluk) of the inhabitants. Walrus is sometimes caught near the edge of the ice pack in the spring, and its flesh is used for food.

CLIMATE.

Continuous records of the various elements of climate have not been made in any part of the region for sufficient length of time to afford accurate data for describing the prevailing conditions. The nearest observation stations, at Nome and at St. Michael, are both situated on the coast and give but little information concerning the interior. At present, therefore, there are few records available for the Nulato-Council region except scanty observations extending over only short periods.

TEMPERATURE.

At Nome the highest temperature recorded during 1909 was 70° F., but it is probable that in the interior, where the temperature is not so much affected by the sea, higher records would have been obtained. The work of the Survey party was carried on in the higher hills during the hottest part of the summer, so that the temperatures were much lower than they would have been near sea level. Ice one-quarter of an inch thick formed on water in a pail during the night of July 24 at an elevation of about 1,500 feet at camp B5. On August 5 ice remained on the small pools of water along Peace River at an elevation considerably less than 1,000 feet until after 10 a. m. The hills north of Mosquito Creek and the head of the Fish River valley were heavily covered by snow on September 1, and on September 16 snow covered the ground down to 800 or 900 feet on the southern end of the Darby Range and remained on hills above 1,000 feet for the rest of the season.

The mean annual temperature at Nome for 1907 was 24° F., and for 1908 it was 25° F. As it seems fully as warm at Nome as in the region to the east at the same time, it is probable that the mean annual temperature is not far different for the two localities. The summer temperatures are higher in Nulato-Council region because of the absence of sea control, which would also make the winter temperatures lower, so that these two factors would tend to balance each other. Further data on the temperatures are afforded by a few observations made at Nulato and at the Omilak silver mine, and published by Abbe.[a]

Extreme ranges in temperature (°F.) at Nulato and at Omilak mine, Alaska.

	Jan.	Feb.	Mar.	Apr.	May.	Oct.	Nov.	Dec.
Nulato:								
Maximum	23	29	44	50	71	47	28	31
Minimum	−62	−60	−33	−23	7	−13	−36	−54
Omilak mine:								
Maximum	43	36	43	55	63	36	32	....
Minimum	−33	−52	−36	−24	16	− 2	−29	−29

The observations at Nulato from which this table was compiled were carried on for 12 months, from October, 1894, to May, 1895, and from January to April, 1896; those at Omilak mine were also carried on for 12 months, from January 2 to May, 1884, from October 18 to December, 1884, and from January to April 16, 1885. In the report it is noted that in the fall of 1894 the Yukon was closed at Nulato on October 16, and opened in the spring of 1895 on May 22. Near Omilak mine, Fish River opened on May 21, and was closed by ice on September 25, 1884; in 1885 this river opened on May 9.

Dall,[b] who spent a winter at Nulato, has published the following table of temperatures for the different seasons at that place:

Range of temperature at Nulato, Alaska, by seasons.

	°F.
Spring	29.3
Summer	60.0?
Fall	36.0?
Winter	−14.0
Year	27.8

PRECIPITATION.

During the summer of 1909 the precipitation in the western part of Seward Peninsula was abnormally low, and it seems probable that

[a] Abbe, Cleveland, jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 133–200.
[b] Dall, W. H., Alaska and its resources, p. 436.

the amount of rain received by the Nulato-Norton Bay region was also less than usual. There were less than a dozen really rainy days from the latter part of June to the end September, but in this period there were 38 days on which it showered.

The following table gives the results of previous instrumental observations at Nulato and at the Omilak silver mine.[a]

Mean precipitation, including melted snow and mean number of days with days with 0.01 inch or more precipitation at Nulato and Omilak mine, Alaska.

	Jan.	Feb.	Mar.	Apr.	May.	Oct.	Nov.	Dec.
Nulato:								
Mean total	0.68	0.91	1.46	0.16	0.36	1.36	1.20	1.42
Days	5	7	12.5	2	4	8	6	8
Omilak mine								
Mean total	0.40	0.32	0.15	0.07	0.02	0.23	0.45	0.18
Days	3	3	3.5	4	2	....	3	3

The record for Nulato was for 10 months, from October, 1894, to May, 1895, and from January 3 to March, 1896; the record for Omilak mine was for 9½ months from February to May and from October 18 to December, 1884, and from January to March, 1885.

From what is known of near-by areas, it may be stated that the amount of precipitation during the 8 winter months is roughly between one-half and one-third of the total for the year. If a factor of this value be applied to the tables so as to correct the total for the year on the basis of the entire 12 months, it follows that the annual precipitation at Nulato is between 15 and 20 inches and from 10 to 12 inches at Omilak mine. This would make the Fish River region about equivalent in moisture to the region near Nome and the region around Nulato much more moist. The region as a whole, however, would be classed as semiarid and similar to a large part of the States of Montana, Idaho, Wyoming, and Colorado. As the larger part of the precipitation comes from June to September, the impression gained by a summer traveler is of a region of much greater rainfall than is actually the case.

WIND.

Throughout the region the northerly winds are the fair weather winds, whereas those from the south usually bring rain. During 1909 the predominant wind direction was from the north, and the weather was accordingly dry for the greater part of the time. Owing to the absence of a heavy cover of vegetation over most of the upland area, the force of the winds is strong and the effects are marked. On the bare limestone hills pieces of detritus are moved by the wind, and the small sand grains are quickly removed from the places where

[a] Abbe, Cleveland, jr., op. cit., pp. 162–165.

they are formed by disintegration. In many places the foliage on the lower lands is covered with the wind transported dust.

Dust whirls caused by convectional currents of air induced by overheating the lower layers were seen several times along river bars. One such whirl started on the Shaktolik River with such explosive violence that it threw up sun-baked pieces of mud several inches in diameter and scooped out a shallow depression. Several dust whirls were noted on the lower part of East Fork and Koyuk rivers and could be traced for several miles across country.

SETTLEMENTS AND POPULATION.

The only villages in the Nulato-Council region are Nulato, Kaltag, Cheenik, Bluff, and Council. Road houses are, however, numerous along the coast and form a complete line from east to west. During the summer there is but little travel, but during the winter the mail and travelers furnish patronage to road houses along the coast at Carson Creek, Walla Walla, Kuiuktulik, Miniatulik, Moses Point, Isaacs Point, Ungalik River, and Shaktolik River. Along Fish River there are road houses between Cheenik and Council, at the mouth of Fox River, and at the mouth of the Niukluk. On the Yukon River are numerous road houses from Kaltag eastward.

A few scattered cabins are the only other habitations in the region, and these are occupied but a short time each year, mainly by trappers. On the lower part of the Inglutalik, 6 or 8 miles from the coast and on this same stream near camp B7, are cabins of this sort.

The mining and prospecting centers of settlements are principally in the vicinity of Bluff and Council on Ophir, Melsing, Mystery, and Goldbottom creeks. There are several cabins, however, on Bonanza Creek occupied by placer miners who hold ground on this stream. At the Omilak silver mine on Omilak Creek, a tributary of Fish River, a mining camp has been established since the early eighties and, although now practically abandoned, at different times has had more than a score of inhabitants. On Bear Creek, a tributary of the Buckland from the west, there has been a small settlement of placer miners since 1902. Two cabins near Alameda Creek, a tributary of Koyuk River from the west, mark a small placer settlement. Ditch camps with one or two men each have been established along the Candle ditch line on Kiwalik River, but are vacant during the winter.

Native encampments are found principally along the coast and belong almost entirely to Eskimos. Along the Yukon are Indian villages, generally established on the outskirts of the white men's villages. The Indians, as a rule, have a more or less permanent abode, but the Eskimos migrate along the coast and are seldom found several seasons in the same place. There is an exception, however, in the case of those owning reindeer. These people usually summer in nearly the same place, but during the fall and winter they are constantly moving their herds from one pasture ground to another. The largest reindeer settlements are near Shaktolik and Cheenik, where the Government herds are located. These herds are mainly tended by natives.

No attempt was made to obtain a count of the population, but, from the best estimates it has been possible to make, it is probable that there are between 1,000 and 1,500 whites and natives in the Nulato-Council region.

DESCRIPTIVE GEOLOGY.

In the Nulato-Council region there are two major geologic provinces, namely, the Cretaceous basin and its inclosing rim. In the mapped area only portions of the western borders of the basin were studied, and neither the northern nor the southern boundaries were determined. In the Cretaceous areas only exploratory surveys were made, and the eastern rim was not visited by the party of 1909. By reason, therefore, of the relatively slight amount of geologic information, this field is shown on the comparatively small scale map, Plate V (in pocket), of the Nulato-Norton Bay region. Farther west, however, the previous work of Mendenhall, Moffit, Collier, Brooks, and Richardson, supplemented by the surveys of 1909, has warranted publication on the larger scale of Plate VI (in pocket), the geologic map of southeastern Seward Peninsula. It should be pointed out that neither map presents the details of the geology, for there are many problems which must await much more searching investigation than the hasty trip of 1909 would permit.

The rocks or deposits of the region may be assigned to six main groups—the undifferentiated metamorphic rocks mainly of pre-Silurian age, the Paleozoic rocks, the Cretaceous sedimentary rocks, the igneous rocks mainly pre-Cretaceous but in part later than that period, the veins, and the unconsolidated deposits mainly of Quaternary age. Each group shows individual characters which are described in the following pages and the areal distribution is indicated on the geologic maps, Plates V and VI. Plate VI is the more serviceable for showing the distribution of the metamorphic and igneous rocks, and Plate V for showing the nonmetamorphic consolidated sediments, but both maps are necessary for a complete idea of the areal extent of the different geologic members.

UNDIFFERENTIATED METAMORPHIC ROCKS.

The greater part of southeastern Seward Peninsula and the southeastern part of the Nulato-Norton Bay region are formed of a series of metamorphic rocks, much folded, sheared, and so changed that in but few places are their original characters preserved. This complex consists of a variety of different rocks grouped on the basis of structure or lithology as schists, limestones, and quartzites.

AREA EAST OF THE YUKON.

The eastern area of metamorphic rocks has not been studied in detail, but the following quotation from Maddren [a] will serve to describe the general lithology:

> The oldest group of sedimentary rocks consists of the quartzite and mica-quartz schists, with associated crystalline limestones, garnet schists, and fine-textured slaty schists or phyllites that form a large part of the Kaiyuh Mountains and extend northeastward across the Yukon to the basin of Tozitna River and possibly southwestward to the Haiditarod. Succeeding this belt of schistose sediments is an extensive group of ancient diabasic effusive rocks that appear to be stratigraphically associated with the schistose rocks. These diabasic rocks have not been deformed nearly so intensely as the schistose group. In places they show greenstone schist phases, but for the most part they have not been greatly altered. Their contact relations to the schists are not known in this region. They appear to flank both the northwest and the southeast sides of the schist belt in the Kaiyuh Mountains, where they extend southwestward to the Innoko, and they have extensive development toward the northeast north of the Yukon as far as Gold Mountain and beyond. No statement as to the thickness of this diabasic group can be made at present.

SOUTHEASTERN SEWARD PENINSULA.

CHARACTER AND DISTRIBUTION OF METAMORPHIC ROCKS.

The schists form the greater part of the metamorphic complex and may be described according to the mineral or minerals characteristic of them. The schists most commonly found are quartzose, graphitic or carbonaceous, biotitic, feldspathic, and calcareous. Gradations between different types are frequent and the differentiation is by no means certain. It appears, however, that the present lithologic differences are in considerable measure due to original characters, so that in a broad way identity of lithology may be taken as indicating deposits formed at essentially the same time. This is generally true of the graphitic schists, is sometimes true of the calcareous schists, and is seldom true of the biotite schists.

Owing to the complexity of structure and the insufficient examinations of parts of the field, it has not been possible to indicate on the map consistently the areas occupied by the various types of schist. It has been found necessary to show areas which, for want of a better name, have been called "undifferentiated metamorphic rocks." These undoubtedly contain representatives of some of the rocks that have

[a] Maddren, A. G., Innoko gold placer district, Alaska: Bull. U. S. Geol. Survey No. 410, 1910, p. 43.

been differentiated as well as others, but, as stated above, either the scale of the map or the absence of definite data has precluded accurate mapping. In a measure the lumping together of diverse units has obscured geologic relations, and on the map it frequently happens that the undifferentiated metamorphic rock symbol terminates some other symbol in an abnormal manner. As a specific instance of this kind may be cited the region for 10 miles north and west of Bluff. Detailed traverses along the western margin of this area showed the presence of the feldspathic schists of igneous origin, but no other data are available south of Fox Creek, except in the immediate vicinity of Bluff. Therefore, although it is probable that much of the region is of the feldspathic schist type, it seems unsafe to map the distribution in this 100 or more square miles on such slight evidence. Thus at the risk of obscuring the important fact that the feldspathic schists along the western margin of the map are continuous with the feldspathic schists of the Bluff and Fox Creek regions it has seemed best to adopt the more noncommittal course of showing that the rocks have not been adequately differentiated.

As shown in Plate VI there are five main areas of undifferentiated metamorphic rocks—(1) around Kwik River, (2) between the two lava flows north of the Koyuk, (3) the Bendeleben Range from the head of Death Valley westward, (4) the western part of the mapped area south of the Niukluk, and (5) along the western flanks of the Darby Range extending southward across the head of Kachauik River to the coast of Norton Bay east of Bluff.

KWIK RIVER AREA.

The schist area at the head of Kwik River shows few exposures in place, and practically nothing was learned regarding the structure and relationship of the rocks of the region except that they are quartzose schists. Toward the east or near the limestone area at the head of Kenwood and Mukluktulik creeks the schists are predominantly very dark and somewhat graphitic, and the rocks may be the equivalent of some of the black slates and quartzites found in places intimately connected with dark limestones. Farther west, however, the similarity to the carbonaceous schists is not so marked, and it is possible that one of the other types of schist is represented.

This schist is highly quartzose in all places, contains some chlorite, practically no garnet or feldspar, and few specimens of it effervesce with acid. Numerous cubical cavities show that it contained pyrite in considerable amounts. It finds topographic expression in a series of massive, slightly dissected hills with gentle slopes covered with waste and devoid of outcrops. Owing to the absence of structural determinations no statement can be made of the thickness or relations of the member. Looked at in detail, however, the minor structures show that the rocks have been so deformed that schistosity has been produced throughout. On the flat-topped, massive hill east of camp C4 the float shows in almost all instances clearly marked evidence of two structures—that is to say, the plication of a previously developed cleavage and color banding. As this structure was not seen in place, however, the relation of the two structures in age could not be determined. The only fact bearing on this point is the occurrence of a shattered anticline west of camp C3, the axis of which strikes northwest-southeast and pitches strongly to the northwest.

AREA NORTH OF THE KOYUK.

The area of undifferentiated metamorphic rocks north of the Koyuk was not visited by the party of 1909. From the manuscript notes of Moffit, who studied the region in 1903, it is evident that a number of different types of schist were found. East of Kiwalik Mountain black slates and carbonaceous schists are closely associated with the limestone area. As the granite contact of Kiwalik Mountain is approached biotite forms an important constituent, although it is of no stratigraphic significance, as it is undoubtedly due to the intrusion of the granite. West of Kiwalik Mountain the schists, according to Mendenhall's field notes, are mainly calcareous, with some greenish schists which may correspond to the feldspathic schists to be described later. Quartz-chlorite schists are abundant in places, but their stratigraphic position, with respect to the others, has not been determined.

BENDELEBEN MOUNTAIN AREA.

According to the geologists who studied contiguous areas in 1900, the metamorphic schists of the Bendeleben Mountains were considered distinct from the other schists of the region and were therefore given a name and assigned to a more or less definite stratigraphic position. In 1908 the senior writer of this report made a cross section of the range along the western margin of the area, and in 1909 the party had the opportunity of studying the section north and west of Death Valley, where rocks previously considered as belonging to the Kigluaik group are exposed. These studies have caused considerable doubt as to the desirability of retaining the stratigraphy as outlined formerly, and these rocks will therefore be treated as "undifferentiated metamorphic rocks."

Mendenhall [a] mapped the Bendeleben Range as two large areas of massive intrusives, mostly granite, with a metamorphic series sep-

[a] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901.

arating the two. In the text the following statement[a] of this schist area is made:

About the head of Fish River the mountains are chiefly granitic, but along their flanks and sometimes extending through them in belts of varying breadth which mark the passes are areas of schistose sediments.

About a mile above the camp of July 20 along the creek is an outcrop of a rusty and very graphitic schist associated with more calcareous phases. Five miles farther along the right bank of this same branch of Fish River is an outcrop of bluff slates with very little calcareous matter, while 2 miles farther northwest in a gap between two branches of Fish River the series is represented by a white, coarsely crystalline marble. This narrow belt of the crystalline series between two great intrusive granitic masses expands to the northwest.

Collier[b] states in a report published in 1908, the field work for which was completed in 1903:

The only section across the Bendeleben Range which has been examined by the writer is along Parantulik (Pargon) River and Ella Creek, between the heads of which there is a low pass. The structure here appears to be anticlinal and the prevailing rocks are dark-colored quartz-biotite schists and gneisses similar to those of the Kigluaik Range. Sills and dikes of coarse-grained granite or pegmatite are also present. White crystalline limestones containing scattered grains of graphite occur in beds 20 feet or more in thickness interbedded with the schists along Parantulik River from a point near its head to the edge of the Fish River lowland.

Smith in 1908 studied a section along the upper Niukluk across the range to the northern margin. The examination showed that the section was composed of quartzose schists, a few much dislocated limestones, a complex and very numerous series of granitic intrusives, and black carbonaceous slates and schists. All of the rocks were highly biotitic. North of Birch Creek black slates and calcareous schists predominated. All the rocks were much sheared and original structures were not discoverable, but the diversity of trends of the cleavage noted were such as to lend but slight support to the idea that the structure is in general east and west.

The observations of the party in 1909 in the Bendeleben Range were confined to the extreme eastern part and consisted of a study of the 2,200-foot hill northwest of camp C7, and of the 3,000-foot hill north of camp C8. On the first traverse were found biotitic schists with some thin limestone members and greenstone schists, all thoroughly cut up by granitic intrusions of later date. On the second traverse the same kinds of schists were also found, but in addition there were some carbonaceous schists and greenstones were more abundant.

[a] Op. cit., pp. 200–201.

[b] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 67–68.

Southwest from camp C8 to C9, 3 or 4 miles from camp C8, the schists are not much intruded by granites and belong almost entirely to the group of feldspathic schists with here and there a few limestones and a little black slate. These schists appear to be fully as metamorphosed as those to the north and strongly suggest a trend more nearly north and south than east and west.

On account, however, of the small amount of investigation in the larger part of the Bendeleben Mountains it seems unsafe to differentiate the schists on the map. They are characterized as a whole by the presence of biotite, but this is of late origin and is not stratigraphically significant. Otherwise all the various kinds of schists and other metamorphic rocks have been recognized, and the series therefore can not be regarded as a unit.

AREA SOUTH OF THE NIUKLUK.

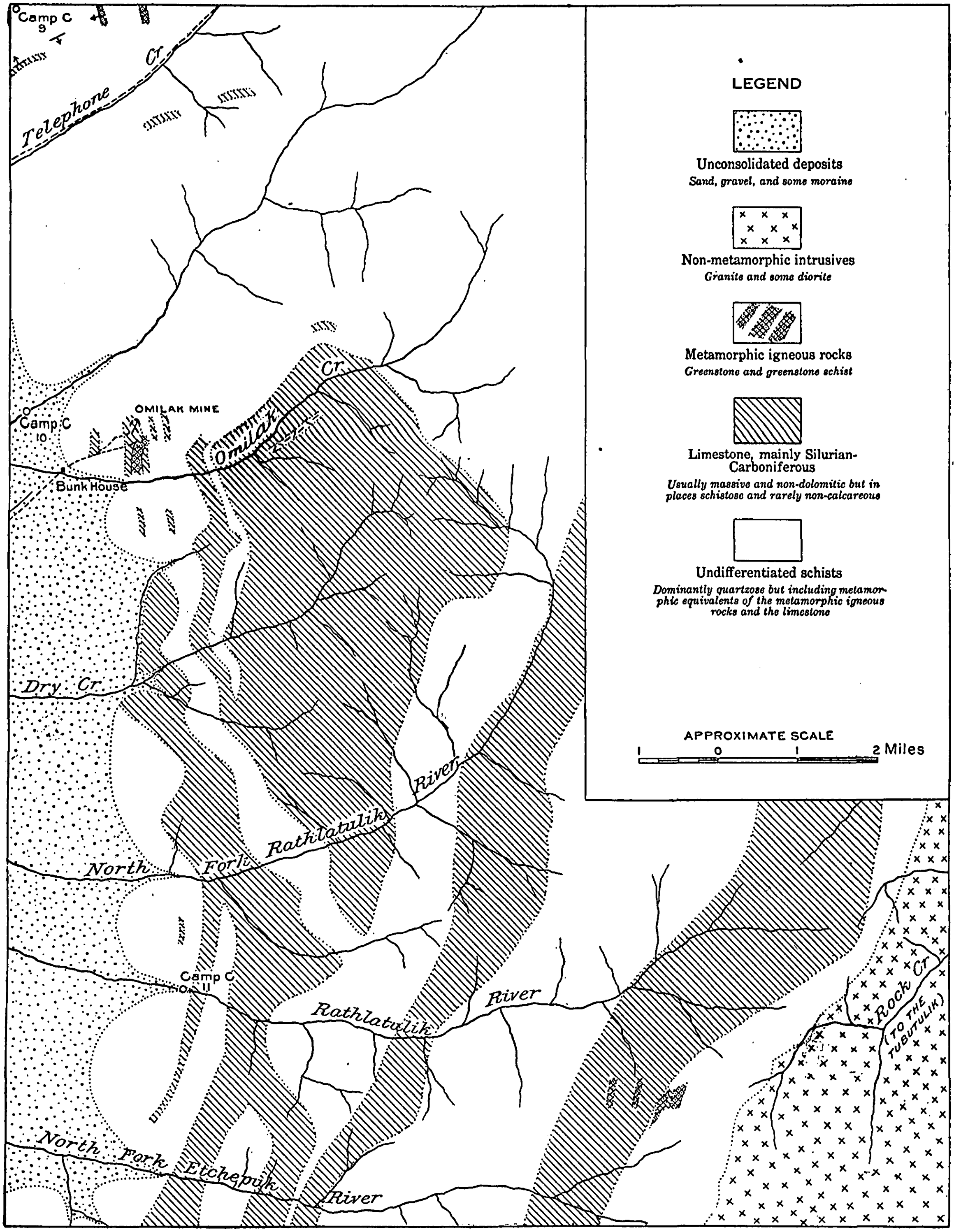
The undifferentiated metamorphic rocks along the western margin of the mapped area south of the Niukluk have been studied in detail where they enter the Solomon and Casadepaga quadrangles. From this study it was determined that the schists were mainly of the quartz chlorite type and that they underlay the limestone near the head of Fox Creek. North of the Niukluk, however, younger schists, called in the region to the west the Puckmummie schist,[a] consisting mainly of black slates and thin limestones, probably overlie the limestone. These rocks seem to merge with the black slates that form the southern flanks of Mount Bendeleben and would indicate enormous deformation not recognizable by surface features.

West of the belt of greenstone schists the rocks show many different lithologic types, but black quartzitic schists, quartz chlorite schists, and calcareous schists predominate in such complex relations that no separation of them has been made. Undoubtedly some of the quartzose schists correspond to the older schists to the west, but some are the sheared equivalents of the heavy limestones and others may belong to the black slate series, which will be described later. In the southern part of this western area a large part of the undifferentiated metamorphic series is the equivalent of the greenstone and feldspathic schist series, but this part has not been closely examined.

AREA WEST OF THE DARBY RANGE.

The fifth large area of undifferentiated metamorphic rocks is along the western flank of the Darby Range and extends southward along the head of Kachauik Creek to the coast west of Rocky Point. In this area schists of a great variety of lithologic types are found in such intricate interrelations that considerable generalization is re-

[a] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles: Bull. U. S. Geol. Survey No. 433, 1910, pp. 62-66.



GEOLOGIC MAP OF OMILAK REGION.

quired in mapping them. Plate VII shows a part of this region south of the Omilak mine on a scale of 2 miles to the inch and indicates the geology in some detail. For the present the main interest in this map centers in the arrangement of the various schist and limestone bands. Even on this larger scale map, however, it is impossible to show the actual complexity of the geology. Schists of many different lithologic characters are found in the area covered by this map, but practically all of them are more or less biotitic. Some carbonaceous schists and quartzites suggest the presence of younger members of the schist series, whereas the relations of others show that they are older than the limestones which are believed to be higher in the series.

In the undifferentiated schist area at the head of Kachauik Creek the schists are biotitic, chloritic, and sometimes calcareous, and discrimination of the various types is impossible with the poor exposures. Southward, however, schists lying below the limestone at White Mountain have been recognized by Mendenhall and Collier on Fish River. Similar schists extend southward and probably form most of the hills in the low divide between Norton Sound and the Golofnin Bay drainage. Unfortunately, however, this area has not been studied in detail and the differentiation of the rocks must await further investigation.

SUMMARY.

The undifferentiated metamorphic rocks are highly sheared and cleavage is the dominant structure observed. In many parts of the field the cleavage is at a low angle. In many outcrops where an earlier structure is recognizable the two structures do not coincide, and it is believed that this is the general rule. Faulting is also common in the schists, but the amount of dislocation is generally not determinable on account of the absence of clearly defined horizon markers.

In the typical schist areas where igneous intrusions have not afforded more resistance to erosion, the topographic forms produced are smooth and rolling. Characteristic schist topography is dominant in the eastern part of the Kwik River Basin and is typical of a considerable part of southeastern Seward Peninsula. Here and there on the summits of the ridges rocky knobs of irregular form rise 10 to 30 feet above the surrounding uplands. In the mountainous regions the schists form rugged hills with steep slopes. As a whole, however, the schists are less resistant to erosion than the limestone or igneous rocks and are therefore found in the lower land and passes.

Intrusive activity of several periods has affected the undifferentiated metamorphic rocks. Greenstones, granites, diorites, and other igneous rocks cut these schists and have each had a share in the metamorphism and obliteration of the original characters and distribution of the schists.

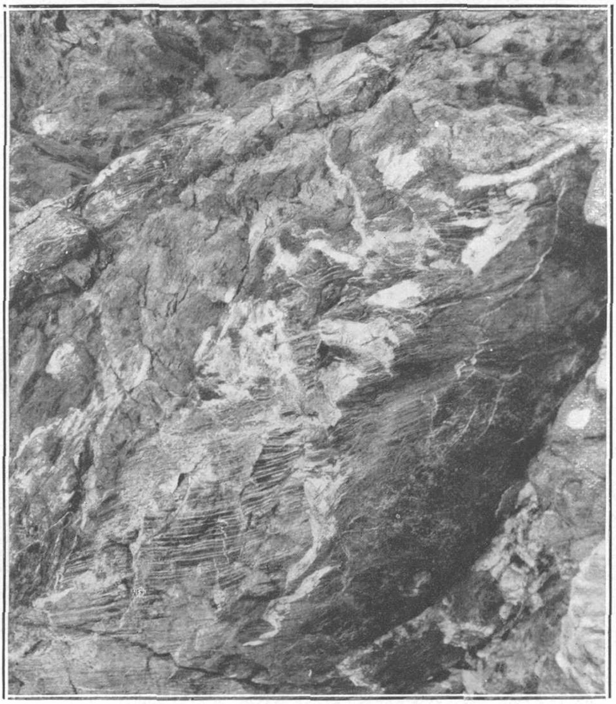
As the undifferentiated schists as mapped include several stratigraphic units of different origin, form, and age, no general statement can be made of the relation of these rocks to the others of the region. It is clear, however, that some of these schists are older than the limestones and other rocks which will be described later, for they underlie them. The question of age and relationship will be discussed more fully in the section on historical geology. For the present, however, it seems justifiable to state that, taken as a whole, the area of undifferentiated metamorphic rocks is composed of rocks older than any of the other areas indicated on the map and is chiefly pre-Silurian.

PALEOZOIC ROCKS.

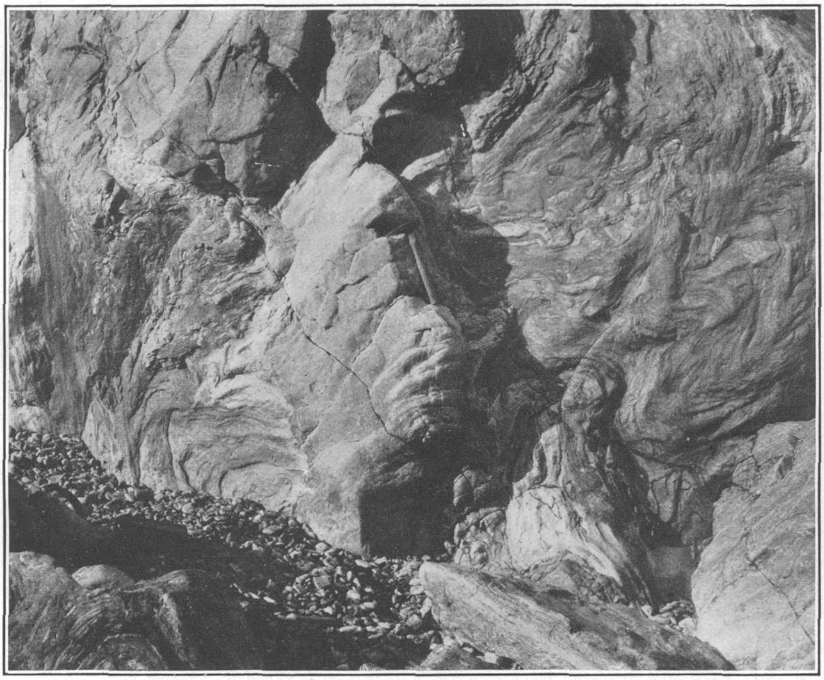
There are five main areas of rocks which are presumably of Paleozoic age, and, although more detailed investigation will undoubtedly show that parts of the undifferentiated metamorphic rocks are of similar age, the lack of information and the complexity of the structure forbid closer correlation at this time. Characteristically all the known Paleozoic rocks are metamorphosed and lithologically consist of limestones and schists complexly folded and faulted. As indicated on the map (Pl. VI), these five areas are as follows: The ridges east of the Darby range extending from the coast of Norton Sound on the south to beyond the Koyuk on the north; the hills east and west of the Fish River gorge from the head of Kachauik Creek to Ophir Creek, including the limestone hills on Fish River near White Mountain; the region south and east of the Omilak mine; the area exposed on the seacoast from Bluff to Topkok Head extending inland an undetermined distance; and the hills at the head of the Mukluktulik. In addition to these larger areas there are smaller areas, some shown on the map and others included in the undifferentiated metamorphic rocks.

AREA EAST OF THE DARBY RANGE.

Along the eastern flank of the Darby Range a group of rocks, consisting mainly of limestones with some schistose bands and closely associated with black slates and quartzites, was noted by Mendenhall in 1900, and studied in some detail by the survey party in 1909. This belt extends from the seacoast with a general northerly trend across Kwiniuk River and along the Tubutulik, forms the eastern divide of Death Valley, and is exposed north of the Koyuk in the hills east of Kiwalik Mountain. Although it probably extends still farther north, its obvious continuation ceases at this place. In this distance the average width of the belt is from 4 to 6 miles. Capital



A.



