DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 533

GEOLOGY

OF THE

NOME AND GRAND CENTRAL QUADRANGLES

ALASKA

BY

FRED H. MOFFIT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS.

ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

The investigation of the mineral resources of Seward Peninsula by the United States Geological Survey was begun in 1899 with a brief examination of the then newly discovered gold placers near Nome. During the succeeding five years geologic and topographic reconnaissance surveys (scale 4 miles to 1 inch) were carried over nearly the entire peninsula. There still remained a small area north of Norton Bay, which was surveyed in 1909, thus completing the reconnaissance mapping of the peninsula.

Although these reconnaissance surveys have been of great value, it was recognized that a full understanding of the problems of stratigraphic and economic geology of the district could be achieved only by means of detailed surveys. Moreover, topographic maps of a larger scale were needed for the use of a community engaged in many engineering projects. Accordingly detailed topographic surveys (scale 1 mile to the inch, with 25-foot contours) of the Nome and Grand Central quadrangles were made in 1904 and of the Solomon and Casadepaga quadrangles in 1905.

Detailed geologic surveys and investigations were made at Nome in 1905 and 1906 and at Solomon in 1907 and 1908. After the completion of the surveys of the Nome and Grand Central quadrangles it was found that many geologic problems concerning those areas were so complex as to defy solution unless the investigations were extended into adjoining fields, and therefore the publication of the report was deferred until the Solomon and Casadepaga quadrangles could be surveyed. The expectation that the information thus gained would help to solve the problems referred to was, however, only in part fulfilled. It was found that the stratigraphic results obtained in the Solomon region could be correlated with the geology of the Nome region only by surveying the intermediate area, a belt some 30 miles in width. Unfortunately the urgent need for investigations in other parts of Alaska made it necessary to defer the making of any more detailed surveys in Seward Peninsula. These conditions left but two courses open in regard to the results obtained from the survey of the Nome and Grand Central quadrangles—either to defer their publication indefinitely or to print the report embodying them in essentially its original form, with only an incomplete statement of detailed stratigraphy and structure. In view of the importance of the mining interests within the area described, it was determined to adopt the latter course. The reader of this report, therefore, must not expect to find herein an exhaustive treatment of all the many geologic problems of the region.

In justice to Mr. Moffit it should be stated that since the completion in 1906 of the field work on which this report is based, he has made five other important investigations in different parts of Alaska and published the results. His assistants, Mr. Hess and Mr. Smith, have also been transferred to other fields of investigation. Meanwhile as mining advanced new information regarding the occurrence of the alluvial gold has become available, which should properly find place in this report. Therefore there has been good reason for the unfortunate delay in issuing this volume. This delay has worked no great hardship to the mining industry, for most of the accounts of the gold placers here presented have been published from time to time in other reports. It seemed desirable, however, to bring together in one volume all the information at hand regarding the occurrence of the auriferous gravels. Much of this is now only of scientific interest, as many of the rich placers have been worked out. A knowledge of their mode of occurrence will be valuable, however, not only in this but in other regions, in helping to establish the natural laws which determine the distribution of gold in alluvium. As a record of one of the richest placer camps of Alaska, this report will have permanent value.

Bonanza mining in the Nome region, which has produced over $50,000,000 worth of gold, is now nearly a thing of the past. There are still, however, large bodies of auriferous gravels, many of which can be profitably exploited. It is not unlikely that in the future more gold will be won from these deposits than has been mined in the past. Of lode mining less definite statement is possible, but it may be said that the field is well worthy of careful prospecting for vein deposits.

GEOLOGY OF THE NOME AND GRAND CENTRAL QUADRANGLES, ALASKA.

By Fred H. Moffit.

INTRODUCTION.

FIELD WORK.

The field work on which the following descriptions are based was begun in 1905 and completed in 1906. During the first year the field investigation was carried on by Frank L. Hess and Fred H. Moffit, but in the following year Mr. Hess was unable to continue the work, and his place was taken by Philip S. Smith. Publication of the results was delayed for various reasons until it became necessary to rewrite a considerable part of the manuscript, in order that the geologic descriptions might receive such additions and corrections as later detailed work in neighboring areas showed to be necessary and that later mining developments might be given. Such delays necessarily detract from the interest and value of geologic reports on regions of gold placers like that at Nome, where changes follow one another rapidly, but fortunately many of the conclusions of the work have already been given in the reports on progress of investigations in Alaska in 1905 and 1906.[1]

The earliest study of the Nome gold placers undertaken by the Federal Survey was made by Brooks and Schrader in 1899. They spent a portion of October of that year at Nome and vicinity and published a brief preliminary report on that region. In the following year (1900) a reconnaissance survey of the southwestern part of Seward Peninsula was made by Brooks, assisted by Collier and Richardson. The area studied included the region south of Koyuk River and the depression in which lie Kuzitrin River and Imuruk Basin, but the eastern portion was examined in a more hasty manner than the western and central portions. The published report of this work is the most important contribution that has been made to the geologic literature of the Nome region, for it laid the foundation for all subsequent work.

[1] Bull. U. S. Geol. Survey No. 284, 1906; No. 314, 1907.

A further brief study of the region was made by Collier and Hess in 1903 in the course of an investigation of various placer districts of southern Seward Peninsula. During the summer they visited the gold-producing districts near Nome, Teller, Council, and Solomon, also a part of the Kougarok region. They determined the presence of tin in its bedrock source and were present when the first location of tin-bearing ledges was made in Seward Peninsula.

The next work of the Federal Survey at Nome was that of 1905 and 1906, which is the basis of the present paper. Since 1906 Smith, in connection with detailed geologic work in the Solomon and Casadepaga districts, has investigated the development of lode and placer-mining properties in the vicinity of Nome, and Kindle has made at various localities on Seward Peninsula paleontologic studies that have increased the knowledge of the stratigraphy.

PUBLISHED REPORTS.

The published results of the studies that deal more particularly with the Nome district are contained in the following papers:

SCHRADER, F. C., and BROOKS, A. H., Preliminary report on the Cape Nome gold region, Alaska: Special publication U. S. Geol. Survey, 1900.

BROOKS, A. H., RICHARDSON, G. B., and COLLIER, A. J., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901.

MOFFIT, F. H., Gold mining on Seward Peninsula: Bull. U. S. Geol. Survey No. 284, 1906, pp. 132–144.

——— The Nome region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 126–145.

COLLIER, A. J., HESS, F. L., SMITH, P. S., and BROOKS, A. H., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908.

SMITH, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, pp. 206–250.

——— Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, pp. 267–301.

——— Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, 1910. This paper does not deal directly with the Nome region, but treats many of the same problems that are found there.

PURINGTON, C. W., Methods and costs of gravel and placer mining in Alaska: Bull. U. S. Geol. Survey No. 263, 1905. This paper deals with the commercial rather than the geologic side of mining in Alaska and gives considerable attention to the Nome district.

In 1906 the investigation of the water supply of the Nome district was begun, and its results have been published as follows:

HOYT, J. C., and HENSHAW, F. F., Water supply of Nome region, Seward Peninsula, 1906: Bull. U. S. Geol. Survey No. 314, 1907, pp. 182–186. Also Water-Supply Paper No. 196.

HENSHAW, F. F., Water supply of the Nome and Kougarok regions, Seward Peninsula, 1906–7: Bull. U. S. Geol. Survey No. 345, 1908, pp. 272–285.

HENSHAW, F. F., Water-supply investigations in Alaska, 1906–7; Water-supply Paper U. S. Geol. Survey No. 218, 1908.

——— Water supply investigations in Seward Peninsula in 1908: Bull. U. S. Geol. Survey No. 379, 1909, pp. 370–399.

——— Water-supply investigations in Seward Peninsula in 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 372–418.

HENSHAW, F. F., and PARKER, G. L., Surface water supply of Seward Peninsula, Alaska: Water-Supply Paper U. S. Geol. Survey No. 314, 1913.

LOCATION AND AREA OF THE DISTRICT.

The district under consideration is situated in the south-central part of Seward Peninsula (fig. 1), and is included between meridians 165° and 165° 30′ west longitude and parallels 64° 25′ and 64°

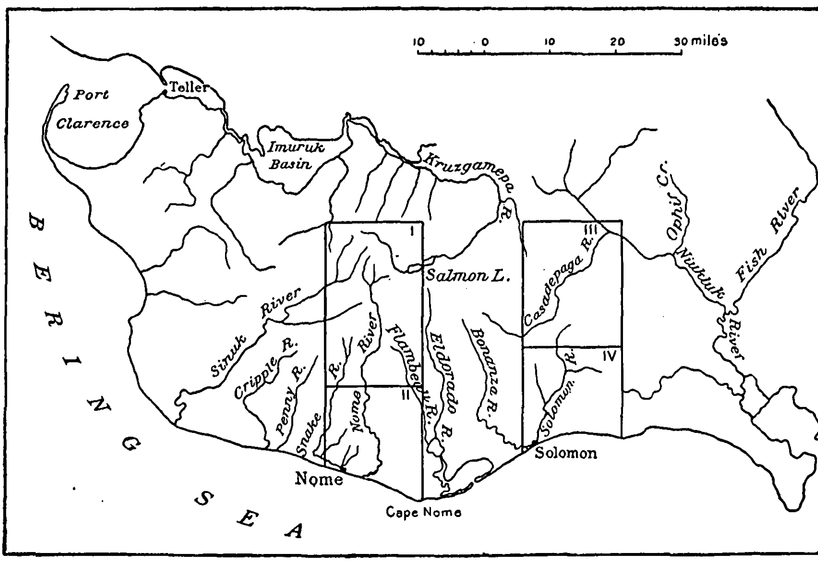


FIGURE 1.—Index map of southern Seward Peninsula, showing areas represented by detailed topographic and geologic maps. I, Grand Central quadrangle; II, Nome quadrangle; III, Casadepaga quadrangle; IV, Solomon quadrangle.

57′ north latitude. It has a width from east to west of almost 15 miles, and extends north from its most southern point, Cape Nome, a distance of about 35 miles. Its area is thus approximately 525 square miles. This district is herein represented on two topographic maps (Pls. I and II, in pocket).

Seward Peninsula projects west from the main body of Alaska between Bering Sea and the Arctic Ocean. Its northern coast touches the Arctic Circle; and Cape Prince of Wales, the most westerly point of the peninsula and of the North American mainland, approaches within 60 miles of East Cape, Siberia. The Arctic Ocean and Kotzebue Sound on the north and Bering Sea and Norton Sound on the south almost surround it, and give propriety to the name peninsula. Its coast line is monotonous. In places the highlands reach the sea, but for the most part its shores are bordered by low sand and gravel plains that slope gradually up to the hills. Lagoons cut off from the ocean by sand bars form a notable feature of the Arctic coast, but are less numerous on the side toward Bering Sea. Shallow water extends far off shore, and the landing of freight and passengers is difficult in bad weather, for ocean steamers are obliged to anchor a mile or more from the beach, where deep water gives them safety. Port Clarence is the only protected harbor of the whole coast, and is so situated as to be of comparatively little use to shipping.

Bering Sea is the chief avenue of communication with the outside world, but is closed to navigation for nearly seven months of the year. During this season no supplies are received at Nome, although mail is brought in over the winter trail from Valdez. Nome, the principal mining center of Seward Peninsula and the second largest town in Alaska, is about 2,300 statute miles from Seattle by direct water route. It is the distributing point of supplies for almost the entire peninsula, as nearly all freight not destined for Nome itself is here transferred to smaller vessels or unloaded for overland shipment.

Nome River, which flows southward through the middle of the area from a point within a few miles of the northern boundary, furnishes an easy route of communication with many of the producing creeks as well as with the interior of the peninsula. The track of the Seward Peninsula Railway follows its valley northward, and, crossing the divide to Salmon Lake, continues to the Kuzitrin by way of the Kruzgamepa or Pilgrim River valley. A smaller stream, Snake River, at whose mouth Nome is situated, affords a highway to the southwestern part of the district, and the southeastern and eastern parts may be reached by wagon trail to Osborn and Buster creeks. Until the wagon road leading north from Nome to the head of Dry Creek was constructed in 1906, the stream beds and the ridges were the regular routes of travel, and they still continue to be the only practicable ways of getting into much of the region.

TOPOGRAPHY.

GENERAL FEATURES OF SEWARD PENINSULA.

Seward Peninsula is an ancient land mass whose surface has been exposed to the agents of erosion so long that it has lost most of its youthful angularity and appears now with the smooth contours that indicate great age. Broad rounded hilltops and wide shallow valleys characterize the region. This kind of topography prevails through most of the northern half of the peninsula and in much of the southern part, although in the latter it is modified by a chain of younger rugged mountains, which lies nearly parallel to and just south of the east-west axis of the peninsula. This chain is composed of the Kigluaik and Bendeleben mountains, with which the Darby Mountains were formerly included, although their direction is more nearly north and south than east and west and they probably do not belong to the Kigluaik-Bendeleben chain. The Kigluaik and Bendeleben mountains are separated from the northern half of the peninsula by a depression formed by the valleys of Kuzitrin and Koyuk rivers, two streams that with their tributaries drain most of the interior region. These rivers have their sources in the broad, flat lava fields north of the Bendeleben Mountains. The Kuzitrin flows west through Imuruk Basin to Port Clarence, but the Koyuk takes a southeasterly course to Norton Bay. Several smaller streams, including the Kiwalik, Kugruk, Inmachuk, and Goodhope, rise in this same lava field and with Serpentine River, farther west, flow north to the Arctic Ocean. The largest river of the south coast is the Niukluk, but Solomon, Nome, Snake, and Sinuk rivers, although much smaller, are important because of their gold-bearing gravels.

RELIEF.

Three types of topography—coastal plain, dissected upland, and rugged mountain mass—are represented in the Nome and Grand Central quadrangles (Pls. I and II, in pocket).

A narrow coastal plain, the Nome tundra (Pl. VI, *A*), slopes gently upward from Bering Sea to the foot of the hills that border the coast. Near Nome this plain has a width of nearly 4 miles from north to south, but it narrows toward the east till it disappears at Cape Nome. Its surface is not a plane, for it has been cut by many streams and its former more nearly uniform slopes have given place to many irregularities, which, however, when viewed in a large way are not great.

A second type of topography is seen in the region between the Nome tundra and the east-west depression formed by the valleys of Sinuk River and Salmon Lake. This region for the most part is one of rounded hills and broad ridges whose altitudes increase with considerable regularity from south to north. In the southern part of the area the higher summits stand at an elevation of about 1,000 feet above the sea, but in the northern part the average height is not far from 2,000 feet, although one or two of the highest hills reach or exceed 2,600 feet. This area is part of an elevated land mass whose original surface has been destroyed by the cutting of numerous streams and the weathering action of sun, frost, and rain through countless ages. It is a dissected plateau whose early form is suggested by the accordance in elevation of those parts that have resisted the destroying agents most strongly.

The third type of topography is found in the east-west range of the Kigluaik or Sawtooth Mountains, only a small portion of which is shown on the Grand Central map (Pl. II, in pocket). This is a region of jagged peaks and sharp ridges separated by steep-walled glaciated valleys (Pls. VI, *B;* VIII, *A*, p. 24; XI, p. 62). Many of the summits have elevations greater than 3,000 feet. Mount Osborn (4,126 feet), the highest point on Seward Peninsula, stands at the head of Grand Central River, 3 miles beyond the northern limit of the quadrangle. Moderate southern slopes and precipitous northern slopes are prominent features of these mountains and help to make them a great storehouse for snows that supply water to numerous streams throughout the summer, as the lofty southern valley walls protect the snow from the sun and preserve it from rapid melting in the spring.

DRAINAGE.

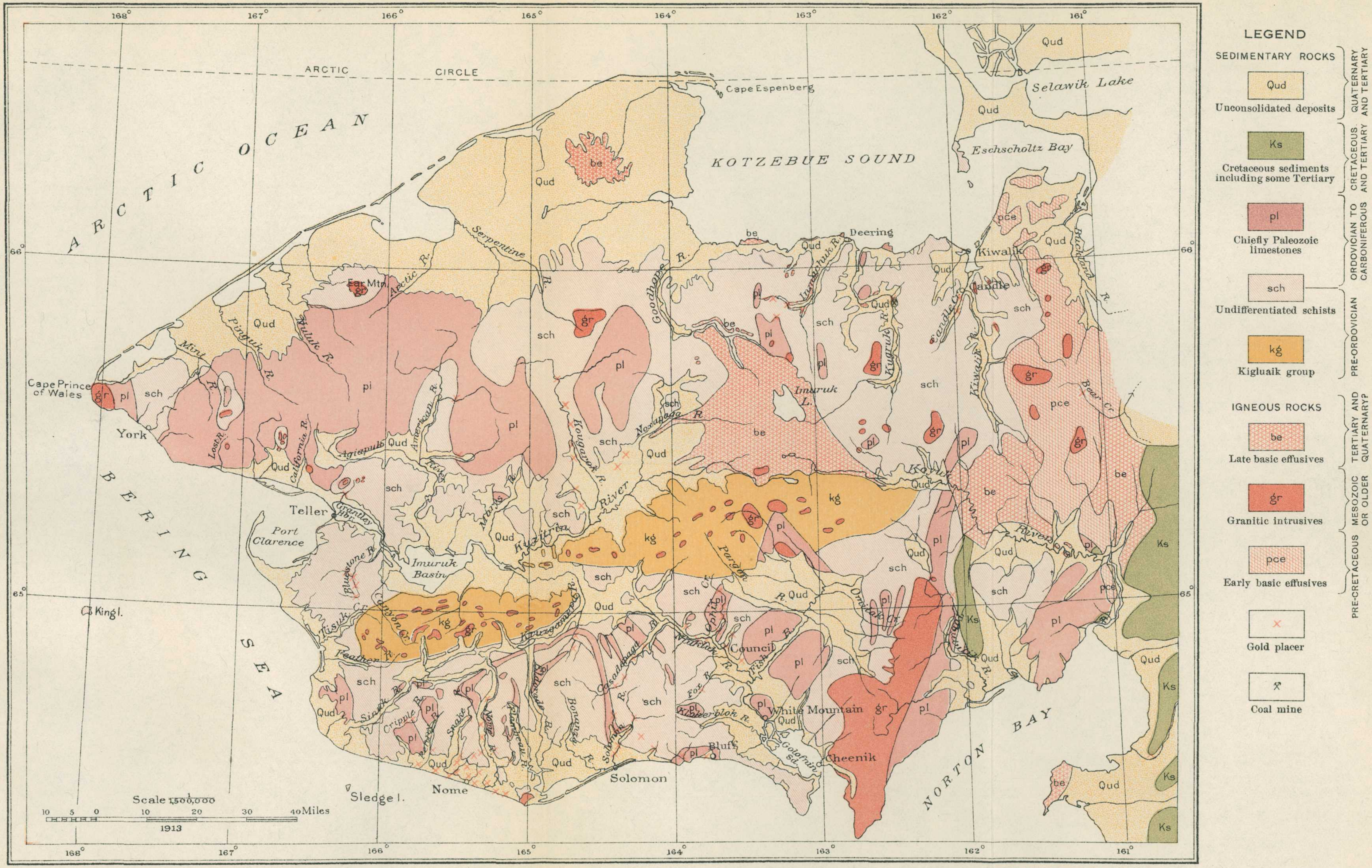
Nearly all the larger streams of southwestern Seward Peninsula originate in or near the Kigluaik Mountains. One of them, Nome River, lies wholly within the area under consideration and drains the larger portion of it. A second river, the Sinuk (often called the Sinrock), with its southern branch, Stewart River, drains the northwestern part of the area and flows southwest to Bering Sea. Grand Central River and its tributaries drain the northeastern part. The Grand Central flows into Salmon Lake, whose waters are carried north around the east end of the Kigluaik Mountains and into Imuruk Basin by Kruzgamepa River.

The other larger streams originating within the plateau region are Snake River, which lies west of and parallel to Nome River, and Flambeau River, whose upper part only is shown on the maps. Nome and Snake rivers flow in meandering courses through broad gravel-floored valleys, but with few exceptions the small streams outside of the coastal plain flow in narrow steep-walled valleys. One very noticeable difference between these streams and those of similar regions in more temperate climates is that few of them are ever dry in summer. Melting ice beneath the blanket of moss supplies some water throughout the warmer season, although most of the water from this source is probably lost by evaporation. The moss itself absorbs the rainfall like a sponge and prevents a rapid run-off. When nearly saturated, however, the moss has a much lessened effect in holding water.

DESCRIPTIVE GEOLOGY.

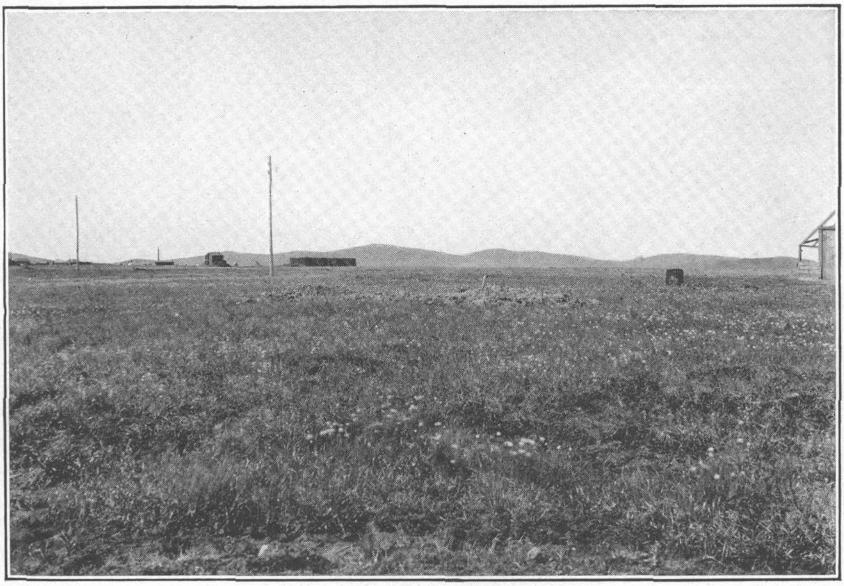
OUTLINE OF THE GEOLOGY OF SEWARD PENINSULA.

Most of the rocks of Seward Peninsula are of sedimentary origin, and are highly metamorphosed. They comprise chiefly schists of various kinds and much-altered limestones. Plate V shows the



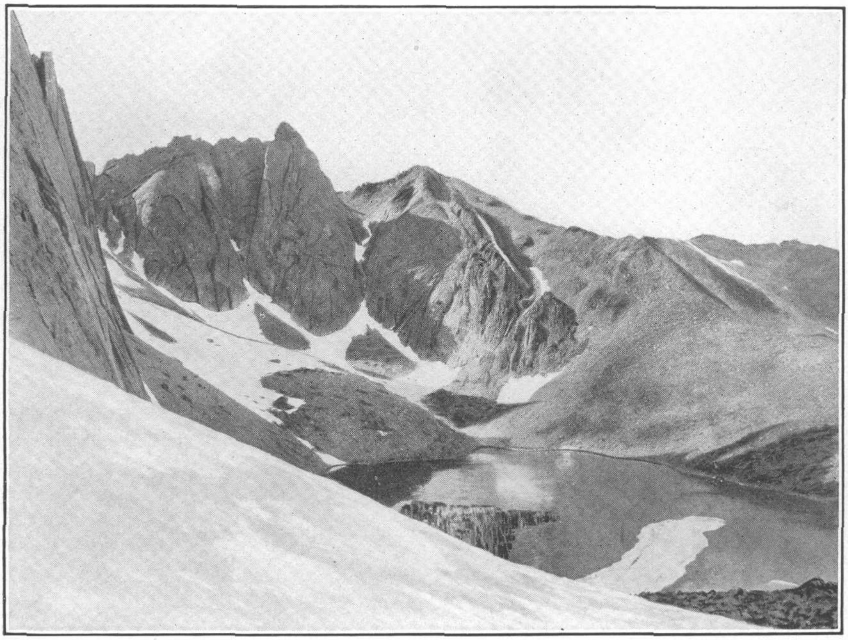
GEOLOGIC MAP OF SEWARD PENINSULA, ALASKA

Compiled and arranged by Philip S. Smith



A. VIEW NORTHWARD FROM NOME ACROSS THE TUNDRA.

Anvil Mountain in the distance, 4 miles away.



B. GLACIAL CIRQUE 1 MILE WEST OF PASS BETWEEN WINDY CREEK AND COBBLESTONE RIVER.

general distribution of these rocks. Undifferentiated schists and massive limestones occupy most of the peninsula, except a narrow belt extending westward from Koyuk River to Bering Sea. This belt is also made up of schist and limestone but includes many granitic intrusives. Sedimentary beds younger than any of these occur in the vicinity of Norton Bay. Unconsolidated gravel and sand deposits occupy wide areas of lowland and reach their greatest development on the Arctic coast, in the Imuruk Basin, and in a narrow belt along Bering Sea.

Igneous rocks are represented by the granitic intrusives already mentioned and by basic lava flows, some of which are of very recent age. The lava flows are not found in the western part of the peninsula and with a few minor exceptions do not appear west of Norton Bay in the southern part.

In the southern and western parts of the peninsula fossils have been collected that show all the great systems of the Paleozoic from Cambrian to Carboniferous to be represented. In the northeastern part schist and limestone of much the same character and probably of equivalent age are associated with younger coal-bearing rocks laid down in late Mesozoic or possibly Tertiary time. The consolidated sediments are therefore believed to range in age from early Palezoic to Mesozoic or Tertiary, but no Triassic or Jurassic rocks are known with certainty, and the Cretaceous sediments are practically restricted to the eastern part of the peninsula so far as present knowledge shows. In the region of Nome there are no consolidated sediments younger than Paleozoic.

The older sedimentary formations and possibly the younger also have been intruded by various igneous rocks, of which the most important are granites and diorites, or closely related types, and greenstones. The intruding rocks as well as those penetrated by them are generally more or less metamorphosed. Extrusive igneous rocks are represented by basic lavas in the northeastern part of the peninsula. The lower age limit of these lavas is uncertain and probably lies within the Mesozoic, but the upper limit is not earlier than Pleistocene or Recent, as the latest flows overlie gravels of Quaternary age.

Finally, to complete the geologic column, there must be added the unconsolidated surficial deposits, gravels, sands, and unsorted rock waste, of Pliocene, Pleistocene, and Recent age.

It must be admitted at the outset that in spite of all the work that has been done in Seward Peninsula the stratigraphy and geologic history of the area are very imperfectly understood, and the recent studies have only shown the problems to be more complicated than was supposed. The Paleozoic sediments, comprising much the greater part of the rocks of Seward Peninsula, were divided by the earlier geologists into three great groups called the Kigluaik, Kuzitrin, and Nome "series," the term "series" being used to include successions of associated formations distinct from one another but composed of individual members that could not be separated in reconnaissance work. These three divisions of the sedimentary rocks have been briefly described by Brooks,[1] who proposed them, as follows:

The Kigluaik series is the oldest and is made up of a basal member consisting of heavy crystalline limestones, with mica schists, succeeded by a great thickness of mica schists and gneiss, and the entire succession is cut by large granite dikes. These rocks are overlain by the Kuzitrin formation, mostly graphitic slate and quartzite, with a thickness of probably 1,000 feet. The next horizon is the Nome series, whose basal member includes micaceous and calcareous schists, with some limestone, succeeded by several thousand feet of massive limestone called the Port Clarence limestone, containing Upper Silurian fossils.

The Port Clarence limestone in places is overlain by schistose rocks, which constitute the upper member of the Nome series.

These three divisions have formed the basis of nearly all the geologic descriptions concerning Seward Peninsula since 1900, and two of them, the Kigluaik and Nome groups, are represented in the district to be considered here. They are now known to include sediments of widely different systems, limestones ranging in age from Cambrian to Carboniferous having been mapped as one formation. It is therefore evident that these names can be used only as they were intended to be used, as group names, and that they must finally be displaced altogether or greatly restricted in meaning.

Rocks of the Kigluaik group are found in the Kigluaik Mountains and their eastward extension, the Bendeleben Mountains. The Kigluaik-Bendeleben range marks an axis of anticlinal uplift, which brought the older rocks to the surface and forms one of the most prominent structural features of the peninsula. It extends from the coast of Bering Sea south of Port Clarence east to Koyuk River and the Darby Range north of Norton Bay.

Schists of the Kuzitrin formation, as previously defined by Brooks,[2] are typically developed in the east or northeast end of the Kigluaik Mountains and along Kuzitrin River.

The Nome group, whose name is applied with less definite meaning than that of either the Kigluaik group or the Kuzitrin formation, is the most widely distributed of the three. It surrounds areas of the older group, includes small areas of infolded coal-bearing beds, and comprises most of the hard-rock formations of the peninsula. The schists and limestones of the Nome group have been subjected to distorting forces that have resulted in the production of two distinct sets of folds approximately perpendicular to each

[1] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 217, 259.

other. The axis of one set of folds runs north and south. This folding was intense, and its results are seen in the southern and eastern parts of the peninsula but not in the northwestern part. The other set of folds is much more open and is most distinct in the vicinity of the Kigluaik and Bendeleben mountains, to whose axes the folds are parallel.

Coal-bearing sediments are found chiefly in the east end of the peninsula, although thin coal beds whose age has not been determined occur at one locality on Sinuk River, in the southwestern part. It appears probable that the coal and associated shales, sandstones, thin limestones, and conglomerate of the eastern part of Seward Peninsula are all of Cretaceous age, as there is now conclusive evidence that part of them are and the field relations favor such an assignment. These younger beds have been much folded, but they do not show such intense metamorphism as appears in the older rocks. They are known in only a few comparatively small areas on the peninsula, and these appear to be outliers of the great Cretaceous area extending east from the head of Norton Bay.

Surficial deposits occur throughout the peninsula and are locally of great commercial importance because of their content of placer gold.

STRATIGRAPHY OF NOME AND GRAND CENTRAL QUADRANGLES.

The oldest rocks within the area represented on the Nome and Grand Central maps are found near its northern boundary (Pl. IV, in pocket) and make up the greater part of the Kigluaik Mountains. They occupy about 45 square miles, or 8.5 per cent of the mapped area, and consist of biotite gneisses, coarsely crystalline limestone, biotite schist, and siliceous graphitic schist. They have a general dip to the south and are intruded by dikes and sills of granite, diorite, and diabase. The granite forms one area of considerable size. This series or group of rocks, omitting the graphitic siliceous schist but including limestones and gneiss not represented in the Grand Central quadrangle, was named Kigluaik by Brooks.[1]

Overlying the Kigluaik group and occupying nearly all the remainder of the area mapped (Pls. III and IV, in pocket) is another series of rocks consisting chiefly of chloritic and feldspathic schists and altered limestones with many greenstone intrusives. Beds of black graphitic schist or slate not distinguishable from those of the Kigluaik group occur in many places, and several small areas of granitic rocks, the largest being that of Cape Nome, are present. This series of sedimentary and igneous rocks, except the granites,

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 27.

shows a more intense folding than is seen in the schists of the Kigluaik group, and its structure appears to be far more complicated. Brooks applied the name Nome to this group.