B.

PALEOZOIC LIMESTONE, DARBY PENINSULA.

A, Intruded by greenstone; *B*, Intruded by granite.

exposures are afforded along the seacoast from the mouth of the Miniatulik southeast nearly to Carson Creek. Studied in detail, the exposures show a great thickness of limestones, considerable dolomite, black carbonaceous slates, and schists, all cut by greenstones, granites, and diorites.

The limestones are in places grayish blue but in other places nearly black. Associated with them in such intimate and complex relations that they can be separated only by refined investigation are dolomites usually of a light-gray, slightly pinkish color. Light-colored dolomites have been recognized in the sea cliff exposures, in the hills between the Kwiniuk and the Miniatulik east of camp C15, and in the hills near camp C5, and east of Death Valley. No measurement of the thickness has been made, but it seems certain that not less than 1,000 feet are required to account for the field distribution.

Although highly metamorphosed, poorly preserved fossils were found in the light-colored dolomite $2\frac{1}{2}$ miles east of camp C15 on Kwiniuk River. According to Kindle, who examined the collection—

Lot 9AS130, locality 9AS180, Kwiniuk divide, is represented by a single specimen. This is the now well-known though undescribed thick-shelled lamellibranch which has generally been compared with *Megalomus canadensis*. This fossil indicates a late Silurian age for the bed from which it comes. It is interesting to note that it occurs here as at White Mountain (and at the Ramparts of the Yukon) in a highly magnesian limestone. The indexical value of this fossil rests upon our knowledge of its faunal associations in southeast Alaska, where it occurs in association with various late Silurian fossils.

At this place the areal relations are indeterminate. There is some very dark-colored limestone which seems to be either a thin band between two dolomitic bands or else unconformably overlies the dolomite. Northward, however, near camp C5, at the head of Lost Creek, the dolomite lies to the east; that is, apparently on top of the dark limestone. This may be due to intense folding or faulting, or it may be normal depositional sequence.

The limestones associated with the Silurian dolomite range in color from light bluish gray, nearly white, to dark gray, almost black. They are exposed at a number of places in the mapped belt, but the most significant outcrops are those found in the divide between the Kwiniuk and the Tubutulik and along the coast from camp C16 to camp C19. In all places the limestone is folded and contorted with many faults and with calcite and some quartz veins. It has been intruded by greenstones, granites, and diorites. Plate VIII, *A* and *B*, show exposures of these limestones in the neighborhood of the intrusions and afford a fairly good idea of the general characters. Plate VIII, *A*, especially shows the well-marked bedding of the limestone, emphasized by the alternation of bands of light and dark colored limestone. Plate VIII, *B*, shows a more schistose phase, with the bedding marked by the color banding particularly evident in the right-hand portion.

At many places along the sea cliffs poorly preserved fossils were found, and, although none of them was sufficiently perfect or distinct to permit specific determination, there seems to be no question that they represent a higher horizon than that of the dolomite already described. According to Kindle, who examined the collections, a Devonian or Carboniferous horizon is represented, and in his opinion the higher rather than the lower portion is more probable. Ulrich, who examined the fossils hastily, also agreed with the probable Devonian or Carboniferous determination, but appeared to think the lower rather than the higher position was the more probable. There does not seem, however, to have been any marked difference between the amount of metamorphism or deformation undergone by the Silurian and the Devonian-Carboniferous rocks.

In the limestone hills south of the Kwiniuk River conditions similar to those noted on the coast were observed, and it is evident that the same group of rocks is represented. The higher hills are usually formed of limestone, but the saddles are here and there formed of feldspathic schists presumably of later origin. Owing to the scale of the map it has not been practicable to indicate these later schists except in a most general way, but it should be stated that these schists and greenstones are principally of igneous origin; they are not included in this group of sedimentary rocks, but will be described later under the igneous rocks.

In the region between the coast and Kwiniuk River there are, however, slates and schists of sedimentary origin which at the present time are not to be separated from the Paleozoic limestones already described. The precise relation has not been satisfactorily determined and fossils have not been found in them. There is small reason, however, to doubt that they are closely related to the Devonian-Carboniferous group.

These schists and quartzitic slates are perhaps most extensively exposed in the upper part of Mount Kwiniuk, but their structure and other characters are most clearly seen in the coast section. Usually these rocks are of a black color due to the presence of finely divided carbonaceous matter which, in some places at least, is graphite. The rocks are very quartzose and are low in other minerals. Cleavage is commonly developed; but schistosity is not so pronounced as in the older schists. Apparently schistosity is more common in the less quartzose parts of the rock. In the normal quartzose phases the rock has fractured and has had jointing developed, which causes the rock to disintegrate into a talus of small rectangular blocks. No measurements of the thickness of the slate-schist member were obtained, but it must be at least several hundred feet.

From the foregoing description, it is evident that a large mass of Paleozoic sediments which have undergone more or less fully the same general history lies east of the Darby Range. These rocks, which are complexly folded, faulted, and metamorphosed, consist mainly of dark-colored limestones with subordinate thicknesses of dolomite, black slates, and schists. They are cut by intrusives of greenstone, granite, and diorite and in age include members ranging from Silurian to Devonian or Carboniferous, with neither the overlying nor the underlying rocks exposed in close relationship. They have a thickness of at least 2,500 feet and, if considerable reduplication has not occurred, their thickness possibly exceeds this amount many times. They form bold prominent hills with scanty vegetation, covered with an angular frost-riven talus of float, and are widely developed throughout Seward Peninsula.

FISH RIVER AREA WEST OF KACHAUIK CREEK TO OPHIR CREEK.

In the hills east and west of the Fish River gorge from the head of Kachauik Creek to Ophir Creek, including the limestone hills on Fish River near White Mountain, is an area of Paleozoic rocks to be correlated with the rocks of the Kwiniuk region. The most definite data regarding the geology of this field are afforded by the exposures near White Mountain. Fossiliferous beds were found here by Mendenhall in 1900 and have been further studied by Collier, Hess, Kindle, and Smith, but were not visited by the party in 1909. In the description of the exposures on the lower Fish River it will not be possible except at great sacrifice of brevity to credit the particular contributions of each of the different geologists, but it may be remarked that the present writers are acting more in the rôle of compilers than contributors.

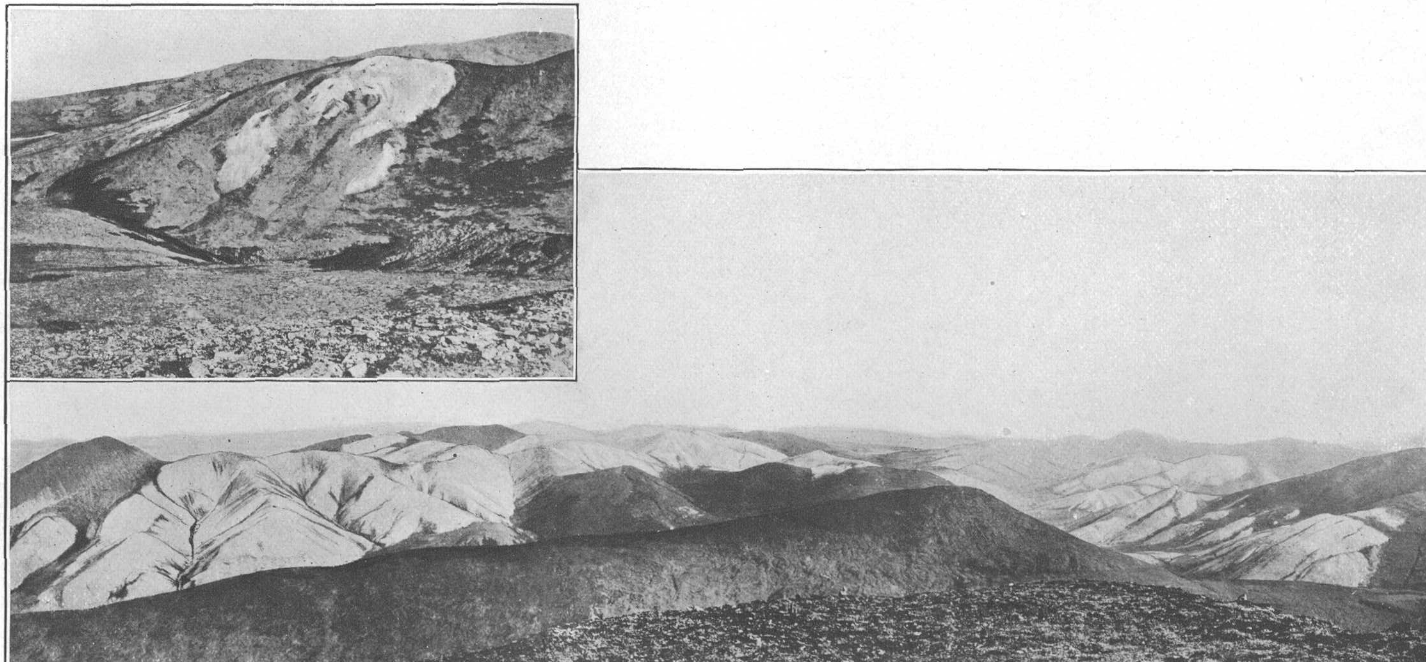
Three miles southeast of White Mountain micaceous, highly metamorphic schists dipping north underlie, probably unconformably, the rocks farther up the river. There is a considerable area of river flood plain in which exposures are lacking, and then come white dolomite hills from which the settlement of White Mountain is named. The dolomite is lithologically identical with the dolomite of the Kwiniuk region, and furthermore contains the same thick-shelled lamellibranch (*Megalomus canadensis*) together with certain other Silurian forms; the correlation seems therefore well founded. Less schistosity has been developed in the dolomite than in the rocks to the southeast, and for that reason there is believed to be an unconformity between the two.

Farther upstream and—if the apparent structure of the rocks is the true structure—overlying the dolomite is a series of schists. Considerable doubt is felt as to the relation of these schists, and it has been deemed expedient in this report to place them among the undifferentiated schists rather than to express their possible correlation with the Paleozoic black slate of the Kwiniuk region, though the latter is by no means impossible. Still farther upstream near the point where Fish River makes an east-west bend south of Steamboat Slough fossil corals have been found in a nearly black limestone. This limestone is lithologically identical with the black limestone of the Kwiniuk locality, and the fossils have been determined to be analogous. As a whole the rocks on lower Fish River are less metamorphosed than in the Kwiniuk region. Near the black Devonian or Carboniferous limestone are black graphitic slates the relation of which is not determinable, but they seem to be lithologically similar to the slates on Mount Kwiniuk in the more eastern locality.

Along the divide between the Fish River lowland and Golofnin Sound from camp C23 west to the head of Mystery Creek limestones with black slates form the country rock. None of the beds, however, were recognized as dolomitic. As a whole the rocks from camp C23 to Fish River are more schistose than their equivalents at White and at Black mountains, but the dominant north-south trend seems to be strong reason for connecting the rocks at the two places. Apparently, the dip of these beds east of Fish River is to the west at rather high angles, but original bedding is seldom recognizable, and the occurrence of diverse dip at places where the two structures have been determined points strongly to the conclusion that the great thickness represented by the surface exposures is due to reduplication through folding.

West of Fish River gorge the schistose character of the limestones is less pronounced, the rock becomes more massive and, although shattered and deformed, shows not much cleavage and but few secondary minerals. Immediately beneath the limestone at the head of Mystery Creek lies a considerable thickness of black quartzitic and graphitic slates. These have not been adequately differentiated in the field, and it is probable that part of the undifferentiated schists on Melsing Creek may belong to the same schist series as those in the Kwiniuk region, for black graphitic slates closely associated with limestones are known to occur at many places in the basin of this stream.

Whether the Paleozoic rocks extend northward across the Fish River flats and are represented by the limestone-slate group at the head of Fish River and Boston Creek has not been definitely proved. It is assumed, however, in the absence of conflicting evidence, that the two areas are the same, and it is on this basis that they have been represented by the same pattern on the geologic map (Pl. VI). According to Mendenhall's field notes the eastern part of this area



WESTERN FLANKS OF DARBY RANGE.

A, Limestone and schist at Omilak mine; *B*, General view from south.

consists mainly of white crystalline limestone associated with graphitic and rusty schists. So far as his records show, the predominant dip is to the west and the strike northwest.

In 1909 F. F. Henshaw traversed the lower slopes of the hills north of the Fish River lowland from Pargon River as far east as Boston Creek and the geology for that part of the range is represented according to his observations and is only approximate. Whether this belt of limestones may not continue still farther north across the range is not known because of the absence of any field investigation. Although such an interpretation is probable, it has been deemed expedient to truncate abnormally the Paleozoic pattern by representing the northern part of the range as formed of undifferentiated rocks.

In the vicinity of the mountains the Paleozoic rocks are cut by granite dikes and are locally as well as dynamically metamorphosed. South of the Fish River lowland the Paleozoic rocks are also cut by granites and in addition are intruded by greenstones. The latter undoubtedly would be found in the northern area also if more of the region had been examined. It should be noted that where mica-like minerals occur in the Paleozoic rocks near the granitic intrusives the mineral is usually biotite, whereas in the parts remote from the influence of the granite the mineral is chlorite, and biotite is absent.

OMILAK MINE AREA ON WEST SLOPES OF DARBY RANGE.

East of the area of Paleozoic rocks just described there are limestones which resemble in many features those of the Kwiniuk region, and although the correlation is by no means conclusive, it is the closest that can be made with the data now available. No fossils have been found in these rocks and their structure is so complex that any relation between the various units may be postulated. The correlation between the limestones east and south of the Omilak mine has been based almost entirely on lithologic evidence. The geologic map of the Omilak region (Pl. VII, p. 45) shows the distribution of the rocks in greater detail than the general geologic map (Pl. VI). Even this scale, however, fails to express the complex character of structure and areal distribution of the rocks. Plate IX, *B*, shows a view northward from a point on the divide between the two branches of the Rathlatulik about 3 miles east of camp C 11. The white areas in the view are limestones and the darker parts are schist. Some of the schists are undoubtedly derived from rocks of igneous origin, but others were unquestionably deposited as sediments. Most of the limestones are ordinary calcareous rocks, but some are dolomitic. In the view above referred to at several places in the eastern or right-hand belt of white rocks light-colored dolomites have been found. This fact points strongly to the conclusion that these beds represent the dolomitic portion of the Paleozoic rocks of the Kwiniuk region.

With these limestones black graphitic quartzites have been found here and there similar to those on Mount Kwiniuk. This type of rock is not so abundant as at the other places. Its apparently small extent is believed to be due in part to the greater amount of deformation and contact metamorphism whereby it has been transformed into a biotite schist or into a nearly white quartzite.

BLUFF-TOPKOK HEAD AREA.

The westernmost mapped area of rocks correlated with the Paleozoic rocks of the Kwiniuk region occur near Bluff and appear at several points along the western border of the area. Unfortunately, this part of the field has not been thoroughly surveyed, and considerable areas which, if more fully known, might belong to this series have been placed in the undifferentiated metamorphic rocks.

The Bluff region was not visited in 1909 and the account here given is taken from a summary report by Brooks [a] in 1906.

> Richardson, who through his acquaintance with adjacent areas had a broader knowledge of the Bluff region than the writer, divided the bedrock terranes into three groups—(1) a massive gray crystalline limestone, (2) a mica schist with some interbedded graphitic limestone, and (3) a formation of massive limestones and mica schist. The writer's observations hardly bear out the correctness of this succession of beds, for it appears to him that there is only one massive white limestone which is succeeded by a mica schist and graphitic limestone formation. Some facts are presented below which would indicate that the mica schists are, in part at least, altered intrusives and hence do not mark any definite stratigraphic position.
>
> The larger structures of the Bluff region appear to be simple, but there are many minor complications. The heavy limestone has been uplifted into a low dome, whose longer axis stretches approximately N. 70° E. About 3 miles northeast of Bluff this structure carries a limestone underneath the younger mica schists.

It is evident from this description that lithologically the same rocks are represented here as in the Kwiniuk region, namely, limestones, some of which are dark-colored, suggesting the Devonian-Carboniferous limestone and black graphitic slates. The fact that these rocks are cut by intrusives of greenstone is also indicative of a similarity between the two regions. Although Brooks correlated these rocks with the Port Clarence limestone, the fact that Devonian-Carboniferous rocks, as well as Silurian and possibly older ones, may be represented makes it undesirable to continue that correlation, and these rocks are therefore mapped as Paleozoic.

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[a] Collier and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908—The Bluff region, pp. 285–286.

AREA AT THE HEAD OF THE MUKLUKTULIK.

The fifth and last large area represented on the southeastern Seward Peninsula map as belonging to the Paleozoic rocks is the eastern area in the Mukluktulik divide. This belt trends north and south. On the south it forms Bald Head or Isaacs Point where it is cut off by the sea. To the north a prominent hill locally called Haystack Mountain, on the north side of the Koyuk Valley, marks the farthest extent in that direction; beyond that point more recent igneous rocks have cut or covered the formation.

At the eastern margin of the area is a belt of white quartzite a mile or so in width. This is cut off by basic lavas that form the hills east of Alameda Creek. It is believed that the quartzite is equivalent to the black quartzitic and graphitic slates of Mount Kwiniuk, so metamorphosed locally by the igneous rocks that the carbon has been destroyed. West of the quartzite ridge there is a considerable thickness of calcareous schist with some white limestone bands, but on the divide at the head of Coal Creek a white, completely recrystallized limestone forms knobs trending a little east of north. Sink holes 500 to 600 feet above the sea are common, and some of them show ledges of limestone. This limestone has a strong fetid odor when freshly broken, and shows no original bedding or signs of organic remains. Farther west, about 7 miles from camp B17, at the mouth of the Koyuk, alternations of black graphitic quartzitic slates or schists and limestone beds form an intricate complex about 2½ miles wide trending northeast. The dips, so far as observed, were all to the east, but the arrangement of the different lithologic units is such as to suggest extensive faulting or overturned and crumpled folds.

Northwest of this belt of alternations of black slates and limestones for 4 miles is a series of dark limestones and calcareous schists dipping southeast and striking northeast-southwest. Exposures in this field are rare and unsatisfactory. The western part of this area is formed of a belt 2 miles wide of black carbonaceous slates and schists. No outcrops in place were observed, but the unmixed character of the float points to the conclusion that this is the country rock. It is in all essentials lithologically identical with the slates in the belt farther east already described, and slight hesitation is felt in ascribing it to the same series. More detailed work would undoubtedly permit further differentiation of these two distinct lithologic phases. For the present it may be stated that whereas if, on the one hand, the dip is considered to be dominantly to the east the section shows a black slate and quartzite at the base, succeeded by a thick limestone and limestone-schist member, succeeded by an alternating series of limestones and black slates, succeeded by another thick series of limestones with some schistose phases, and this in turn followed by a massive quartzitic horizon. On the other hand, there are strong reasons for believing that reduplication through faulting and folding may occur, hence there may be only one limestone and one black slate member. No dolomite was observed in this section.

Mendenhall, who saw the section of these rocks near Bald Head, says:[a]

Along the west side of Bald Head gray and white marbles occur infolded with thin-bedded limestones and schists, and blocks of these rocks cover the beach. The point of the promontory is a mass of heavy black graphitic beds, and the eastern face exhibits a slaty and schistose phase, the rocks being generally dark. Dip and strikes are variable and the relations are obscure, but evidently complex.

SUMMARY.

From the foregoing description it is evident that there is a group of limestones, dolomites, and quartzose graphitic schists which, from the few fossils found, is known to include Silurian and Devonian-Carboniferous horizons. These rocks are on the whole less metamorphosed than certain quartz-chlorite schists on which they are supposed to rest. In general, the trend of the formation is north-south, with complex folding and faulting. No signs of a conglomerate were noted in any part of the section, and it is presumed that the Paleozoic rocks were laid down at some distance from the shore line. This conclusion is further suggested by the wide distribution of lithologically identical rocks over the southeastern part of Seward Peninsula where the metamorphic rocks outcrop. Further investigation might lead to a more precise differentiation of the various lithologic units, but such subdivision would probably not add greatly to the understanding of the economic problems connected with this group of rocks.

CRETACEOUS SEDIMENTARY ROCKS.

In the eastern part of the Nulato-Council region a large area, extending from Norton Bay and Koyuk River on the west to beyond the Yukon on the east, is occupied by a series of sedimentary rocks, including conglomerates, grits, sandstones, shales, and thin lignite beds. These deposits extend north and south beyond the field investigated. The only other rocks within this area are a few dikes near Bonanza Creek, the intrusive massif of Christmas Mountain, and relatively small areas of Tertiary effusives on the Koyuk and near the mouth of the Koyukuk.

Beds similar to certain of those found in the main sedimentary area are exposed at the mouth of Koyuk River and on its north bank at a point about 4 miles west of the mouth of East Fork, also

[a] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 202.

in the long ridge which forms the Kwik-Tubutulik divide. These outlying areas of sedimentary rocks comprise only a few square miles.

The unmetamorphosed, consolidated sedimentary rocks of the region apparently comprise a single conformable series of great thickness. Two distinct types of deposits are recognized and will be described in their order of occurrence as follows: First, a basal conglomerate called in this report the Ungalik conglomerate; second, an overlying group of sandstones and shales called the Shaktolik group. The Shaktolik group is separated into two divisions, the lower distinguished by a preponderance of sandstones over shale, and the upper in which shales are in excess.

UNGALIK CONGLOMERATE.

The lowest member of the Cretaceous sedimentary series, a basal conglomerate of marine origin, is called the Ungalik conglomerate, after the river of that name, along whose lower course it was first noted. This formation occurs along East Fork of the Koyuk River and on the Kwik-Tubutulik divide. (See Pl. V, in pocket.)

The Ungalik conglomerate is exposed in steep-faced cliffs along Ungalik River and forms most of the prominent range of hills between the river and the coastal plain from Bonanza Creek north to a point about a mile below camp A17. Here the strike changes and the conglomerate appears in the hills east of the river. Its eastern limit was not determined, but its characteristic pinnacled topography does not extend far beyond this point.

In this locality the conglomerate ranges in texture within moderate limits, the coarsest phases carrying bowlders up to 3 feet in diameter. Assortment and bedding are poor. The most characteristic materials are a variety of porphyritic rocks and abundant angular feldspar crystals in the sandy matrix. A strong red coloration on weathering indicates an abundance of iron. The bedding is so indefinite and obscure that no conclusive evidence as to the attitude or thickness of the formation could be obtained. However, a thickness of at least several hundred feet is certain.

That deformation has been intense is indicated by the abundant slickensides developed both in the conglomerate and at its contact with other members. On the Ungalik east of camp A16 it is faulted against black slates which represent a much higher horizon in the series. At this point the slates are approximately vertical. In the bluff on the Ungalik south of camp A16 are several dikes intruded in the conglomerate. They are much faulted and indicate the amount of deformation which has occured throughout the vicinity. The conglomerate area is characterized by a rather rugged topography. Where there is considerable relief the hilltops and sharp ridges are often marked by bare, rugged pinnacles.

The conglomerate is the basal formation of the sedimentary series. It is made up of rounded débris derived from the older formations, on which it rests unconformably. It chronicles a period of more or less gradual advancement of shore conditions.

On East Fork the conglomerate occupies a belt about 8 miles wide, trending north and south. It is similar to that in the Ungalik Valley in texture and in the lack of assortment and bedding. The materials include a variety of igneous rock types in the outcrops near camp B11. Farther west, near camp B12, it consists of a variety of granitic rocks of local derivation. No conclusive evidence as to the attitude or thickness of the conglomerate in the East Fork region was available, but the relief developed in the formation indicates a thickness of at least several hundred feet.

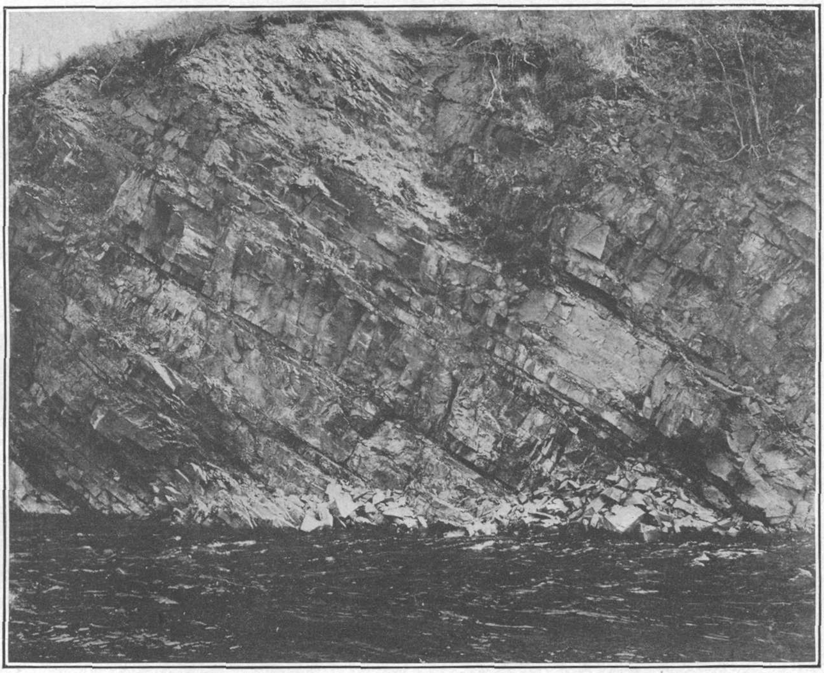
Along the Kwik-Tubutulik divide the Ungalik conglomerate belt has a width of from 3 to 5 miles. The main ridge forming this divide and its northward extension into the Koyuk drainage basin is composed almost entirely of limestone. The bowlders are smaller as a rule than those in the Ungalik and the East Fork localities. There is also greater variation in texture, the deposits including grits and limy sandstone layers. Some of the latter furnished fossil plants of Cretaceous age. Fossil corals taken from a limestone bowlder in the conglomerate on the Kwik-Tubutulik divide about 5 miles south of the camp C4 were of Paleozoic age.

Along the col at the head of Lost Creek the conglomerate is relatively free of limestone and schist material, being made up mainly of igneous rocks and quartz. Vertical dips were observed at a number of places and probably represent the general attitude of the beds in most of this area. The high dips and the fact that the conglomerate area is surrounded by Paleozoic rocks show that the younger beds have been folded or faulted downward from their former relative position, and indicate the extensive removal of Cretaceous sediments from areas which they formerly occupied. As in the other occurrences, the conglomerate marks a period of littoral erosion and deposition, and being derived from the rocks upon which it rests, its relation to them is that of unconformity.

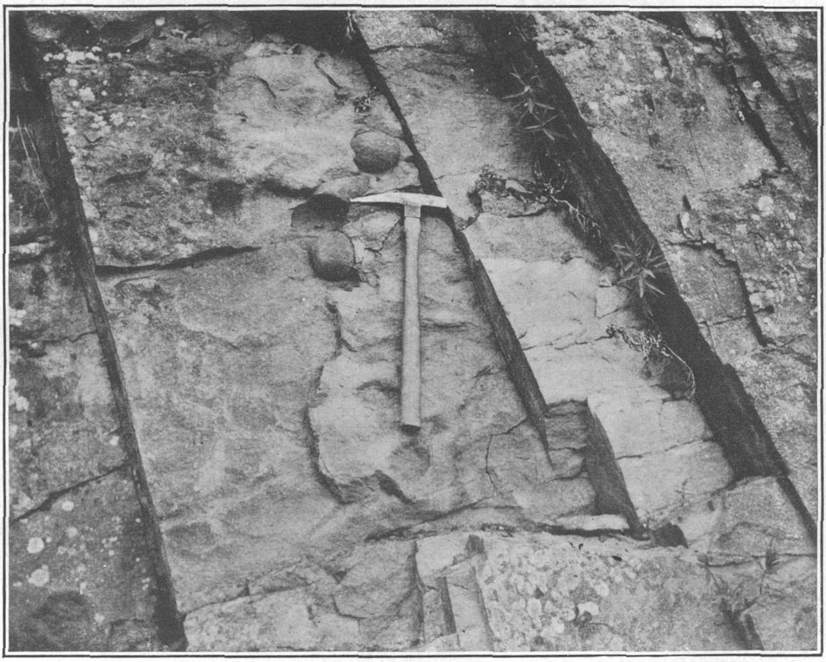
Mendenhall notes[a] the occurrence of unaltered sediments at two points along Tubutlulik River. He says:

> Eleven or twelve miles above the mouth of the Tubutulik some bluish and shaly sandstones and fine quartz conglomerates, entirely unaltered, but dipping 50° or 60° NE., outcrops along the river bank. Two or three miles above this exposure is another of soft, brown sandstone and fine conglmerate with blue clay shales.

[a] Mendenhall, W. C., Reconnaissance in the Norton Bay region, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 205.



A. SANDSTONES AND SHALES OF SHAKTOLIK GROUP, SHAKTOLIK RIVER.



B. CONCRETIONS IN SANDSTONES OF SHAKTOLIK GROUP.

Being immediately adjacent to the conglomerate area and having suffered similar deformation, these sediments probably belong with the conglomerate in the same general series.

About 70 miles east of Nulato, below the mouth of Melozitna River, a series of conglomerates, grits, and shales is exposed along the Yukon. According to Spurr[a] these beds overlie Paleozoic rocks and are made up of materials derived from them. Farther down the Yukon the conglomeratic beds are less important and the series consists mainly of grits, sandstones, and shales.

The determination of fossils collected by Atwood in 1907 from a number of horizons of this series refers them all to the Upper Cretaceous. The Melozitna locality may be regarded as having been at one time the eastern margin of the area of Mesozoic deposition, as the conglomerate areas near Norton Bay indicate the one time western margin.

An exact correlation of the conglomerates of Melozitna River and of the Norton Bay localities is not advocated, though by no means impossible. The similarity of deposits means that the same conditions which prevailed at one time at one of the localities prevailed at some time during the same general period at the others, littoral condition necessarily existing throughout the life of the Mesozoic Basin.

SHAKTOLIK GROUP.

The Shaktolik group, so called after the river of that name, which affords a good section of the beds, includes a thick series of sandstones, shales, and grits. This name is used to designate all the beds between the Ungalik conglomerate and the top of the sedimentary series. Beds of this group are widely distributed in the sedimentary area and occupy most of its space.

For convenience of description a separation into two divisions is made, the lower characterized by abundance of sandstones, the upper by the predominance of shales. Each will be treated separately in the order of stratigraphic position and localities.

LOWER DIVISION OF THE SHAKTOLIK GROUP.

Shaktolik River and westward.—Along Shaktolik River and westward the Shaktolik group is made up of alternating beds of sandstone and shale, the latter aggregating only a small part of the total thickness. (See Pl. X, *A*.) The sandstones are usually fine grained, dense, and compact, and in some places resemble fine-grained igneous rocks so closely in apearance and in constituent minerals that their

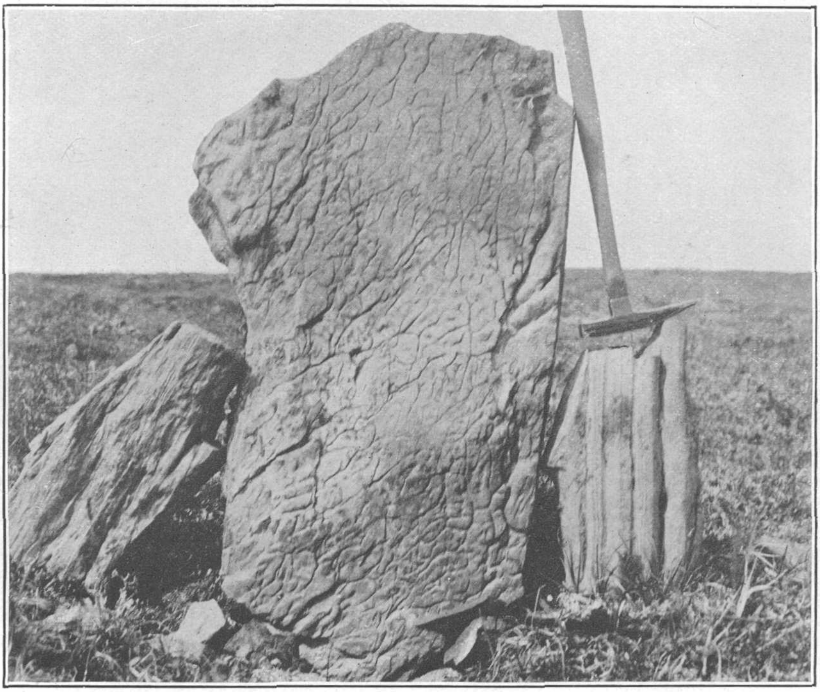
[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 189.

true character was determinable only with the aid of the microscope. Near camp A10 some of the beds exhibit a peculiar concretionary structure, large spherical masses breaking down in concentric shells under the blows of a light hammer. (See Pl. X, *B*.) Another unusual structure shows in the form of weathered surfaces seen at a number of places in the sandstone area, especially near camps A12 and B6. The surfaces mentioned were marked by linear striations and flutings and by lobate forms suggesting surface flow. (See Pl. XI, *A*.) Whether these structures are original or have been developed by postdepositional movements between beds is not known. Ordinary ripple marks are absent in the same localities.

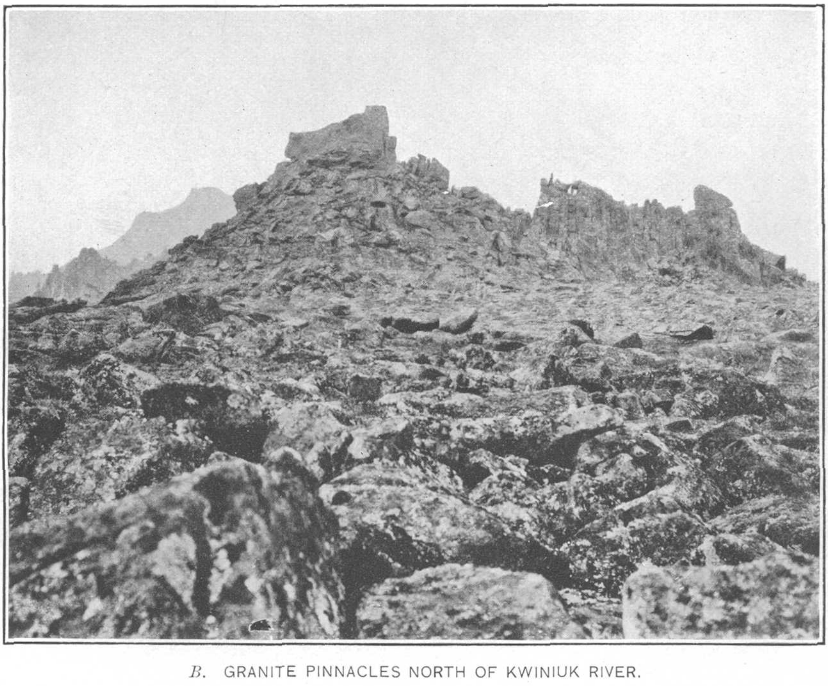
Microscopically, the sandstones show a very even texture. The sand grains are seldom well rounded and are especially sharp in the finer-grained beds. In composition they include feldspars, quartz, calcite, pyroxenes, amphiboles, micas, and fragments of dense igneous rocks. Most of the material of the sandstones could be derived from the rock types that are found in the Ungalik conglomerate. Some of the lower sandstone beds resemble the matrix of the conglomerate closely, pointing to continued sedimentation from the same source. Other beds approach limestone in composition, the sand grains being mainly calcite derived from older limestones. Calcite deposited from solution is the principal cement. Locally, secondary minerals of a serpentinous character, due to the post-depositional alteration of femic minerals, forms the cement, giving the rock a speckled or mottled appearance. Such alteration, however, is not general, the sandstones being remarkable for the unaltered condition of the minerals they contain. The rocks are not highly colored as a rule, shades of gray being most common in fresh specimens. Many of the finer deposits are colored black by carbonaceous matter which they contain. Others have reddish and reddish-brown tones, due to iron oxides. Iron staining is common on weathered surfaces.

The beds have been extensively deformed, close folding along northeasterly and southwesterly axes having occurred. The dips are very high over most of the area, varying within a few degrees on either side of 90° along the Shaktolik. The stronger beds often find topographic expression in prominent ridges, but much of the topography has smooth rounded forms in which both lithology and structure are obscured.

Where good exposures were observed much faulting was noted. In other places, where the structure was obscure in detail, the relation of beds indicated extensive displacement. It is safe to assume that faulting on both a large and a small scale has been an important part of the deformation of the group. Schistosity has been developed locally in places near the structural axes, especially in the fine-grained carbonaceous members.



A. SURFACE MARKINGS ON SANDSTONES OF SHAKTOLIK GROUP, INGLUTALIK DIVIDE.



B. GRANITE PINNACLES NORTH OF KWINIUK RIVER.

The actual thickness of the Shaktolik group at any point is not known. A partial section exposed on the headwaters of the Inglutalik River gives an apparent thickness of tens of thousands of feet. Due allowance for the repetition of beds by faulting being made, the group is still of very great thickness.

The lower or sandy division of the Shaktolik group overlies the Ungalik conglomerate in apparent conformity, and probably grades upward without a break into the upper division of the group, which consists mainly of black shales, and though recognized as distinct in type, could not be differentiated from the lower beds in mapping without more detailed survey.

Near Nulato.—A group of sandstones, shales, and grits with minor lignitic beds outcrops along Yukon River near Nulato. These beds have been known as the Nulato sandstone since first visited by Dall in 1866. They are only a part of a great series of similar deposits which are included in the Shaktolik group. The work in this region has not been sufficiently detailed to determine whether it will be possible to retain the name Nulato for one of the formations of this group.

The early writers, Dall and Spurr,[a] considered these beds of Tertiary age, but subsequent visits of Collier (1902), Hollick (1903), and Atwood (1907) and the study of their collection by Stanton and Knowlton have shown them to be of Upper Cretaceous age. The investigation of 1909 indicates that not only are these beds of Cretaceous age, but that a thickness of several thousands of feet of beds of undoubtedly Cretaceous age overlies them.

In the Nulato section sandstones predominate over the shales, grits, and lignite beds that make up the rest of the group. Notes furnished by Atwood [b] show that different types of beds alternate in close succession. Fossil plants, lignite deposits, cross-bedding, and ripple marks indicate shallow water conditions during part of the period of deposition, but alternating with these are beds bearing marine shells and worm borings. Some of the sandstones are of the even-grained, dense type common in the Shaktolik region and also noted near camp A2. On the whole, the sedimentary rocks near Nulato show a greater variation in type and indicate more changeable conditions of deposition than the rocks of the localities farther west.

The structure near Nulato is rather simple, the beds dipping in general to the northwest at angles up to 40° or 50°. Locally the beds are much faulted and crushed along the axes of minor folds. No definite measurement of the section was attempted, but it must be many thousand feet in thickness. The relations of these beds to the

[a] Dall, W. H., Bull. U. S. Geol. Survey No. 84, 1892, pp. 247–248. Spurr, J. E., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 196.

[b] Unpublished information; report in preparation.

underlying formations are not evident at this locality. They occupy the area west of the Yukon to the locality of camp A5, where they are overlain, probably conformably, by the black shales which form the upper division of the Shaktolik group.

Bishop Rock.—Bishop Rock is a low, rocky knob on the Yukon about 10 miles above the mouth of the Koyukuk. It is composed of compact limy and shaly sandstones. Fossils collected here by Atwood in 1907 were determined as Upper Cretaceous.

Near Melozitna River.—Overlying the basal conglomerate correlated with the Ungalik conglomerate near the mouth of the Melozitna River and downstream for 30 miles or more a series of sandstones, grits, and shales outcrops along the Yukon. In lithology, fossils, and relation to the basal conglomerates these beds are similar to the Shaktolik group farther west and are regarded as belonging to that group.

UPPER DIVISION OF SHAKTOLIK GROUP.

The upper division of the Shaktolik group occupies the central part of the sedimentary area along the Nulato-Gisasa divide and westward to the head of Shaktolik River. It consists predominantly of black shales, but contains subordinate beds of calcareous sandstone. Some of the latter 5 miles west and 2 miles south of camp A5 furnish invertebrate fossils of Upper Cretaceous age.

This group of beds probably represents a vertical gradation into finer sediments upward in the series, though lateral gradation is not impossible. The shales are very carbonaceous, indurated, and on weathering in places break down into pencil-like fragments. Schistosity has been developed locally near structural axes in some of the more carbonaceous members. The more resistant members stand out in strong ridges; the slopes are steep, covered with fine talus, and almost barren of vegetation. Structurally the shales agree with the underlying standstones, with which they are conformable. Black shales accompany the sandstones throughout the Shaktolik group, but the part of the group in which they predominate strongly enough to be distinguished as a separate division probably does not include more than a few thousand feet.

IGNEOUS ROCKS.

From the foregoing description of the sedimentary rocks it is seen that the Cretaceous deposits give a good horizon to which to refer different geological activities. The pebbles in the conglomerate at the base of the Cretaceous show what rocks were in existence when the beds were deposited, and all igneous rocks cutting the Cretaceous must be later than the beds they cut. For this reason the igneous rocks of the region have been divided into pre-Cretaceous and post-Cretaceous. Each of these main subdivisions contains rocks of different mineralogic composition and field relations and was formed under different conditions; both show intrusive and effusive rocks and afford much material for detailed petrographic studies, which, however, have not been attempted in the preparation of this report.

The larger areas of pre-Cretaceous igneous rocks are the flanks of the Kaiyuh Hills, the Buckland-Kiwalik divide, the Bendeleben and Darby ranges, the region around Bluff, and numerous small areas in the metamorphic complex. The larger areas of post-Cretaceous igneous rocks in the Yukon Valley are at the mouth of the Koyukuk and south of Kaltag; in Seward Peninsula they are in the Koyuk River Basin, especially in the central portion, extending to the head of Kiwalik River; at the very head of the Koyuk, extending to Noxapaga River; and at the lower part of East Fork, extending into the Buckland River basin.

PRE-CRETACEOUS IGNEOUS ROCKS.

In the long time represented by the pre-Cretaceous history of the region there are two distinctly marked periods of much geological significance. One of these preceded the dynamic metamorphism of the region and the other followed it. Rocks formed in the earlier period show structures due to this deformation, whereas those formed afterwards have not been much metamorphosed. A division of the pre-Cretaceous igneous rocks into two groups, metamorphic and nonmetamorphic, may be made, and this grouping will be followed in this report.

METAMORPHIC IGNEOUS ROCKS.

Rocks of igneous origin earlier than the period of metamorphism have been recognized in many parts of the region. The four larger areas mapped are in the Kaiyuh Hills, east of the Darby Range, in the belt extending northward from Bluff in the western part of the area, and north of Omilak Creek. All of these areas have features more or less in common, but it is by no means certain that all of them have been formed at the same time or are mineralogically identical. Furthermore, there is but little doubt that other metamorphic igneous rocks might be recognized if investigations had been carried on in greater detail, and doubtless some of the area mapped as undifferentiated metamorphic rocks is formed of igneous rocks.

Reference has already been made on page 40 to the belts of metamorphic igneous rocks occurring on both flanks of the Kaiyuh Hills. These were described by Maddren as consisting of diabasic rocks of probably effusive character. They are less metamorphosed than the older sedimentary rocks which form the Kaiyuh Hills on which these ancient lavas probably lie unconformably.

In Seward Peninsula the metamorphic igneous rocks are usually greenish in color, and differ much in degree of foliation; in the central part of the peninsula they are high in soda and low in quartz. Usually, where schistose, the rocks have had secondary albite developed and become greenish feldspathic schists. Although the feldspathic character may be produced in other ways, as, for instance, by the contact effect of igneous rocks, it is believed that in a large way the presence in this field of highly feldspathic schists is strongly suggestive of the igneous origin of the rocks in question, and this is assumed to be true if contradictory evidence was not observed.

The clearest evidence concerning the greenstones and associated feldspathic schists is afforded by the cliff exposures along the east coast of the Darby Peninsula. Along this part of the coast are numerous dikes and sills of basic composition cutting the Paleozoic rocks. A particularly clear example of a greenstone intrusion of this sort is shown in Plate VIII, *A* (p. 46). At this place, which is between

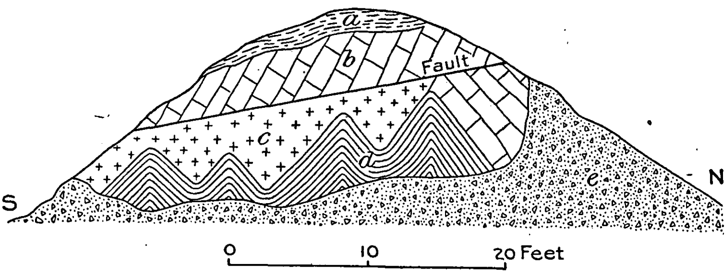


FIGURE 4.—Relation of greenstone, limestone, and slates, east coast Darby Peninsula. *a*, Soil and waste; *b*, limestone; *c*, greenstone; *d*, black slates; *e*, talus.

the Kuiuktulik and Walla Walla, light and dark banded Paleozoic limestones have an unusually low dip. These have been intersected by nearly vertical cleavage, and parallel to this cleavage the greenstones have been intruded. The large white masses shown in the picture are calcite veins of later formation, probably contemporaneous with the succeeding period of mountain building.

The structural relations of the greenstones are in places complex and show that these rocks have been subjected to considerable disturbance. Figure 4 illustrates an exposure of slates, limestones, and greenstones on the eastern coast of the Darby Peninsula about midway between the mouth of the Miniatulik and the Kuiuktulik. The greenstone intruded slates and limestones and has subsequently been folded into a number of appressed folds. Thrust faulting then took place along the plane indicated so that the south-dipping limestone was superposed on the greenstone and the slates giving a section as indicated in the figure. The axis of folding at this place is about N. 70° E. and the folds pitch toward the west.

In many places the deformation and accompanying metamorphism of the greenstones has gone so far that the original characters of the rocks are obliterated and it is not certain what origin is to be assigned. Brooks, in a study of the Bluff region, found schistose rocks which seemed to show by their areal relations igneous rather than sedimentary characters. Concerning these schists he says:[a]

> Mica schists occur as irregular masses within the limestone belts and although they do not differ lithologically in any very essential way from the schists believed to be of sedimentary origin, their mode of occurrence strongly suggests that they are altered intrusions. The most striking example of this is seen in the cliff exposures just east of the mouth of Daniels Creek (fig. 5). Here an irregular mass of mica schist is inclosed in limestone walls. Lines of faulting have obscured the original relations of the two rocks, but the outline of the schist mass is very suggestive of an intrusion. Further evidence of the intrusive character of some of these schists is found in the fact that at various localities the limestone walls near the contact with the schists are more or less metamorphosed. These facts, together with the irregular distribution of the schists, indicate an igneous origin, though it must be confessed that the evidence is by no means conclusive.

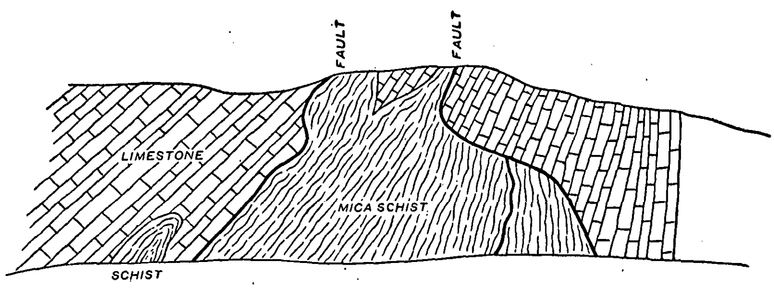


FIGURE 5.—Cliff exposures near mouth of Daniels Creek, Bluff region.

At several places the actual gradation from an unquestionably igneous rock into a green feldspathic schist has been observed. Here and there in the hills south of camp C15 are examples of this sort, and although it is not intended to assert that all the feldspathic schists are of this origin, it is certain that many if not most of them are formed in this way.

An exposure of metamorphosed igneous rock is afforded near the Omilak mine. Figure 6 shows the general geology in the neighborhood of the mine, with the intrusive cutting across the western limb of the limestone. Plate IX, *A* (p. 50), supplements this map by showing the general appearance of the same hill from the south. In this view the dark area in the center of the view is the igneous rock, and an apophysis is represented by the dark band which cuts across the right-hand limestone area. From a study of this rock under the

[a] Collier and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908—The Bluff Region, pp. 285–286.

microscope it has been determined that it consists of olivine, a light-colored amphibole probably tremolite, very abundant light-green garnet and muscovite, with some accessory ilmentite and apatite and secondary serpentine. This is an unusual phase of the greenstone series and has not been recognized elsewhere.

NONMETAMORPHIC IGNEOUS ROCKS.

There are three large areas of pre-Cretaceous nonmetamorphic igneous rocks to which attention should be called. These are the Darby Range, the Kiwalik-Buckland divide, and the Bendeleben Mountains. In addition, several smaller areas, such as Kiwalik Mountain, are found in the region, but as they show the same features

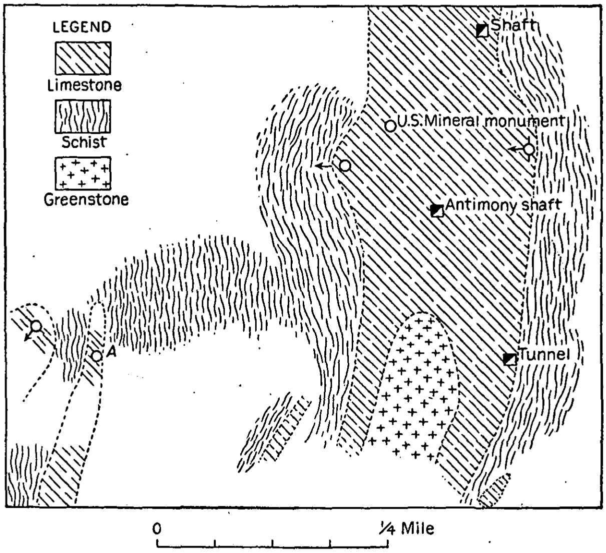


FIGURE 6.—Sketch map of the vicinity of the Omilak mine.

as the igneous rocks in the larger areas they will not be described separately.

Mendenhall, who studied portions of the Darby Range in some detail, says:[a]

Cape Darby and a broad belt of country extending 55 miles northward from it with a maximum width of about 12 miles is occupied by a great intrusive body of granite and granitized rock which exhibits considerable variation in texture and mineralogical composition, but is regarded as belonging to one geological body.

A few miles below Cheenik, along the eastern shore of Golofnin Bay, the rock is diorite porphyry with large tabular phenocrysts of andesine or andesine-oligoclase, some colorless pyroxene, and abundant hornblende in part at least secondary. Quartz is present but often in very inconsiderable amounts, and

[a] Mendenhall, W. C., op. cit., p. 204.

titanite is an inconspicuous accessory. This phase or a slightly more acid one is rather largely represented in this portion of the mass extending at least 5 to 6 miles east from its western border.

Near the eastern edge of the northern part of the area in the Tubutulik Valley the rock appears as a coarsely crystalline aggregate of pale brownish orthoclase and smoky quartz with a little biotite. A gneissoid phase of the same rock occurs along the western side of its western limit.

Distinct contact phenomena in the schists and slates while sometimes present are not so abundant as one would expect. The inference is that the intrusion was slow and deep-seated and affected the intruded rock generally, rather than locally. This inference finds support in the coarse texture and porphyritic character of the diorite even at its borders.

In 1909 it was the intention of the party to avoid revisiting the areas already studied by Mendenhall, so that in but few instances does the work overlap. From this later study it was found that the areal distribution as already given by Mendenhall required but slight modification, but that the number of different kinds of rock was more complex than his report indicated. There are at least two distinct types of granite, one with marked porphyritic development and the other of even grain.

The largest area of the porphyritic granite is in the Kwiniuk basin extending from a little east of camp C14 to at least 4 miles north of camp C15. In addition, the same rock was found on the seacoast at the mouth of Carson Creek and is probably the same as the granite with brownish feldspar described in the northern end of the belt. This rock is characterized by a coarse-grained mass of quartz, orthoclase, and a little biotite, the various grains averaging about 0.2 inch in diameter, with large orthoclase crystals averaging about 1½ inches in length scattered abundantly through the rock. A few inclusions of diorite were found in the porphyritic granite, one of which showed calcite-filled cavities, probably amygdaloidal in origin. Typically the porphyritic granite weathers into fantastic knobs and pinnacles similar to those shown in Plate XI, *B* (p. 58). This feature is also shown more extensively developed in Plate III, *A* (p. 30), the pinnacles shown being probably of granite of this type.

The even-grained granite may be of the same age as the porphyritic granite. If this is the case the two may have consolidated under different conditions. It does not seem evident from the field relations, however, that the porphyritic rock cooled under essentially different conditions except that the porphyritic granite forms larger masses than the finer-grained type. Mineralogically the even-textured granite consists of quartz, both orthoclase and plagioclase feldspar and biotite. Dark-colored silicates, although present, form but a relatively small amount of the rock. It occurs usually in rather narrow dikes, and no large area of this type is known in the Darby Range. Dikes of this granite have already been noted in previous pages as cutting the Paleozoic rocks at many places. Plate VIII, *B* (p. 46), shows a nearly vertical granite dike, the light-colored rock (on which the hammer rests) cutting across the structure of the metamorphic limestone and sending apophyses into it.

Diorite also occupies large areas in the Darby Range. In composition it ranges from a normal amphibole plagioclase rock to one containing quartz and orthoclase in addition to the usual constituents. The plagioclase is apparently andesine-oligoclase; that is, about midway in the soda-lime series. Accessory apatite, titanite, muscovite, and metallic minerals in small amounts were noted in several examples of this rock studied microscopically.

From the fact that inclusions of diorite are found in the porphyritic granite, it is assumed that the latter is younger than some of the diorite. Plate XII, *A*, however, shows that there is more than one diorite represented in the region. In this view the large light-colored area on which the hammer rests is porphyritic granite with numerous inclusions of diorite. Unfortunately in this picture the further fact that the porphyritic granite itself is an inclusion in the dark igneous rock which forms the lower left-hand portion of the view is not shown, although this fact is clearly proved by the exposure in the field. It should further be noted that in this later diorite intrusion are inclusions of the older diorite. Although the similar color makes the two diorites difficult to distinguish in this view, several of the older diorite inclusions may be recognized at the extreme left below the porphyritic granite-diorite contact.

In addition to the granites and diorites there are several other types of rocks, the distribution and relations of which are not sufficiently clear to allow their differentiation. One of these rocks is a quartz porphyry with double terminated quartz crystals and plagioclase as phenocrysts in a ground mass of quartz and orthoclase in a micropegmatitic intergrowth. Accessory green hornblende, apatite, and magnetite with secondary kaolin, muscovite and chlorite were also present. This type of rock was found particularly in the hills south of camp C13 in the divide between the Kwiniuk and the Etchepuk.

Another unusual type of rock forms a large area in the Kwiniuk divide south of camp C13, extending westward an undetermined distance and southward to beyond camp C14. It is dark colored, with lath-shaped phenocrysts an inch or more in length of orthoclase feldspar. The groundmass is composed of orthoclase, albite, oligoclase, green hornblende, ægirine augite, and biotite, with accessory titanite in great abundance, and some apatite. Usually the pyroxene forms cores around which amphibole has been developed, probably by the alteration of the pyroxene. The absence of quartz and the high soda content distinguish this rock from the others already described.

A. INCLUSIONS, EAST COAST OF DARBY PENINSULA.

B. VENATION IN LIMESTONE, EAST COAST OF DARBY PENINSULA.

Another unusual type of igneous rocks was found on the hill about three-fourths of a mile north of camp C22 on a branch of Kachauik Creek. It is rather closely associated with rocks of the fine-grained granite type, but the precise relations are not known. It is a light-colored fine-grained rock with a few scattered phenocrysts of nepheline and sanidine. In the ground mass, which is very fine-grained, are albite, nepheline, sanidine, ægirine augite, fluorite, eudialyte, riebekite, and biotite. The high soda content suggests correlation with the other soda-rich rock previously described. which was also wanting in quartz.

Rocks similar to the Darby range intrusives, with the exception of the last three phases, have been found in the pebbles of the Cretaceous conglomerate, and no hesitation is felt in ascribing them to an age prior to the Cretaceous. It is also evident from the studies in the field that all of these rocks cut the Paleozoic series and have not been dynamically metamorphosed to any marked extent. That there have been several periods of intrusive activity is shown by the relations of the diorites and porphyritic granites described on page 66. Whether, however, these periods were separated by any considerable time interval or whether they really mark only one major period of intrusive activity has not been determined.

Few new facts of importance have been added to those already published by Moffit concerning the igneous rocks of the Kiwalik-Buckland divide. According to this geologist [a]—

Much the larger part of the undissected mass which forms the divide between the drainages of the Kiwalik and the Buckland Rivers, and contains the highest elevations of the northeastern part of the peninsula, is made up of light-colored granular rocks and andesites associated especially toward the outer portions of the area with basalts and diabases.

In crossing the main part of the mass from the westward after leaving the highly metamorphic rocks of the Kiwalik Valley one meets first with basic rocks of the basaltic and diabasic type, followed by andesites which are well developed and form a large part of the ridge; finally, in the central portion of the complex, and forming a core for the whole, are discontinuous areas of more siliceous rocks, including a number of different varieties of 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 larger size of orthoclase crystals, which usually show Carlsbad twinning and have a rough parallel arrangement with the small intervening spaces filled with hornblende, biotite, and a small amount of quartz. Titanite is abundant.

An unusual and highly interesting type was observed in the most southerly area of the granular rocks. The hand specimens show a dark-gray rock, composed of abundant large tabular feldspar crystals with a small amount of dark-

[a] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, pp. 27–31.

greenish fine-grained filling. In thin section the rock is seen to consist of large crystals of orthoclase feldspar with a microscopic intergrowth of parallel plagioclase plates embedded in a groundmass of ægirine-augite, melanite, and small scattered plagioclase. The three last-named minerals fill spaces between the large orthoclase crystals, which are very subordinate in volume to the spaces occupied by the crystals themselves. Titanite and apatite are present, and a cloudy zeolitic decomposition product appears at times. The rock corresponds very closely in appearance and composition with the garnet-pyroxene malignites, which Lawson has described, from Maligne River in Ontario.

The diorites present no unusual features. They are nearly always of a light-gray color and are sometimes porphyritic. The prevailing feldspar is plagioclase with zonal structure. Some quartz is always present and the dark mineral is usually hornblende, but at times biotite. In one or two instances a well-developed flow structure was seen in large blocks of the diorite which were cut by small granitic or aplitic dikes largely feldspar.

Monzonites intermediate in composition between granites and quartz diorites are frequent. Orthoclase and plagioclase predominate while hornblende, biotite, and quartz are present; also titanite, magnetite, apatite, and occasionally zircon. All the granular rocks of this region are abundantly supplied with titanite which may often be easily seen in the hand specimen and is very noticeable under the microscope.

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

Little can be added from the work of 1909 to these descriptions and, although it has been possible in a measure to extend the mapping of these rocks, the additional data are so clearly evident on the map that further description is not required, except to note that the extension south of the Koyuk is formed mainly of rocks of the effusive rather than of the intrusive type. It should also be pointed out that whereas the intrusive rocks, which form the core of the Kiwalik-Buckland divide, are in all respects similar to the igneous rocks in the Darby Range, the effusive rocks which occur along the flanks have no recognized representative in the latter mountains.

The igneous rocks of the Bendeleben Mountains so far studied belong mainly to the group of granites, and, although here and there these rocks show gneissic phases, it is believed that, as a group, they are essentially contemporaneous and are later than the post-Paleozoic deformation. Lithologically the granites are indistinguishable from the granites of the Darby or Buckland-Kiwalik ranges, and it is assumed that such close similarity could not have occurred unless all these rocks had been derived from essentially the same magma at nearly the same time. It is on the basis of this assumption that the pre-Cretaceous age of the granite masses in the Bendeleben Mountains is postulated.

In the Bendeleben Mountains the geologic mapping is extremely conventionalized and the reader should regard this part of the map as suggesting the kind of geology probably to be expected rather than as a faithful portrayal of the actual areal distribution of the different types of rock. As mapped, however, this area serves to bring out the fact that there are numerous large bodies of igneous rock, in places many miles in diameter, and also that there is a most complex network of small dikes and sills, many of which are from a few inches to a few feet wide. The lithology and mineralogy of the two types, however, do not materially differ. Some of the small sills and dikes have as coarse texture as the more central parts of the larger masses. Both modes of occurrence are typically quartz-feldspar granites with some dark silicates and various accessory minerals. Even in the gneissic phases, Collier [a] states the structure must either be original or else the whole rock has recrystallized, for the microscopic examination shows little, if any, evidence of distortion or dynamic movement. In other places it is evident that the apparent gneissic structure is due to the replacement of adjacent schists, some of which are so thoroughly saturated by the igneous rock that much of the original character has been destroyed.

The contacts between the granites and the schists, however, are not always vague and ill defined, but in places are sharp and clear-cut. These differences are probably to be explained by the variations in composition of the wall rocks and also by the different depths of burial of the schists when the intrusions took place.

Associated with the normal granites are a few rocks of pegmatitic and aplitic phases which seem to have marked the later or closing stages of the intrusive period. In the pegmatities tourmaline is in places an important accessory mineral. One such pegmatite in particular was noted on Birch Creek near the pass to the head of Niukluk River. Mica in plates sometimes 6 inches or more in diameter is found in the pegmatites. A locality where particularly large mica plates have been reported is near Oregon Creek, a tributary of Fish River heading on the south slopes of the Bendeleben Mountains, and some attempts have been made to develop a commercial deposit.

At a few places dark basic dikes have been reported cutting the granites. Whether these belong to the pre-Cretaceous igneous rocks

[a] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 104.

similar to the latest dioritic intrusion noted in the Darby range or whether they are post-Cretaceous is not known. They form relatively narrow dikes and occupy such small areas in the Bendeleben Mountains and so little is known about them that they will not be treated further in this report.