The Kigluaik and Nome groups comprise all the hard-rock formations of the Nome and Grand Central area, but the area contains widely distributed unconsolidated deposits. An extensive mantle of gravel, sand, and finely ground rock waste covers the lowland bordering Bering Sea, floors the stream valleys, and in the southern part of the region locally reaches well up on the hill slopes or covers the low parts of divides. These water-worn fragmental deposits are overlapped in most places by the more or less angular, unassorted débris that covers the upper slopes, in places even the tops, of all the hills, and that under the influence of frost and rain slowly works its way to lower levels. Less widely distributed but of local importance are the unconsolidated accumulations resulting from glaciation. A blanket of moss and other vegetation, overlying both the unassorted and the water-laid accumulations resulting from rock weathering, makes it impossible in nearly all places to see where the first begins or the other leaves off, and it is necessary to rely on a few scattered prospect holes for aid in drawing a boundary between them.

The outline of the stratigraphic succession just given is represented in the following table:

Quaternary (possibly including some Tertiary):
- Unconsolidated deposits—
  - Sands and gravels of marine and of fluvial origin; glacial deposits; mantle of unassorted débris due to weathering.

Paleozoic (probably middle Paleozoic):
- Nome group—
  - Schists with thin limestone beds and intruded greenstone sills.
  - Limestone with thin schist beds.
  - Schists with thin limestone beds and greenstones.

Early Paleozoic (possibly in part pre-Paleozoic):
- Kigluaik group—
  - Tigaraha schist (biotite schist, garnetiferous and staurolitic in places).
  - Limestone.
  - Gneiss.

The two lowest formations of the Kigluaik group are not present in the Grand Central quadrangle.

On the geologic maps (Pl. III and IV, in pocket) are represented the upper part of the Kigluaik group—the Tigaraha schist, the only formation of the Kigluaik group that is exposed in this area—and the Nome group, together with the larger areas of igneous rocks accompanying them and the gravel deposits.

The Tigaraha schist is distinguished from the schists of the Nome group by its lithologic character. Biotite is a characteristic feature of the Tigaraha schist and is in many places associated with staurolite. These minerals are not characteristic of the overlying rocks, and on the geologic maps the boundary between the top of the Tigaraha schist and the base of the Nome group is placed at the top of the staurolitic biotite schists. Thus an area of about 45 square miles occupied by the upper formation of the Kigluaik group is shown on the map. Within this area one principal granite mass occurs and there are smaller dikes and sills of granite or granitic rocks in a number of places, more especially south of Thompson Creek.

Much the greater part of the mapped area is occupied by the Nome group. Two principal types of rock are represented—schists and the most important limestones. Greenstone areas also are mapped in several places, but no attempt has been made nor does it appear possible to differentiate the greenstone schist of igneous origin from that of sedimentary origin. In outlining the limestone areas it was not found desirable to indicate many of the thin schist beds occurring in the limestone, because the exposures in most places are too poor to allow it to be done with a reasonable degree of accuracy. Poor exposures also have made it impossible to correlate many of the limestone outcrops, and as no fossils were found in any of the limestones, and there are no other distinctive features that permit individual beds to be recognized over any considerable area, the detailed structure of the Nome group is not fully understood. The surprising irregularity of the limestone areas is due in part to faulting, in part to variation in thickness of the beds, and possibly (see p. 29) in part to unconformities within the Nome group, although no definite evidence of this possibility was obtained. Many thin limestones interbedded with the schists as well as calcareous phases of the schist are not represented. A number of granite areas, one near Copper Creek, several east of Mount Distin, and a large one at Cape Nome appear within the Nome group and are outlined on the map. The boundary of the granite mass at Cape Nome, however, is only approximate, as the contact is nowhere exposed.

In representing the gravels it is necessary, owing to the small scale of the map, to leave the color off most of the smaller streams, hence in examining the areas of the deposits it should be remembered that gravels are present on all the creeks, at least in their lower portions. Only surficial deposits that have undergone sorting by water or have resulted from glacial action are shown. Undoubtedly there are on hill slopes and in some of the saddles areas of gravel that are not represented on the map. Inaccuracies in the boundaries of gravel areas will also be found, but these are inevitable in a region where so much of the surface is covered with moss or with rock waste from the upper hill slopes.

KIGLUAIK GROUP.

LOWER FORMATIONS.

The Kigluaik group, as it is seen in the region of Mount Osborn, comprises three principal formations—a basal gneiss, an overlying heavily bedded limestone, and an upper formation consisting of a great thickness of schists and a few thin limestone beds.

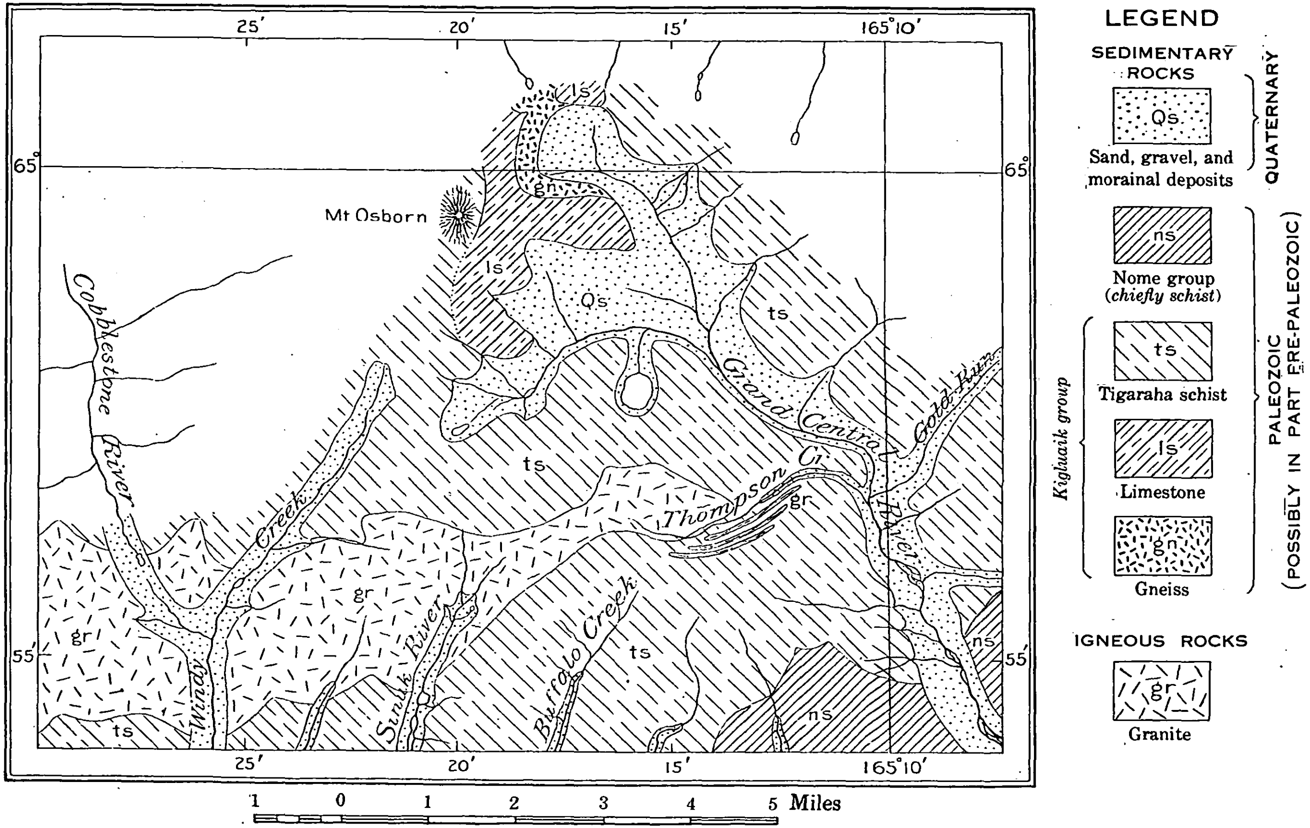
The lowest formation is not exposed within the area represented on the Grand Central map. It is found at the base of Mount Osborn and consists of a biotite gneiss cut by many intrusive masses. (See Pl. VII.) These two rocks are mingled in a most intimate way. The light-colored granitic portions intensify this appearance, as they are drawn out and folded and show a well-developed flow structure. The gneiss is a dark coarse-grained rock containing a large amount of biotite and forms more than half the vertical section of Mount Osborn. (See Pl. XI, p. 62.)

The coarsely crystalline limestone overlying the gneiss does not appear at the surface in the Grand Central area. It has a thickness of 800 to 1,000 feet and is well seen on the east side of Mount Osborn, where its complete section is exposed (Pl. XI). In the central mountain mass it lies horizontal, but on the south and east, possibly on the west and north also, it dips under the schist.

The limestone gives rise to some of the most striking topographic features of the region. It forms the uppermost precipitous slopes of Mount Osborn, on whose top, however, a small mass of schist still remains, and it caps the lower summits on the north, where the white cliffs stand out prominently. All exposures are much weathered, the crumbling débris lying in small talus slopes at the base of the ledges. Although this limestone has been subjected to alteration in various ways and is entirely recrystallized, it does not show secondary minerals like those found in some of the thinner limestone beds of the Kigluaik group.

TIGARAHA SCHIST.

Overlying the limestone of Mount Osborn is a great thickness, at least several thousand feet, of brown-weathering biotite schist, to which the name Tigaraha is applied. The type locality includes a sharp peak near the head of Buffalo Creek, which is here given the name Tigaraha Mountain, ti-ga-rah′-a being the Eskimo word for pointed. As used in this paper the term Tigaraha schist denotes all that part of the Kigluaik group between the top of the limestone of Mount Osborn and the base of the Nome group. Between Mount Osborn and the upper valleys of Sinuk and Nome rivers the schist dips uniformly to the south at angles less than 35° in most places



GEOLOGIC SKETCH MAP OF REGION AT HEADS OF GRAND CENTRAL RIVER AND WINDY CREEK.

where observations were made. The south wall of the west branch of Grand Central River, which is made up entirely of the Tigaraha schist, exposes at least 2,500 feet of the formation, but does not include its upper and probably greater part.

The Tigaraha schist as defined shows variety in the character of the sediments from which it was produced, but the presence of biotite is a constant feature and was used by the earlier workers, as it has been in this report, as a means of distinguishing the schists of the Kigluaik Mountains from those of the Nome group. Collier,[1] in describing the schists of the Kigluaik group, says: "The schists which comprise the greater part of this group are generally dark gray in color and consist essentially of quartz and biotite, with various accessory minerals in the different beds, such as graphite, pyrite, magnetite, garnet, staurolite, hornblende, augite, orthoclase, plagioclase, etc."

The schist is for the most part fine grained and has a rather smooth cleavage. Biotite is the conspicuous mineral. Large red garnets are not uncommon. Locally many small flakes of graphite are present, and on hasty examination might readily be confused with the mica. The brown color by which the outcrops may be distinguished at considerable distances is due to a small amount of iron oxide resulting from the weathering of iron-bearing minerals in the schist. Thin dikes and sills of coarse pegmatitic granite are numerous, and larger masses of finer-grained granite have been intruded.

Above the brown-weathering lower part of the schist lies more biotite schist, which is highly siliceous in most places and may possibly represent altered sandstones or quartzites. Still higher, forming the upper part of the group, are beds of staurolite-biotite schist and black siliceous graphitic beds. Staurolite schist was found in the upper part of the Kigluaik group wherever the top of the group was observed. The black graphitic beds are irregular in their areal distribution and exceedingly variable in thickness, being far more prominent east of Buffalo Creek than west of it. It should be said, however, that west of Buffalo Creek they may be covered by the gravel deposits of Sinuk River. The black graphitic schist is a hard siliceous rock with a platy cleavage and is entirely distinct from the graphite-bearing schist overlying the heavy limestone. In the former the carbonaceous matter is present as a fine dust throughout the rock, whereas in the latter graphite occurs as well-defined scales or flakes.

These black beds were considered by the earlier workers to be entirely distinct from the Kigluaik group and were believed to be

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 66.

part of the Kuzitrin formation. It is difficult to determine exactly the relation between the two, but in the Grand Central region there can be no doubt that in some places the thinner beds are entirely conformable with the biotitic schist with which they are interbedded.

From evidence obtained along Kuzitrin River northeast of the Kigluaik Mountains, where the black beds are best developed, Brooks considered their probable relation with both the underlying biotite schists and the overlying Nome group to be one of unconformity, but states that the evidence is not conclusive.[1]

Although the name Kuzitrin has been applied to the black carbonaceous schists on the south flank of the Kigluaik Mountains east and west of Nome River, the separation is not made here, because the black schists occur interstratified with biotite and staurolite schists that have been included in the Kigluaik group. At the same time it should be kept in mind that, as previously stated, these black beds are not distinguishable lithologically from the black carbonaceous schists of the Nome group. The relative age of the beds is known only by their stratigraphic position, for no organic remains have been discovered in any of the rocks described. Moreover, there is a doubt whether they can be correctly correlated with the black schists or slates of the type locality on Kuzitrin River. There seems, therefore, to be no good reason in this particular region for separating schists that differ no more than these do in lithologic character and that follow one another in conformable succession, unless the separation can be made on evidence afforded by fossils. Consequently the siliceous beds with their staurolitic and intercalated carbonaceous members are regarded as forming the upper part of the Tigaraha schist.

Thin limestones appear here and there in the Tigaraha schist, but are not so numerous as in the schists of the Nome group, to be described later. The limestone beds are invariably much altered. They have become coarse, crumbling marbles and in places contain secondary minerals, such as spinel, malacolite, and a light-brown mica. These minerals were found in limestones that have been highly folded and are associated with granitic intrusions. In the upper part of the Grand Central River valley there are bowlders which consist of a highly altered malacolite-bearing limestone containing many rounded pebbles of various dark eruptives, but the rock from which these bowlders were derived was not found in place. The limestone beds in the upper part of the Kigluaik group are less altered than those in the lower part, and the secondary minerals mentioned above were not seen.

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 29.

AGE.

The basal beds of the Kigluaik group are believed to be among the oldest strata exposed on Seward Peninsula and possibly in Alaska, although the rocks themselves contain no fossils to support this belief, and it is not now susceptible of proof. The evidence in its favor is derived from the stratigraphy, from the character of the rocks, and from comparison with other districts.

The oldest known fossiliferous sediments of Seward Peninsula are exposed in the York Mountains, about 60 miles northwest of the head of Nome River. Upper Cambrian fossils were found there by Kindle in limestone that had been regarded as part of the Port Clarence limestone. There is no proof that the Cambrian limestone of the York Mountains is equivalent to the massive limestone at the base of the Kigluaik group, but there can be little doubt that the latter is older than part of the limestone that has been called Port Clarence. The limestone of Mount Osborn rests on gneiss and is itself highly metamorphosed. Moreover, it underlies the Tigaraha schist, and the best available evidence favors the view that it is older than the schists and limestones of the Nome group south of the Kigluaik Mountains. A large part of the schists and limestones of the Nome group are considered to be of Silurian and Ordovician age, although, as stated, Cambrian and Carboniferous limestones have also been included in it.[1] The age of the Nome group will be considered more fully later, but evidently there is ground for considering the Kigluaik group as early Paleozoic rather than late Paleozoic, and it may be Upper Cambrian or earlier, possibly even in part pre-Paleozoic.

INTRUSIVES ASSOCIATED WITH THE KIGLUAIK GROUP.

All the formations of the Kigluaik group are cut by intrusives, the most common of which is granite. These intrusive rocks, however, are far more abundant in the lower part of the group than in the upper part. Besides the granite intrusives, dikes and sills of diorite, diabase, and pegmatite are present.

GRANITE.

The granite is a normal biotite granite belonging to two or more periods of intrusion, as is shown by intersecting dikes and possibly by differences of alteration. Its color is light gray, and it varies greatly in the amount of alteration it has undergone. In some places it is massive, with no marked cleavage, but in others it is a coarse

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 62.

gneiss or schist. The gneissoid or schistose phases show the development of a considerable amount of biotite. Although they may possibly represent older intrusions that now form part of a larger granite complex, it is probable that, in part at least, they belong in zones where pressure on the whole mass has found relief in the development of the secondary structure.

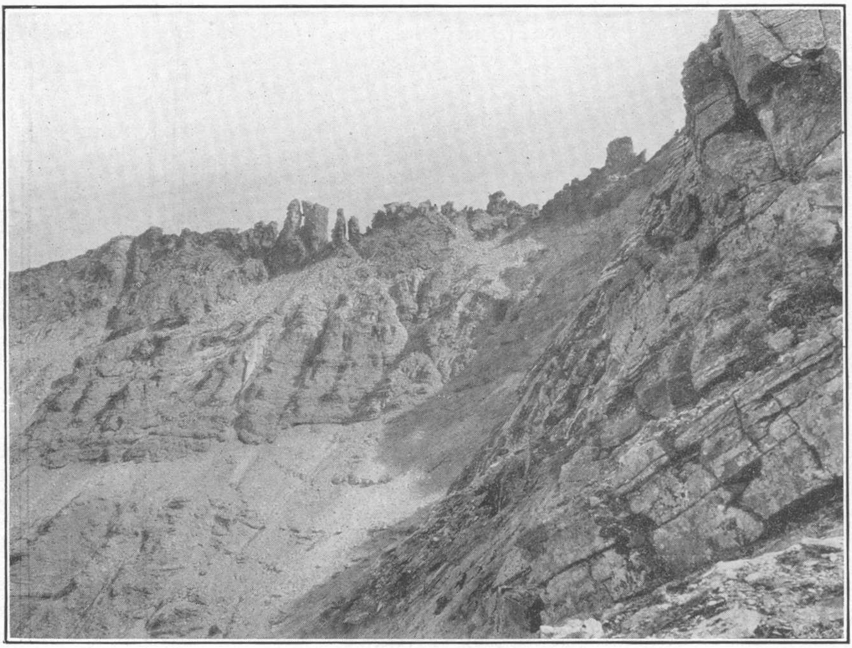
Some of the finest scenery and most rugged topography of the Kigluaik Mountains is due in part to the presence of these intrusions of granite. The lofty southern walls of several valleys are formed by it, and many of the gentler slopes are entirely covered with the massive blocks pried off by the winter's ice. Perpendicular joint planes have permitted frost to carve the rock into all sorts of fantastic shapes, and the spires and pinnacles rising from the steep ridges (Pl. VIII, *A*) have given this range the name by which it is commonly known—the Sawtooth Mountains.

The largest granite mass of the region extends from the western limit of the Grand Central quadrangle eastward across Windy Creek and Sinuk River to the head of Thompson Creek, occupying a wedge-shaped area with its narrow end toward the east. It is intruded along the bedding planes, underlying the schists on the south and overlying those on the north. At the head of Thompson Creek it loses its individual character and splits up into many sills (Pl. VIII, *B*), which are well shown on the steep slope south of the stream. The separate sills there continue for long distances with only little difference in thickness or character. In places the large granite mass is cut by black diabase dikes and more rarely by dikes of diorite.

In the Kigluaik group small dikes and sills are most numerous near the main intrusive masses and show themselves to be of different ages by the manner in which they intersect one another and possibly by their different degrees of metamorphism. On one of the tributaries of Cobblestone River, north of Windy Creek, a banded gneiss is cut by a dike of fine-grained light-gray granite. This in turn is crossed by a second gray granite, and all three are cut by black diabase dikes.

DIORITE.

Diorite is not a common rock in the Kigluaik Mountains. It was observed in only a few places, where it occurs as small dikes associated with the granite. Dikes of diorite cut the granite in the vicinity of Windy Creek and are conspicuous because of their dark color. These dikes are fine-grained rocks with a pepper and salt appearance, produced by the little grains of feldspar and black hornblende. They are more or less sheared wherever they were seen and have a good cleavage. When examined under the microscope sections of the dike rock are found to consist almost entirely of horn-



A. CHARACTERISTIC RUGGED RIDGE IN THE KIGLUAIK MOUNTAINS.

View to the northeast from saddle at head of East Fork of Grand Central River.

B. GRANITE SILLS IN THE SOUTHWARD-DIPPING BIOTITE SCHIST OF THOMPSON CREEK.

blende and plagioclase feldspar, with magnetite, apatite, and zircon as accessory minerals. Some sections show biotite and titanite also. In spite of the well-developed cleavage, the rock is remarkably fresh.

DIABASE.

Dikes of diabase are more numerous than dikes of diorite in the portion of the Kigluaik Mountains included in the Grand Central quadrangle. In the lower part of the Kigluaik group, in the vicinity of Mount Osborn, they are abundant. They appear to be the most recent and least altered of all the intrusive rocks of the region. All the dikes seen were small, most of them not more than 2 or 3 feet thick. The microscope shows them to be typical diabases having a felty groundmass of lath-shaped feldspar with pyroxene crystals between. Magnetite and a little biotite are present. A slight alteration is usually seen, and in some sections the alteration is considerable but not enough to hide the original characters of the rock.

PEGMATITE.

Pegmatite dikes are numerous in the Tigaraha schist between Sinuk River and the granite area on the north, particularly in the little area of schist west of Windy Creek. None of them were traced into the granite mass, but it is believed that their origin is directly connected with the granite intrusion. A small dike about a mile west of the mouth of North Star Creek is typical of these pegmatites and attracts attention because of the beauty of some of its well-crystallized minerals. It is light gray in color and consists principally of gray quartz and bluish-gray feldspar that are in places intergrown in such a way as to produce the structure of graphic granite. The associated minerals seen in the hand specimen are brown and white micas, tourmaline, garnet, and beryl. Feldspar crystals up to 1 inch or 1¼ inches in diameter are plentiful. Black tourmalines 2 or 3 inches long and up to half an inch in diameter are probably the most conspicuous of the minerals. They are arranged radially in places but near the edge of the dike assume positions perpendicular to the walls. Tourmaline and white mica are most abundant near the contacts with the schist. Red garnets are exceedingly abundant and range in size from those almost too small to see without the microscope to those one-quarter inch in diameter. Their crystal forms are finely developed. Some crystals of beryl are seen.

In the schists about the head of Windy Creek coarse pegmatites carrying graphite are present as sills and dikes, but they resemble coarse granite and do not present the interesting features of the dike just described. The occurrence of such dikes in the vicinity of Windy Creek and the presence of stream tin on Goldbottom Creek only a few miles to the south suggest the possibility that some of the pegmatites may be found to carry tin.

AGE.

It has been shown previously that the intrusives in the Kigluaik group were injected at several different periods. This is well illustrated by the occurrence on Cobblestone River, where the gneisses are cut by three distinct intrusions, and by that on Windy Creek, where diorite dikes cut the massive granite. Granite dikes cut the Nome schists also, and very extensive intrusions of diabase in the form of sills and dikes are widely distributed through the Nome group. All these igneous rocks are more or less metamorphosed and are therefore distinctly older than the recent lavas of northeastern Seward Peninsula. No evidence to show that the granitic intrusives of the Kigluaik group are older than those of Nome group has yet been found, but it is believed that the pegmatite dikes of the Kigluaik Mountains are associated in origin with the granitic intrusives. The pegmatite dikes show little alteration and are therefore assigned to one of the later periods of intrusion. It is recognized, however, that the degree of metamorphism may be an unsafe guide in determining the relative age of rocks in this region. Smith and Eakin[1] have shown that the massive Cretaceous conglomerate east of the Darby Range contains granitic bowlders and pebbles derived from the Darby and Bendeleben mountains, and further that there are minor granitic intrusions in the Cretaceous sediments. Without much doubt the principal periods of intrusion for the granites and related granular rocks are pre-Cretaceous. Possibly part of them may belong to the period of intrusion that occurred in late Jurassic time and is well represented in many other parts of Alaska, such as the south coast region. Others are probably very much older.

For lack of definite evidence as to the age of the inclosing rocks, it is not possible now to do much more than determine the relative age of such intrusives as afford favorable conditions for observation, like those in the localities noted.

NOME GROUP.

The Nome group within the area under discussion consists mainly of schist but includes limestone, which is present in most of the area and is important in several parts of it. Calcareous schist or impure schistose limestone is locally well represented and is in many places of such character as to cause doubt whether it should be mapped as limestone or as schist.

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

SCHIST.

The different kinds of schist may be broadly classified as chloritic schist, feldspathic schist, and siliceous graphitic schist, but these all present numerous variations.

Chloritic schist is the most common kind. In fact, chlorite is rarely absent in any of the schists except the siliceous graphitic varieties, although the amount is in places very small and may not be sufficient to give any marked greenish tinge to the rock. In such less chloritic phases of the schist, quartz is more prominent and with the mica gives a gray color to the fresh specimens. Contrasted with such types are those in which chlorite is the most prominent mineral, and the rock takes on a characteristic green color. Such schist in places grades into the least feldspathic of the feldspar-bearing schist, which carries the albite crystals in amounts not readily seen without the microscope.

The feldspathic schist is so called from the presence of small albite crystals, most of which are not over an eighth of an inch in greatest dimension, though some reach diameters of one-quarter or three-eighths of an inch. The feldspar gives a peculiar speckled appearance to the rock and is best seen on a surface cutting across the cleavage. On cleavage surfaces the small white crystals may be entirely hidden by scales of mica or chlorite. Chlorite is present throughout, and usually more or less quartz may be recognized. The schist is green or greenish gray because of the chlorite constituent, but in certain places the color may be due in part to a considerable content of epidote and hornblende.

A part of the feldspar-bearing schist is derived by metamorphosis from rocks of sedimentary origin and another part results from the alteration of igneous rocks described on page 32. Proof of the sedimentary origin of some of the feldspathic schist is afforded chiefly by its field relation with the associated schist or limestone. Exposures of thin-bedded feldspathic schist and limestone are found at a number of localities and are of such a character as almost to preclude the possibility of the schist having any other than a sedimentary origin. A 6-foot ledge of this kind on the south side of David Creek was found to be made up of alternate beds of feldspathic schist and yellow-weathering limestone, none of which were over 2 inches thick and which averaged probably not over 1 inch.

It is possible that feldspathic schists of this kind have been derived either from sediments resulting from the rapid breaking down of igneous rocks and the accumulation of the waste material in arkose or graywacke beds, or from beds of tuffaceous material formed at times of volcanic outbursts and outpourings of lavas such as are abundant in parts of Seward Peninsula. This theory of origin is suggested as a reasonable explanation of the similarity between feldspathic schists believed to be altered sediments and those believed to be altered igneous rocks. The proof of such an origin for the schists under discussion is lacking, however, for the rocks are now too greatly changed to give reliable testimony as to their original condition. The outcrop on David Creek is believed to furnish evidence of rapid and repeated changes of conditions of sedimentation, causing the deposition of calcareous material to be frequently interrupted by that of argillaceous material whose chemical composition was such that on being metamorphosed it was capable of producing feldspathic schists similar in appearance to those of igneous origin. The second kind of feldspathic schist will be considered in connection with the eruptive rocks associated with the group.

The siliceous graphitic schist is black or dark gray. Quartz is its chief constituent, and a fresh surface is commonly covered with a fine black dust which soils the hands. The rock is hard, weathering into angular platy fragments that ring under the feet like cinders when the shattered outcrops are crossed. Many exposures are recognizable at considerable distances by their color, but may be confused with the black lichen-covered débris of some of the more siliceous chloritic schist. As far as external appearance is concerned, the rock is exactly like much of the siliceous graphitic schist of the Kigluaik group, but none of it shows any biotite on the weathered surface.

No definite constant relation was made out between the black schist and the other schists or the limestones. The black schist occurs irregularly in many parts of the region, the largest area of it being on the ridge between Anvil Creek and Snake River. The south end of this ridge is made up of the black schist, which continues along the top of the ridge about three-quarters of a mile. Another large area is at the north end of the top of the hill between Goldbottom Creek and North Fork. Still another is at the top of the ridge between Charley Creek and Stewart River.

The black schist beds of the Nome group are in most places thin, rarely reaching a thickness as great as 50 feet. On the ridge between Charley and Silver Creeks beds of black schist from 1 foot to 2 or 3 feet thick are interstratified with chloritic schist. At this locality the amount of graphitic material appears to vary along the strike of the beds, so that in places the rock becomes a gray quartzite. The same variation in the proportions of quartz and graphitic material was observed at other places.

LIMESTONE.

Limestone beds are interstratified with schist in all parts of the Nome group. They are for the most part light gray or bluish gray in color, but in places they are dark gray owing to the presence of carbonaceous matter. All these limestones are metamorphosed in some degree, many being entirely recrystallized. A careful examination of beds that at first glance appear to be little disturbed may show that they have been intensely folded and that the overturned portions have been compressed so that the limbs of the folds lie parallel with the bedding. Folds of this kind occur at short intervals. (See fig. 2.) Large exposures show that the limestones are cut by many joint planes and by small faults.

Heavy limestone beds form prominent topographic features in many localities. The cliffs and ledges or the rounded hills strewn with white limestone fragments are recognizable at considerable distances and easily lead to the belief that the rock covers far greater areas than it does. Irregularity in thickness characterizes most of these beds. Heavy strata thin out abruptly or disappear altogether. Some of these changes are due to faulting, but others have resulted

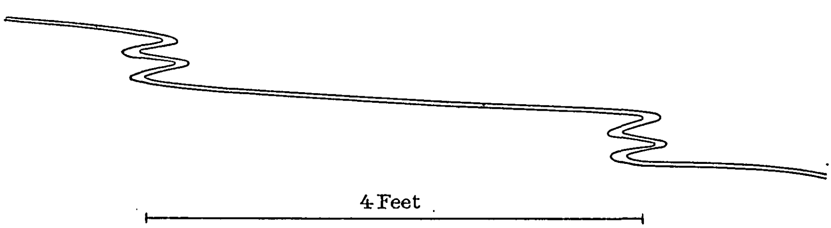


FIGURE 2.—Folded beds in thick horizontal limestone stratum.

from a rapid decrease in thickness, some possibly from a change in sediment along the strike, although no unmistakable example of such a change was seen. Unconformities within the Nome group might give rise to such an irregularity also, and this explanation was kept in mind during the field work, but no definite proof of it was obtained. Some evidence was collected, however, which indicates that unconformities may exist. Another explanation of this variation which seems to apply in some places is that the beds have been either thickened or compressed by the pressure and folding that they have undergone. An overturned fold pressed tightly together could give rise to the condition described.

Many limestone beds, too small or too poorly exposed to be separately mapped, occur throughout the Nome group. These range in thickness from a few inches to possibly 50 feet or more. The most extensive limestone area shown on the map includes Mount Distin and vicinity. Mount Distin is a mass of interbedded limestone and chloritic schist cut by greenstone dikes, limestone being by far the most abundant member. It is a synclinal mountain with the strata dipping in on all sides. The base of the mountain, as is best shown on its southern slope, is made up of alternating beds of limestone and schist, capped by not less than 800 feet of heavily bedded limestone, in which are a few brown-weathering impure beds. These interbedded limestone and schist strata make up the area included by Stewart River, Goldbottom Creek, and Nome River, but they are folded and faulted so that their areal distribution is extremely complicated.