POST-CRETACEOUS IGNEOUS ROCKS.

Later than the deposition of Cretaceous sediments, intrusive and extrusive igneous rocks have been formed. As has already been noted, the main areas of the latter are in the Yukon and Koyuk basins and the only area of the intrusive rocks studied is in the lower part of the Ungalik Valley.

INTRUSIVE ROCKS.

Christmas Mountain, east of the lower part of Ungalik River, is the only center of post-Cretaceous intrusion noted. This prominent landmark is formed of an igneous complex, the relations of the various members being uncertain. The series of rocks grade according to texture from augite andesite to augite diorite. The main mass of the mountain is of the more granular type, in the coarsest phases having crystals up to 3 millimeters in diameter. This coarse phase contains abundant plagioclase, which has been determined to be albite, andesine, and labradorite. Augite, biotite, and olivine are also present as important constituents. Among the accessory minerals are magnetite and apatite, the latter being notably pleochroic. Secondary biotite, chlorite, sericite, and serpentine have also been recognized in this section.

Associated with the diorites in the western part of the area, probably in the form of a dike, is a porphyritic rock composed of orthoclase, plagioclase, biotite, and augite as the essential constituents, and with pyrite and calcite as accessory or secondary minerals. The phenocrysts in this rock are mainly feldspar, but a few are of light-green pyroxene.

The clearest evidence concerning the age of these rocks is afforded by exposures along the Ungalik, near camp A16, where dikes of essentially similar composition are found cutting the Ungalik conglomerate. Subsequent faulting has dislocated the dikes, but the amount of displacement indicated is not more than a few yards. Thin sections of specimens from these dikes show a light-colored porphyritic rock with phenocrysts of oligoclase and a monoclinic amphibole. In the main the ground mass has a trachytic texture and is composed largely of oligoclase and albite, with accessory apatite. Calcite, quartz, magnetite, kaolin, muscovite, and limonite, all probably secondary, were recognized. The limonite is in more or less rectangular patches, which points to its having been derived from the alteration of ferromagnesian minerals originally in this rock. At Bonanza Creek an intrusion of similar character cutting the black slates was found.

On the Shaktolik, at camp A12, a fine-grained quartz porphyry was recognized in the float, but the fragments were well rounded, as though they had been carried far, and there is no clue as to where the rock outcrops. The presence of this float, however, strongly points to the conclusion that it is from an intrusive later than the Cretaceous sediments. It is probable that a more extensive exploration of this region would show intrusive centers like that of Christmas Mountain in other parts of the Nulato-Norton Bay region.

EFFUSIVE ROCKS.

Effusive rocks of late geologic age are found at many places. All of these flows are probably not contemporaneous, but when they are considered in a broad way it is believed that they mark essentially one period of volcanism. Thus, though many years may have elapsed between successive flows, even in the same district, there seems to be strong reason for correlating them together as one group and regarding them all in a geologic sense as synchronous. Although the rocks described in this section are essentially lavas or surface flows, there are, of course, here and there dikes by which these rocks were brought to the surface. All of these rocks are characteristically olivine basalts with a vesicular structure.

The eastern locality of the post-Cretaceous effusives, the one near the mouth of the Koyukuk, was first carefully described by Spurr,[a] from whose account the following quotation is taken:

> Megascopically (the rock) is dark green and amygdaloidal, the amygdules being partly quartz and calcite. Under the microscope a large vesicle whose walls are lined with serpentine is filled with barite in interlocking plates. Many small óvoidal vesicles are lined with serpentine and filled with chlorite. These are comparatively large phenocrysts which are now pseudomorphed by calcite and serpentine, but were probably originally olivine. The structure of the groundmass is as if originally composed of holocrystalline plagioclase and augite. The augite is abundant and not greatly decomposed but the plagioclase crystals have been replaced by pseudomorphs of some other mineral in part, at least, isotropic. The rock is evidently a true olivine basalt considerably altered and decomposed.

Although the lavas represented in the Yukon Valley to the south of this place have not been described in detail they probably belong to the same period of volcanic activity. Similar lavas have been reported by Collier along the river south of Kaltag, but their extent has not been determined and there are no published descriptions of

[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 245–246.

the occurrences. It seems probable, however, from the wide-spread distribution throughout the lower part of the Yukon basin of rocks of this same lithologic character that they must have formed extensive sheets.

Along the eastern border of Norton Bay volcanic rocks of a relatively recent age have been reported at many places. Within the region covered by this report two areas of vesicular lavas have been orally reported to the writers by Mr. J. T. Watkins, of the Coast and Geodetic Survey. These two areas are the Reindeer Hills and Besboro Island. No collections were made, but the description of the rocks clearly points to the conclusion that they are both to be included within this group. They probably mark a connecting link between the well-known volcanic flows of St. Michael on the south and of the Koyuk Valley on the north.

Concerning the lavas along the Koyuk, Mendenhall says: [a]

> The lava is a green, gray, or black rock, the color depending in part upon its freshness. It is compact or vesicular and usually porphyritic, olivine being the most conspicuous of the phenocrysts, although plagioclase is recognizable megascopically in some instances. Sometimes the vesicles are filled with opal; more frequently they are without filling. The rock varies in texture, having sometimes a very glassy groundmass and in other cases showing a coarse, well-defined, interstitial arrangement with almost no glass. * * * The basalt beds have not been disturbed since they were poured out. They are horizontal wherever their attitude is determinable and overlie all the other rocks. * * *

Moffit, who studied portions of the large lava sheet occupying the northwestern corner of the mapped area, as well as numerous other flows in contiguous areas to the north, writes as follows concerning these basalts: [b]

> 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 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 partly eroded sheets. Agglomerate breccias were observed at several points. A study of the numerous specimens collected shows them to be made up of diabase and basalts, both rich in olivine. In the basalts, especially, olivine phenocrysts are abundant and very noticeable even in the hand specimens. Iddingsite is not infrequent as an alteration product of the olivine.
>
> That a succession of outbreaks of lava has taken place is shown in a number of places, but probably most plainly in the region about the head of Kuzitrin River, where positive evidence is afforded in the terraced condition of the different flows, three distinct benches occurring in one locality.

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[a] Mendenhall, W. C., op. cit., p. 206.

[b] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, pp. 31, 32–33.

Observations made by Collier on Noxapaga River showed these more recent lavas overlying gravels which are cemented near the contact by indurated clays and contain pebbles of an older flow—conclusive evidence that considerable time must have elapsed between the first outbreak and the solidification of the flows just described. The source from which the recent basalts of Noxapaga and Kuzitrin rivers were discharged lies to the southwest of Lake Imuruk, this being shown by the scattered lava cones as well as by the direction of movement of the flows themselves.

On the upper part of Koyuk River a similar relation of basalts and gravels was observed by Mendenhall. He found on the truncated edges of the schist 5 feet of gravel made up of schist, vein quartz, and granite; this in turn was covered by an undisturbed horizontal sheet of olivine basalt, which has been but little affected by the erosive action of the stream since it came to rest and was, therefore, believed by him to be of Pleistocene age.

During the field season of 1909 little detailed study of the lavas was made, and although the areal distribution of this group of rocks has been extended in certain places the additions are mainly concerning details rather than essentials. It seems evident that in the main they occupy the lowlands of the period in which they were formed, so that a thorough understanding of the distribution of the lavas would indicate the former topography. It is probable that more extensive investigations might show that these basalts occupy a greater area than is shown on the maps. For instance, the lava area at the head of the Mukluktulik probably connected at one time with the lava areas represented to the north of the Koyuk west of Peace River, and if the exposures were better in the gently sloping spurs west of Kenwood Creek it is highly probable that remnants of this sheet might still be found overlying the undifferentiated schists and the Paleozoic rocks. This patch of lava is probably older than those very late effusives that overlie gravel deposits of recent date, but, as before stated, it is believed that they both belong to the same general geologic group and were poured out on the deformed and eroded surface of the Cretaceous and older rocks.

Another small area of recent effusive rocks was reported by Mendenhall in the hills near Grouse Creek, a tributary of the Tubutulik. It covers the contact of the granites and Paleozoic sediments. This fact strongly suggests that the contact, being a zone of weakness, had been topographically a lowland, in consequence of which the lava flowed into the depression and being thickest there had remained, whereas the thinner parts had been entirely eroded away. There is no direct evidence as to the direction from which this lava came, but as no near-by areas of similar rocks are known except to the north it is assumed that this is the direction from which they flowed, although it is realized that this is little more than a working hypothesis.

On Bear River west of Council a small area of recent lava has been reported and specimens of the rock have been examined. It is a vesicular basalt similar in lithologic character to those from the Koyuk. There is probably only a small amount of the rock present, but little is known of the manner of occurrence or the areal relations.

VEINS.

Veins of different mineralogical character formed at different times and under different conditions have been noted at many places. They are abundant in the areas of metamorphic rocks, but are practically absent in the greater part of the area occupied by the Cretaceous sediments. Based on mineralogical composition there are two main types of vein filling; in one quartz predominates, in the other calcite. The former are of widespread distribution and are found in all the various kinds of rocks; the latter class, however, is almost entirely limited to the immediate vicinity of the limestone areas.

The veins in which calcite is the main filling are seldom extensive either horizontally or vertically. They appear to be formed usually as the result of shearing and infiltration of the calcite derived from the adjacent limestones. Plate XII, *B* (p. 66), shows a portion of the Paleozoic limestones on the east coast of Darby peninsula, where an intricate network of calcite veins forms a stockwork through the brecciated limestones. Although the veins are slightly more numerous in this view than in the majority of exposures, the arrangement and general characters are quite typical. Plate VIII, *A* (p. 46), already referred to, shows other calcite veins of the same general mode of occurrence near a greenstone intrusive. Some of these veins are undoubtedly younger than the intrusion of the greenstones, as they cut them or occupy joint planes in them, and it is believed that most of the veins were produced either during or subsequent to the deformation of the Paleozoic rocks.

Calcite is practically the only mineral found in the calcite veins. No sulphides or other metallic minerals have been noted in them, and they are consequently, in this region, of no economic importance.

At least two distinct series of quartz veins have been recognized in the region; in one the veins are much contorted and sheared, in the other crystalline quartz with characteristic comb structure is found. This difference in structure is to be explained by the difference in age of the two types. It seems evident that to have been crushed, sheared, and otherwise deformed the veins must have been in existence at the time of the post-Paleozoic deformation, whereas on the other hand the slightly sheared, relatively undisturbed character of the other group of quartz veins points to the fact that they were formed subsequent to that period. Although these two main groups have been recognized, it is almost certain that the older ones include veins of at least two different ages, one earlier than the Silurian and one later than the Carboniferous, but this point has not been definitely settled and will be difficult to prove owing to the great amount of post-Paleozoic deformation.

So far as can be determined the content of both classes of quartz veins are nearly identical. Sulphide mineralization is usually absent and, although a few copper or iron stains are found at places, the larger part is formed of white quartz seldom even iron stained. Both classes in places carry small quantities of gold. This has been determined mainly by chemical means, for the gold is in the native state and is usually in too small particles to be recognized by the eye. Pieces of quartz from both the older and the younger quartz veins, however, have been seen in which gold was visible. Assays from different auriferous quartz veins have yielded widely varying values, but there is no evident difference between the quantity of gold carried in the two groups. Although the gold content of the older and the younger veins does not seem to be materially different, the fact that the older ones are more shattered and discontinuous renders them on the whole less adaptable to economic development than the younger veins.

Few of the contorted and sheared veins are more than a few inches in width and are usually lens-shaped. Here and there, however, much thicker lenses have been noted, and Mendenhall calls attention [a] to a conspicuous example a few miles north of Cheenik, which is 30 feet by 10 feet by 15 feet. It is described as compact and barren, and exhibiting a brilliant fracture. Other large lenses were seen in the Darby Range and in the Bendeleben Mountains, but they seem to hold no promise of economically valuable minerals. Mendenhall also notes a vein 6 feet wide striking north and south in the sea cliff 4 or 5 miles from Rocky Point, but in this vein the quartz was rusty, as though sulphides were originally present but had been decomposed.

The younger quartz veins are less sheared and shattered than the older veins already described. It should not be concluded, however, from this statement that they have not been subjected to deformation, for they are faulted and discontinuous. Probably like the older veins they may belong to more than one period of formation, but evidence concerning this point is not conclusive. The terms "younger" and "older" quartz veins are therefore to be regarded as purely relative, though in a broad way the former are pre-Paleozoic, whereas the latter are post-Paleozoic. Some of the younger quartz veins cut the pre-Cretaceous granites so that a clue to their age is afforded. No quartz veins have been found in the more recent olivine basalts, and thus the upper limit of their age is determined.

Like the older veins the more recent quartz veins are usually narrow and seldom can be traced for long distances. They are particu-

[a] Mendenhall, W. C., op. cit., p. 211.

larly numerous in the black quartzites and slates of the Paleozoic rocks and in that relation form an intricate network of veinlets, many of which are only a fraction of an inch in width. Sulphides, although on the whole relatively unimportant even in the later veins, are more abundant than in the older group. They are usually iron and copper pyrite, but galena, arsenopyrite, and stibnite are found. The latter minerals, however, where found in considerable quantities, as at Omilak and Bluff, are not associated with quartz veins but seem to fill fractures in the country rock.

Considering the metamorphic area as a whole, it may be stated that the mineralization is widespread, but that the veins are seldom individually continuous. The mineralization is more in the form of a stockwork or mineralized zone than in sharply defined single veins. Owing to this disseminated character of mineralization the localization of ore bodies is not pronounced, and it is believed that, if commercially valuable deposits are found, they will be more or less similar to the Juneau type of deposits.

Further consideration of the veins which have been prospected will be given in a later part of this report dealing with the economic geology of the region (pp. 127–136).

UNCONSOLIDATED DEPOSITS.

Unconsolidated deposits occur throughout the Nulato-Council region and are important because some of them contain economically valuable minerals. In the following section the distribution and general characters of the different types will be described, the economic features being left for separate treatment in the later chapter on the economic geology of the region. For this reason specific description of the different creek gravels will be omitted here and the main attention will be directed to the more general features of these deposits.

Broadly considered, the unconsolidated deposits may be divided into two classes; in one class the material is practically unsorted, whereas in the other the material has been transported, mainly by water, and deposited at some distance from the place where the waste originated. To the first class belong the talus of frost-riven material and hillside waste covering the surface of most of the upland region; to the second class belong the gravels of various origins and also, for the purposes of this paper, the glacial deposits. There are gradational phases between the two classes, but the main difference on which emphasis is placed is that the latter are in the main water sorted, whereas the former are not.

UNSORTED DEPOSITS.

As has already been stated, the main characteristic of this group of deposits is that they have been little, if at all, affected by running water. Some sorting has, of course, been effected by the gravitative, downhill creep of the material, but this is relatively unimportant. These deposits are, therefore, normally made up of angular material derived from the ledges directly up the slope from the place where they are formed, or they are the frost-shattered fragments of the country rock immediately beneath the surface.

Deposits of this sort are particularly characteristic of the uplands, where the strong temperature changes allow rapid disintegration of the underlying rock. Plate XI, *B* (p. 58), shows a typical view of this sort of deposit in the granite area north of the Kwiniuk, and might be duplicated by pictures from all parts of the field. Of course the waste is not always as coarse as is shown in this view, for the size of the fragments depends upon the physical features of the rocks from which the material was derived. Therefore, in the sandstone shale regions the float is in smaller pieces than in the places where the bedrock is granite.

When the disintegration takes place on a hillside, as shown in the plate (XI, *B*), instead of on top of a hill, the waste as it is formed spreads down the slope and forms a mantle of rock fragments similar to that shown on the hillsides across the valley in Plate III, *A* (p. 22). The foreground of this view shows the general character of this waste sheet on the near side of the valley. Waste sheets of this sort are usually coarser and thinner toward the ridge and become gradually finer and thicker toward the valley floor.

The deposits of unsorted rock waste are so universal that if they were shown on the geologic map they would obscure all the other patterns; hence they have not been represented. This course is further justified by the fact that they have no economic value and are therefore unimportant to the present study. If, then, the reader desires to reproduce the surface features of the Nulato-Council region precisely it would be necessary to imagine practically all of the area not occupied by gravels as covered by the unsorted deposits, except here and there where bedrock outcrops. Such ledges, however, probably do not form one per cent of the entire area.

DEPOSITS OF TRANSPORTED MATERIAL.

The deposits of transported material may be divided into marine deposits, nonmarine water-laid deposits, and glacial deposits. Typical examples of each of these three classes have been recognized in the field, but the gradations between the different classes and the absence of detailed investigations prevent the separation of the three groups on the map. The marine and the nonmarine water-laid deposits show examples of deposits formed at more than one time, so that these two are further divisible into older and younger gravels. The glacial deposits have not been so thoroughly studied as the others and only one division has been recognized. It is by no means improbable that with further investigation these deposits also might be subdivided. It should be noted that the terms "older" and "younger" refer to the relative age within the group and that it by no means follows that one of the older marine deposits is equivalent in time of formation to a particular example of an older deposit of nonmarine water-laid gravels. Such refined correlations must await future investigation. Broadly speaking, however, the group of older marine sediments are equivalent in age to the group of older nonmarine water-laid deposits.

MARINE GRAVELS.

Lithologically the younger marine gravels present great diversity depending in large measure upon the material of which the shore line is composed. The topography also exercises a considerable influence on the physical characters, for in the bights between headlands the materials are fine-grained, whereas near the promontories bowlders and coarse gravels predominate. Near the mouths of the larger streams the mixture of fluviatile and marine deposits is so complex that it is impossible to separate the two. On the present shore line from the mouth of the Koyuk to Cheenik the marine gravels present a great diversity, ranging from fine muds to bowlders 10 feet or more in diameter. Here and there sea stacks interrupt the continuity of the gravels so that the floor on which the present deposition is taking place is irregular. In the sheltered stretches of the coast enormous quantities of drift wood, probably brought down by the Yukon, are accumulating and are being buried as part of the marine deposits. Marine shells, except near the mouth of the larger streams, are not abundant in the deposits being formed at the present time. Garnet and magnetite sand so common along the beach from Topkok westward is almost entirely absent in the eastern part of the coast line.

Marine deposits now somewhat elevated above the position in which they were laid down and consequently belonging to the class of older gravels have been found at many places. These deposits are perhaps best shown by the coastal plain east of Norton Bay north of the Reindeer Hills. Few sections of these gravels have been made, so that their depth and character are not well known. A prospect hole near the mouth of the Ungalik was sunk nearly 100 feet without reaching bed rock. The fact, however, that bed rock outcrops at Island Point only a few miles away shows that the floor on which these sediments have been deposited is uneven.

On the east coast of Darby Peninsula old sea caves 20 to 30 feet above present sea level were recognized at a number of places and are shown in Plates III, *B* (p. 22), and XIII, *B* (p. 66), already described.

Mendenhall also observed evidence of former higher stands of the sea, for he says,[a] "On the west shore of Golofnin Bay raised gravels were observed capping the schistose bluffs at Rocky Point. From this point westward evidence of uplift is increasingly abundant and consists of terraces, high gravels, and superposed streams." From this evidence it follows that at a time not remote geologically the sea stood in places at least 25 feet above its present position, so that considerable areas now dry land were formerly covered by the sea. Therefore marine gravels are to be expected inland from the present shore and have been recognized at many places. Some of these deposits have, however, been subsequently reworked by the streams, so that their marine characters have been obliterated. There is but little question that parts of the gravel deposits at the head of Golofnin Bay and in the bight between the Miniatulik and Isaacs Point are of marine origin, but the transition between the evident marine material and the equally evident fluviatile gravels is so gradual that no line of separation can be drawn without numerous sections not now available.

Not only are there evidences of former higher levels of the sea, but at Bluff a beach line is developed several feet below the present sea level so that at an earlier time the marine gravels did not extend inland so far as they now do. This emphasizes the point that the various members of the unconsolidated marine deposits are not of the same age, but that the sea level has oscillated considerably during a long period.

RIVER GRAVELS.

Every stream in the region is forming gravel deposits and examples of this class are abundantly represented. Owing to the scale of the map, however, only the larger deposits have been shown, so that in reading the map this fact should be constantly borne in mind and it should also be remembered that even in the headwater branches of the smallest streams water-transported gravels are found. As has already been pointed out the creek gravels may be divided into an older and a younger group. These two may so grade into each other that no sharp line of demarcation can be drawn. In this report, however, the lower bench gravels up to 10 or 20 feet above the stream are considered as belonging to the younger group.

The lithologic character of the stream gravels depends very largely on the kind of rocks exposed in the valley in which they occur. Thus in the case of a small stream flowing in a valley carved in only one kind of rock the pebbles are entirely of this kind of rock, whereas in the case of the larger streams, such, for instance, as the Yukon, the

[a] Mendenhall, W. C., op. cit., p. 210.

gravels have been derived from a great variety of different rocks outcropping within the basin and show a great diversity of lithologic character. So far as has been determined almost all of the younger stream gravels are of local origin; that is, have been formed in the valleys in which they now occur. This point, however, requires considerable additional study, for similarity of rock types and the large area covered are likely to give an appearance of simplicity not justified by more searching examination. An exception to this rule is afforded by the gravels of Melsing Creek, where granite bowlders derived from the Bendeleben Mountains are intimately associated with gravels of distinctly local origin.

On the smaller streams the thickness of the gravel is only a few feet, but on the larger streams, especially those that have undergone a complex geologic history, the gravels may be more than 100 feet thick. These deeper gravels undoubtedly belong, in part, to the older ones, but as they grade directly into the present creek gravels differentiation can not be made here, and they will be described at this place. On Mystery Creek, midway between its junction with the Niukluk and the point where it leaves the hills, a shaft penetrated gravels to a depth of 102 feet. The gravels were but slightly waterworn and contained small shells in a perfect state of preservation. Bearing on this same question is the fact that in 1906 a hole was sunk midway between Bear and Fox Creeks west of Council in a bench deposit about 50 feet above the river. This drill hole reached a depth of 250 feet, all this distance being in gravel. Such a depth would make the bottom of the hole at least 50 feet below sea level. As bedrock outcrops within 2 to 3 miles of this place, this thick deposit of gravels strongly suggests the probability of having been formed by an earlier stream which carved its channel when the land stood relatively higher with respect to the sea than it does now.

Another deep gravel deposit has been located in the hills west of the Koyuk near camp B16. At this place a shaft 192 feet deep was sunk all the way through well-rounded gravels. The bottom of the deposit is a considerable distance below sea level and points to a change in respect to sea level since the channel was carved. This channel was probably due to the effusion of some of the post-Cretaceous lavas which obstructed a former stream course, but the fact that the bottom of the channel is far below sea level can be explained only by assuming that since it was formed the region has been relatively depressed. A further description of this deposit is given on pages 110–113.

Although practically nothing is known of the depth of bedrock in the bottom of the Yukon Valley, there are many things which lead to the conclusion that the gravel filling may in places be very thick. This is also true of the Koyukuk and of the lower parts of the

Kateel, the Gisasa, and other large tributaries. It is possible that these deeper gravels are not solely of fluviatile origin, but data are too few to permit a final analysis of the problem.

In addition to the gravels known to belong to an older group, because they underlie the present stream gravels, there are also older gravels whose age is determined by the fact that the stream has cut its valley down into them. In other words, there are bench deposits which mark either a relative uplift of the land or a change in the erosive power of the streams in the recent past. In elevation above the adjacent streams the benches range from only a few feet to several score feet, the higher, of course, being more obliterated by having been exposed to erosin a longer time than the lower.

Russell,[a] who ascended the Yukon in 1890, called attention to certain obscure indications of terraces or sea cliffs at an elevation of 1,500 or 2,000 feet on a number of the hills below Nulato. In traversing these ridges in 1909 the party found no traces of gravel at such high elevations, and it is believed that the appearance of nearly horizontal benches is due to the beveling of the stratified rocks of the Cretaceous, which outcrop in these hills. Lower down, however, at an elevation of about 50 feet above the river, silts and sands form pronounced benches. Although these deposits have not been studied in detail, their position and topographic expression suggest that they mark former river-laid gravels and sands subsequently dissected by the relative down cutting of the present river.

Bench gravels are found in the Shaktolik Valley and were especially noted near camp A10, where a broadly open older valley floor covered with gravels has been dissected by the narrow rock-walled canyon of the present stream. Much of this bench gravel is heavily iron stained. This feature was also noted at several places farther downstream near camp A13. From the topographic similarity it is probable that bench deposits corresponding to those noted on the Shaktolik occur also in the Gisasa and Kateel valleys, but they were not searched for.

In southeastern Seward Peninsula bench gravels are by no means uncommon along the lower slopes of many of the valleys. The deep holes on Alameda Creek and on the Niukluk were started to explore some of these bench deposits and part of the other gravels belonging to this class, but as they grade insensibly into the lower gravels they have been described with the older ones. There are, however, many places, as, for instance, along Ophir Creek, in the Council region, where bench gravels only a few feet thick have been found. Some of these are auriferous and some are not.

[a] Russell, I. C., Notes on the surface geology of Alaska: Bull. Geol. Soc. America, vol. 1, p. 139.

The geologic significance of the finding of bench deposits at different elevations widely distributed throughout the entire Nulato-Council region is that there have been frequent oscillations of the streams with respect to sea level. These oscillations may have been due in part to climatic changes, but in part they are to be accounted for only by assuming movements of the land with respect to the sea. Although the presence of benches above the streams at the present time shows that there has been an uplift of the land, the fact that some of the larger streams have their rock-cut floors below sea level shows that the sum of the recent upward movements indicated is not at present equal to the sum of the downward movements in the recent past.

A peculiar type of gravel deposit, in part fluviatile in origin, but probably also produced by other agencies, is found in the basin lowlands, such as Death Valley and the Fish River lowland north of the gorge. Sections in these basins have not been made, and little can be determined from the examination of their surficial aspects. Mendenhall states [a] that the Fish River lowland is filled with deposits, "coarse near the borders and fine near the center of the basin. The depth of this filling is purely conjectural, but presumably is not great. No islands of bedrock exist within it, as far as known, but sand and gravel prominences, rising in some instances 30 or 40 feet above the general level, are abundant over it, and are interpreted as remnants of a slightly higher level generally destroyed by the meanderings of the stream." Brooks [b] attributed the origin of these basins to warpings of the crust, whereby depressions were formed, which have been subsequently filled. So long as the topography of the floor on which the gravels rest has not been determined, it seems unsafe to attempt an explanation of their origin. The fact, however, that the uplands are so abruptly cut off by the lowland suggests that the basin is mainly due to erosion rather than to deformation. The question of the origin of the basin is not important in this discussion, for under either view the flats are believed to have been formed by the filling of a depression either by fluviatile or lacustrine deposits.

Owing to the high northern latitude, many of the deposits are permanently frozen, and as the presence or absence of frost in the ground has an important effect upon mining enterprises a general statement of the distribution of the ground ice may be made. Generally the older gravels are permanently frozen and some of the bench deposits contain beds of clear ice in places a score or more feet thick. So far as is known, the presence or absence of trees on the gravels is no sure indication that the ground is thawed, for many

[a] Mendenhall, op. cit., p. 207.

[b] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 282.

instances are known of trees of large size growing on frozen ground. For instance, at Nulato, as Russell[a] states, a well 25 feet deep went through clay and sand beds, which were frozen solid with the exception of certain dry sandy layers, and yet spruce was abundant in the neighborhood before it was cut off. Although most of the older gravel deposits are frozen, those near the present streams are usually thawed. Whether this condition is due to the better drainage of the present stream gravels which prevents the formation of ice is not known. There is a strong suggestion, however, that the frozen condition is due to past climatic controls and is in a way an inheritance rather than a process now in progress. This possibility receives some support from the distribution of ground ice in the marine gravels. In the present beach deposits permanent frost is unknown, whereas in the older ones it is almost universally present.

GLACIAL DEPOSITS.

Glacial deposits are limited to the mountain regions, and there is strong reason for believing that the Nulato-Council region has not been covered by a large ice sheet in sufficiently recent time to have had any effect on the general topography or on the unconsolidated deposits. Near the Bendeleben and Darby highlands, however, there are indisputable evidences of former valley glaciers of the alpine type. Deposits formed by this agency are of three kinds—in one the materials are unsorted and are dumped in irregular heaps essentially as they were deposited when the ice melted away; in another the glaciers obstructed the normal drainage and thus formed lakes on which ice-rafted bowlders were transported and deposited; in the third the morainic material was transported away from the melting ice by water and so, although originating through glacial action, the present form of the deposits is characteristic of stream deposition.

A particularly clear example of the unsorted morainic material has been reported by Henshaw in the Pargon River valley. At the edge of the mountains where the stream debouches into the Fish River lowland a long spur on the east side of the valley marks the margin of a former glacier. West of this stream, near the same place, the low divide between the Pargon and Ophir Creek is also formed of morainic material, with small kettle holes or depressions irregularly distributed over its surface. Farther up Pargon River a moraine from McKelvie Creek extends out into the main valley and shows characteristic morainic topography. This same condition is also true of Helen, Decatur, and many of the other tributary creeks. The absence of frontal moraines marking the recessional stages of the main glacier is probably to be explained by assuming that the

[a] Russell, I. C., op. cit., p. 129.

material was washed away by the water from the melting ice and not allowed to accumulate. According to this interpretation, part of the gravels of the Fish River lowland and of Pargon River are of glacio-fluviatile origin. The presence of granite bowlders in the gravels of Melsing Creek is probably due to this period of glacio-fluviatile activity when the ice stood sufficiently far south to allow a discharge from its front across the low divide at the head of Melsing and Ready Bullion creeks.

In the upper Niukluk Valley, near Mount Bendeleben, glacial deposits were observed, in 1908, on both the north and the south sides of the range. Moraines are also reported on Baker Creek and Oregon Creek, so that glacial phenomena are observable throughout the Bendeleben Mountains; but the consensus of opinion by all observers is that these glaciers were never very extensive.

Around the higher parts of the Darby Range there are also strong evidences of local glaciation in the past. Marginal moraines, however, have not been recognized beyond the front of the hills and it is probable that they were not deposited. Whether their absence means that they were not allowed to accumulate because of the rapid removal of débris by the water flowing from the front of the glaciers or whether the ice did not extend beyond the front of the mountains has not been determined.

Near camp C13, where the branch of the Etchepuk makes an abrupt angular turn from a southwest to a northwest course, there is abundant evidence of a morainic ridge which is probably responsible in part for the sharp bend in the stream. Although there is no clear proof of the conclusion, it is believed that at one time there may have been a discharge of this branch by way of the Kwiniuk basin. Although the evidence is conflicting, there is a possibility that the Fish River lowland also may be due to glaciation, but this interpretation requires much more detailed investigation and is advanced with many reservations.