These rocks are probably to be correlated with those in the area extending southwest from Salmon Lake to Nome River, also with those east of Nome River below Hobson Creek, but whether they correspond with the limestone forming the south front of Anvil and Newton peaks or with those at the head of Osborn Creek or on Fox Creek is questionable. The limestone forming the north front of the hill south of Salmon Lake is not less than 800 feet thick, but toward the southwest interbedded schists appear and faults are so numerous that the structure and thickness are uncertain. It is evident, however, that the limestone has no such thickness as is shown in Mount Distin. Between Sampson and Basin creeks the upper part of the limestone is a heavy bluish-gray bed at least 600 feet thick. It overlies interbedded schist and limestone which also have a thickness of not less than 600 feet. It is much faulted and toward the south disappears altogether.

Collier[1] has correlated the limestone of Mount Distin and the limestone south of Salmon Lake with the Port Clarence limestone of Cambrian and Ordovician age, which is typically developed in the northwestern part of Seward Peninsula, and was named from its occurrence near Port Clarence. This correlation was made on stratigraphic and lithologic grounds and not on fossil evidence or structural continuity. No new evidence on this question was discovered during the field work of 1905 and 1906, but in view of the fact that Cambrian and Carboniferous limestones have been mapped as part of the Port Clarence such a correlation can now mean no more than that the limestone of Mount Distin corresponds to some part of the Port Clarence limestone.

The southern faces of Anvil Peak and Newton Peak are formed by a limestone that extends from Anvil Creek to Nome River. It dips north under the schists that make up the greater mass of these hills, but stops abruptly at Anvil Creek. Drill holes along Nome River from Laurada Creek to Tripple Creek show limestone bedrock, which probably is part of its eastward continuation. It is folded and faulted, and its base in most places is covered by débris from the hill slopes and by gravels of the Nome tundra, so that its thickness is uncertain, though it can hardly be less than 400 feet.

[1] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 15; The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 62.

Another limestone mass of considerable size lies between New Eldorado Creek and Flambeau River, and its cliffs form a prominent topographic feature of the region. It overlies and is overlain by schist, thus forming an irregular zone around the central schist mass. The overlying schist is in part an altered intrusive, a fact which may account for the apparent great variation in the thickness of the limestone.

AGE.

In discussing the age of the Nome group it is necessary to make reference to previous geologic work in other parts of the peninsula that has had to do with the same problem. The Nome group has been held to consist essentially of three formations, two of schist, separated by the third, a massive limestone formation called the Port Clarence limestone, from its type locality north of Port Clarence. This limestone occupies extensive areas in the northwestern part of the peninsula and from fossil evidence was considered by Collier[1] to be of Ordovician and Silurian age. It overlies a succession of arenaceous slates that are exposed a short distance northwest of Cape York,[2] but its relation to the graphitic, chloritic, and calcareous schists north of Grantley Harbor is obscure, although it has been supposed to overlie them also. These last-named schists, as mapped by Collier, underlie the limestone of Baldy Mountain north of Kuzitrin River, which he considered as belonging to the Port Clarence and from which Carboniferous or Devonian fossils are reported by Kindle.[3]

Kindle also found Upper Cambrian fossils in the Port Clarence limestone of the York Mountains. In brief, the rocks that have been mapped as Port Clarence limestone are not a single formation, but are composed of various limestones ranging in age from Cambrian to Carboniferous. They can not be correlated as a whole with the limestone of Mount Distin and the south side of Salmon Lake valley. Probably the limestone of Mount Distin is equivalent to some part of the Port Clarence limestone and is of Paleozoic age, but no evidence has yet been obtained for any more definite correlation. We are thus at a loss for satisfactory evidence as to the age of the other formations of the Nome group, as correlation of the schists is even more difficult and uncertain than correlation of the limestones. It seems probable that a middle Paleozoic age for the limestones and

[1] Collier, A. J., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, Pl. XI, in pocket.
[2] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: Bull. U. S. Geol. Survey No. 358, 1908, p. 13.
[3] Kindle, E. M., The faunal succession in the Port Clarence limestone: Am. Jour. Sci., 4th ser., vol. 32, 1911, p. 349.

schists of the Nome group may some day be established, but it can not be done with the evidence now at hand.

IGNEOUS ROCKS ASSOCIATED WITH THE NOME GROUP.

The igneous rocks associated with the Nome group are of two general classes—greenstones or altered basic intrusives and granitic rocks. Greenstones are distributed irregularly through the entire area under consideration. The granitic rocks, on the other hand, are not abundant and are found in notable quantity in only one locality.

GREENSTONE.

The rocks called greenstone are all more or less altered intrusives occurring as dikes and sills that cut the limestone and schist formations of the Nome group and the granite of Cape Nome. No igneous rocks of exactly the same character were seen in the Kigluaik group. The dark basic dikes found there are all of diabasic or dioritic varieties; and although the greenstones are probably related to the diabasic dikes they are in a measure distinct.

The less schistose greenstones are heavy dark-green rocks of fine grain, in which the most conspicuous minerals are red garnet and pyrite or the iron oxide resulting from its decomposition. The bright cleavage faces of small hornblende crystals and the lighter green of the chlorite may also be distinguished. In some of the greenstone, however, garnet and pyrite are present only in small quantity and may not appear in a hand specimen. The most typical and least schistose greenstone, such as is found near Osborn Creek, when examined with the microscope shows garnet, green and blue hornblende (glaucophane), chlorite, epidote, and titanite surrounded by albite, which contains many small inclusions and forms a sort of groundmass. Magnetite or ilmenite, pyrite, titanite, rutile, quartz, and calcite are found in some of it. The rock of this locality is an eclogite and where most metamorphosed has become a feldspathic schist. It is extensively exposed in the southern two of the three rounded hills between Osborn and Buster creeks, where it is associated with limestone beds and with chloritic and feldspathic schist. Its relation to these rocks is not clear, but the greenstone probably occurs in them as large sills or dikes. The outcrops are few, and little débris other than that of the greenstone is seen on these hills.

Greenstone intrusives are common east of Nome River, but are less prevalent west of it. They are found in the vicinity of Newton Peak and Mount Distin and at a few other places as dikes cutting the limestone. As a rule the greenstones do not appear as ledges in place, but as heaps of blocks or smaller débris strewn over the hill slopes or tops.

The degree of metamorphism varies greatly, but greenstone is found which has not been highly altered. Where it is inclosed in limestone it seems to have suffered less from pressure and is less schistose than where it cuts the other rocks. Even the hard massive blocks, which appear to have undergone little metamorphism, are seen, when studied microscopically, to contain a large proportion of secondary minerals.

GRANITE.

The largest granite area is found at Cape Nome. It includes gray granite, some of it slightly yellow from weathering, and gray gneiss, apparently derived from the granite by metamorphosis. The seemingly homogeneous granite when looked at in a large way is seen to have a banded structure like the gneisses. Both granite and gneiss are intruded by greenstone and by a coarse dark-gray porphyritic rock containing feldspar crystals, many of which are 1 to 1½ inches in diameter. The porphyritic intrusion in turn is cut by granite.

The granite is a fine-grained biotite rock more or less metamorphosed. Allanite is commonly present. Epidote is seen in many of the thin sections, also microcline and titanite or leucoxene. The common secondary minerals are chlorite and albite. The degree of alteration expressed by the development of schistosity varies in different parts of the mass and is greatest near the boundaries, especially toward the north, where the granite either has become a feldspathic schist or grades into it. The porphyritic phase is a darker gray than most of the other granite, but its most notable feature is its abundant content of large crystals of orthoclase feldspar. Quartz, orthoclase, microcline, albite, epidote, and biotite are the principal minerals seen with the microscope. Allanite is present in much of it. The large feldspar crystals are filled with minute mineral inclusions, chiefly quartz.

Only part of the granite area, about 3¾ square miles, is included in the Nome quadrangle, and the greater portion may lie east of it. The boundaries, however, are indefinite, for the contact is nowhere seen, and outcrops, except on the seaward face of Cape Nome, are few. It is not possible with the data available to determine whether the granite of Cape Nome was intruded into the Nome group or whether the rocks of the Nome group were laid down upon it. Furthermore, there is no means of telling what age relation exists between the granite of Cape Nome and the granite intrusions of the Kigluaik Mountains. Like the latter, it is the product of several intrusions, but whether the intrusions took place at widely different times has not been determined. The greater alteration of the granite of Cape Nome and the presence in it of allanite, a mineral not seen in the northern granites, may be considered as indicating greater age and a different source, but these differences seem to be hardly sufficient to warrant the statement that the two granites are entirely unrelated.

Two or three small areas of much-altered granite are found within the Nome group, the most notable lying northeast of Mount Distin in the vicinity of Lost Creek and on the north slope of the hill west of Copper Creek. They are most probably associated with the granite intrusives of the Kigluaik group.

AGE.

Little more can be said about the age of the intrusives in the Nome group than has been stated in considering the intrusives in the Kigluaik group. They belong to several widely separated periods, possibly ranging from the Paleozoic into the Mesozoic.

A large part of the greenstone intrusives, both sills and dikes, are extensively metamorphosed. Most of them are entirely recrystallized and show the secondary structure of the inclosing schists. A smaller part, represented chiefly by dikes in limestone and in schist, have undergone severe alteration, but do not show the secondary structure, such as cleavage or schistosity, of the inclosing rock. Good evidence for a number of distinct times of intrusion is shown in the granite area of Cape Nome, where the oldest granite and the gneiss, which may themselves be of different ages, are cut by dikes of greenstone and of porphyry, and the porphyry in turn is cut by granite. Such relations show the complicated character of the history of the intrusions and indicate the relative age of the intrusive rocks. They do not, however, reveal anything as to the time of intrusion, and such information must be gained from the inclosing rock and from the relations between it and the intrusives. Probably the periods of intrusion extended into post-Cretaceous time, but no lower age limit can be given, because the age of the sediments composing the Nome group is unknown further than that they were probably laid down in Paleozoic time.

VEINS.

Deformation and rupture of the rocks, especially those of the Nome group, have given opportunity for the circulation of mineral-bearing solutions and the deposition of veins of quartz and calcite. Quartz occurs principally as lenses and stringers in the schist, but also as well-defined veins cutting the schist. The small quartz deposits in the schist and perhaps some of the larger veins also are believed to have been introduced during the time in which the principal deformation of the Nome group took place, for many of them are found to be folded with the schist and to have suffered alteration with it.

Veins of white quartz of considerable thickness—10, 12, or even 20 feet—occur, but none yet observed have been traced for more than short distances. It is suggested that they may be connected genetically with the pegmatite dikes found in the Kigluaik Mountains, but of this there is no definite proof, and in fact their small horizontal and vertical extent would seem to oppose this idea. They are believed to be younger than the small veins and lenses just mentioned but have been subjected to the later movements that affected the schists in which they occur. In several localities small prospect holes or short tunnels driven in the large quartz masses show the quartz to be much broken and faulted, and though the weathered surface is milky white the joint planes and cracks are stained with iron oxide. They show little mineralization, however. Few of these large quartz masses appear to occupy well-defined fissures; as a rule they seem to fill spaces of very irregular outline. The schists nearer them are always greatly disturbed, and the veins themselves are broken and crushed.

Small quartz veins, though less conspicuous, are far more numerous and here and there are well mineralized. They appear as small lenses, either lying in the cleavage or crossing it, as fillings along joint planes, and as narrow veins or flattened lenses of fairly regular thickness but small longitudinal extent. A broken surface of such a vein may show sulphides, such as pyrite, or more commonly a cavernous interior filled with iron oxide derived from the alteration of pyrite. Some of these veins are known from numerous assays to carry gold in small quantity.

Calcite veins are restricted to the limestone areas or at least to these areas and their immediate vicinity. They reach thicknesses of several feet at various exposures but like the quartz veins have not been found to continue horizontally for any considerable distance. It should be stated, however, that the lack of outcrops, due to the covering of loose weathered material or of moss, is a serious obstacle confronting the prospector who attempts to trace veins in this region and makes it quite impossible without much labor and expense to determine the course of the veins on the surface. Numerous calcite veins are exposed in the limestone area of Anvil Mountain and its continuation east of Dry Creek. Prospect holes have been sunk on some of them, and many have been staked as mining property. Free gold is found in small amount in some of these veins.

Besides the veins of quartz and calcite described above, there are also veins made up of quartz, chlorite, and albite. Most of these were observed in the Anvil and Newton Peak area. They were not found in well-defined fissures and their forms are irregular. They are thought to have been deposited later than the small lenses and stringers in the schists, and so far as the writer knows they carry no gold.

SURFICIAL DEPOSITS.

The surficial deposits of the Nome region (see Pls. III and IV, in pocket) include accumulations of loose material that result from weathering processes without the sorting action of streams, lakes, or the sea and accumulations that were deposited in water. To the first of these belongs the material of angular and subangular form that is found on the tops and slopes of hills, gradually creeping down under the action of rain, melting snow, or frost to join or overlap the margins of the valley gravels. To the second class belong the elevated bench gravels, the stream and lake gravels, and the gravels and sands of the Nome coastal plain. The loose deposits resulting from glacial erosion and transportation belong in part to one class, in part to the other.

UNSORTED WASTE.

Two classes of unconsolidated fragmental material make up the unsorted waste of the Nome region. One class consists of the mantle of coarse and fine angular and subangular débris resulting from subaerial weathering, which is found on the tops but more especially on the slopes of hills. The other class includes part of the morainal accumulations left by glaciers and will be treated in connection with glacial deposits (pp. 51–52).

Most of the loose rock material on the slopes and tops of hills has received no further sorting by water than that brought about by rain and melting snow, and deposits of this kind do not take the orderly form seen in accumulations of gravel and sand laid down in streams or lakes. Much of the material has traveled only short distances or practically not at all, and such movement as has taken place is down the hill slope, except in the case of wind-blown sands or dust. This material represents the destruction of country rock brought about by the ordinary processes of weathering, especially that produced by change of temperature and the expansive power of freezing water. Although the material is properly described as angular, a small part of it is more or less rounded and might even be mistaken for water-worn material. This rounding is probably due in part to weathering, in part to the rubbing of the fragments as they creep down the slopes under the action of frost, rain, and gravity.

The forms taken by some of these slowly downward-moving accumulations constitute one of the noticeable features of the hills of this region. The débris, consisting of fine and coarse material, in most places covered with vegetation, moves gradually down the hill slope in a manner resembling the movement of tar on a slightly inclined plane. Each individual flow, of which there are great numbers, shows on the lower edge a steep face from 1 foot to perhaps 6 or 7 feet high. The face does not extend straight along the hillside but consists of a series of lobes, the central part of each moving faster than the sides. In many places the advance is plainly made by a rolling movement, the upper part of the lobe pushing out beyond the lower and overhanging it. The general effect when viewed at a distance is that of a roof with irregularly laid tiles. It seems probable that frost and ice are more effective in moving these terrace-like bodies than the summer rain, and that the movement begins in the fall, when the "freeze up" comes, but takes place chiefly in the spring, when the frost goes out of the ground and leaves it in a soft, sometimes almost fluid, condition. The tendency of all this fragmental material is to travel slowly from higher to lower levels. Consequently it should have covered the margin of the water-laid valley and tundra gravels and in fact is found to have done so. This downward creep is one of the factors that have given rise to confusion between water-laid and unsorted material, especially among some of the tundra gravels.

STREAM GRAVEL.

Under the term stream gravel are described those gravel accumulations that are directly referable to present creeks or rivers or that compose the valley floors in which these streams are flowing. Part of the deposits lie considerably above the present watercourses and in places were laid down under conditions different from those now prevailing; yet they owe their formation to transportation and deposition by streams.