That glaciation has considerably modified the topography within parts of the Darby Range by the deposits of glacio-fluviatile material is well shown by the ridges south of camp C11, which form part of the Etchepuk divide. These ridges are mainly due to the work of glaciers that occupied the valleys on either side, but the presence of water-worn cobbles intimately associated with angular ice-transported débris shows that both agencies were operative in the deposition of the material. From the topography it seems probable that this morainic deposit accumulated, as is indicated in fig. 7, where the tongues of ice are represented by CC, with nunataks, or islands of the underlying rocks (AA), separated by low saddles now filled with moraines (BB). The elevation of the top of the morainic material above the floor of the present stream is about 400 feet. East of this point and farther up the ridge there is no evidence of glacial deposits, and bare rock ledges outcrop.

All of these examples of glaciation have been taken from the west side of the range, the one to which the main attention of the party of 1909 was paid. Apparently glaciation is more notable on this side than on the eastern, for Mendenhall says:[a] "Many of the higher areas have not been examined in detail and it is possible that small local glaciers may have existed in the heads of some of the valleys, but no evidence of their existence was gathered during the summer, and views into the mountains from levels but little below their highest points revealed no forms suggestive of ice work."

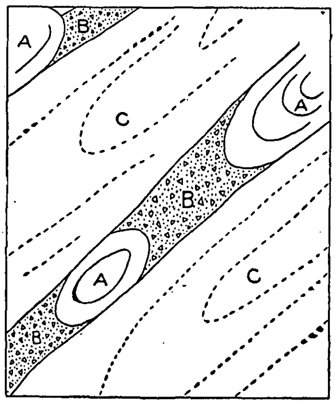


FIGURE 7.—Diagram showing relations of glacial material on Etchepuk divide. (A, Rocky knobs. B, marginal glacial deposits. C, Valley glaciers.)

AGE OF UNCONSOLIDATED DEPOSITS.

A consideration of the unconsolidated deposits as a whole indicates a great diversity of age, represented by the different types. It is not possible as yet to correlate these various deposits definitely, but in a broad way they are more or less closely related; the larger part are Quaternary, but probably none are older than the upper Tertiary. From that as the maximum age they grade down to the present day as the minimum. Assuming that the period of maximum glaciation was practically contemporaneous in the northern hemisphere, the glacial deposits already noted may be regarded as Pleistocene. Certain bench deposits contain mastodon and mammoth bones, which show that they, too, may have been deposited during Pleistocene time. Gravels containing bones of this age have been reported in the Buckland Valley, near Candle, on Ophir Creek, and along the Inglutalik, where they are numerous.

From the accounts of Henshaw, the well-recognized moraine, at the point where the Pargon River leaves the hills, has been deposited on top of the gravels of the Fish River lowland. Whether this means that all these gravels are older than the glaciation or whether the recognized moraine may only be one of the recessional stands of the ice after a much farther southward advance has not been determined, so that no statement of the age of the two types of gravel can be made. From the meager evidence, however, it seems probable that these gravel-plain deposits are in part contemporaneous with the

[a] Mendenhall, W. C., op. cit., p. 208.

glacial deposits and in part older than the period when the ice stood at the point where Pargon River leaves the hills.

Concerning the age of the marine gravels there is considerable uncertainty. Direct observations in this actual area reveal no evidence, but from analogy with better-known parts of the peninsula there are grounds for regarding them in part, at least, as late Tertiary. The evidence bearing on this point is as follows: In the coastal plain near Nome, which topographically resembles the coastal plain east of Norton Bay, fossils which, according to Dall, are of Tertiary age have been found; furthermore, glacially striated rocks at Nome in the upper part of the deposit indicate that this part was contemporaneous with the period of glaciation. In other words, the lower part of the coastal-plain deposits may be Tertiary and the upper part Pleistocene, and perhaps still more recent gravels rest on top, deposited as the former sea bottom emerged from the water and took on its present relation to sea level. As has been already pointed out, however, a long time is required for the various oscillations of the coast, so that the marine deposits have a considerable range in age.

STRUCTURAL GEOLOGY.

From the foregoing description of the various rocks in the Nulato-Council region it is evident that the structures they present are complex. Already the facts have been brought out that there are a group of metamorphic rocks which were dynamically deformed before the laying down of the Cretaceous sediments, that the Cretaceous rocks have themselves been folded and deformed, and that, latest of all, there have been undeformed lava flows and gravel deposits. It is thus evident that at least two periods of mountain building and deformation have affected the older rocks, and that their present distribution and characters are the resultants of these perhaps opposed actions. These actions have produced enormous dislocation and folding, which can only be vaguely realized and which can not be represented in section except so diagrammatically as to obscure the facts. Furthermore, precise details of complex structure can not be gained on an exploratory survey. It has seemed best, therefore, not to draw cross sections with the appearance of finality, but rather to call attention to the geologic maps (Pls. V and VI, in pocket), from which sections may be constructed. In this way the hypothetical condition will be more clearly discriminated from the actual facts.

The large scale structural features of the region are folds and faults. Many examples of each were observed in the field, and many others must be assumed in order to explain the areal distribution of the various rock groups. In the areas of metamorphic rocks the structure seemed to be simple in places where outcrops were scarce, but was found to be very complex in places where outcrops were frequent or continuous, as, for example, along the seacoast of the Darby peninsula; profound disturbance alone could explain the facts there revealed. In the areas of post-metamorphic rocks, on the other hand, the structures, although deformed, showed larger scale and consequently less complex relations. For this reason the two areas may be treated more or less independently.

The folds and faults produced by the post-Cretaceous deformation are most strongly marked in the Nulato-Norton Bay region. Here the predominant structure trends northeast-southwest and is very pronounced. This structure has had a marked effect upon the

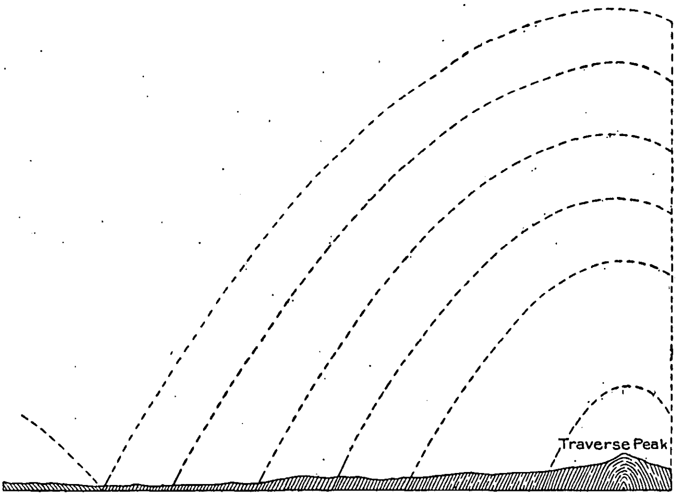


FIGURE 8.—Diagrammatic section west of Traverse Peak.

distribution of the topographic features, such as ridges and valleys, which are dominantly parallel to this direction. Although the trend of the ridges is undoubtedly due to the structure, the surface in no way corresponds to the surface of the old folded structure; for, although some of the ridges are anticlinal, many are synclinal. Such a condition, of course, would not be produced unless long-continued erosion had dissected the hills. In the part of the divide between the Yukon and the Norton Bay drainage near Traverse Peak the structure is distinctly anticlinal, but the present surface of the hills must be many thousand feet below the former surface. Figure 8 shows in diagrammatic fashion the observations made eastward from near the forks of the Inglutalik, 2 miles below camp B8, to the top of Traverse Peak. The observed dips are indicated by the heavy lines, whereas the implied consequences are shown by dotted lines. In this figure the vertical height of the structure is undoubtedly somewhat too great, for faults of greater or less displacement are to be expected. While, therefore, the diagram is not to be taken too literally, it indicates that an enormous cover has been removed; hence the divide is an erosional rather than a constructional feature. In this connection, it should be pointed out that the thickness of the Shaktolik group, indicated in this diagram, can not be taken as indicating the total thickness of the cover, for the top of the group is not exposed near the forks of the creek in the bowl of the syncline, and there is no evidence as to the distance to the upper surface of the group that has been removed by erosion.

Considered in a broad way the region from the Buckland-Kiwalik divide eastward to the Kaiyuh Hills is synclinal, the folding having a general northeast-southwest trend. It is complicated by numerous folds and faults, so that when examined in detail its larger features become obscured, and in general it shows a rim of the oldest Cretaceous rocks near the margins, with younger rocks toward the center of the synclinorium. In the central part of the area the post-Cretaceous deformation has been expressed mainly by folding, but toward the western part of the region, at least, faults of enormous throw seem to have resulted. This fact is clearly shown by the relation of the Ungalik conglomerate near the Tubutulik. This block, isolated from the rest of the Cretaceous area by a belt of schistose rocks of Paleozoic age or older, appears as a down-faulted remnant of the former extension of the Ungalik conglomerate of the East Fork of Koyuk River. So also the Cretaceous area west of the mouth of the Koyuk seems to be an inset block of sandstone dropped down so far that the conglomerate which should underlie it is not exposed. The absence of the conglomerate at this place shows conclusively that the beds could not have been folded into their present condition, but must have been inset by faulting. No estimate of the displacement represented by this fault was obtained, but it was at least many hundred feet and was possibly several thousand feet.

As suggested in the preceding paragraph, it is believed that many if not most of the larger faults in the area dominantly occupied by the Cretaceous rocks were produced at the same general period as the folding in the central part of the region. Folds passing into faults are well-known phenomena, and it seems reasonable that where the deformation was greatest the beds would be more apt to rupture and produce faults. That the regions outside of the great Cretaceous area were the most uplifted is indicated by the fact that sediments of this age have been removed by erosion more extensively than in the Nulato-Norton Bay region. It is not believed that the absence of Cretaceous rocks over much of the area of metamorphic rocks which form the rim of the present basin is owing to their not having been originally deposited there. The reason for this belief rests on the inset blocks on the Tubutulik and at the Ramparts of the Yukon as well as at many of the less well known localities. It seems that these blocks point conclusively to a former much greater extension of this rock system, which has been gradually decreased as erosion removed the higer parts and exposed the underlying rocks. As to the position of the former shore line of the maximum extent of the Cretaceous sea there is no known evidence, and it is doubtful whether proof can be obtained, as erosion has so extensively removed the traces.

To return to the faults in the Cretaceous area—it has been suggested that many of the larger faults have been the result of the post-Cretaceous deformation, and the reasons for this belief have been stated. Although the validity of this argument may be questioned, as it rests so much on hypothesis, there can be no doubt that certain faults belong to this period. Numerous examples were observed along Shaktolik River where closely appressed folds have been broken and faults have been produced by the deforming forces. It is a notable fact well shown by the excellent exposures along the canyon walls of the Shaktolik that, where the deformation is most intense, as indicated by the close folding, faults are most numerous. Of course, it is only at intervals that the age of these faults with respect to the folding can be determined by direct observation. The intimate relation, however, of faulting to areas of close folding and the observed passage of folds into faults make it almost certain that much of the folding and faulting were contemporaneous.

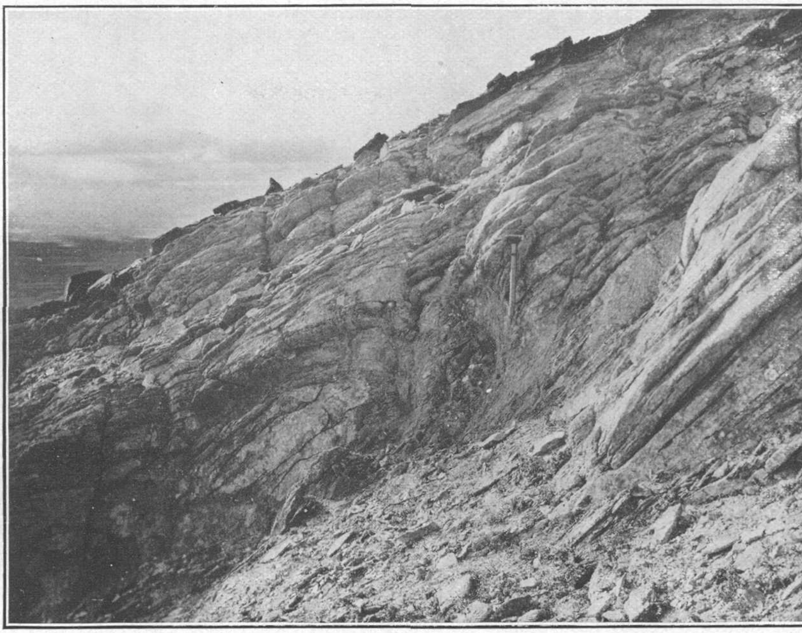
That there has been faulting in the Cretaceous area subsequent to the main period of deformation is clearly shown by the fact that faults have been observed cutting the post-Cretaceous dikes which form apophyses of the Christmas mountain intrusion. Faults of this age were observed near camp A16, on the Ungalik, and there was evidence that larger movements had taken place elsewhere. It is to be borne in mind, however, that the opportunities for obtaining data on the age of the faults are infrequent, and it is by no means improbable that faults later than the post-Cretaceous deformation may be more common and widespread than the single faulted area noted indicates. So far as known, however, it is certain that none of the later faults exercise a direct effect on the present topography.

As has already been pointed out, the period of post-Cretaceous deformation was one of mountain building, and its effects were not confined to the Cretaceous area between the Yukon and the Koyuk, but were extended to the already greatly deformed rocks of Seward Peninsula. Traces of this folding may still be recognized in the dominant north-south trend of many of the structures. An illustration of this trend is seen in the band of Paleozoic rocks along the east side of the Darby Range and also in the various limestone bands west of this range. Although this direction is also the trend of the Darby Range and of the highland of the Buckland-Kiwalik divide, the rocks in both of which are older than the Cretaceous, it seems probable that this form is a post-Cretaceous feature, so that the intrusions were not controlled by this structure. According to this explanation the Darby and the Kiwalik hills are due to the post-Cretaceous deformation, and the fact that the igneous rocks of the two areas are not continuous or aligned gives support to this interpretation. It is not intended, however, to assert that these hills necessarily mark the axes of the deformation, for it is believed that these areas are highlands mainly because the rocks of which they are formed have been strengthened and made resistant by the intrusives which characterize them.

A difficulty in the way of the acceptance of this interpretation is the undeformed character of the granites and other igneous rocks of these areas. Although on the face this is a vital objection, the incontrovertible fact that these rocks form the bowlders in the Ungalik conglomerate makes them certainly older than the post-Cretaceous deformation. Either, then, these rocks were unaffected during this period of mountain building or else they passed through it without marked folding and shearing. That a belt of rocks, averaging in width only about 6 miles and nowhere over 12 or 14 miles wide, should have withstood pressures great enough to fold perhaps 6 miles of Cretaceous sediments into great waves as one would fold the leaves of a magazine is almost inconceivable. It seems far more probable that the deformation that occurred in this part of the field was characterized by faults rather than by folds. According to this explanation great blocks practically undeformed may have been uplifted and oriented in a north-south direction without having been folded or without having had pronounced shearing induced.

With such pronounced post-Cretaceous deformation noted so widely throughout the region, it is evident that the untangling of earlier structures is possible only by the most detailed investigation. Inasmuch as such studies have not yet been made, it follows that interpretations are to be regarded as tentative and as indicating the kind of structures to be expected rather than as stating the precise structure at any particular locality. In order to emphasize the complex character of some of the pre-Cretaceous deformation a few examples of field observation may not be out of place.

Plate XIII, *A*, shows one of the closely appressed folds in the immediate neighborhood of the Omilak mine and very clearly illustrates the point in hand. This illustration is, of course, only one of the smaller folds, for, as is indicated by the hammer, which is about 18 inches long, the outcrop is only about 10 to 12 feet high. It should also be noted in this view that although the folded character of the



A. FOLDED LIMESTONE NEAR OMILAK MINE.

B. FOLDED AND SHATTERED LIMESTONE ON OPHIR CREEK.

beds is very clearly shown in the central and left-hand portion of the picture, the beds on the opposite sides of the axis in the right-hand portion are so nearly parallel that except under favorable conditions of exposure the divergence might be attributed to minor faults or might even pass undetected.

Where the beds are so closely folded it is evident that it is very difficult, if not impossible, to distinguish between the two or more periods of deformation known to have affected the region. For instance, the fold shown in Plate XIII, *A*, has a strong pitch to the west—that is, away from the point of view. Whether this pitch is due to the same deformation which overthrew the fold toward the north (to the right) or whether the overturned fold has itself subsequently been folded parallel to a north-south axis is not known. Figure 9 shows in diagrammatic manner the conditions probably existing at this place, the right-hand part of the diagram representing the part of the area shown in Plate XIII, *A*. As the north-south folds of the post-Cretaceous deformation are the latest mountain building in the region, it follows that the east-west trend noted in the vicinity of the Omilak mine preceded that period and was later deformed by the forces producing the north-south trend. On the other hand, it is entirely within the bounds of reason to suppose that in a period of deformation such as that which followed the laying down of the Cretaceous deposits the dynamic forces would not be equal over the entire area; hence the sag shown in the diagram might occur at a place marking inequality of the deforming force.

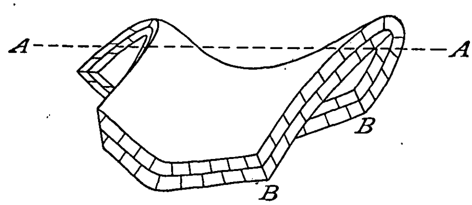


FIGURE 9.—Diagram showing folding in two directions.

Whatever the final determination may be as to the origin of this structure, the fact remains that it is by no means uncommon in the region. The irregular distribution of the different formations seems to suggest a structure of this kind. For instance, if the present erosion surface be indicated by a plane passing through the dotted line AA in figure 9, it is evident that the limestone bed BB would be exposed in the field by two isolated outcrops in which the fold, if it was as closely appressed as the one shown in Plate XIII, *A*, would probably escape detection, owing to the close parallelism of the two limbs.

The reverse of the condition shown in figure 9 might also occur where the field relations would be as though the diagram were looked at upside down and the erosion surface were still represented by the dotted line AA. Under this condition only the synclinal bowls where the rocks had been folded down lowest in the latest period of deformation would be preserved. This condition might, of course, expose either anticlines or synclines of the earlier period of deformation, so that a single observation would afford no conclusive idea of the relations.

With each subsequent folding some of the earlier features are obliterated and structures formed in the previous period of deformation become contorted. Plate XIII, *B*, shows a limestone outcrop about a quarter of a mile above Dutch Creek on Ophir Creek in the Council region that has very evidently been folded so that now the dominant structure is standing vertical. When this exposure is studied in detail it is evident that the thing which has been folded is a previous cleavage and not the bedding. In places, of course, the bedding corresponds to the cleavage, but in this picture it is evident that it is a cleavage that has been folded. This indicates that two periods of folding have taken place; in one the cleavage was produced, and in another it was folded.

Examples of this twofold structure are to be seen in all parts of the field and are not limited to any particular kind of rock, except that two structures are never seen in the later igneous rocks nor in the Cretaceous sediments. Evidences of two structures are particularly notable in the schists and limestones, but the black quartzites of the Paleozoic rocks seem to have fractured rather than folded in the post-Cretaceous period of deformation. Usually in the schists the later folding is recognized by minor transverse plications. The small hand specimens are the miniatures of the larger features, and the reason for the difficulty in recognizing the larger ones is the complexity of the structure and the absence of clearly distinguishable horizons in the schist complex. On the 1,200-foot hill east of camp C4 almost every piece of float gives striking illustration of this double plication.

Of the existence of the two periods described there can be no doubt, for they have been recognized not only in this field but in many other parts of Seward Peninsula. Moffit, who studied the region to the north where the rocks are similar in many respects to those found in the southeastern part of the peninsula, says:[a]

> This complex (the metamorphic group), both sedimentary and igneous in origin, was affected by the two movements mentioned, which acted in very different directions. One produced a structure in which the axes of the folds extend in an east-west direction, and is most plainly expressed in the uplift constituting the Kigluiak and Bendeleben mountains. * * * This east-west structure corresponds in the direction of its folds with the main structural lines of the whole of western Alaska, and is believed to have been produced before the deposition of the coal beds; that is, before Cretaceous or lower Tertiary time.
>
> The second movement resulted in the production of folds whose axes have a general north-south direction and are the dominant structural feature of the northern portion of the peninsula.

[a] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 35.

It has already been suggested that the schists which underlie the Paleozoic rocks were probably deformed prior to the deposition of that member of the stratigraphic sequence and that the later rocks lie unconformably upon them. This is a difficult thing to prove and is advanced tentatively. There is no place where the underlying and the overlying rocks occur so intimately associated that the possibility of faulting is precluded, and, although the underlying rocks are much more schistose and apparently more deformed, there is necessarily the uncertainty as to the weight that should be given to this evidence when applied to lithologically different rocks. In spite of these objections it is believed that there was a period of profound pre-Silurian deformation. Definite proofs of this event have been, in the main, removed by the two subsequent periods of mountain building, but the constant greater metamorphism of the supposedly older schists, the field relations of the two groups, and the presence of certain structures in the older schists not found in the Paleozoic rocks lead to the conclusion that there was a period of pre-Silurian deformation.

If this hypothesis proves to be correct, it follows that an exceedingly complex arrangement of the lithologic members of the older schists is to be expected, and that the final determination of the succession in that group will be accomplished with the utmost difficulty. For the purposes of this paper, however, it will be sufficient to point out that the effect of each period of deformation has been to make the distribution of the older rocks more and more irregular, and, if the term may be applied to distribution, smaller "textured." As to the trend of the deformation of the oldest folding, there are no data available on which to base even an approximation.

HISTORICAL GEOLOGY.

To one who has followed the preceding descriptions with geologic insight the successive events which occurred in the region have already been given. As the facts for making a relative chronology, however, have been scattered through many pages, it seems desirable to collect these details into sequential order which shall give an epitome of the geologic history of the Nulato-Council region.

The oldest recorded event from which a start can be made was the laying down of quartzose and calcareous sediments over much of what is now western Alaska under presumably marine conditions. No definite age for this event can be given. It was, however, undoubtedly earlier than the Silurian. From the evidence secured by Kindle in the York region of western Seward Peninsula, where the Ordovician and Upper Cambrian seem to form a continuous relatively uninterrupted sequence overlying similar rocks, there is some warrant for considering the oldest rocks as possibly pre-Cambrian. This suggestion as to the age is to be regarded only as a working hypothesis and is by no means definitely proved.

After the deposition of these sediments there were probably some veins formed which are now represented by the knotted and contorted quartz strings found in the older schists. Either coincident with this venation or following it, probably the latter, a period of mountain building ensued in which the quartzose and calcareous sediments previously deposited were consolidated and deformed and cleavage was probably developed. Erosion followed and sediments from this old land were carried out and deposited in the sea. This process must have continued for such a long time that the highlands were reduced by erosion and the region subsequently became depressed below the marine waters, for the rocks formed of the waste thus washed from the land were apparently deposited unconformably on the underlying rocks. If the tentative assumption of the pre-Cambrian age of the oldest sediments is correct, this period of mountain building may mark the gap between the Paleozoic and the pre-Paleozoic. In this period undoubtedly many oscillations and minor deformations may have occurred which are now unrecognizable.

After the period of mountain building the material eroded from the land mass was deposited in the marine waters off the coast. The land from which this waste was derived was remote from the area under consideration, for the sediment derived from it that now covers part of Seward Peninsula was laid down as limestone. In the Nulato-Council region this deposition corresponds with the laying down of the Paleozoic rocks. In the western part of the peninsula, however, as has already been pointed out, there are limestones containing Cambrian and Ordovician fossils, and as there is no known break between these limestones and the Silurian-Devonian-Carboniferous (?) rocks of this region it is assumed that the period of deposition may have continued practically uninterruptedly from the Cambrian to the Devonian or Carboniferous. During most of this time limestones were being laid down, but the intercalation of highly quartzose carbonaceous sediments, such as those now found near Mount Kwiniuk, indicates movements of the sea floor and changes in relation to the source of waste supply.

After the deposition of the Paleozoic rocks there was probably an uplift, for the next event recorded was the intrusion of greenstones, some of which formed surface flows. Such flows could hardly have taken place while the limestones were being laid down, and it is therefore necessary to believe that a part of Seward Peninsula was at that time dry land. This period of greenstone intrusion was well marked through many parts of Alaska and has been recognized not only in Seward Peninsula, but also in the northern part of the

Koyukuk, in the basin of the Melozitna, and in the Kaiyuh hills. If the extrusions of greenstone materials took place on land they must have unconformably overlain the older rocks. In the Nulato-Norton Bay region none of the effusive types were recognized, but farther west effusive character was strongly suggested by the exposures in the Solomon-Casadepaga quadrangles. In the central Yukon region the age of the greenstone intrusion is Devonian. For this reason it is possible that in the determination of the fossils from the sedimentary rocks as either Devonian or Carboniferous, preference should be given to the older rather than the younger system. In the Copper River region and in southeastern Alaska, on the other hand, a period of greenstone effusion has been described as Carboniferous or later, so that correlation by analogy is inconclusive.

With the intrusion of the greenstones there was some local or contact metamorphism of the rocks they penetrated, but the effects were slight. There was also the formation of some veins, but many of the older veins were already in the Paleozoic rocks before the intrusion by the greenstone, for in places the veins are abruptly cut off by the later rock. With the greenstone probably a little mineralization was introduced, but its effects upon the metalliferous resources of the region were slight.

After the formation of the greenstones a period of mountain building ensued in which the previously formed rocks were metamorphosed dynamically and profoundly faulted and folded. When this occurred can not be told with definiteness owing to the uncertainty of the ages of the Paleozoic rocks and the greenstones. From the evidence afforded by other parts of Alaska there are two dates to which the deformation may reasonably be assigned—one is in the late Devonian, and the other is in the early part of the Mesozoic. If the Devonian instead of the Carboniferous age of the sedimentary rocks is assumed, it follows that either of these periods will fulfill the requirements of the field evidence. If, on the other hand, however, the upper part of the deposits is Carboniferous it is evident that the period of mountain building following the deposition and consolidation of the Paleozoic sediments and their intrusion by the greenstones must have been the one occurring in the Mesozoic. No conclusive evidence on this point has been obtained, and the question must still remain an open one.

As a result of the deformation, the rocks were cleaved and folded and probably high mountains were formed. As soon as they were formed, erosion began to wear them down and to transport the material toward the sea. No clear idea is possible of how long this process continued uninterruptedly, for the only part of the Mesozoic represented by stratified rocks in this field is Cretaceous. An interruption occurred some time after the mountain building and prior to the deposition whereby igneous activity became dominant. There is no evidence as to whether during the early part of this vulcanic cycle the region was land or was beneath the sea, but for the purposes of the present report this is not of great importance.

The first recorded intrusion of this period was the formation of diorites, which were subsequently intruded by granites, and these in turn were intruded by other diorites. Although these various phases could not have been formed within a short time of each other (for each of them had cooled and consolidated sufficiently before the next succeeding intrusion so that they broke into angular fragments), from a geological standpoint they were closely associated in age and may be considered as a unit. Evidence as to the age of these rocks is afforded only by analogy with other parts of Alaska. In the Matanuska-Talkeetna region of south central Alaska, Knopf and Paige determined the age of the great granodiorite-diorite intrusions as later than the Middle Jurassic and earlier than the deposition of the late Jurassic strata.[a] The Wrights in southeastern Alaska stated that, although the date of the major period of intrusive activity (the time of the Coast Range intrusion) was in doubt, it continued at least until late Middle Jurassic time.[b]

Although long-range correlations of this sort are clearly liable to gross errors, the absence of other data is sufficient justification for tentatively accepting the only available facts at hand. On this assumption the most reasonable age determination of the intrusives of the Darby and Bendeleben mountains is that they are Middle Mesozoic.

In the section dealing with the descriptive geology of the pre-Cretaceous igneous rocks it was stated that in the Kiwalik-Buckland divide there were ancient effusives along the flanks of that highland. It is practically inconceivable that effusive rocks of geologically the same age as granular intrusives should occur in contact with those intrusives. The granular rocks by their texture require relatively slow cooling under considerable cover. It follows, therefore, that when the intrusives of the Kiwalik-Buckland highland were injected there had been a considerable thickness of strata over the region, which was removed before the effusion of the older lavas. No precise measure of the time required for eroding the superincumbent rocks can be made, but it must have taken a long time. After erosion had exposed the plutonic rocks of the mid-Mesozoic, andesitic lavas were extruded.

During the latter part of this period this portion of Seward Peninsula, at least, must have been land. Gradual submergence occurred

[a] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 20.

[b] Wright, F. E. and C. W., Ketchikan and Wrangell mining districts, Alaska: Bull. U. S. Geol. Survey No. 347, 1908, p. 76.

and marine waters beat against the shore forming a heavy conglomerate which, as time went on and the shore line gradually encroached farther and farther on the land, was buried in the deeper parts of the basin by finer sediments. At no time, however, was the water in the basin very deep, for mud-flat markings and cross bedding are observable at many places. Probably by stages more or less equal with the filling of the basin with detritus the bottom sank until a great thickness of sediment was deposited. Where the farthest encroachment of the sea on the land occurred is not known, but marine waters must have covered the larger part if not the whole of what is now Seward Peninsula. In this sea the deposits accumulated and covered the pre-existing topography that had not been effaced by the beat of the sea upon it.

The geologic age of the sediments deposited during this period is Cretaceous. As has already been stated, on page 56, the Ungalik conglomerate at the base may be Lower Cretaceous, but the upper part, or Shaktolik group, contains no fossils other than of Upper Cretaceous age. In other parts of Alaska there has been reported a pronounced break between the Upper and the Lower Cretaceous and the two are in uncomformable relations. In this province no break was noted. If, however, subsequent studies should show a period of diastrophism between the Upper and the Lower Cretaceous it would seem rather conclusive evidence that the Ungalik conglomerate is of Upper Cretaceous age, for the fossil evidence which seemed to indicate a Lower Cretaceous age is very weak. Under such conditions the Lower Cretaceous would be represented in Seward Peninsula by the erosion interval at the base of the Ungalik conglomerate.

Succeeding the period of Cretaceous deposition was the last epoch of mountain building. By this deformation enormous folds and faults were produced which must have made mountain ranges of great height. There is no direct evidence as to the time when this folding occurred. From analogy with other parts of Alaska, however, it is known that there are two possible ages to which the epeirogenic movements may be referred. In southwestern Alaska the Kenai or upper Eocene is unconformable on the Upper Cretaceous.[a] This unconformity is marked by a break in faunas rather than by mountain building, but the fact that in places the Kenai is known to rest directly upon the Jurassic indicates a long period of changes. The other period to which the great orogenic movements of the post-Cretaceous may be referred is later than the deformation of the Kenai. There is but little to show which of these is the correct correlation, for there is no Kenai in the region studied. With full

[a] Stanton, T. W., and Martin, G. C., The Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, p. 410.

recognition of this uncertainty it is believed that a pre-Kenai age for the period of orogenic movement, which closed the Cretaceous deposition, fits more of the known facts than any other interpretation. According to this hypothesis the larger outlines of the geology of western Alaska were marked out before the Kenai and the sediments of the latter period were deposited mainly on the eroded surface of the earlier rocks and mostly as fresh water deposits.

After the great post-Cretaceous deformation, intrusion of granular rocks, such as those of Christmas Mountain, occurred. It is unsafe to assign a more specific age for this period of volcanism than the middle Tertiary. Whether the mountain building was closed before the intrusion is not definitely proved. The fact that some of the dikes from the Christmas Mountain mass are faulted shows either that the deformation had not entirely ceased or that the dikes were formed at a later time.