Most of the gravel deposits are frozen throughout the summer as well as during the winter. The exceptions include sand and gravel in stream channels, accumulations not covered by moss or muck, and irregular deposits that never freeze, probably because of water circulating in them.

The gravels found along a great majority of the small tributary creeks and gulches are of local origin, being derived from bedrock within the limits of the present drainage basins. The character of the material forming them will, therefore, depend on the character of the rock occurring in their own basins. South of the Kigluaik Mountains the gravels on most of the small streams consist almost entirely of schist and quartz, in many localities with limestone and greenstone. Much of the material is angular or subangular and the deposits are shallow. Within the Kigluaik Mountains also the gravels are of local origin, being derived from the schist, gneiss, and limestone formations of the Kigluaik group and from the intruded igneous rocks. They include an immense quantity of glacial bowlders and angular blocks.

In the larger stream valleys, such as those of Nome River or Snake River, the gravels are derived from more widely distributed sources and are consequently more heterogeneous in character. They contain not only material from the rocks of the Nome group but also some from the Kigluaik group. Such gravels have traveled farther and are more worn than gravels on the small streams. They contain, therefore, a greater proportion of fine gravel and sand, and in general there is greater uniformity in the size of their fragments. Angular material also is less abundant in them.

The greatest depth of stream or valley gravels known to the writer occurs at the place where Snake River leaves the hills to cross the coastal lowland. At a distance of 4 miles north from the coast the gravel accumulations near the river have a thickness of 75 to 100 feet, bedrock lying about 75 feet below sea level. It is therefore evident that they occupy a region which has been depressed, and it is even probable that the lower part of these gravels constitutes part of the coastal-plain deposits. From Goldbottom Creek, 10 miles farther north, down to this point Snake River flows in a widely meandering course over a gravel valley floor averaging between three-quarters of a mile and 1 mile in width. The thickness of these gravels has been tested in only a few places, but where examined is considerable.

Gravel of such depth as occurs on lower Snake River is not known in the Nome River Valley. From the mouth of Osborn Creek to Bering Sea bedrock lies below sea level, although along the river channel between Osborn Creek and Laurada Creek it is only a few feet lower. Where the gravel deposits of lower Nome River above Osborn Creek have been tested they were found to range in thickness from 10 to 40 feet. At Sparkle Creek the thickness of the gravel ranges from 58 to 73 feet and just below Sampson Creek from 49 to 60 feet. No records were obtained for the portion of Nome River above Sampson Creek. Nome River, like Snake River, flows over a broad gravel floor. Below Hobson Creek this valley floor has much the same character as that of Snake River, but above Hobson Creek the valley contracts and the amount of gravel filling decreases.

Extensive and deep deposits of gravel are present in the valleys of Sinuk River, Stewart River, Salmon Lake, and Flambeau River, but there are no drill records at hand showing their thickness.

ELEVATED BENCH GRAVEL.

The elevated bench gravel is treated separately from the stream and coastal-plain gravels, not because it is necessarily of a different origin but because of its position. It is evident, then, that the distinction is in some measure arbitrary. The term refers to those deposits, excluding coastal-plain gravel, which lie above the influence of the present streams and whose deposition therefore does not appear to be referable to them.

The bench gravels are best known in the southern part of the Nome quadrangle, because they here carry gold in sufficient amount to be of economic value. They are made up of the same kinds of material that are found in the other gravel deposits—waste from the rocks of both the Nome and Kigluaik groups.

The more important accumulations occur in the saddles between Deer Gulch and Nekula Gulch, between Grass Gulch and Specimen Gulch, between Dry Creek and the Left Fork of Dexter Creek, and on the south side of King Mountain. (See fig. 9, p. 78.)

At the first-named locality, just north of Dexter station on the Seward Peninsula Railway, the depth of gravel is between 130 and 140 feet, but a quarter of a mile east of the station a shaft was sunk 130 feet through gravel to what was apparently a schist ledge and then with a slight offset was continued 100 feet deeper to bedrock. The gravel consists of schist and quartz with a few pebbles of granite. It is possible, however, that the granite occurs only at the surface. The appearance of the gravel shows it to be stream wash. A further indication of this is that two "pay streaks," representing old stream beds at different levels, led from the saddle southeastward across the point of the hill. The lowest depression of bedrock in this saddle lies near the head of Nekula Gulch but is filled by gravel, and the drainage divide is at Dexter station, several hundred feet southeast, so that water which, if the gravel were removed, would reach the sea by way of Dexter Creek and Nome River now reaches it by way of Anvil Creek and Snake River.

The gravel in the divide between Grass Gulch and Anvil Creek has a depth of 110 feet and fills a comparatively narrow channel. A very marked difference between this deposit and that at Dexter is the much greater quantity of granite and other foreign bowlders here. This granite débris is found at the surface and continues southeast toward Dry Creek and southwest into the Anvil Creek valley. The gravel in the saddle between Dry and Dexter creeks is shallower than that in the other two localities and contains almost no granite.

A filling of gravel and sand occurs also in the saddle separating the two round hills between Buster and Osborn creeks. The driller who investigated this locality reported that his drill passed through 6 to 10 feet of gravel, 90 feet of muck with yellow mud and ruby sand, and 20 feet of clear ice into an unknown depth of sands and gravel containing much water.

Gravels are found also in some of the low saddles along Nome River, such as that at the head of Darling Creek, but whether they are related in origin to those already mentioned is uncertain.

COASTAL-PLAIN GRAVEL.

The coastal-plain or tundra gravel occupies the crescent-shaped area included between the sea and the hills and extending from Cape Nome to Rodney Creek, 14 miles west of the mouth of Snake River. Only the eastern half of this crescent lies within the Nome quadrangle.

This coastal lowland consists of a great accumulation of fragmental material, silt, and fine sand interstratified with well-rounded gravels and beds containing finer stream wash, together with angular slabs and blocks up to 2 feet or more in greatest diameter. With the exception of comparatively small areas, these deposits are frozen from top to bottom. Beds of pure ice appear near the surface in many places. The rock here is similar to that which occurs in the streams of the large valleys, including schist, quartz, limestone, and various eruptives derived from the Nome and Kigluaik groups. Most of the very coarse angular material consists of schist, and a small proportion is limestone. Granite was not found in beds of this character, but large bowlders of granite, worn and more or less rounded, occur at the surface. Flattened and striated limestone fragments also are found near the surface. Much the greater part of these surficial accumulations was laid down by the sea or by streams, but there is a considerable portion whose present condition is the result of subaerial weathering and a much smaller part which was probably brought here by floating ice.

Since the discovery of gold in the old beaches of the tundra and more especially since the very rich beach placers of Little Creek became known a large number of shafts have been sunk in various parts of the coastal lowland and a much greater number of holes have been drilled. These shafts and drill holes have given most of the information obtained concerning the gravels.

Near the coast by far the greater part of the gravel was laid down originally in the sea or has been sorted and redeposited by its action. Farther north, near the hills, only the lower beds are of marine origin and the upper ones are stream-laid or represent the débris creeping down from the hill slopes.

In some places marine gravels and stream deposits may be recognized without much difficulty, but in others the two grade into each other. It is especially hard, at some points perhaps impossible, to distinguish them near the mouths of streams that brought a large quantity of rock waste into the sea, as at Little Creek, while the beach deposits were forming. As a rule, the marine sediments are cleaner, more rounded, and more thoroughly sorted than the stream wash.

Beds of "ruby sand" (garnet) are common. Stratification is apt to be obscure in the thick heavy beds, but beds of fine and those of coarse material and also beds of different materials are usually sharply separated from each other. From a number of shafts marine shells have been obtained.

The stream wash, on the other hand, comprises both rounded and angular or subangular fragments. It contains less quartz and does not show the wear that characterizes beach deposits. It further contains a large amount of mud and is less distinctly stratified. Stream gravels may be confused with unsorted débris, which rain and frost carry from the hill slopes out over the margins of the sedimentary accumulations.

The numerous shafts and drifts along the buried ancient beaches give the best exposures of the tundra deposits. Two well-defined shore lines of this sort have been explored nearly from end to end, and others are known. The one nearer the sea lies about two-thirds of a mile from the present beach at Nome and extends eastward to a point within a short distance of Cape Nome, but here its distance from the coast is less. At Hastings Creek it lies about one-fourth of a mile from the coast, but east of that locality its position is not known and it appears to have been removed through erosion. Its elevation above sea level is 37 feet, and its location is indicated in places by a moss-covered gravel scarp at whose foot it lies.

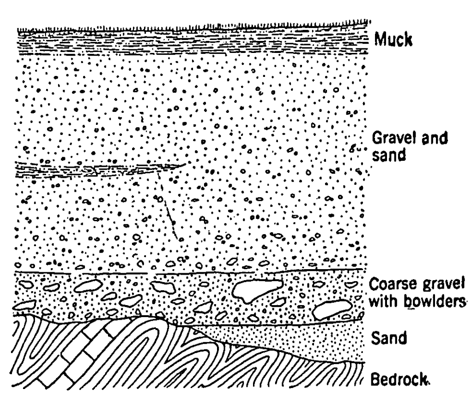


FIGURE 3.—Generalized section of gravel deposits north of Nome, on the third beach.

The other buried beach is definitely located from Little Creek, where it is crossed by the railroad tracks, to McDonald Creek, a distance slightly more than 5 miles. It has been traced between these points in a line slightly bowed toward the north like the present beach, yet showing slight undulations, and is interrupted by the valleys of Nome River, Anvil Creek, and Snake River, whose streams lie below its level. Its elevation above sea, from reliable information obtained at Nome, is 79 feet. These two old shore lines are generally known as the second and third beaches, the present beach being counted as the first.

A generalized section (fig. 3) of the deposits exposed along the third beach shows gravel or sandy gravel with coarse bowlders resting either on schist bedrock in which are a few limestone beds or, as at the east end of the beach, on fine sands, which in turn rest on schist bedrock. Above this is a considerable body of gravel overlain by "muck" and the surface vegetable matter. This general section, however, is subject to wide variations. The thickness of the "muck" ranges from 1 foot to 15 feet or more. A blue clay is found underlying the "muck" in several shafts. In places a heavy wash, consisting chiefly of schist, occurs near the surface. At some points the gravels are slightly cemented by the deposition of lime or iron oxide. Marine gravels are interbedded with creek wash. The character of the material varies in both composition and coarseness. In fact, as previously stated, the deposits where first exposed on Little Creek were so varied in appearance and manner of deposition as to cause some geologists to doubt whether any of them were of marine origin.

Only part of the shafts on the second beach have been sunk to bedrock, as the pay streak in most places lies on a false bedrock of clay or sandy clay and gravel. There are not many data, then, on which a complete generalized section can be based, but apparently coarse angular material, although by no means lacking, is not as abundant as on the third beach line. The quantity of garnet ("ruby sand") is also far greater on the third beach. This is probably accounted for by the fact that much of the material of the third beach has traveled a shorter distance from its source and has been less subject to wear by streams and waves.

In 1907 and 1908, after the field work on which this report is based was completed, a number of other buried beaches were discovered, but much less is known of them than of those already mentioned. The "intermediate" beach is between the second and third beaches and has an elevation of 22 feet above sea level. It is thus lower than the second beach. One of the prospect holes on this beach was examined by Smith,[1] who says:

At this place the bedrock consists of black, graphitic, somewhat quartzitic schist breaking into small rectangular blocks. The pay gravel is made up of poorly rounded schist fragments mixed with a good deal of mud. The gravels are very dirty. Above, in the south end of the drift, there is a sand layer, which rises very steeply toward the north. In the north end there is a thin layer of muck between the pay gravels and an overlying bed made up of large bowlders. The bowlders are well rounded, and some of them are 2 feet in length. Marine shells were found in the "intermediate" beach near Center Creek.

The two so-called "submarine beaches" lie between the second beach and the present beach. They have been described by Smith[2] as follows:

The easternmost of the properties on this beach is located on the coastal plain just west of Snake River and almost directly south of the pumping plant, a

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, p. 215.

[2] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, p. 271–273.

quarter of a mile north of the present beach. The ground has been opened by means of two shafts, the eastern of which has a depth of 69 feet and the western of about 65 feet. At this place the pay streak is 19.6 feet below sea level and for that reason the beach is called the "submarine." * * *

The unconsolidated deposits at this place consist of irregularly distributed alternations of gravel and sand, the latter usually forming the base of the section. Many of the sandy layers show abrupt terminations which seem to have been formed by faults, but none of these dislocations could be traced into the gravel lenses. In the gravel beds pebbles of all kinds of rocks were found. Numerous fragments of black slate, similar to that occurring in places as the bedrock of the "third beach" and in the hills back of Nome, were seen, as well as various schist and limestone pebbles. Feldspathic schist and greenstone fragments, however, form only a small percentage of the deposit. It is interesting to note in this connection that several blocks of granite were also found in the gravels. The significance of this lies in the fact that the granite fragments are similar to the granite of the Kigluaik Mountains, and the conclusion is practically inevitable that they must have been derived from this source. In the gravels some large blocks of quartz were found, some of them 2 feet in longest dimension. Their general outline was more or less angular, but their corners were well rounded, and they had all the appearance of having been water worn. No constant direction of the shingling of the gravel deposits was observed, and it would appear that deposition was effected by strong variable currents such as would be expected to occur near a shore line.

In the west end of the southern drift a series of ramifying streaks of a black peaty material cut in irregular directions across the layers of sand and gravel. Because of the difference in color these bands are far more noticeable where they cut across the light-brownish sand, but a careful search shows that they are almost equally numerous in the coarser gravel layers. Pebbles showing well waterworn outlines are scattered irregularly but not abundantly in these peaty seams. When first examined it was believed that they represented cracks which had been subsequently filled by material from the surface. Similar cracks are observed at the present time in many places where the melting of the ground ice allows settling and cracking of the deposit previously formed. In the light of more careful study, however, such an interpretation seems inadequate, for many of the seams taper off toward the top as well as toward the bottom, so that a connection with the surface is not indicated. It is believed that their occurrence is due in some way to the settling of the ground subsequent to the formation of a part at least of the gravel deposits, but the information concerning these seams is as yet too meager to allow an explanation of their origin. Although as the matter now stands an explanation of these seams does not appear to be directly connected with the economic problems, it is believed to be important, for everything which throws light on the physical conditions under which the coastal-plain deposits were formed should assist in determining the factors which led to the deposition of the economically valuable placers in this area.

In the north end of the eastern drift a layer of sand with a few pebbles scattered irregularly through it lies underneath a gravel deposit, only the base of which is exposed in the drift. This sand bed is interesting because it contains numerous shells that can be used in determining the relative age of the gravels at this point. The most abundant of the shells is one that is large and clamlike, but numerous other fossils also abound. All the shells occur in the sand layer, none being found in the overlying coarser gravel. The physical condition of these shells is interesting and, it is believed, throws some light on the relative age of this beach and the earlier known and previously described beaches. Practically none of the shells show water rounding or other evidence of having been subjected to the pounding of surf, but in spite of this almost all are broken into small bits or are so decomposed that it is almost impossible to remove them from the layers in which they occur. Such a condition would seem to indicate that they have undergone a large amount of decomposition and fracturing since they were laid down. When it is remembered that the shells found on many of the beaches farther inland, such as the "intermediate beach," are practically undecomposed, the suggestion that the "submarine beach" is much older than the others receives considerable support from the physical character of the fossils.

There is some reason for thinking that the tundra deposits gradually increase in thickness from the south toward the north and reach a maximum somewhere in the vicinity of the third beach. North of that beach they decrease rapidly till they disappear on the lower hill slopes of the plateau area. This condition, though it may not be true of all places, is well brought out in the section shown in figure 4, compiled from records of drilling along Bourbon Creek

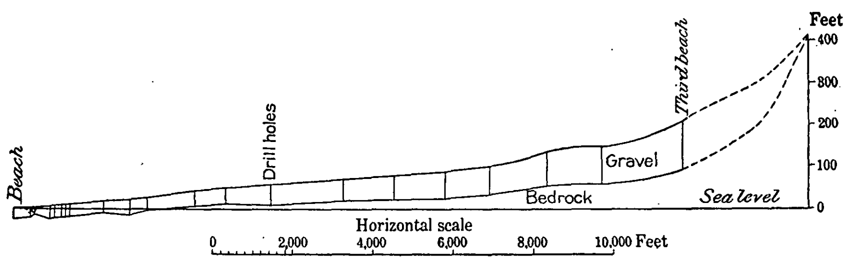


FIGURE 4.—Section of coastal-plain gravel deposits along Bourbon Creek.

from a short distance north of the beach to the hills. The drilling was done near the stream channel and therefore shows a less thickness of deposits than would appear if the holes had been placed at a distance from it. The shallowest hole is 17 feet deep and the deepest 120 feet. Between the two the increase is fairly regular.

Although this statement concerning the increasing thickness of gravels toward the north is believed to be true in general, it must not be expected to hold true in every individual case, for there is considerable unevenness in the bedrock surface beneath the gravel. This surface may and undoubtedly does differ greatly from the upper surface of the gravels. As an example of this difference may be mentioned the fact that a well at the Golden Gate Hotel in Nome was put down 140 feet before striking bedrock, whereas the depth of gravel along lower Bourbon Creek averages not far from 20 feet.

Marine shells were found in the coastal-plain gravel at several places during the course of the field work and may be seen in the dumps from some of the shafts. Many of them are in an almost perfect state of preservation, which suggests that they accumulated in comparatively quiet water. Two localities furnished most of the collection submitted for determination. Near Center Creek, almost

2 miles from the coast, they occur in gravels 32 feet below the surface and at an elevation of about 20 feet above sea level. Two forms collected from this locality were determined by W. H. Dall as *Pecten* (*Chamys*) *swiftii* Bernhardi, now living at Hakodate, Japan, and *Maconia middledorffii* Dall, now living only south of the line of winter ice in Bering Sea.

A larger collection was obtained from Otter Creek,[1] 2 miles from the coast. They were found 50 feet below the surface, at an elevation of 20 feet above the sea. At this locality they are very numerous, and may be obtained without difficulty. The collection was submitted to Mr. Dall, who divides them into two classes, those now living south of the line of winter ice and those living both north and south of it.

Species now living south of the winter ice line in Bering Sea:
- Monia macroschisma Dall.
- Panomya ampla Dall.
- Pecten[2] n. sp., temperate type.

Species now living north and south of the ice line:
- Barnacle, Balanus sp.
- Cardium, sp. undet.
- Hemithyris psittacea L.
- Macoma sabulosa Spengler.
- Pecten islandicus Müller.
- Venericardia alaskana Dall.
- Venericardia crassidens Brod. and Sby.

Several of these forms, particularly *Venericardia crassidens* and *Macoma sabulosa*, do not appear in the longer list that follows. Mr. Dall says of these fossils: "The shells from Nome are most interesting. They are probably Pliocene, and show conclusively a milder climate than now prevails there—say, something like that of the Aleutians or north Japan."

These fossils came from the lowest part of the tundra gravels. No fossils appear in the surface water-laid gravel, much of which is not marine, or if it was deposited by the sea has since been reworked by streams.

Pieces of wood and walrus tusks have been found in the sands of the second beach and are much later than the gravel from which the shells above-mentioned were collected.

Very much larger collections of shells were made from the tundra gravels by E. M. Kindle in 1908. Mr. Kindle also made collections of marine shells of forms now living along the coasts of Seward Peninsula, which are of interest because they show that about one-

[1] Most of the shells from Otter Creek were obtained through the kindness of Mr. J. J. V. Beaver, of Nome.

[2] Dall, W. H., On climatic conditions at Nome, Alaska, during the Pliocene, and on a new species of Pecten from the Nome gold-bearing gravels: Am. Jour. Sci., 4th ser., vol. 23, pp. 457–458.

third of the fossil forms are those of living species. Lists of these collections are given below. Shells are rare on the Nome beach, and that locality is not represented in the lists, but all the shells, with one exception, were obtained within 150 miles of Nome. The determinations were made by Mr. Dall.

Marine shells from the old beaches in the vicinity of Nome.

	1. Submarine beach, ¼ mile west of Snake River.	2. Submarine beach near locality 1.	3. Center Creek.	4. Galatin claim, Otter Creek.	5. Submarine beach ½ mile west of Nome.	6. Near locality 5.	7. Black Diamond claim, near Tripple Creek.	8. Near locality 7.	9. Second beach, 1½ miles east of Nome.	10. Second beach, ½ mile east of Nome.	11. Cyrus Noble claim, third beach.
BRACHIOPODA.											
Hemithyris psittacea Gmel				×			×	×	×		
Magasella aleutica Dall							×	×			
CRUSTACEA.											
Balanus aff. crenatus Darwin			×					×	×		
aff. hameri Darwin			×								
MOLLUSCA.											
Astarte near striata Leach	×					×					
n. sp	×		×	×					×	×	
Buccinum sp., fragments	×								×		
Cardium sp., fragments	×										
ciliatum Fabr			×	×		×			×	×	
Chrysodomus n. sp., fragments			×								
aff. lirata Martyn			×								
sp. ind	×		×								
Cryptobranchia n. sp			×							×	
Littorina n. sp. aff. palliata Say										×	
n. sp.?, aff. grandis Midd										×	
Macoma middendorffii Dall		×	×						×	×	
rotundata Sby			×						×	×	
sp., fragments	×					×					
Monia macroschisma Deshayes			×	×					×	×	
Mya sp., fragments	×		×			×					
arenaria L			×								
truncata L			×						×		
Mytilus edulis L		×	×			×			×		
Panomya ampla Dall			×						×		
norvegica Spengler?			×								
sp., fragments				×							
New genus (allied to Panomya), fragments	×										
Pecten swiftii Bernhardi			×	×					×		
(Chalmys) lioicus Dall				×							
Pecten? islandicus Müller								×			
Purpura n. sp. near crispata			×								
(Thais) sp., fragments	×										
cf. lima Martyn, fragments		×				×					×
Rictocyma n. sp	×										
Saxicava artica L			×	×					×		
rugosa L					×						
Serripes grönlandicus		×							×		
Siliqua sp. aff. patula Dixon			×								
Spisula alaskana Dall		×	×	×						×	
Thais n. sp. aff. lamellosus Gmel			×								
aff. lima Martyn, fragments								×		×	
Trichotropis insignis Midd			×						×		
Venericardia alaskana Dall	×?		×	×					×		

Recent marine shells from Seward Peninsula and vicinity.

	Cape Prince of Wales.	Deering.	5 miles east of Deering.	Cape Deceit.	Cape York.	Lost River.	Point Hope.
BRACHIOPODA.							
Hemithyris psittacea Gmel		×					
MOLLUSCA.							
Acmæa testudinalis Müller	×	×	×				
Admete couthouyi Jay	×						
Æirsa borealis Beck	×						
Amouropsis purpurea Dall	×		×	×			
Arctoscala grönlandica Perry	×						
Astarte borealis Schum		×	×				
near striata Leach	×			×			
vernicosa Dall			×				
Bela sp. indet		×					
lævigata Dall		×					
simplex Midd	×						
Buccinum angulatum var. normale Dall	×		×				
angulatum var			×				
polare Gray	×						
glaciale Ph							×
tenue Gray	×						
Bulbus flavus Gould	×						
Cancellaria middendorffii Dall	×						
Cardium californiense Desh	×		×				
ciliatum Fabr	×	×					
Chrysodomus fornicatus Gray	×		×	×			×
liratus var.?	×	×					
spitzbergensis Reeve	×						
Drillia kennicotti Dall	×						
Fuspira pallida Brod	×			×			
Liomesus canaliculatum Dall	×						
ooides Midd	×						
Littorina grandis Midd				×	×		×
Lunatia pallida Brod. and Sby	×	×					
Macoma carlottensis Whiteaves	×	×	×	×			×
inconspicua Brod. and Sby	×		×	×			
Margarites albula Gould	×						
striata Brod. and Sby		×					
Modiolaria lævigata Gray			×				
nigra Gray	×						
Mya arenaria L	×						
truncata L	×						
Mytilus edulis L	×	×	×	×		×	
Natica clausa Brod. and Sby	×	×	×	×		×	
Pecten islandicus Müller	×						
Purpura lima Martyn	×						
Saxicava arctica L	×						×
Serripes grönlandicus Müller	×						×
Siliqua media Gray	×		×	×			×
Solariella albula Gould	×						
cinerea Couth	×						
Spisula alaskana Dall	×						
Tachyrhynchus polaris Beck	×						
Tellina alternidentata	×						×
Thais lima Martyn	×						
Trichotropis arctica Midd	×						
Valvata mergella West			×				
Velutina velutina Müller			×				
Venericardia alaskana Dall	×						
Volutopsius attenuatus Dall	×						

Mr. Dall concludes from his study of the faunas from the buried beaches at Nome that the gravels of the so-called "submarine" beach are either Pliocene or upper Miocene, and that the remaining gravels, so far as their age is determined by the shells given in the lists, are undoubtedly Pliocene. The relative age of the "submarine," "intermediate," and "third" beaches is indicated by the order in which they are named, the "submarine" beach being the oldest.

The order of formation and relative age of the buried beaches have been given in some detail by Smith,[1] from whom the following is quoted:

From the present evidence it would seem that the earliest event recorded definitely in the history of the region is the formation of the "outer submarine beach." What the condition of the region was prior to this incident is not known, but it is probable that the older coastal-plain deposits had been formed and were eroded by the waves to form this beach. After the outer beach had progressed to a certain stage gradual depression with respect to the sea brought the shore line at the level of the "inner submarine beach." The amount of this depression must have been about 14 feet. Still later further subsidence of about 42 feet brought sea level to the elevation of the "intermediate beach." The movement continued and the land sank with respect to the sea about 56 feet, so that the shore line was on the level of the "third beach." After remaining for some time in this position further depression took place, and the sea attacked the schist and limestone bluffs which rise

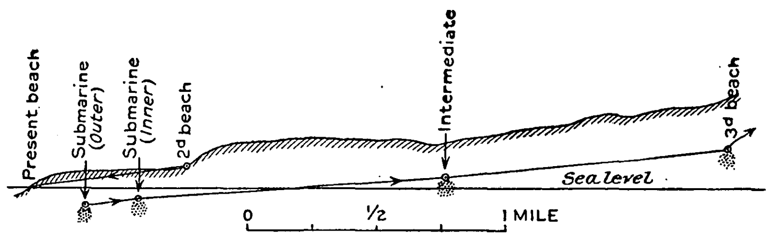


FIGURE 5.—Diagrammatic cross section showing beaches near Nome. Vertical scale about 12 times horizontal.

steeply about half a mile north of the "third beach." While each of the beaches was being formed by the sea, deposition was taking place on the sea floor, and sands and gravels brought down by the rivers and worn from the cliffs by the waves were covering the earlier beaches, thus producing a surface such as the sea floor of the present day might show if it could be examined.

After the shore line had taken a position landward of the "third beach" a change in the progressive depression of the land took place, and uplift began. The result of the uplift was to cause more and more land to emerge from beneath the sea. The uplift seems to have gone on at first without any interruption, for there are no signs of long halts and the accompanying formation of beaches on the surface of the coastal plain. At length, however, when the shore line was some distance south of the "second beach," a period of relative stability ensued, and the sea gradually cut back into the coastal-plain gravels until a cliff, in places nearly 75 feet high, towered above the beach. This feature can be most plainly seen in the vicinity of Rocker and Martin gulches, a little east of Nome. When this stage of cutting had been reached an uplift of about 38 feet brought the shore line to a short distance seaward of its present position, and then, in a period of stability, the sea renewed its cutting on the shore and formed the low cliff which rises from the present beach.

[1] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, pp. 277–279.

According to this interpretation the recognizable portion of the history of the coastal plain shows an earlier series of depressions amounting to between 100 and 200 feet, followed by an uplift of about 34 feet less. That there were oscillations in these movements can not be doubted, but that the sum of the changes of level was of the character noted seems obvious. The absence of all surface topographic forms characteristic of beaches, save in connection with the present, the "second," and the most inland beaches, seems to indicate conclusively that these three were the last ones formed and have not been subjected to marine erosion since their formation. Furthermore, the condition and character of the fossils already described would seem to substantiate this conclusion.

SILT.

One of the most widespread of the surficial deposits is the covering of "muck" or silt present throughout the whole of Seward Peninsula and in many other parts of Alaska as well. It is present everywhere on the Nome tundra and on all the gentle lower hill slopes and the valley floors, though it is not usually found on the flood plains of the streams. In consists of finely divided rock particles, much finer than ordinary sand, with more or less vegetable matter, and its color is black or bluish gray. There is scarcely any coarse material in it. Its thickness ranges from a few inches to 15 feet or more. It is frozen and is covered by low vegetation, which is a poor conductor of heat and protects it from thawing. When the vegetation is removed the "muck" becomes a thin mud and flows readily. This fact accounts for the origin and growth of many of the small ponds scattered over the Nome tundra.

In some parts of Seward Peninsula thin lenses and veins of ice give some of the muck a brecciated appearance. Larger beds of ice occur in the muck, but the ice beds of greatest thickness are found below the muck and overlying the gravel. These thick ice beds are not everywhere present and are most likely to be found along the streams. The blanket of vegetation above protects the muck and ice and the gravel deposits from sun and rain and keeps them always frozen. When the gravels are uncovered they thaw, but whether the deep gravels would thaw to the bottom is an unanswered though highly important question.

Concerning the origin of the muck and the manner in which the ice beds formed there is some difference of opinion. Brooks,[1] in a recent description of the hill slopes of the Dahl Creek region on Kaugarok River, states the "muck" to be "a subaerial accumulation due in part to the decay of vegetable matter, in part to the deposition of silts during the rainy season." This idea was not put forward as a general explanation of all the silts, though it may be said

[1] Brooks, A. H., The Kougarok region: Bull. U. S. Geol. Survey No. 314, 1907, p. 168.

that they contain much vegetable matter and are most highly developed on the lowlands, as would be the case if they were made up of the finer material from the weathering of the hills above them. Against this hypothesis may be urged the fact that some of the silts occur at long distances from the hills and in places where it is difficult to see how they could accumulate under present conditions. Such accumulations are the low cliffs along the beach, where the frozen silts have a thickness of 8 or 10 feet in places. The silts are not derived by decomposition from the gravels under them, for the line between the two is always sharply drawn and the silt is fresh and angular, containing little or no coarse material.

Another and more widely applicable explanation of the silts is that they accumulated under water, either in the sea during a period of land subsidence or possibly in fresh water. Subsidence of the land in recent time is shown in many parts of the peninsula by abundant evidence, some of which is given in the discussion of the coastal-plain gravels. It is not improbable that part or all of the silt in some regions, such as the Kuzitrin lowland above the mouth of Kougarok River, could have accumulated in fresh water, but its distribution is too widespread to be accounted for entirely by causes of so local a nature.

The character of the material suggests that part of it at least may be the fine rock flour ground up by glaciers, yet here again its widespread distribution seems to raise an objection to this theory of its origin, for there is no evidence at hand to show the existence of glaciers of sufficient extent to account for all the deposits of this kind on Seward Peninsula, perhaps not even for those of the area here discussed.