With the conclusion of the period of granular intrusions and of the great post-Cretaceous deformation, the region as a whole has been a land area subjected to erosion which has continued down to the present time. An enormous amount of erosion is indicated before the next recorded event in the history of this complex region. As a result of this erosion valleys were cut and the region was reduced from a mountainous country to one having something like the present topography. Then volcanic activity began and continued spasmodically from the later part of the Tertiary almost down to the present. The recent basaltic lavas of the Yukon and of the Koyuk and its environs bear witness to this period. As has already been pointed out some of these lavas are so recent that they overlie the gravels of the Noxapaga basin, whereas others are so much older that they stand at least a hundred feet above the present streams, which have carved their valleys through them.

Many of the lavas flow down the lowland areas of the preexisting topography. In these depressions they were consequently thicker and have therefore been less thoroughly removed by erosion. From the distribution of the residual patches it is therefore possible to reconstruct in a measure the former topography, and it is from this reconstruction that one is able to state that much erosion must have affected the structure produced by the post-Cretaceous deformation before the effusion of the lavas.

While the volcanism was in progress, erosion still continued over much of the area and the highlands were degraded and deposits were formed off the coasts. The erosion, however, did not proceed uniformly, for there were undoubtedly movements of the earth's crust whereby certain parts were uplifted and others depressed. On the whole, however, these movements were gentle, broad, regional uplifts and were not acute mountain-building deformations. Because of uplift movements the streams were at times forced to cut their channels deeper into the bed rock of their valleys, but at other times, because of depression, they found the rock floors too deep and were forced to lay down some of the waste they were transporting, and thus aggrade their courses. Changes of this sort, however, did not exercise any considerable effect on the form of the region except to reduce the relief consistently.

After erosion and deposition had been in progress for a long time a change in the climatic conditions resulted whereby glaciation of the valley type was developed in the highland areas. Apparently this event took place when the sum of the preglacial movements had resulted in the region standing relatively lower than it does now with respect to sea level and grade level. The main result of the period was to scour out the mountain valleys and distribute the waste thus formed beyond the area occupied by the ice. From fossils associated with the deposits formed at this time it seems probable that this occurred in the Pleistocene, which was also the period of maximum glaciation in other parts of the northern hemisphere.

As the vigor of glacial conditions abated, the glaciers receded into the hills and finally disappeared. A long time, however, is required for this process, as is shown by the various moraines in the Pargon Valley and elsewhere in the mountain region. All this time deposits of glacio-fluviatile, 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 late Tertiary to Recent movements have been described as resulting in certain general conditions, it should be distinctly understood that these movements 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 variables.

In order to summarize the history of the region as determined the table shown in figure 10 has been prepared. It is at best but a graphic representation of the facts already given, and has the disad-

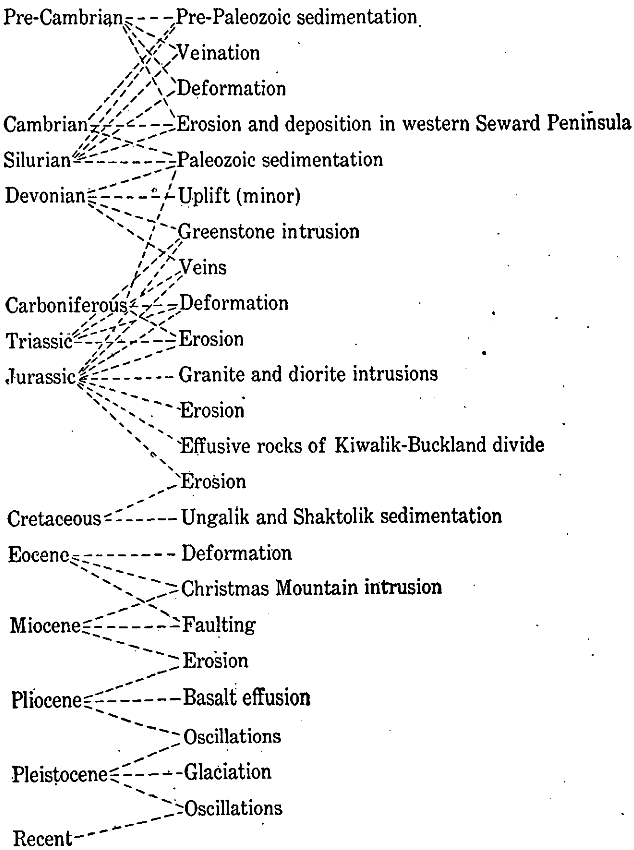


FIGURE 10.—Diagrammatic summary of geologic history of Nulato-Council region.

vantage of giving an appearance of finality to the correlations, some of which the text has shown to be founded on insufficient data; for these reasons it should be regarded as a summary and should not be used independently of the text.

ECONOMIC GEOLOGY.

In the preceding description of the areal geology of the region it has been shown that east of Koyuk River the country is formed of late sedimentary rocks that are little if any metamorphosed, whereas the region to the west of this stream is predominantly one of schists, limestones, and igneous rocks. So far as has been indicated by mining in contiguous areas the metamorphic rocks are those in which deposits of gold may be sought with some promise of success, whereas the unmetamorphosed sedimentary rocks are the ones in which deposits of coal may be found.

PLACERS.

GOLD IN AREAS OF UNMETAMORPHOSED SEDIMENTS.

CONDITIONS OF PLACER FORMATION.

In the unmetamorphosed sedimentary deposits the chances of finding economically important gold deposits are relatively slight, except under local conditions. The Cretaceous and Tertiary deposits, the unmetamorphosed sediments, were formed of material eroded from the earlier rocks and deposited on the sea floor and in estuaries and marshes in essentially the same way that sediments are being deposited at the present day off the coast. Some of the present-day sediments, however, are auriferous, and it might be asked why similar placers should not be found in the older sedimentary deposits. Gold placers should occur in the Nulato-Norton Bay region under conditions similar to those prevailing in the coastal plain at Nome, but there are few places where similar conditions exist.

In order to make clear the different conditions in the two regions it is necessary to point out the salient facts concerning the productive placers of the coastal plain—for instance, those at Nome. A discussion of the character of the surface of the bed rocks is omitted as not important in bringing out the point of the following paragraph.

The known placers are not more than 3 or 4 miles from the old land from which the sediments were derived; the depth of gravel covering the bed rock is seldom over 100 feet; the gravel is as a whole fairly coarse; the rich ground occurs in ancient beaches, which mark concentration by the sea; and the country immediately adjacent to the rich placer is heavily mineralized. Consider the physical and geographic conditions which these facts entail. First, the short distance from the ancient shore line suggests that the gold did not travel far seaward from the place where it might have been formed. This is, of course, a conclusion which would have been reached by anyone accustomed to the action of gold in a sluice box. It might be safely assumed that in general the farther from the source the less gold there would be, other conditions being equal. Evidence of the proximity of the placer deposits to the old land is shown by the second criterion, namely, that the depth of gravel is seldom over 100 feet. This condition, like the preceding, is valuable in establishing the nearness of the gold to its source. The third fact also is of value in further establishing this conclusion, but it is also important as showing that the agencies by which this material was transported were of sufficient strength to permit considerable sorting of the gravel and thus to allow concentration of the particles of gold. As the coastal plain placers are found along old strand lines it follows that in order to make a deposit of economic importance it is necessary to have a marked concentration of once disseminated particles. It is, of course, unnecessary to have this concentration effected by the sea, for streams would do it equally well, as is shown by the numerous creek placers. Perhaps the most important condition which must be fulfilled in order to make a rich placer is the presence of a highly mineralized area in the more or less immediate vicinity. Without this, the other conditions are ineffective.

It has also been pointed out by others that certain physiographic conditions are essential for the production of placers, such as long continued subaerial erosion followed by rapid sweeping off of detritus by revived drainage. As the physiographic history of northwestern Alaska has not yet been worked out in sufficient detail to permit the application of this criterion it can not be critically applied in this discussion.

If now the Nulato-Norton Bay region is considered in the light of the premises enumerated above it at once becomes evident that few of its conditions are analogous to those enumerated. It is true that there are places where the Cretaceous basin is in immediate contact with the old land. This has been proved by the extension of the basal conglomerate from near the Tubutulik northward along the east side of the Buckland-Kiwalik divide. The conglomerate was noted also by Mendenhall[a] on the Kobuk, from which place it swings southeastward. It was recognized, although not correctly correlated, by Schrader on the Koyukuk and by Dall, Collier, and Spurr on the Yukon, and was correctly correlated by Maddren on the Yukon near the Melozitna.

In the belt occupied by the heavy conglomerate the deposits were certainly near enough the shore to permit the formation of placers; but the physical conditions under which this conglomerate was deposited do not seem to have been well suited to the unlocking of gold from bed rock. Instead, the bowlders were riven from sea cliffs and were subjected to trituration rather than to decomposition or disintegration, and whatever gold may have been in the rocks was so abraded before it was deposited that it undoubtedly formed flour gold, which would be much more widely disseminated than flake or shot gold. Furthermore, over a considerable part of the region where the basal conglomerate was seen by the survey party the

[a] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: Prof. Paper U. S. Geol. Survey No. 10, 1902, pp. 39–41.

country rock forming the old land shore line against which the sediments were deposited consisted of limestones and igneous rocks. So far as is known from a careful study of the known placer camps farther west, practically no gold is found in the limestones and none is known associated with the granites or other igneous rocks. It will be seen therefore that in the shoreward portion of the metamorphic area the important condition of near-by highly mineralized country rock from which the sediments were derived is wanting. It is believed, therefore, that search for commercial placers, although not entirely out of the question in the conglomerate area, is to be discouraged, unless the field evidence shows the existence of conditions other than those generally encountered in the basal member.

Over the greater part of the Nulato-Norton Bay area it has been shown that the lower member marking proximity to the old shore line is not exposed. It seems probable that through this part of the region the deposits are much higher geologically. From the physical character of the sediments and from the structures observed, such as cross bedding, it seems certain that the higher geological members

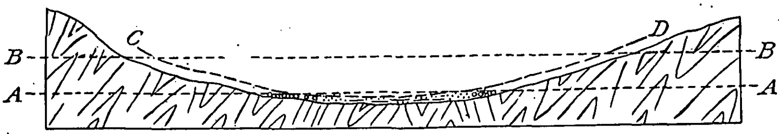


FIGURE 11.—Diagrammatic cross section of the Nulato-Norton Bay region during Cretaceous deposition.

were deposited in relatively shallow water. This fact, however, does not mean that the deposits were near the old land of metamorphic rocks. Figure 11 shows in diagrammatic manner the conditions believed to have prevailed in the Nulato-Norton Bay region. The metamorphic rocks to the left in the figure may be taken to represent the schists of Seward Peninsula, and those to the right the rocks near the Melozitna; the intervening area is the Nulato-Norton Bay region at the beginning of Cretaceous deposition, with sea level indicated by the line AA. At this stage conglomerates were laid down close to the shore of the old land and sandstones and shales toward the center of the basin. Gradually depression took place and continued at such a rate that the surface of the deposits was always within a short distance of sea level. It is evident, therefore, that if this depression continued until the surface of the deposits and the sea level stood at the line BB, no part east of C as far as D had ever been close enough to the metamorphic area, which is assumed to have been the source of mineralization, to have received any notable amount of gold. Consequently, in this part of the region, unless subsequent folding exposed rocks at the surface outside of the part included within the line CD, the probability of finding auriferous deposits is slight, and then only if the old land area from which the sediments were derived was sufficiently mineralized to afford placer gold.

It has been the object in the preceding paragraphs to point out that on the whole the chances of finding gold in the area of unmetamorphosed rocks are slight. From the fact that only under exceptional conditions are valuable deposits likely to be found it seems that the ordinary prospector for gold should be warned against spending much time in the region east of Koyuk River. Not only does this conclusion seem sound from a theoretical standpoint, but it was learned from prospectors on the Inglutalik that they had been from that river eastward to beyond the Gisasa and had not been able to raise a single color of gold.

It is not the purpose of this warning, however, to assert that no gold will be found in the region, for there are three conditions under which deposits may be found. The first of these conditions, already described, is that the unmetamorphosed sediments considered may have been originally deposited at no great distance from the shore of a mineralized area of metamorphic rocks. Such deposits might be found at several places, even in the middle parts of the basin, if subsequent deformation brought the underlying rocks up to the level of erosion. As an example of this condition may be cited the area of metamorphic rocks which appear between Kwik and Koyuk rivers.

The second condition which might permit the formation of valuable gold placers in the Nulato-Norton Bay region is long continued concentration of the material, either by streams or by the ocean. Concentration of this sort may have been effected either during the time the sediments were being deposited or at a much later time. Throughout the period occupied by the deposition of the sands and gravels the region was apparently undergoing almost uninterrupted depression, so that, although there was sorting by water, it was nowhere so effective as it would have been if the region had been one of alternate erosion and deposition, as the coastal plain at Nome has been. In other words, the ancient placers at Nome seem to have been subjected to at least two periods of concentration, whereas the deposits of the other region seem to have undergone but one. Since consolidation, the sandstones and shales of the Cretaceous have been eroded by the streams and a present day concentration is being effected. Some of the reported gold placers in the Yukon basin are probably due to this sorting, but they may have been formed by original sorting before the consolidation of the sediments, for little is known about the deposits.

The third type of locality where search for gold placers or lodes in the area of nonmetamorphic rocks would be warranted is at those places where mineralization has occurred since Cretaceous times.

Such places are, so far as known, closely associated with the areas of intrusive igneous rocks. The effusive rocks or lavas of Tertiary-Recent age do not seem to have brought any valuable minerals, and therefore placers or lodes due to post-Cretaceous mineralization are not to be sought in those areas where only these rocks occur.

Intrusive rocks later than the Cretaceous have been noted at but two places, although a more detailed investigation of the area undoubtedly might result in discovering others. The two places where these later granitic rocks have been examined by the Survey party are at Christmas Mountain, east of Ungalik River and at Bonanza Creek. From reports of prospectors it seems that the placer-bearing gravels of Anvik River may have been derived from a similar area of intrusive granitic rock, although too little is known of the geology of the country to advance this interpretation more than tentatively. Spurr[a] in his summary of the occurrence of gold in southwestern Alaska says:

> The gold in this region is by no means so abundant as it is along the belt of the Yukon geanticline, where the ancient schists with their inclosed quartz veins are found. The mineralization of southwestern Alaska is of a later date and not so intense or widespread. Within the area examined by the writer's party last summer (1898) the Tordrillo Mountains are undoubtedly the chief seat of mineralization, and this appears to be directly dependent upon the fact that these mountains have also been the chief seat of intrusion of igneous rocks.[b]

PLACERS OF THE BONANZA CREEK REGION.

Bonanza Creek is the only stream between the Koyuk and the Yukon where placer mining has been successfully carried on. This creek is only about a mile long, but values have been found almost the entire length of its course, and, from the character of the gold, they seem to be of distinctly local origin. Gold was originally discovered and staked on this creek in 1899 by Thomas Moon and his partner. The absence of water and the boom that the Seward Peninsula placers were having prevented any considerable development for the first few years on Bonanza Creek. After the lower claims had changed hands several times they were bought by the Nelsons, who have since been the most industrious miners there. Other miners have held ground on No. 2 and No. 3 above the Discovery claim, and some work has been done for the last two or three years. It is hard to realize that during the boom days of this camp nearly a hundred men rushed to the creek, and several road houses and three or four saloons were in operation, for now the creek is practically deserted, and only four or five white men are living there.

[a] Spurr, J. E., Reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 261.

[b] It is extremely doubtful if the intrusives of the Tordrillo Mountains are post-Cretaceous, as the sedimentary rocks they cut are Jurassic or older.

At first the creek claims were the ones from which the values were obtained. On the lower claim the pay streak was 400 feet wide, but it narrowed upstream and at the northern line of No. 1 above Discovery the width was only about 75 feet. The gravels are typically river wash in form and consist of material from near-by rocks, although some of the pebbles were undoubtedly derived from higher level gravels which were not of local origin. Bed rock is a much shattered black slate or shale, on the whole rather thinly laminated and not so quartzose as the black quartzitic slates of the Paleozoic section. The slates are cut by igneous rocks of the granite family. An exposure of one of the intrusive dikes occurs a short distance north of the cabins at the junction of Bonanza Creek and the Ungalik. Here the dike is apparently about 10 feet wide and shows by its undeformed character that it was injected subsequent to the period of folding and faulting of the slates. It trends obliquely to the slates, having a strike of N. 5° E. and stands vertical. It is heavily iron stained in places. This iron is probably derived from the decomposition of sulphides, some of the unaltered material showing pyrite in microscopic sections.

Above the stream on the northeast side of the valley is a bench on which gravels have been found that are highly auriferous. After the exhaustion of the creek gravels attention was turned to this high-level ground, and satisfactory returns have been obtained from it. Aneroid readings give the elevation of the bench as about 80 feet above Bonanza Creek at the cabins, but some gravels have been found up to an elevation of 150 feet above the stream. The gold on the benches is medium coarse and of a dark reddish color. None of it is black gold. Several nuggets were seen that had small pieces of quartz attached. From the owners it was learned that the largest nugget taken from this creek was worth about $21. The value of the gold is high—that from the lower claim being reported as worth about $19.25 an ounce, and some from higher up on the creek and not from bench ground assaying from $19.05 to $19.15 an ounce.

Concentrates from the bench ground show a good deal of magnetite or black sand. Some of the fragments of this mineral were as much as one-fourth of an inch in length. Together with the magnetite is also ilmenite or the oxide of titanium and iron, which is nonmagnetic. Garnet or the so-called "ruby" sand is practically absent in all parts of the creek. This was to be expected, for none of the rocks in the neighborhood show any such development of this mineral as is the case in the Seward Peninsula placers. Some float pieces of antimony are occasionally found in the gravels of Bonanza Creek.

Bonanza Creek has such a small supply of water that the extraction of the gold from the gravels has been a serious problem. In the early days the separation was accomplished by the use of rockers, and even during the summer of 1909 this method was still in use on some of the creek gravels half a mile or so above the mouth of the stream. The discovery of gold in the high benches called for a supply of water at considerable elevation. Ditches except of such length as to be prohibitive in cost were not feasible, and the experiment of pumping water from Ungalik River was resorted to. Wood cut in the neighborhood of the mines was used for fuel. Although no figures are available as to the cost of the water delivered on the ground, it seems that the fact that this method was pursued until the claims were worked out is sufficient proof that the owners were satisfied with the project.

The method of work was to make cuts at intervals at right angles to the trend of the old channel. In these trenches sluice boxes were placed in such manner that their lower end discharged toward Bonanza Creek. The abrupt cliff that occurs at the edge of the bench deposit offered particularly favorable topography for the discharge of tailings on the lower ground so that the boxes would not become choked, and this was taken advantage of. The water pumped in two lifts was delivered to the nozzles on the bench ground and the gravels and overburden were washed through the sluice boxes. After the gravels had thus been sluiced off, the bed rock was taken up by hand and cleaned. In places three feet of the rather angular blocky slate had to be picked up to recover the pay values, but over much of the bench ground it was necessary to take up only from 12 to 18 inches.

During 1909 the last of the bench and creek ground nearest the mouth of the creek was exhausted, and the boiler and pump were dismantled and put into condition to be shipped away; the lower claims may now be regarded as worked out. Good bench placer ground, however, continued from the end line of the claim, and the next upstream claim undoubtedly contains valuable deposits. During the early part of 1909 the owner of this ground was engaged in building a small ditch from the upper part of Bonanza Creek to bring water to this bench. The small amount of water available, however, makes it probable that the operations will be much hampered. The bench ground is frozen, and either a strong head of water will be required to break down the gravels or else the owners will be forced to resort to thawing.

On the fourth claim above the mouth of Bonanza Creek little work was accomplished during 1909 and that mainly of a prospecting character. The unusually dry season made this part of the stream practically dry by the middle of July, and the only gold taken out was by means of rockers. At this place specimens of gold in a black graphitic slate were seen. This occurrence suggests that the carbon, which is abundant in the slates, may have been effective in causing the deposition of the gold.

At the mouth of Bonanza Creek some gold has been found in the gravels of Ungalik River. Several rather shallow holes have been put down in the river flats, a few score yards north of the mouth of Bonanza Creek, and good prospects have been reported. On the whole, however, the tenor of the gravels of Ungalik River is low, and, although occasional 5-cent pans have been found, the average indicated is so low that the ground could not be worked without labor-saving devices capable of handling large quantities of gravel at a low cost. The gold is reported to be irregularly distributed; rich pockets separated by intervals of barren ground are to be expected, which condition is not one calculated to encourage the development of large undertakings.

The other placer where post-Cretaceous mineralization apparently associated with igneous intrusions has been reported is at Christmas Mountain. Scores of lode claims have been staked on this mountain, but, with the exception of a little sulphide mineralization, few indications of profitable veins have been disclosed. In spite of the apparent absence of lodes that would warrant extensive development it is believed that there is a disseminated mineralization in the vicinity of this mountain that might justify search for placers in the neighborhood. From the reports of prospectors it was learned that colors of gold had been found in the gravels of many of the streams heading in this mountain and draining either into the Ungalik or the Shaktolik. Several placer claims have been staked on Christmas Creek, which enters the Ungalik 3 to 4 miles north of camp A16, but no mining has been done. It seems probable that the inaccessibility of the region would make it unprofitable to work any but a rather high grade placer at the present time at this place.

It is further reported that stibnite (antimony sulphide) float has been found on the divide between the Shaktolik and the Ungalik, about 4 miles northeast of Bonanza Creek, on the slopes of Christmas Mountain. This mineral was not found at this place by the Survey party. Its presence would indicate that there has been a good deal of mineralization and would show that the sulphide mineralization already noted may have introduced many different minerals.

In the same general region, but not definitely associated with intrusive igneous rocks, are streams that are said to have some auriferous gravels; the geology of these places is too indeterminate at the present time, however, to warrant even a suggestion of the origin of the valuable minerals contained. Garryowen Creek, a tributary of the Inglutalik heading in the Ungalik divide, is reported to yield colors of gold. Negromoon Creek, which joins the Inglutalik from the west upstream from Garryowen, also shows gold-bearing gravels. The values, however, on both these streams are so low that they are of no commercial significance at the present time and can not be worked under existing conditions. No adequate prospecting has been done on any of these streams, and it is therefore impossible to make even an approximation of the tenor of the gravels.

GOLD PLACERS IN AREAS OF METAMORPHIC ROCKS.

DISTRIBUTION.

As the metamorphic rocks are older than the nonmetamorphic rocks they have been subjected, broadly speaking, to at least the same number of periods of mineralization as the latter plus whatever number occurred before the laying down of the Cretaceous sediments. It is, of course, realized that mineralization may be distinctly local and may affect one region and not another, and it is not intended to assert that the richness of a region is necessarily dependent upon the number of periods of mineralization it has undergone, although, according to the law of chances, such a generalization is sound. This view receives corroborative support from the field evidence, for in most of the Seward Peninsula placer regions there were at least two periods of vein formation, during each of which gold lodes were made, whereas in the area of unmetamorphosed sediments only one period has been recognized.

Valuable gold deposits have been mined most extensively in Seward Peninsula where the metamorphic rocks are most abundant, and it is believed that regions underlain by them are the most promising areas in which to prospect for new placers. In general, the richest placer areas are near the contacts between the heavy overlying older limestones and the underlying quartz chlorite schists. So far as known, the intrusive igneous rocks older than the Cretaceous are not auriferous, and neither are the more recent lava flows. Therefore, areas deriving their surficial deposits from such rocks are not likely to afford valuable placers.

Several of the various placer camps located within the area covered by the map of southeastern Seward Peninsula were not visited during 1909. It has been thought desirable, however, to summarize the investigations made during previous years in order to gain a more comprehensive idea of the mineral industry as a whole, rather than to omit districts so important as Council and Bluff simply because they have been already described. Consequently, to complete this part of the report it is necessary to refer to the published reports of Brooks, Moffit, Collier, and others. In the treatment of the gold placers of the areas of metamorphic rocks a geographic order will be adopted. The placer deposits of a single river basin will be treated from the mouth toward the head of the stream. The various river basins tributary to Norton Sound will be described from east to west, beginning with the Koyuk, and then will follow descriptions of the various basins emptying into Kotzebue Sound from Buckland River westward.

KOYUK RIVER BASIN.

In the Koyuk Basin no gold placers are now being mined and commercial mining has been done in but few places in the past. Colors of gold have been found on many of the streams and many attempts at mining have been made in the region, but so far without sufficiently encouraging returns to keep a permanent force on any of the streams.

About a mile west of camp B17, at the mouth of the Koyuk, there is a black limy schist and limestone that occurs east of a lighter-colored schist, the dip of both being practically vertical. On the beach at this place and extending for a considerable distance both east and west are many large angular pieces of quartz float that suggest vein material. Pans of broken-up material from the schists near this place show a number of very small colors of worn placer gold. From a prospector living near the place it was learned that 1-cent pans had been found, but the small returns were not sufficiently encouraging to warrant any considerable expenditures of either time or money.

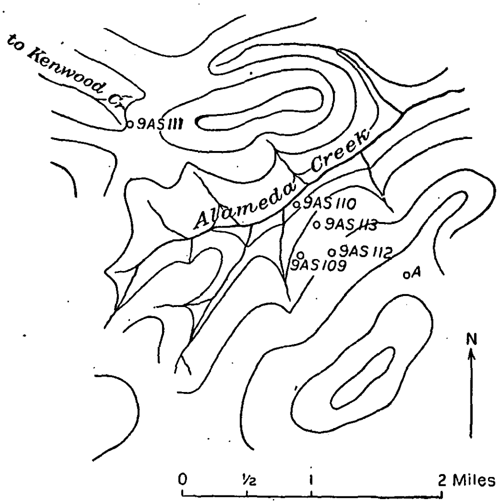


FIGURE 12.—Sketch map of Alameda Creek.

Alameda Creek, a small tributary to the Koyuk from the west, joining the river a short distance below the mouth of East Fork, was visited in the early part of August. Although no active work was in progress the problems that have been raised by earlier prospecting are such as to attract the attention of the geologist. Figure 12 shows the headward portion of this stream with the location of the different prospect holes that have been sunk. The elevations are only approximate, as the weather was so changeable that an aneroid was of no assistance.

At locality 9AS109 south of Alameda Creek a shaft 192 feet deep was sunk all the way through well-rounded, predominantly quartz gravel. The upper part of the gravel is whitish, with black quartzite pebbles and some glassy lava; not many pebbles of the latter material were found. Midway in the shaft the gravels are more yellowish and more iron stained than in the upper part. In the lower part of the hole the fine material is of a greenish-white color but is otherwise similar to that above. On reaching a depth of 192 feet the miners were forced to abandon the shaft, as they encountered a great deal of water. This condition suggests that they were approaching bed rock. This conclusion receives some support from the fact that in the bottom of the shaft pieces of ancient lava, probably the country rock here, became more numerous.

It is reported that in the general gravel section cut by the shaft a few thin sedimentary layers were found that gave fairly good prospects. A pan of the gravel from the dump which was said to have come from near the top of the shaft gave two small colors. Samples from the gravels said to be near the bottom of the shaft showed also minute specks of gold. In the concentrates from the same part of the section there was a good deal of black sand, but garnet was practically absent. A good many pieces of undecomposed sulphides were also recognized in the concentrates. Within 100 feet of the shaft a pan from the surface gravels directly under the grass roots showed several bright colors of gold, some magnetite sand, and ilmenite.

Nearly due east of the last locality and at an elevation about 100 feet higher another shaft has been sunk (locality 9AS112). The depth of the shaft is somewhat over 70 feet and it has not reached bed rock. The material on the dump consisted mainly of well-washed white quartz gravel, with some pebbles of black quartzite and red lava. Twenty-five feet east of this hole and at a slightly higher elevation a shaft had been sunk 45 feet without reaching bed rock. The material on the dump at this shaft was more sandy and the pebbles were smaller than at the shaft at locality 9AS112.

Northward down the slope at locality 9AS113 another shallow shaft has been put down. It was only about 15 to 20 feet deep, and in it no gravel at all was reported.

On a low bench on the south side of Alameda Creek, at an elevation of less than 10 feet above the water, there is a caved shaft (locality 9AS110). This was originally 32 feet deep and reached bed rock, which belonged to the group of ancient igneous rocks. There was a great deal of well-rounded quartz gravel, but as a whole the material on the dump was much darker than at locality 9AS109, and there was a much greater proportion of lava fragments. The prospectors who sunk this shaft reported that the values were found entirely on bed rock and that the lower gravel went about 1 cent to the pan. Upstream from this shaft the present gravels of Alameda Creek are reported to carry no gold, whereas northeast, or downstream, the creek gravels yield about 7 cents to the 10-pan bucket. A mile and a half downstream, however, even this amount of gold disappears and the gravels are barren. From these facts it would appear that the present creek may derive its gold from the earlier channel. It should be remembered, however, that if the values occur mainly on bed rock in this channel the bottom is still below the level of Alameda Creek, and therefore the reconcentration has not affected the richest portion of the old channel.

Directly across the creek and at the same elevation above the stream as locality 9AS110 a shaft 12 feet deep has been sunk to bed rock. The bed rock at this place also was dark, much fractured, fine-grained lava. A pan of gravel from the dump at this place showed an abundance of green lava sand with numerous hornblende crystals. Several well-rounded garnets were also noted.

A mile and a half west of this shaft and on one of the small tributaries of Kenwood Creek some further prospecting has been done to try to locate the northwest continuation of the old channel. At locality 9AS111 there is a shaft 24 feet deep, now badly caved. The material on the dump is nearly all angular, almost completely decomposed rock, which seems to contain some rounded black pebbles. The material is so badly changed that it is impossible to assert definitely whether it represents a recent slightly consolidated gravel or a more ancient sandstone or fine grit. It was claimed by the prospectors that bed rock was reached in this shaft and samples of the material supposed to be from the bottom of the hole showed thin quartz and calcite veins with decomposed material between. Some of the quartz was much slickensided.

Forty-five and sixty-five paces west of locality 9AS111 were two other prospect pits at a slightly lower elevation than the one last described. The western one showed undoubted gravel on the dump, some of the pebbles being 3 to 4 inches in diameter. There were very few white quartz pebbles, the greater number being of black quartzite. There seems to be little room to doubt that this is a portion of the same deposit encountered in the deep shaft at locality 9AS109. It is unfortunate that the depth to bed rock has not been determined at the two places, for it might afford information either as to the direction of the old drainage or as to the amount of deformation since the cutting of the channel.

On the broadly open saddle, 1½ miles southwest of locality 9AS109, quartz gravel is reported to be abundant, and it is believed that this low pass may mark the southern continuation of this channel. On this assumption a party of three or four men was engaged in prospecting during the winter of 1909–10. From a recent letter it seems that little was accomplished at this place during the winter, and although seven holes from 18 to 24 feet deep were sunk their location is not sufficiently explicit to show the relation to the surrounding topography. It was stated, however, that they found but little of the well-rounded wash noted at locality 9AS109. In several of these holes colors of gold were found, but apparently not enough to warrant further prospecting. It should be pointed out, however, that even if this be the old course of the valley it does not follow that the gravels will be commercially valuable, for, as has already been noted, so far as prospected the gravels in the deep hole on Alameda Creek are not sufficiently gold bearing to be mined at the present time.

Not enough facts are yet available for more than a tentative interpretation of the conditions under which the old channel was formed. It is evident from the presence of lava in the gravels of the channel filling that the channel was carved and occupied by a stream later than the effusion of the recent lava. It seems probable that a rearrangement of drainage may have resulted from the extrusion of the tongue of lava which occupied the low country between Koyuk and Buckland rivers and flowed down the present Koyuk Valley below East Fork. This may have resulted in turning the lower part of the Koyuk out of its former course and allowing it to cut its gorge. After the gorge had been eroded, either by change in the relation of the land with respect to sea level or by capturing, the old valley was filled and the stream was so diverted that it took up a course parallel with the tongue of lava that flowed down the Koyuk Valley. It eroded the lava, thus etching out and uncovering its former valley, in which it now flows.

In regard to the origin of the gold found in the old valley gravels there is some question. Alameda Creek is near the area of metamorphic rocks, and the presence of a great number of pebbles of vein quartz in the gravels suggests that they at least have been derived from the quartz stringers in this series. If this vein quartz has been derived from this source there is a strong presumption that the gold has also come from the same place. On the other hand, it should be noted that there are indications that some of the ancient lava is mineralized. A shallow prospect pit has been sunk on a ledge of amygdaloidal trap outcropping on the divide between the Koyuk and Alameda Creek at A, on figure 12. Assays made at Nome of material from this pit are reported to have given as high as $3.72 in gold per ton. The rock shows no macroscopic mineralization, and considerable doubt is felt of the accuracy of this determination.

Kenwood Creek, which enters the Koyuk from the south above East Fork, has been prospected near the head, as already noted, and a little work has been done also on the lower part. Two prospectors, who were reported to have found good prospects at this place several years ago, went to the lower part of Kenwood Creek during the summer of 1909. The low water prevented their getting upstream far enough with their boat and they returned. It is probable, however, that bed rock through the lower part of the creek is deep and difficulty with water will be experienced.

On Willow Creek, which enters the Koyuk from the south above Kenwood Creek, there are signs of former prospecting, but the stream is now deserted. McPherson says that at the time of his visit (1907) location notices were seen, which showed that the prospecting had been done about five years before.

Peace River is one of the northern tributaries of the Koyuk west of East Fork. About 12 miles above the mouth it forks, and near this place some prospecting was done during the winter of 1908. Two shafts were put down on the east bank of the river, but they were so badly caved that only the upper 3 feet or so was visible. This part of the section shows brown, irregularly bedded sands of even texture, having in general a dip toward the west—that is, toward the stream. The material on the dump is fairly well-rounded river wash, consisting almost entirely of igneous rocks with some red, iron-stained gravel of the same nature. The eastern of the two holes was probably not more than 15 feet deep, but the other may have been 25 feet deep. Some material put aside as though it were the pay gravel was a greenish-brown sand.

About 100 yards east of this place and on a slightly higher bench there is another shaft now filled with water. This pit was probably not more than 5 or 10 feet deep. From the material on the dump it appeared that the gravel is not so well rounded and there is much more mud mixed with the sand. The upper 2 or 3 feet, which was the only part visible, instead of consisting of sands as in the western holes, was entirely formed of muck. From prospectors it was learned later in the season that some gold had been found in these holes, but not enough to warrant further exploitation. It was currently reported that one piece of gold found there was worth 4 cents, but this was the largest piece. The presence of gold at this place suggests the possibility of some of the ancient lavas having been more or less mineralized, but the evidence is not sufficiently definite to preclude other sources of origin.

Mendenhall notes that in 1900 Big Bar Creek had been prospected and a mining district established there. He was unable to learn the success of the operations, but the fact that in 1903, when this region was visited by Moffit, no work was in progress and the creek was deserted shows that the gold tenor of the gravels must have been too low to make mining profitable.

A tributary creek farther up stream and heading in the hills near the low pass into Death Valley and the upper part of the Koyuk basin is mentioned by Mendenhall as follows: [a]

Just above the camp of September 5 another tributary enters from the south carrying only schistose pebbles. These, however, are very calcareous. Most of the streams which enter the upper course of the river from the north lie

[a] Mendenhall, W. C., op. cit., p. 213.

without the lava belt, but the schists here have not the aspect of the gold-bearing members. At Cheenik in the fall we met prospectors who had been up the river and reported finding colors all along its course.

Moffit in 1903 reported no mining in this part of the river basin, and no signs of recent work were seen by the party in 1909.

KWIK RIVER BASIN.

No mining was in progress during 1909 on any of the streams in the Kwik River basin, and so far as could be learned little or no prospecting has been done in the past in this area. On the head of Quartz Creek, about 3 or 4 miles east of camp C3, there were some old claim stakes and some sluicing had been done several years ago. McPherson, who visited this region in 1907, noted that he found location notices of about five years previous date on this creek.

TUBUTULIK RIVER BASIN.

During the time that the survey party of 1909 was in the vicinity of the Tubutulik no prospectors were seen and no evidence of any recent mining was observed. Practically the only thing that is known about the mining in the basin is furnished by the report of Mendenhall,[a] in which the following statements are made:

> This stream, while farther from the known productive districts than the Fish, was the object of considerable attention during the season of 1900. The surface gravels of the river bars gave colors quite as heavy as those on Fish River, wherever a pan was washed out—at least as far up as the granite area. We had no reports from the head of this stream and did not have an opportunity to examine it ourselves, but the area drained by it is not particularly promising. Mr. C. C. Alexander and members of his party, who had been prospecting on Chukajak and Vulcan creeks during the fall of 1899 and the summer of 1900, report the finding of coarse gold early in their work on the former stream, but more thorough development did not fulfill the promise of this first find. Reports of favorable prospects here had, however, reached Golofnin Bay and Nome, and a small stampede toward the Tubutulik resulted. When we left the river, late in August, many outfits were reaching the field. Reports toward the end of September did not tend to confirm the earlier accounts of rich strikes there.

It was reported that some mining was done several years ago on the next stream above Lost Creek. According to Mendenhall the name of this creek was Admiral, but the claims were described as on Camp Creek. It seems probable that the two names are applied to the same stream, but which is correct could not be determined. From the character of the bed rock near this stream it would appear that the geology is complex and that the older schists form the lower part of the valleys, so that it is presumed the gold was derived from them. Placer mining on Camp Creek was carried on by means of horse

[a] Mendenhall, W. C., op. cit., p. 212.

scrapers, but the absence of any recent work in the vicinity seemed to show that the returns were not satisfactory. From the strong evidence of glaciation of the valley type in many of the streams heading in the Darby Range and entering the Tubutulik from the west it seems unlikely that any rich placers will be found in that part of the basin. The eastern boundary of the basin in the southern part is formed of the Ungalik conglomerate so that strong mineralization is not to be expected from it. Farther north the eastern part of the Tubutulik divide is formed of the Paleozoic limestones, and these are not promising rocks from which to derive placers. It is felt, therefore, that a large part of this drainage basin is not particularly favorable for commercially important placers.

KWINIUK RIVER BASIN.

Practically the whole of Kwiniuk River and its tributaries flow in valleys carved in the igneous rocks that make up the Darby Range. So far as is known these rocks are but slightly mineralized. Consequently there is but little chance that the detritus worn from these rocks would form valuable placer deposits. In the lower part of the course, where the bed rock is heavily covered by unconsolidated deposits, the character of the country rock is not evident, and the more mineralized schists may occur. If this is the case, there is some possibility, where concentration has been effective, that placers may be discovered. The depths of covering and the question of handling water would make the development of such placers difficult.

FISH RIVER BASIN.

MAIN STREAM.

The main Fish River basin has not been important as a placer district, although the tributaries of the Niukluk, its longest western branch, have produced more gold than those of all the rest of the region. The name of the principal town, Council, will be used to designate this placer region in order to distinguish it from the rest of the Fish River basin. According to Mendenhall [a] Fish River carries gold from its mouth to the northern end of the gorge. Throughout the lower part of the river the colors are very light, but they become heavier in the constricted part of the valley, where the stream crosses the belt of limestones and schists. Opposite the mouth of Anaconda Creek, as the lower part of Pargon River is called, pans taken from the broken rim rock yielded from one-half a cent to 1 cent each. According to the same author prospectors found nothing in the upper flats of Fish River, and so far as reported the streams flowing out of the mountains to the north do not yield colors.

[a] Mendenhall, W. C., op. cit., p. 212.

From the geologic description of the northern and eastern part of the Fish River basin it is seen that the rocks are schists and limestones, which appear to be the same as the rocks in some of the placer regions, except that the schists contain much greater quantities of biotite. Veins are equally abundant in both types, and it is believed that the absence of placers may be explained in part by the valley glaciation that has scoured out the water-sorted deposits from most of the valleys heading in the Bendeleben and Darby mountains. This process has scattered the deposits, which may have existed in the valleys prior to this erosion. Information on the subject is still too meagre to allow a final judgment as to the reason for the absence of placers in this part of the basin, but it is believed that the physical history rather than the lithologic character is responsible for the apparent absence of placers.

COUNCIL REGION.

Placer gold has long been known in the region around Council, for it was reported by members of the Western Union Telegraph Expedition in 1865, and in 1892 John Dexter is said to have notified members of the silver-lead mining company that he had found gold there. It was not until 1896–97, however, that the discovery of Ophir Creek, the richest one in the Council district, was made by Mordant, Melsing, Libby, and Nelson. Although, apparently, gold was found at that time, it was not until the spring of 1898 that the district was organized and active placer mining begun. So valuable have the placers turned out that in 1903 Collier estimated that the gold output up to that year was between $5,000,000 and $6,000,000.[a] Since that time $2,000,000 to $3,000,000 more has been taken out, so that this camp has been second in production to that of Nome.

The productive creeks in this so-called Council region from southeast to west are Fox, Mystery, Melsing, Ophir, Goldbottom, Camp, and Elkhorn creeks. All except Fox Creek are tributaries of the Niukluk, and Fox Creek joins Fish River less than 4 miles below the Niukluk.

Fox Creek has never been a rich creek. The only valuable ground was on a small tributary known as I. X. L. Gulch, and on the main valley at the mouth of this stream. At this place, according to Collier,[b] about 2 ounces of gold were taken from about 4 cubic yards of pay dirt. A little prospecting has been done here in every year since 1906, but the production is practically negligible.

Collier[c] reported that on Mystery Creek, 1 mile from its mouth, $6 to $8 nuggets have been found. Part of the gold was bright and

[a] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 236.
[b] Idem, pp. 237–238.
[c] Idem, p. 240.

part was rusty, but all is rough and angular as though derived from near-by sources. On Mud Creek, a small side stream from the west, one claim was operated in 1903. The gold here, according to Collier, is found both in the gravel and to a depth of 3 or 4 feet in crevices of the bed rock. It is very rough, spongy, and somewhat rusty, and is coarse and easily saved. Near the mouth of Mystery Creek a hole 102 feet deep was sunk, but no values were found. In 1907 and for the succeeding two years there has been mining on this creek, but the production was small though the returns were commensurate with the amount of time spent.

Melsing Creek was one of the first creeks on which gold was discovered, and it has been a constant though small producer ever since. According to the 1900 report, 40 men were engaged on the creek. Collier estimates that up to 1904 about $50,000 had been taken from this stream. The auriferous gravels seem to occur only below the mouth of Basin Creek. From this part of the creek the small pieces of gold are reported to be nearly all smooth and bright, whereas the larger ones are rusty. Richest concentration occurs on a clay layer. At the mouth of Basin Creek the gold is found throughout the gravel, but is most abundant on and in bed rock. Collier states that the average yield per man per day in 1903 was about $50.[a] One of the nuggets examined by him from this claim showed a small, square hole filled with hydrous iron oxide, probably the mould of a pyrite crystal associated with the gold.

In 1906 there had been four parties of 3 to 10 men each on Melsing Creek below Basin Creek. In 1907 a steam scraper was built at the mouth of Melsing Creek, but delays in building prevented its running full time. Work still continued near the mouth of Basin Creek and a short distance down stream. During 1908 and 1909 work was continued on about the same scale and at the same places as in the past, and, in addition, during the last-mentioned year, some mining was done on the lower part of Basin Creek. The operations were, however, on a small scale and the production was slight.

Ophir Creek is the most important gold producer in the Council region. By 1903, according to Collier, the entire creek had been prospected, and during that year 1,000 men were at work on the main stream and its tributaries. Gradually the number of men employed has decreased, but this has been due in part to the replacement of hand labor by mining machinery. Some mining was done in 1903 at the mouth of this stream in the Niukluk River flats. These gravels are estimated to carry from 50 cents to $1 a yard in bright, nearly flour, gold. Concentrates show much magnetite and garnet, with smaller quantities of pyrite and ilmenite. This deposit was developed

[a] Idem, p. 242.

by a steam dredge with an estimated capacity of about 3,000 cubic yards per day. Bed rock is rather deep and the difficulty of handling the water makes mining expensive. According to Collier, the gold has been derived not only from Ophir Creek, but also from the other streams.

Farther up Ophir Creek the gold becomes coarser and the values per cubic yard are higher. After a short experiment on the ground near the mouth of Ophir Creek already described the dredge was moved upstream and has been in successful operation ever since. In an account of this dredge recently published by Rickard[a] it is shown that the average cost is 32 cents a yard and the average gold tenor of the gravels worked is 84 cents a yard. The low value per yard is in part due to the fact that some of the ground had been worked before by more primitive methods.

Next upstream on Ophir Creek from the dredge, hydraulic mining has been tried and some good placer has been uncovered. The ground mined is now mainly on a low bench, but in the past the creek gravels have been worked by pick-and-shovel methods with satisfactory results. Still farther upstream and only a short distance below Sweetcake Creek is the Discovery claim. It has been worked for several years but was finally exhausted by the use of hydraulic elevators. The values were in fairly coarse gold of a bright color. This claim was probably the second richest on the entire creek and it is reported that $1,000,000 was taken from it.

Sweetcake Creek was staked in 1898 and was the scene of probably the first successful placer mining in the precinct, it being reported[b] that $36,000 were taken from one claim that year. The only productive claims are on the lower part of this stream; they were notable contributors in the early days of the camp, although since 1903 little gold has been won from them. Some of the gold was angular and showed quartz attached.

Little of value has been found on the main stream for nearly 1 mile above Sweetcake Creek. At this place, however, there is creek and bench ground that has been very rich. Pick-and-shovel methods were used even in the early days and in 1907 an unsuccessful attempt was made to use a dry-land dredge, which was followed by the successful use of a derrick and horse scrapers. The pay streak in the creek was from 100 to 200 feet wide. The bench gravel near this place, according to Collier, was not well sorted.[c] The pay streak is said to run 10 to 15 cents a pan. One nugget worth $3.75 is reported by Collier to have been found here, but nearly all the gold is fine and flaky.

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[a] Rickard, T. A., Dredging on Seward Peninsula: Min. and Sci. Press, vol. 97, 1908, pp. 234–240.

[b] Collier, A. J., and others, op. cit., pp. 250–251.

[c] Idem, p. 245.

From this place nearly to the mouth of Dutch Creek the Ophir Creek gravels and benches have yielded probably nearly $750,000 in gold. In the central portion of this part of the valley the presence of limestone bedrock allows a large portion of the water to flow in subterranean channels and it is notable that the quantity of gold in the gravels decreases also. At the mouth of Dutch Creek the richest claim in the whole Ophir Creek basin was located, and, although now exhausted, this claim and the claim next below probably produced nearly a quarter of the gold won in the entire Council region. Much of the gold seems to have been of local origin, as pieces with quartz attached were by no means uncommon. On Dutch Creek little has been done and then only on the lower claims adjacent to Ophir Creek. Values are reported both in the creek and bench gravels.

Above Dutch Creek the values in Ophir Creek suddenly decrease and then gradually increase toward the northwest to within a mile or so of Crooked Creek. All of the claims between these two side streams have been mined to some extent. A mile and a half above Dutch Creek, according to Collier,[a] excavations show from 5 to 14 feet of gold-bearing gravel resting upon broken limestone bedrock, and three-fourths of a mile to the north 6 feet of sand and muck rest upon about 12 feet of gravel of which the upper 2 or 3 feet carry very little gold.

In 1903 the only other work done on Ophir Creek was near the mouth of Crooked Creek. "Here terrace gravels on the left bank were being exploited. The bedrock of the deposit is probably little above the present creek. A section showed 2 or 3 feet of muck overlying 5 or 6 feet of gravel which rested on calcareous schist."[b] No work was in progress during 1906, but near this place during 1908 and 1909 a small dredge was installed and according to local reports was giving satisfaction in handling creek gravels.

Crooked Creek has been one of the richest tributaries of Ophir Creek. Collier noted that in 1903 more men were employed there than on any one of the other side streams. Near the junction of this stream with Ophir Creek the pay streak is about 250 feet wide, but it narrows rapidly upstream. According to Collier,[c] the pay streak is reported to have been about 6 feet thick. The gold tenor of the gravels mined is estimated at $4.50 to the cubic yard. The gold is comparatively coarse and the pieces well rounded. Some are bright and others are iron stained. In the sluice boxes are found heavy concentrates consisting principally of garnet and magnetite, but including some topaz. Above the lower claim the pay streak is, in the main, not more than 20 feet wide and the bedrock is a schistose limestone.

[a] Idem, p. 249.
[b] Collier, A. J., and others, op. cit., p. 250.
[c] Idem, p. 252.

Balm of Gilead Gulch, which enters Crooked Creek from the southwest, had gold "from the surface down, but is richest in the crevices of the limestone. The gold is rough and angular, with sharp corners,"[a] and is undoubtedly of local origin. Albion Gulch contains auriferous gravels throughout its course. In 1907 two camps were established on this stream, and a rich hillside placer was mined by hydraulicking. The difficulty of obtaining an adequate constant supply of water has much hampered developments on both of these gulches.

Above Crooked Creek the valley of Ophir Creek has been prospected, but little actual mining has been done. Near the upper end of the canyon of Ophir Creek there is a little bench gravel, which was being developed at the time Brooks visited the region in 1903. Although this work may have yielded wages, it was not highly remunerative and was soon abandoned. Further prospecting was undertaken here in 1907, but was not successful in locating placer.

From the general distribution of the values in the Ophir Creek gravels it seems evident that many of the rich placers of the stream are formed by the reconcentration of former bench deposits. At other places, however, it seems clear that the richness is due to proximity to local mineralization. Collier notes that a sample taken from the schists adjacent to some quartz stringers near the mouth of Ophir Creek contained some gold and that samples crushed in a hand mortar and panned yielded free gold. On Crooked Creek there "is a mineralized belt 12 feet wide, which strikes northwest. In this impregnated zone vein quartz is associated with pyrite. It is reported to assay as high as $8 to the ton."[b] Near this place on the divide, between Gold Bottom and Crooked creeks, there is a lode which seems to be similar to the one previously noted; it is significant as pointing to the origin of some, at least, of the Crooked Creek gold, which is very sharp and angular and in many instances has quartz attached. None of these mineralized veins have been mined, and it is doubtful whether the diffused character of the mineralization would permit economic treatment. The absence of valuable placer in the upper part of Ophir Creek, beyond the canyon, strongly suggests that the gold was not derived from the biotite schists that occur in the Bendeleben Mountains.

Farther up the Niukluk is Camp Creek. Mining on this stream was described by Collier[c] as follows:

Camp Creek flows into the Niukluk from the south about a mile below Gold Bottom Creek. Several claims were worked on this creek in 1904. The auriferous gravel is from 50 to 100 feet wide and about 3 feet thick, with an over-

[a] Idem, p. 254.
[b] Collier, A. J., and others, op. cit., p. 252.
[c] Idem, p. 256.

burden of about 3 feet, and is said to carry from 75 cents to $1 a cubic yard. Most of the mining was done by the shoveling-in process, but one claim was hydraulicked.

Only a little desultory work has been done on this stream within the last two or three years.

The next gold-producing tributary of the Niukluk from the north above Ophir Creek is Goldbottom Creek, with its tributary, Warm Creek. Mining began on Warm Creek in 1900 and up to 1903 the basin is estimated to have produced about $100,000. "Most of the gold is rough and iron stained, and some of it is almost black. One nugget, worth $45.10, at $16 an ounce, was found in 1902; and one worth $12.33 in 1903. The concentrates contain ilmenite, scheelite, magnetite, garnet, and some hematite and rutile."[a] Mining has been confined to the portion of the stream near the junction of Warm and Goldbottom Creeks, but colors of gold have been reported from many parts of the basin. During 1906 there was a little mining, but since then practically nothing was done until 1909, when two dredges were erected in the lower part of the valley. It was so late before the dredges were completed that their production for 1909 was slight. Mineralization on a small scale is recognized at many places, and a short distance upstream a vein on which some development work has been done was found at the contact of schist and limestone. "Near the mouth of the creek are two quartz veins, one about 3 feet wide and the other about 1 foot wide, striking N. 30° E. and standing nearly vertical."[b] As the pebbles in the placers all seem to be of local origin, it is probable that the gold is also derived from veins within the basin.

On Elkhorn Creek mining began in 1900 and was reported upon by Richardson[c] as follows:

> Near the mouth of the creek 2½ feet of gravel overlie 6 inches of clay and disintegrated bed rock. It is reported by miners that the pay streak is in patches and that the average yield of pans is 5 cents. The bench near the mouth gives colors, but has not been developed. The bed rock is mica schist, interbedded with limestone, and the strike is at right angles to the course of the stream, with almost vertical dips, giving favorable conditions for the concentration of gold. The gold is medium coarse and bright yellow in color. Some very coarse gold has been found stained with iron. The average assay shows its value to be $19.12 an ounce. Quartz is often found attached to the placer gold, and one nugget was attached to a piece of mica schist. This goes to show that it is of local origin. One nugget worth $55 has been found, and several worth from $12 to $16.

[a] Idem, p. 256.

[b] Idem, p. 255.

[c] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901.

In 1903 this stream was visited by Collier,[a] who reported as follows concerning mining developments:

Since 1900 the placers for about half a mile have been entirely exhausted, but farther up the creek work is still (1903) in progress both in the creek bed and on the benches. It is estimated that the total production of the creek up to date (1903) has been from $110,000 to $120,000.

After 1903 very little work was done on this stream, and when it was visited in 1906 it was practically abandoned and since that time mining operations have not been resumed.

BLUFF REGION.

The region around Bluff has not been visited by Survey geologists since 1906, and the following descriptions are taken from Brooks's report of his visit at that time.[b] In order to condense the account certain parts have been left out and the arrangement has been changed. To connect the retained portions words, phrases, and sentences have been introduced. So many changes have been made that quotation marks have been omitted. Gold is said to have been found at Daniels Creek in September, 1899, by William Hunter and Frank Walker. Beach placer was soon after located and within less than six months $600,000 had been taken from a strip of land less than 1,000 feet long. Meanwhile, the two lowest claims on Daniels Creek were opened and in 1900 yielded probably $200,000 in gold. Most of the production of 1901–2 came from Discovery Claim, at the mouth of Daniels Creek. Meanwhile gold had been found on Eldorado and Ryan creeks and on Swede Gulch. In 1902 a strong company was organized and has ever since been in practical control of the important placer ground. Figure 13 shows graphically many of the more important features of the Daniels Creek placers.

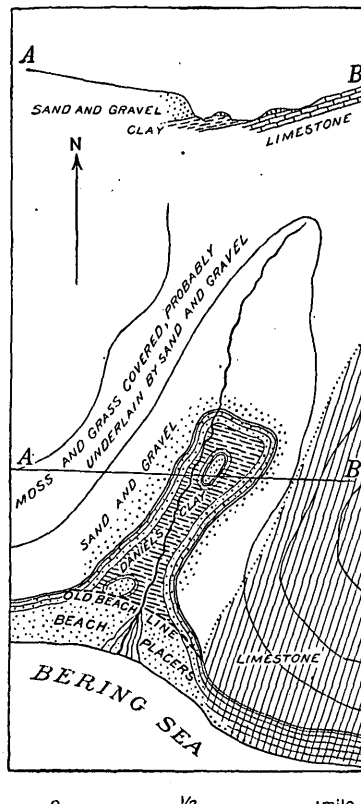

FIGURE 13.—Sketch map and section of Daniels Creek placers.

The placers are of two types, beach placers and creek placers, the former consisting of ancient and recent beaches. The alluvial mate-

[a] Collier, A. J., and others, op. cit., p. 257.

[b] Brooks, A. H., The Bluff region (in The gold placers of parts of Seward Peninsula, Alaska): Bull. U. S. Geol. Survey No. 328, 1908, pp. 283–293.

rial of the creeks is of two general types, that in which clay predominates and that which is chiefly sand. In many places no structure can be made out in the clays; the bedding of the sands and gravels is of the greatest irregularity, locally changing its character every few feet. The indications are very strong that the layers of clay, which in general lie near the bottom of the deposit, are formed almost in place, whereas the sands and gravels appear to have been laid down in swiftly running water. Near the head of the creek the surficial deposits consist chiefly of clay, but near its mouth sands and gravels predominate.

Little can be said of the distribution of pay gravels. The managers of the hydraulic mine report that in general the clay carries higher values than the sand and gravel. This is very significant, for it appears to be established that the sand and gravel have been far more concentrated than the clay. It would indicate a large gold tenor for the rock from which the clay has been derived. In any event there can be no question that the gold is very near its bed-rock source, which appears to be at the contact of mica schist and limestone.

From an examination of the Daniels Creek placers several facts are evident—first, the source of the gold is entirely local; second, where it is richest, as in the red-clay deposits, there appears to have been little sorting action by water; third, the gold is so intimately associated with mica schist débris that most probably the schist has a close connection with its origin. It is evident that the stream gradients must have been low during the period of the formation of the clay. The area was probably exposed for a long time to the agencies of weathering and an irregularly pitted land surface was produced. An uplift followed, as a result of which the carrying power of the streams was increased and the deposits of sand and gravel were laid down. At Daniels Creek this uplift gave the former level a slight tilt to the west, as is shown by the bedding of the gravels. The elevated beach deposit appears to have been formed prior to this uplift, but it would require a very detailed survey to establish this fact. The presence of gold at a depth of 60 feet near the mouth of Daniels Creek reported in 1907 may indicate either a deep zone of weathering or a buried ancient beach line. A subsequent uplift, which probably did not exceed 8 feet at the coast, exposed this older beach in part to wave action and this led to reconcentration of the gold in the gravels of the present beach.

The other creeks of the district besides Daniels Creek have been but little developed, for none of them carry a sluice head of water except early in the spring or during heavy rains. Eventually, however, they will all be hydraulicked with water from the Topkok ditch. Sluicing has been done on about half a dozen claims on Eldorado Creek, and some work has been done on Ryan and Little Anvil creeks. So far as the scanty exposures show, the mode of occurrence of the gold on these streams is similar to that of Daniels Creek, but the deposits are probably not so rich and the auriferous gravels not so extensive.

BUCKLAND RIVER BASIN.

The only stream tributary to Buckland River, on which gold placer has been found, is Bear Creek, which heads in the ancient lava hills that form the western margin of the basin. The first claims recorded on this stream were located by R. S. Hoxie, L. Tendness, and A. Barr, in August, 1901. During 1903, according to Moffit,[a] about 40 men were at work on Bear Creek and its tributaries, Sheridan and Cub creeks, but as only about $10,000 in gold was won from this basin during that year it is evident that the work was not very profitable. Figure 14 shows the location of the principal places where auriferous gravels have been found on this creek.

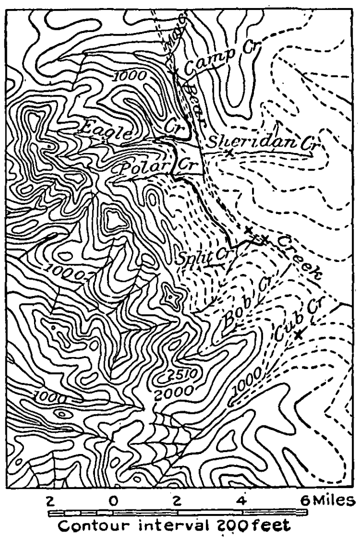

FIGURE 14.—Map showing location of placer camps on Bear Creek.

Mica schist is said not to be found in this creek, although mica does appear in the sands and gravels, which are composed largely of eruptive material, and on some of the bench claims reach a thickness of 20 feet, with several feet of muck overlying. In places on the creek a considerable quantity of a heavy red cherty rock remains in the boxes with the gold and is a source of some annoyance to the miner. This is especially true on Cub Creek. On Sheridan and Bear creeks the gold is mostly on bed rock, differing in this respect from that on Cub Creek, where it is found throughout the whole thickness of the 2 feet of stream gravel; on the other hand, gold from Bear and Cub creeks is light and flaky, while that from Sheridan is heavy. All the gold is bright yellow in color, assaying $19.20 to the ounce. A little "white iron" pyrite is present and also an abundance of black sand, which is entirely removed by the magnet.[b]

From 1903 to 1907 a little desultory prospecting and mining was done, but during the latter year the building of a ditch along the west slope of the valley revived interest in the region. The small precipitation of 1908, however, prevented any extensive use of the new

[a] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 64.
[b] Moffit, F. H., op. cit., p. 64.

ditch, and in 1909 there was no evidence that productive mining was in progress.

In spite of the small production of gold, this region is of interest as indictaing that the placer has been derived from the ancient lavas that form the Buckland and Kewalik divide. It will be remembered that this source of origin was suggested as a possibility for the placers on Alameda Creek in the Koyuk basin, which is on the southern extension of this lava series. It should be pointed out, however, that although a little local mineralization may have affected this group of rocks here and there, so far as can be foretold by present indications, there is slight chance of finding any considerable extent of rich placer on those streams where the ancient lavas form the country rock. In other words, it is believed that only "one man camps" will be established on streams deriving their gravels from areas of ancient lavas.

KIWALIK RIVER BASIN.

The main production of Kiwalik River comes from Candle Creek and its tributaries. As the larger part of this stream lies outside of the area represented on the map accompanying this report and as the region was not visited in 1909 by the geologists of the Survey party it is desirable to omit any detailed description of the placers. As complete descriptions as the facts in hand warranted have already been published by the Survey.[a] From these reports it will be learned that the production from Candle Creek, on which gold was discovered in 1901, has amounted to about $2,500,000 in gold. During the first years of the camp most of the values came from the creek gravels, but afterward high-level deposits were found which seem to be of a type intermediate petween bench and hillside placers. As these deposits are in places deep, mining has been carried on in winter as well as in summer. According to Moffit:[b]

> The gold is usually flattened and black so that when cleaning out the boxes miners are often seen biting a nugget to make sure that it is gold and not one of the iron stones. Quartz is at times embedded in the larger nuggets and gold is observed now and then in the form of fine veinlets through the iron stones. One nugget weighing $62.10 and a second weighing $36 have been taken from the creek.
>
> Black sand is unknown in the clean ups; pyrite and a few small pieces of rutile which occasionally have been mistaken by the miners for tin ore are the heavy minerals associated with the gold; it is not considered a favorable sign when the iron stones fail.

So far as is known all of the material in the Candle Creek placers is of local origin, although the source of the gold in bed rock has not been determined.

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

Henshaw, F. F., Mining in the Fairhaven precinct: Bull U. S. Geol. Survey No. 379, 1909, pp. 364–369.

[b] Moffit, F. H., op. cit., p. 62.

During the early development of this region considerable difficulty was experienced owing to the lack of a sufficient supply of water for mining. This deficiency was met in part by the construction of short ditches within the Candle Creek basin, but as the supply was still inadequate a ditch over 33 miles in length was built in 1907 along the west band of Kiwalik River from the mouth of Glacier Creek to the mouth of Candle Creek. This ditch has a capacity of 20 to 30 second-feet and the height of the lower end above Kiwalik River at that point is about 250 feet. Henshaw [a] in the report already mentioned suggests that the most practical method of obtaining a larger water supply is by pumping from Kiwalik River. Power for such an enterprise might be derived either by using Chicago Creek coal as fuel or by the transformation of water power below Imuruk Lake into electricity.

SUMMARY.

From the distribution of the areas where placers of economic importance have been mined certain facts of value in assisting further prospecting may be learned. Some of the more evident conclusions are as follows: The Cretaceous areas are not promising placer regions and neither are those places promising that derive their deposits mainly from Cretaceous rocks, as, for instance, the marine deposits on the east shore of Norton Bay; no placers of other than distinctly local importance occur in regions deriving their gravels from the pre-Cretaceous igneous rocks; no placers at all have been found in the gravels derived solely from the recent effusive rocks; no gravel deposits derived entirely from the limestones of Paleozoic age contain gold in workable quantities; local placers may occur near the post-Cretaceous intrusions; the most extensive placers occur in the areas of metamorphic sedimentary schists, especially near their contact with the heavy limestones; gold placers are usually found where concentration of gravel derived from the Paleozoic black quartzite has occurred. These general conditions are modified by local conditions; thus in places where concentration has been strong richer deposits are to be expected than in places where less sorting has occurred. From this fact it follows that the glaciated areas hold less promise of placer deposits than the unglaciated areas.

LODE PROSPECTS.

Although, as has been shown, placer gold has been found on many of the streams in the area of metamorphic rocks, no veins sufficiently rich to allow lode mining have been discovered. This is probably in part due to the absence of adequate prospecting. Quartz veins

[a] Henshaw, F. F., op. cit., p. 368.

containing gold have been found at many places and at a few places pits have been sunk; copper sulphides have also been found; and silver-bearing galena has been known almost since the first white men visited the region.

GOLD LODE PROSPECTS.

In order to give an idea of the places where auriferous veins have been exploited the following notes may be of service.

A sample taken from the schists adjacent to some quartz stringers near the mouth of Ophir Creek contained gold in such quantities that when crushed in a hand mortar and panned free gold was obtained. On Crooked Creek, a tributary of Ophir Creek, there "is a mineralized belt 12 feet wide which strikes northwest. In this impregnated zone vein quartz is associated with pyrite. It is reported to assay as high as $8 to the ton."[a] Near this place, on the divide between Goldbottom and Crooked creeks, is a gold-bearing vein which seems to be a continuation of this lead. Mineralization on a small scale has been recognized at several places on Goldbottom and Warm creeks, and a short distance from the mouth of Warm Creek a vein, on which some development work had been done, was found at the contact of schist and limestone. "Near the mouth of the creek [Warm Creek] are two quartz veins, one about 3 feet wide and the other about 1 foot wide, striking N. 30° E."[b]

No productive lodes have so far been found in the Bluff region. Brooks says:[c]

> So far as observed, the schists appear to be mineralized only near their contacts with the limestones. At these places quartz veins cutting the foliation of the schists are not uncommon. The individual veins appear to be of small extent, but at some localities a stockwork forms a considerable mass of low-grade ore. The ores appear to be chiefly iron pyrite with some chalcopyrite and arsenopyrite. * * *
>
> An impregnated zone is well exposed along the sea cliff about three-fourths of a mile east of the mouth of Daniels Creek. * * * At this locality a belt of mica schist about 60 feet wide is more or less impregnated by pyrite-bearing quartz stringers. The belt, including some irregular limestone masses, is bounded by graphitic limestone walls which dip away from the schists and form a small anticline much broken by faults. * * * At the west contact a band of schist 20 feet in cross section lies between one of the included limestone masses and the country rock. In this band the mineralization is more intense than in the rest of the schist. Here a series of gash veins, the largest of which is 18 inches in width, cut the foliation of the schist. [See fig. 15.] A mass of crushed material or gouge forms the hanging wall of this deposit and along this zone, which has been a plane of movement, the quartz veins are cut off abruptly. Stringers of quartz do, however, occur in the limestone on both sides of the schist. The ore appears to be chiefly iron pyrite and mispickel, with some chalcopyrite; the gangue is mostly quartz, with some calcite.

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[a] Collier, A. J., and others, op. cit., p. 252.
[b] Idem, p. 255.
[c] Brooks, A. H., op. cit., pp. 285–292.

Although this mineralized zone was known for several years not much active exploitation was undertaken until 1907. At one claim a shaft 50 feet deep was sunk and a short drift about 15 feet in length was turned off. On the adjoining claim the zone of mineralization is so wide that two shafts, one on the hanging wall and one on the foot wall, have been sunk. One of these is reported to be 100 feet deep; the other is slightly less than half that depth. On the next claim, also, two shafts have been sunk to a depth of approximately 50 feet. Two shorter shafts have been put down on the next claim, and one shaft about 75 feet deep has been sunk near the end line of the next claim beyond. In 1907 the ore from these properties was crushed in an arrastra which was operated by a horse; it was intended to erect a stamp mill later. The developments at this place, however, have not been ascertained for the last two years.

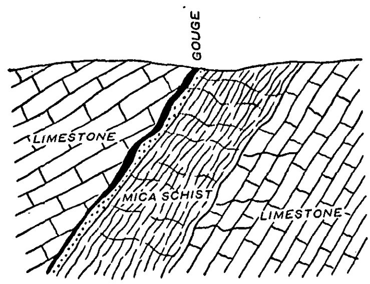

FIGURE 15.—Diagrammatic section of impregnated zones, Bluff region.

According to Brooks, in 1906 a lode 3 miles east of Bluff had been developed to some extent.[a] It was located near the shore, and was said to be 14 feet wide and to yield as much as $30 in gold to the ton. The ore is reported to be iron pyrite and mispickel. A few tons have been sacked and prepared for shipment but practically nothing is known about the mode of occurrence.

A small amount of prospecting has been done near the head of Walla Walla Creek somewhat east of the contact of the igneous rocks and the black quartzitic slates. Although rich specimens are said to have been found here, a careful examination of the rock on the dump failed to disclose enough mineralization to encourage further prospecting. A small amount of limonite staining the joints and fracture planes of the rocks was observed, but there is no vein or distinct lead. Developments at this place consist of an open cut about 25 feet long and a crosscut adit, started about 500 feet away and down the hillside, which has gone in 38 paces (about 100 feet), all the way through barren rock. An analysis of rock from this open cut by Peter Esch, of Nome, gave a trace of gold.

As placer gold is derived from veins, it is certain that auriferous veins must occur widely throughout the area. Whether such veins can be economically mined is a question which can be decided only by more active development. It is probable that if auriferous veins are

[a] Brooks, A. H., op. cit., p. 292.

exploited in the future the mining problems involved will fall within commercial rather than geologic boundaries.

SILVER-LEAD DEPOSIT.

Within the area of metamorphic rocks of southeastern Seward Peninsula one deposit of argentiferous galena has been of some economic value. This lode, staked in 1881, was probably the second one discovered in the entire territory of Alaska. Although the claims were not recorded until July, 1881, galena had been known for a year or more before, and Petrof, in the census report for 1880, mentions that silver-lead ore had been found in the vicinity of Golofnin Bay. The developments at this place have been carried on at a single group of claims located on a low limestone-schist hill on the western flanks of the Darby Range. As has already been stated, the claims were located in 1881. In 1882 a company was formed which in 1883 was absorbed by the Omilak Gold and Silver Mining Company, which continued to hold the ground until 1898, when the Russian-American Mining Exploration Company took the properties. This transfer was one of name rather than of personnel. The claims were patented in 1894.

The geology in the vicinity of the mine is so complex that without more detailed study than was made in 1909 the stratigraphy is not determinable. East of the mine, toward the head of Omilak Creek, is a large area of white crystalline limestone, which, in the main, appears to dip westward at high angles. This is succeeded farther west by schistose rocks containing much biotite and quartz and some graphite. Still farther west, in the immediate neighborhood of the mine, the distribution of the various rocks is as shown in figure 6 (p. 64). Although from this map it appears that the dip is in general to the west, the evidence on the ground shows that the rocks are much deformed, and appressed folds, such as are shown in Plate XIII, *A* (p. 90), have been recognized. This fold, which pitches steeply toward the west, is shown at A on figure 6 (p. 90). It is evident that with such an amount of folding this structure is by no means so simple as appears at first sight, and even the determination of bedding is often impossible. It is believed, though it has not been definitely proved, that the schists represent younger or overlying rocks.

In addition to the dark biotite schist and the limestones there is an area of slightly sheared igneous rock similar to the greenstones of the more western part of Seward Peninsula. Although the exposures were not sufficiently clear to preclude other interpretations, it seems probable that these greenstones intrude the limestones. Owing to the amount of deformation and consequent metamorphism it is probable that some of the greenstones are included in the areas mapped as schist. The fact that the greenstone is more easily recognizable in the midst of the limestone may be due to the protection given it by that rock, which is more easily deformed than the schist, whose resistance to dynamic metamorphism is more nearly equal to that of the igneous rocks.

According to Mendenhall the ore occurs near the contact of this intrusive and the limestone.[a] From the study of the region in 1909 this conclusion could not be verified as the shaft was inaccessible and the only mineralization seen was in the midst of the limestone. In the absence, however, of ore-bearing minerals in the greenstone it seems doubtful whether the galena could have been introduced at the time of the intrusion. Furthermore, the well crystallized character of the ore suggests that its deposition was later than the deformation of the region, whereas the greenstone was earlier.

Two kinds of ore minerals are found in this deposit—argentiferous galena and stibnite. So far no interrelation between the two has been shown, but it is believed that both were introduced at essentially the same time. It should be noted that the deposits containing the galena seem to be topographically above those with stibnite.

From the reports of others—as it was not possible to see the underground workings personally—it was learned that "no continuous vein of galena ore existed, the ore being found only in irregular and disconnected pockets."[b] None of the pockets were of large size and the better ones occurred entirely within the limestone. Some of the ore was thickly covered with products of oxidation, mostly lead carbonate.

About 400 paces south of the galena shaft there are a shaft and an incline which were used to explore the stibnite leads. The limestone is much fractured and the ore occurs in thin streaks in the shattered zone. None of the veins seen by the writers are of sufficient size to warrant mining. The stibnite is well crystallized, the thicker stringers apparently occupying fault planes and sending small offshoots into the limestone, which, near the ore, is abnormally granular and sugary.

Considering the number of years the ground has been held and the large expenditures incurred, the amount of development work is astonishingly small. A shaft 180 feet deep has been sunk near the eastern margin of the limestone on top of the hill, and two short drifts have been turned off in the search for ore pockets. The upper part of the shaft is in limestone, but the lower is in schist, as the contact dips toward the west. The shaft is well timbered and is fairly dry. Hoisting is done by power, a bucket not running on guides

[a] Mendenhall, W. C., op. cit., p. 214.
[b] Idem, pp. 213–214.

being used. Electric lights are used around the shaft house and underground. Two outfits for drilling have been used, one an air compressor and air drills and the other an electric drill plant. Electricity for these uses is furnished by a coal-oil engine located near the main bunk house on Omilak Creek.

At 200 to 300 feet, vertically, above Omilak Creek an adit has been started to intersect the shaft in depth and thus obviate the necessity of hoisting the rock to the top of the hill and then taking it down again for shipment. The length of the adit is 187 paces, or, approximately, 500 feet; this distance was in massive white limestone somewhat shattered, but nowhere showing mineralization.

In addition to the equipment directly at the mine there are bunk and store houses at Cheenik, on Fish River, and also half a mile or so below the mine on Omilak Creek. At the latter place are a repair shop, electric plant, assay laboratory, electric sawmill, stable, and the other equipment usually found only at large producing mines. The company also owns a large river steamer originally built for freighting the mine supplies up the river, but it has never been used.

The production of the mine is not definitely known, but it has probably not been more than 400 nor less than 300 tons. A part of this was obtained from the various pockets below ground, but a considerable amount is understood to have come from hand picking the float found on the hillside. The following tables show the returns from assays of the ore as shipped. It should be noted that owing to the high transportation charges the ore was carefully hand picked and in some cases washed before shipping.

Returns from assays of ore as shipped from Omilak mine.

	Weight (pounds).	Gold (value per ton).	Silver (value per ton).	Lead (pounds per ton).	Lead (value per ton).	Total value per ton.
1	4,230	....	137.29	1,538	61.52	198.81
2	545	2.07	106.62	1,320	52.80	161.49
3	130,000	3.09	98.72	1,128	45.12	146.93
4	68,078	....	104.00	1,300	52.00	156.00
5	12,167	2.07	125.19	1,440	57.60	184.86
6	82,100	....	132.95	1,494	59.76	192.71
7	86,885	7.43	49.60	502	20.08	77.11
8	27,787	1.54	41.40	606	24.24	67.18
9	13,606	1.54	38.10	566	22.64	62.28
10	2,675	1.03	54.93	770	30.80	86.76
11	6,569	2.07	46.46	890	35.60	84.13
12	164	7.53	65.54	816	32.64	105.71
13	595	2.07	71.15	980	39.20	112.42
14	380	2.07	86.86	966	38.64	127.57
15	26,175	2.07	120.33	1,222	48.88	171.28

1 to 6 inclusive, solid ore from Omilak mine, tons of 2,000 lbs.; 7 to 14, inclusive, carbonate ores from Omilak mine; 15, carbonate ore concentrated by washing in sluice boxes.

Unfortunately, in these assays the data are not sufficient to determine the percentage of any of the constituents except the lead, and therefore the following assays, less complete in certain other ways, are given also:

Silver and lead in ore from Omilak mine.

	Silver (ounces per ton).	Lead (per cent).
1	173.00	75.0
2	141.00	80.7
3	158.00	78.0
4	153.70	82.0
5	162.97	78.5
6	149.16	73.0
7	142.20	74.7
8	94.30	55.9
9	60.7	10.27

Assays 1-2 by Herford Copper Works, Swansea, England; 3 by Pennsylvania Lead Company, Pittsburg, Pa.; 4-6 by W. P. Miller, San Francisco; 7 by T. Price, San Francisco; 8-9 reported by W. C. Mendenhall, op. cit., p. 214; 8 yellow carbonate ore; 9 red carbonate ore.

Assays and relative weights of part of the different ores shipped by the Omilak mine in 1889, with the price paid in open market for the same are given in the following table:

Assays and weights of ore shipped by Omilak mine in 1889.

Commercial name.	Weight (pounds).	Gold (ounces per ton).	Silver (ounces per ton).	Lead (per cent).	Price received per ton.
Red carbonate	380	0.1	92.9	48.3	$93.00
Gray carbonate	595	.1	76.1	49.0	81.00
Yellow carbonate	6,569	.1	49.7	44.5	57.00
Argentiferous galena	82,100		142.2	74.7	154.00

It is evident that the ore is high in silver and also usually carries a small quantity of gold. Its metallurgical treatment is simple and the ore is especially valuable to mix with other more refractory ores. The absence of fuel at a reasonable price prevents treatment near the mine and the high charges for transportation restrict shipments to ores of the higher grade.

From the foregoing descriptions certain facts are evident, which may be summarized as follows: The claims have been inadequately prospected and large expenditures have been made, apparently without disclosing a workable vein; the ore found is of excellent quality, but the quantity, so far as could be determined by the writers, is not sufficient to warrant extensive developments. The most promising area to prospect is in the limestone near its contact with the schists, but the deposits likely to be found will probably be pockets not easily adaptable to cheap mining methods and not capable of affording a large, constant amount of ore.

COPPER PROSPECTS.

Attempts have been made to develop copper leads at three places within the Nulato-Council region, but so far the results have not been encouraging, and the general absence of sulphide mineralization throughout Seward Peninsula leads one to doubt whether commercially important deposits of copper will be found. Furthermore, the necessary treatment and refining that copper must undergo before manufacture makes this metal difficult to handle in a country where high wages, high cost of supplies, and absence of transportation facilities exist. It seems likely, therefore, that until one or all of these factors are canceled or reduced, copper mining can be successfully carried on only where the deposit is exceptionally rich. No such places are at present known in Seward Peninsula.

Several shallow prospect pits were sunk in 1906–7 in the hills near Timber Creek in the Tubutulik divide, on copper-stained greenstones, near their contact with limestone. A large outfit was shipped in and extensive plans formulated, but the mineralization was not sufficient to warrant development, and after a little desultory prospecting the ground was abandoned. Specimens of the ore from this claim were assayed and, according to the owners, yielded from 17 to 70 ounces of silver to the ton and from a few cents to $1 a ton in gold as well as copper. From the high copper content reported in these assays, it is evident that the sample for assay was carefully hand-picked. From a personal examination of specimens from this ground it appeared to the writers that the copper occurred almost exclusively in the form of malachite, the green carbonate of copper, and sulphides or other original minerals were practically absent. On account of the secondary character of the ore, it is difficult to ascertain the time or mode of origin of the copper mineralization. The observed facts show that the carbonate occupies fractures and joints in the greenstone, but this does not preclude its having been derived from the leaching of copper minerals originally present in the greenstone. So far as could be determined, the copper mineralization at this place is distinctly local and in such insignificant quantity as to discourage further investigation.

On the east coast of the Darby Peninsula, about 3 miles north of Carson Creek, a little copper mineralization was observed. A small amount of exploration by means of a short, open cut had been made, but no work was in progress at the time of the visit in 1909. The copper occurs mainly in the form of the carbonate, but there is also a little chalcocite present. This ore does not occur in a vein, but seems to be a replacement of parts of the schist, so that its distribution is irregular and discontinuous. Some is also found in the joint planes, as though it had been introduced later than the deformation of the country rock. There is a large amount of slickensiding on the rocks, showing that faulting has occurred, and it is by no means improbable that the shattering effected by these movements may have produced a more or less pervious zone, which allowed easy penetration for mineralizing solutions. The amount of mineralization is, however, slight, and there seems to be no reason for believing that a commercially workable deposit will be found at this place.

A short distance farther south is an outcrop of a nearly pure white limestone, which, though slightly sheared, is in places much brecciated. A short tunnel has been driven in on this brecciated band. Apparently some surface stains had tempted exploitation, but as the work progressed and no vein or other mineralization was found the search was abandoned. From the present condition of the tunnel and the surrounding country rock one fails to understand why mining was ever contemplated at this place.

The only other place where copper prospecting has been undertaken within the Nulato-Council region is in the Bendeleben Mountains on the divide between Kingsland and Nugget creeks. These streams are tributaries of the Niukluk from the east about 4 miles south of the Birch Creek-Niukluk divide. Prospecting in this region has been carried on for five to eight years, but no shipment of ore has been made and no considerable body has been exposed. The ore occurs near the contact of a limestone and schist in a region much faulted and intruded by small granite dikes. The ore is low grade and consists mainly of chalcopyrite, with few alteration products. No distinct vein was found, the ore occurring mainly as a replacement of the country rock in disseminated lenses and strings. A little gold is reported to be associated with the copper, but neither its value nor its relation to the copper mineralization was learned.

Although of no commercial value, the occurrence of copper sulphides in a pink granite, with rather large feldspar crystals, on the upper part of Peace River 2 or 3 miles above camp B13, is noted as giving a suggestion of the time of introduction of some of the copper mineralization. At this place there is only a little copper, but it seems to have been brought in contemporaneously with the granite. As there is no evidence at the other places already described of the age of the mineralization, this occurrence becomes significant.

From the preceding accounts of the meager amount of development work on copper lodes it is evident that no deposits of value are known. In part this may be due to lack of thorough investigation, but it is believed to be due in the main to the absence of cupriferous veins. Therefore, although valuable copper may be discovered in the future, the present conditions do not warrant search unless the enterprise is undertaken with the knowledge that the chances are against rather than in favor of success.

COAL RESOURCES.

Wherever the Cretaceous sediments are extensively developed throughout Alaska there are indications of coal. Some of these croppings in the area under discussion have been prospected and claims staked. Field examinations of some of the Alaskan coal deposits along Yukon River have been recently completed by Atwood, but the results have not yet been made available. Manuscript notes of the facts gathered by him concerning the Nulato region have, however, been furnished and have been of service in preparing the following paragraphs.

Fossils have not been found at many of the coal prospects and it is impossible to refer the various beds definitely to their proper geologic horizons. Closer correlations therefore than that the coals belong to the Upper Cretaceous will not be attempted, although it is believed that most of the deposits belong to the lower rather than the higher part of this series. One exception, in which the material is a very woody lignite, seems to be of much more recent age and is provisionally called post-Tertiary, mainly on account of its physical character.

For convenience of description a geographic order will be adopted. According to this plan, the deposits have been divided into, first, those occurring in the Yukon River drainage basin, and, second, those either in regions draining into Norton Bay or in Seward Peninsula.

YUKON BASIN.

The most eastern locality where coal has been prospected in this part of the Yukon basin is at Nahoclatilten or Louden, west of the mouth of the Melozitna. A description of these coals by Collier is as follows:[a]

> Two beds of coal were seen by the writer at this place, and two more are reported to have been uncovered in prospecting. The largest observed seam has a thickness of 1 foot. Below this seam there are about 5 feet of bony coal or coaly shale with stringers of coal. There are reported to be 3 smaller beds in the foot wall, each having a thickness of 10 inches. Owing to the apparent rather intense folding of these beds, it is impossible to place much reliance on these statements.
>
> The coal in the 1-foot seam is not crushed, although the beds are much disturbed in position. The following analysis shows it to be a bituminous coal of good quality. It is reported to have given satisfactory results in a blacksmith's forge.

[a] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903, pp. 47–48.

Analysis of coal (No. 241) from 1-foot seam 5 miles above Nahoclatilten.

[Analyst, E. T. Allen, U. S. Geol. Survey.]

	Per cent.
Water	6.88
Volatile combustible matter	41.82
Fixed carbon	48.93
Ash	2.37
	100.00
Sulphur	.65
Fuel ratio	1.17

Coke slightly coherent.

These coal beds have been known for several years, and various attempts have been made to open here coal beds of commercial importance, but thus far no seams thicker than 12 inches have been found.

No other coal prospects have been noted lower down on the Yukon until about midway between the mouth of the Koyukuk and Nulato. A mine, called from its owner the Pickart mine, was noted by Schrader in 1899; it is therefore one of the oldest coal mines in Alaska. According to Collier:[a]

At the Pickart mine one coal seam has been exploited which strikes N. 75° E. and dips 35° N. Two rolls, or horsebacks, are reported to occur in the floor of the coal bed. Whether these are in the nature of faults due to movement of strata along the coal bed or irregularities in deposition of the sediments constituting the floor the writer was unable to determine. Near these rolls the coal shows considerable crushing, which suggests that the roll is formed by deformation. The Pickart coal bed has a thickness of 30 inches at a distance of 300 feet from the entrance to the mine, but near one of the rolls above referred to the seam measured only 18 inches. Mr. W. E. Williams, manager of the Pickart mine, reports that in mining this coal a roll was encountered in the workings above the coal mine gangway in which the floor of the bed was raised up, pinching the coal down to a knife-edge thickness. The roll extended in a nearly straight line and approached the gangway at a rate of about 1 foot in 20. On cutting through this roll good coal was found.

Analyses of the coal from near this mine published by Collier are as follows:[b]

Analyses of semibituminous coking coal on the Yukon.

[No. 1 from 12 miles above Nulato, on the Yukon; analyst, George Steiger, U. S. Geol. Survey. Nos. 2 and 3 from Pickart mine, on the Yukon; analyst, E. T. Allen, U. S. Geol. Survey.]

	1.	2.	3.
Moisture	0.86	1.02	1.64
Volatile matter	25.75	27.33	24.98
Fixed carbon	66.51	65.03	58.18
Ash	6.88	6.62	15.20
Sulphur	....	.56	....
Fuel ratio	2.22	2.37	2.32

[a] Collier, A. J., op. cit., p. 50. [b] Idem, p. 62.

In 1907 this mine was visited by Atwood, who reports that no work had been in progress for several years. According to him there are at least four thin seams of coal stratigraphically higher than the one the mine was opened on. These upper beds are only from 6 to 8 inches in thickness, and are associated with carbonaceous shales, which show frequent signs of cross-bedding and ripple marks.

About a mile above Nulato, Collier noted a prospect hole sunk in the sandstones called Nulato sandstone by Dall. The section exposed showed 2½ feet of bony coal with several bands of clay. One 6-inch bed of clean coal was uncovered and, it is reported, was used to some extent for blacksmithing at Nulato. There has been no recent work at this prospect, and it is evident that the seam is too thin to invite further investigation.

Four miles below Nulato, in the name sandstone in which the other prospects already described occur, is a coal bed that has been opened to a small extent. This mine is locally known as the Busch mine. No mining has been done here for several years. Atwood, when he visited the prospect in 1907, reported that the slope had caved so as to make the mine inaccessible. According to Collier, at the time of his visit in 1903:

In the tunnel, which extends about 40 feet, large bodies of crushed coal 4 to 5 feet in thickness are exposed. The coal is regarded as bituminous, having a fuel ratio of 1.76 and a water content of 11.17 per cent. The high percentage of water is probably due to decomposition of the coal in the croppings. No coal has been produced.[a]

Aanalysis of coal from Busch mine, 4 miles below Nulato.[b]

[Analyst, E. T. Allen, U. S. Geol. Survey.]

Moisture	11.17
Volatile matter	29.48
Fixed carbon	52.02
Ash	7.33
	100.00
Sulphur	.44
Fuel ratio	1.76

Coke, noncoherent.

About 5 miles below the Busch prospect is the Blatchford mine, which is also abandoned. Collier reports:[a]

One workable coal bed has been opened at this place. This bed has been crushed and sheared by the movements of the inclosing strata, making it very irregular. Large masses 8 feet in diameter have been found and mined out, showing that before it was disturbed the coal bed probably had considerable thickness. The coal has a tendency to break up into fine pieces, though it is

[a] Collier, A. J., Bull. U. S. Geol. Survey No. 213, 1903, p. 281.

[b] Collier, A. J., The coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, p. 53.

a bituminous coal having a fuel ratio of 3.30, the highest of any coal on the Yukon, and a water content of 1.36 per cent. The ash is only 2.22 per cent, making it, by approximate analysis, the best coal seen by the writer on the Yukon River.

This mine has no visible development or permanent equipment. The workings lie below the level of the river and the entrance is covered with water during the summer months, so that it can be worked only in the winter after the freezing of the river, where the ice filling the upper workings must be mined out before the coal can be reached. The mine has probably produced about 300 tons of coal.

The Williams coal mine is located on the west side of the Yukon just south of the mapped area. It has been more extensively developed than any of the mines already described, but as it does not come within the area covered by this report, description will be omitted except to state that in a broad way conditions are the same there as in the other prospects.

NORTON BAY BASIN AND SOUTHEASTERN SEWARD PENINSULA.

Coal has been reported at a number of places along the eastern shore of Norton Bay, but so far as known no beds of a sufficient size to allow profitable mining have been discovered. Dall mentions a 2-foot bed of shale and lignite, possibly Kenai in age, on Ulukuk River, a tributary of the Unalaklik from the north.[a] It was reported to have no commercial value. Brooks[b] states:

> Capt. D. H. Jarvis informed the writer that some very good-looking coal had been found near Unalaklik Cape near the eastern shore of Norton Sound. These [beds] probably belong to the same series described by Dall.

Several openings have been made near the mouth of the Koyuk on the western side close to camp B17. Unfortunately the shafts were not in condition to be examined, and the only information gained was from a study of the material on the dump, as there are no exposures of the coal-bearing rocks in the neighborhood. Although lignitic material was found at this place, several years of desultory prospecting have failed to disclose a workable bed. The shafts show a series of sandstones and clays which have weathered badly on the dump and appear much less consolidated than the average sandstones near Nulato. It is understood that during 1909 the company formerly interested in this claim abandoned the enterprise.

In this same region coal float has been found on Coal Creek and claims have been recorded, but none of them was being prospected in 1909. Probably little of value was found as the series is without doubt similar to that near camp B17.

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[a] Dall, W. H., Correlation papers, Neocene: Bull. U. S. Geol. Survey No. 84, 1892, p. 246.

[b] Brooks, A. H., Coal resources of Alaska: Twenty-second Ann. Rept. U. S. Geol. Survey, 1902, pt. 3, p. 560.

Mendenhall[a] says concerning his investigation in southeastern Seward Peninsula:

The only rocks encountered in the reconnaissance likely to carry coal are the sediments supposed to be of Tertiary age outcropping on the Tubutulik and Koyuk rivers in narrow belts. No direct evidence of the presence of this mineral was secured on the Koyuk, but along the river bank associated with the sandstone outcrops on the Tubutulik are numbers of small pieces of bright compact coal seemingly of good quality.

The presence of this coal float has long been known to prospectors but so far no beds that would warrant investigation have been discovered.

As previously stated one locality was visited in 1909 where there is a woody lignite of relatively recent age and differing from those previously described. This exposure is on the Rathlatulik, a tributary of Fish River, about 10 miles above the junction of the streams. A shallow pit has been sunk here and slightly carbonized fragments of wood found. Underneath this layer of woody material is a blackish-green calcareous muck which is nearly flat or has a slight slope toward the east. A cross section of the valley at this point shows a low bench about 5 feet above the water, succeeded on the east by another bench 15 feet higher 100 paces beyond the stream and separated from the lower bench by a steep cliff. All the material from the stream to the top of the 15-foot cliff is well-rounded gravel. Several abandoned river beds are found on the lower bench.

The coal is not over 18 inches thick and is of poor quality, having advanced little beyond the wood stage. Resin is abundant in many of the samples of this material. No tests of the coal were made, but from its physical character it does not seem possible that it could be used for fuel except very locally. No accurate estimate of the amount of material available could be made without further exploitation, but it is believed to be of very slight extent and not of sufficient value to warrant further development.

CONCLUSIONS REGARDING THE COAL RESOURCES.

In the foregoing paragraphs the places where the coal-bearing rocks have been prospected to some extent have been described with the object of showing the general character of the known coal deposits. Indications of coal have been noted at many other places, but the types are essentially similar and do not merit specific description. There are certain conclusions that may be drawn from the facts that may save prospectors from spending their time unprofitably in the search of coal. Coal will be found only in the areas of Cretaceous sediments. No economically important beds are to be expected in

[a] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 214.

the unconsolidated alluviums such as those in the Fish River basin on the Rathlatulik. 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. It is improbable, therefore, that workable coal, where it is not now known, will be found in the Nulato-Council area.

INDEX.

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