In places on Seward Peninsula portions of trees and bones of animals are embedded in the silt. These bones include teeth of a horse, probably *Equus complicatus*, and teeth and tusks of a mammoth (*Elephas primigenius*). The trunks, bark, branches, and cones of spruce trees represent the only species of wood known to be present.[1] The condition of the logs is such as to suggest that they are driftwood accumulations, much like those seen on the Nome beach when the region was first visited and still remaining in a few places. There are objections, however, to the view that the silts are of marine origin. It is difficult to see how, if they were exposed to the force of waves, they could remain on such slopes as the coastal plain while that plain was gradually emerging from the sea. A stream of water cuts through them as it would through ice, and where exposed on the hillside by removal of the vegetation they rapidly wear away. The organic matter present is another objection, for it is so widely

[1] Collier, A. J., A reconnaissance in northwestern Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 27.

distributed that apparently it must have been incorporated with the silts originally. It seems improbable that such an amount of organic matter would be found in marine sediments of this nature, unless they were deposited in protected and possibly shallow waters. Doubtless the silts have been modified in places by stream action, but to what extent is not known. Erosion and redeposition would account for some of the variability in thickness and also for the fact that the silts are not found on the tops or high on the slopes of hills.

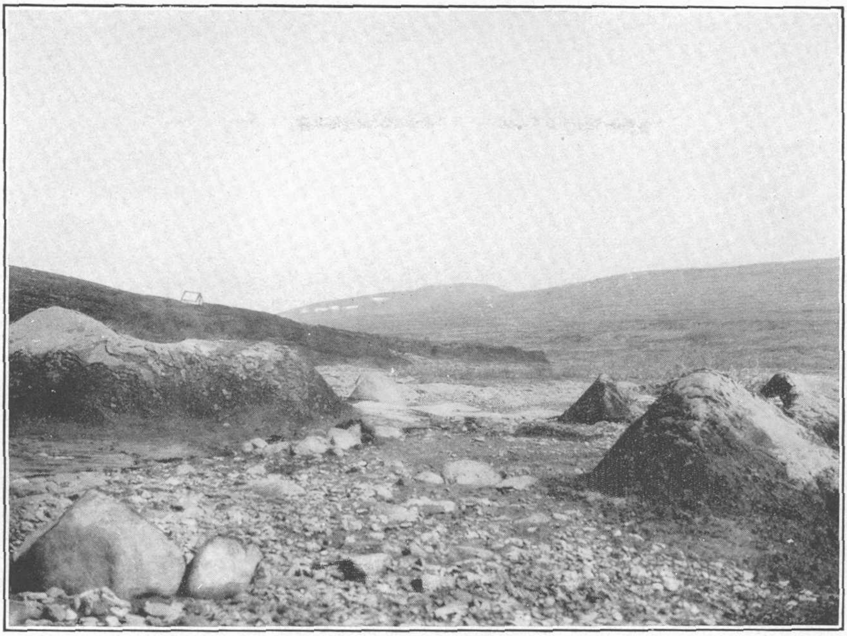
It appears probable that these silt deposits are not due to any single cause and that each of the methods of deposition that have been mentioned may be represented by examples on Seward Peninsula or even in the smaller area of the Nome region. The hypothesis of subaerial accumulation due to the settling of wind-blown particles offers an explanation that is more in accord with the conditions in many localities than either of the other two, but it is evident that if the climatic conditions of the more recent past were similar to those of the present accumulation by this method must have gone on very slowly. For many parts of Seward Peninsula glaciation as an explanation for the origin of the silts is not satisfactory in view of present knowledge of the extent of glaciation on the peninsula, for the distribution of the silts is far wider than that of the ice, so far as has yet been shown.

GLACIAL DEPOSITS.

Débris transported by glacial ice is finally deposited at the end or sides of the glacier, or is left on its bed when the ice disappears. Part of this débris is carried way and deposited by streams flowing from the glacier, or is laid down in glacial lakes or ponds. A second part is not transported or sorted by water, but is laid down in confused masses as morainic material

Such accumulations are present in nearly all the valleys of streams of the Kigluaik Mountains shown on the map, but more especially in the larger ones, such as those of Windy Creek, Sinuk River, and Grand Central River, also at the head of Nome River and in Salmon Lake valley. A terminal moraine consisting of immense blocks of granite and schist crosses the valley of Windy Creek just below the small lake represented near the northern margin of the Grand Central map (Pl. IV, in pocket). Another moraine extends out from Thompson Creek and forms a low barrier halfway across the Grand Central River valley. A small moraine is seen on Fox Creek, north of Salmon Lake. Mounds of morainic débris occur at the head of Nome River and on the divide between Nome River and Salmon Lake. The most abundant of the glacial deposits, however, consist of blocks and bowlders scattered over the valley floors within the Kigluaik Mountains. They do not generally form conspicuous mounds or ridges, but are strewn about in many places just as they were left by the disappearing ice.

Erratic bowlders are found in the valley of Nome River and are distributed generally over the tundra, but whether or not these were left by glacial ice is difficult to decide. The better knowledge of the deposits of the Nome tundra that has come with the development of the gold placers leads to the belief that glaciation was more extensive in this region than was for a long time supposed. Smoothed and striated bowlders are abundant in the gravel accumulations of the coastal plain, and, as has already been pointed out, the fine rock flour from the glaciers may be one of the sources for the material of the silt deposits. There is still little reason to question the conclusion of earlier workers that Seward Peninsula has not been subjected to regional glaciation. All observers have been impressed by the peculiar monument-like residual rock masses (Pl. IX, *B*) resulting from weathering that are seen on the tops of certain hills, and have argued that these hills could never have been covered by a sheet of moving ice unless the monuments were formed since the ice retreated. It is nevertheless highly probable that the valleys of Nome and Snake rivers have been occupied by ice that moved down almost, if not quite, to the coast. Possibly the lower mountains between the coast and the Kigluaik Mountains have been centers of accumulation, although the forms of the valleys, except that of Christian Creek, do not lend much support to this idea. The Kigluaik Mountains, however, were an important center of ice accumulation, and without question contributed ice to the valleys of Nome and Stewart rivers. Granite bowlders from the Kigluaik Mountains are abundant on the south side of Stewart River up to an elevation of nearly 900 feet above the sea, but the ice must have reached higher on the valley wall than this, for the bowlders were carried from Bowlder Creek to Grouse Creek over a divide whose present elevation is 1,041 feet. A rounded granite bowlder was found on the west side of Mount Distin at a still greater elevation, so it is evident that the ice could have moved readily from the Stewart River valley to the head of Snake River, for the divide between these streams is only 633 feet above the sea. There are many granite bowlders in Grub Gulch, but a large part of the morainal débris in this gulch came over the saddle between it and Trout Creek. The numerous granite bowlders at the heads of Dexter and Anvil creeks are believed to owe their presence there, in part at least, to the same means of transportation. The Nome River valley must have offered a more favorable channel for ice movement from the north than any other valley within the Nome and Grand Central quadrangles and was probably occupied by an ice stream of considerable size.



A. SUMMER REMNANTS OF AN ICE SHEET THAT COVERED THE FLOOD PLAIN OF A STREAM DURING THE PRECEDING WINTER.

A layer of gravel and sand lies on the blocks of ice and prevents them from thawing.

B. TYPICAL SCHIST "MONUMENT," AN EROSIONAL FEATURE COMMON IN MANY PARTS OF SEWARD PENINSULA.

ICE BEDS.

Beds of clear ice occur very commonly with the gravel deposits of the streams and the Nome tundra. The ice beds are associated more closely with the silt deposits than with the underlying gravels, although most of the gravels are frozen. Most of the ice beds are either in the silt or between the silt and the underlying gravel. Veins of ice in some places cut across the silt beds, and in general ice forms a considerable proportion of the silt deposits.

Ice beds, where associated with stream gravels, are found along the lower valley slopes between the hills and stream channels. They are always overlain by a protective covering of some kind, either silt or moss, and consequently are not present on the flood plains of the streams. In some localities they are absent altogether, and in others they reach a thickness of several feet. Beds of ice from 12 to 15 feet thick are not unusual along the streams in the Kotzebue Sound region.

The distribution of ice beds in the coastal plain about Nome is irregular and depends on conditions that are not understood. The beds do not differ in appearance or position from those of the stream valleys and probably were formed in much the same way. As a rule they are almost free from silt or gravel, although the exposed faces do not appear so, being covered by thin mud from the thawing silts above.

Concerning the formation of the ice beds of this region and of Alaska in general there is great difference of opinion, and it is evident that the last word on the subject has not been said. Two methods of origin have been given for such beds as are found along the streams in the Nome region—(1) that they are accumulations of winter snow, which were covered by gravel or silt and vegetation and thus preserved from the warmer weather of summer, or (2) that they were formed in place along planes of porosity within or under the silts after the silts were laid down. The burial of ice under a thin covering of gravel by spring floods is a common occurrence on streams of the Nome region. On such of these streams as have wide flood plains and low gradients broad sheets of ice and snow accumulate, some of which even if unprotected last into the summer. Many such ice sheets, however, or portions of them, are covered during the floods of early spring by a few inches of sand or fine gravel, and when thus protected, especially if so situated that the stream does not reach them, they may last throughout the summer. Such gravel-covered ice masses are seen in Plate IX, *A*. The second view concerning the origin of the ice beds has been presented, especially by Tyrrell,[1] whose observations were made chiefly in the Klondike gold-bearing district of Yukon Territory. According to Tyrrell the process is somewhat as follows:

Water issuing from the rock beneath a layer of alluvial material rises through the alluvium and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter, if the flow of water is large and the surface consists of incoherent gravel, the water will still rise to the surface and there form a mound of ice. If, on the contrary, the flow from the spring is not large and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of 32° F., rises until it comes within the influence of the low temperature of the atmosphere above and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness and there freezes, and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent the ice also increases in thickness by additions from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above, after which it continues to increase in exent but not in thickness or depth.

With the advent of the warm weather of summer the growth of the crystosphene ceases; but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent nonconductor of heat, protects it from the sun and wind and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth.

A third method by which ice beds or "glaciers," as they are locally named, might be formed, is mentioned by Maddren.[2]

An hypothesis to explain the occurrence of ice sheets under a mantle of moss under some of the circumstances where it is met with, especially on sloping surfaces such as Tyrrell describes for the Klondike region and which are common elsewhere in Alaska, is similar to a suggestion made by Lieut. Belcher.

The water sinks through the moss blanket from the surface and also seeps underneath it from higher levels. This tends to lift the living moss with its thawed underlying layer of vegetable humus or peat, floating it in a state of semibuoyancy above the frozen substratum of alluvium or peat, so the ice may accumulate season after season, as long as * * * equilibrium [is] maintained between the annually thawed peaty superstratum and the constantly frozen substratum.

There can be no question that veins of ice such as are seen cutting the silts in many places were formed after the silts were laid down, so there seems to be no serious objection to supposing that at least some of the ice beds could have been formed in this way.

[1] Tyrrell, J. B., Crystosphenes or buried sheets of ice in the tundra of North America: Jour. Geology, vol. 12, 1904, p. 236.

[2] Maddren, A. G., Smithsonian exploration in Alaska in 1904, in search of mammoth and other fossil remains: Smithsonian Misc. Coll., vol. 49, pp. 44-45.

STRUCTURE.

The structure of the Kigluaik group within the area mapped is apparently far simpler than that of the Nome group. Within the Grand Central quadrangle all the members of the Kigluaik group have a comparatively low and fairly uniform dip, in most places not over 30° or 35°, toward the southeast or south-southeast. (See fig. 6.) The strike of the beds does not vary greatly. Folding is not general, so that reversals of the dip are uncommon and only local; where northwesterly dips occur the beds stand at high angles.

By far the greater part of the igneous intrusions conform to the bedding and cleavage of the schists, even the large granite mass in the northwestern part of the area following this general rule. The thin limestone bed which overlies it in the Windy Creek valley can be traced for 2 miles along the contact. There is little evidence of faulting, and the upper part of the series appears to be decidedly less disturbed than many portions of the Nome group on the south. The lower part of the Kigluaik group, however, which does not occur within the area mapped, has been subjected to strong movements and is greatly folded, but even here the distortion has taken place within the gneisses themselves and does not appear in any marked degree in the larger structures of the overlying limestone.

The nature of the relation between the Kigluaik and Nome groups is in doubt, at least so far as the evidence within the Grand Central area is concerned, because there is uncertainty as to where the dividing line between the two should be placed. As has been explained, the boundary between the two has been drawn on the map so as to include the biotite-staurolite schists in the Kigluaik group; and if this is correct, the field evidence is thought to point toward a relation of conformity rather than one of unconformity.

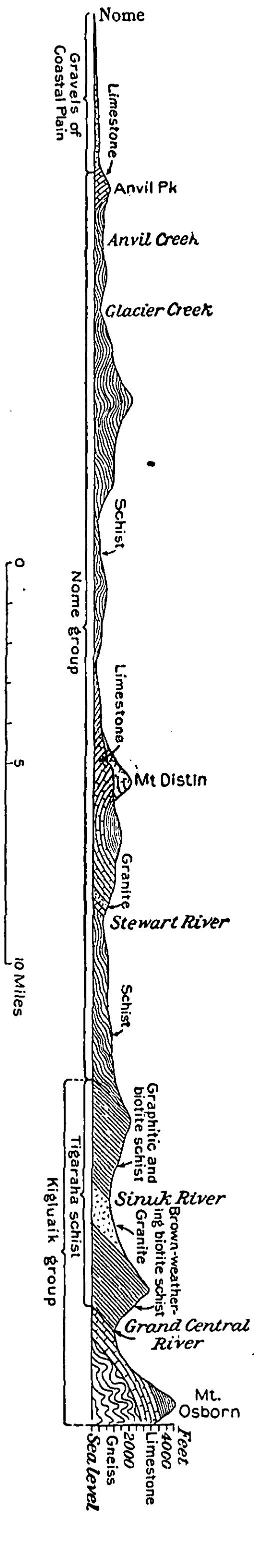


FIGURE 6.—Geologic section, Anvil Peak to Mount Osborn. This figure is diagrammatic and expresses only general relations.

The rocks of the Nome group, more especially the schists, do not present such marked diversity of character or such distinct evidences of bedding as are seen in many unmetamorphosed sediments or in those that are made up of thin beds. Limestones give the best clue to the structure, but even these, on account of their irregularity in distribution and thickness, their interruption along the strike, and their different degrees of alteration or variation in composition, do not furnish sufficient evidence for a solution of many of the problems involved. The difficulties are still further increased by the greenstone intrusions, which, where much metamorphosed, may be confounded with beds of sedimentary origin. Careful field study has led to the conclusion that in general the planes of bedding coincide with the cleavage. This relation does not hold true everywhere, particularly in small close folds, but the exceptions are not apt to lead to misinterpretation of the structure, except in the more massive and highly altered limestone beds. Yet even in these the cleavage commonly agrees with the larger features of bedding. Horizontal cleavage is not uncommon, and cleavage and bedding of low dip—15° to 20°—are the rule rather than the exception.

When the strikes and dips of the various rocks of the Nome group are compared three principal features of the structure are brought out. Throughout a narrow belt from 5 to 6 miles wide bordering the Kigluaik group the strike of the Nome strata is in the main that of the Kigluaik strata—about east-northeast—and the dip is to the south-southeast. The limestone and schist beds forming the south flanks of the Anvil and Newton Peak masses have a west-northwest direction nearly parallel with the coast line and dip toward the north. Throughout the rest of the Nome and Grand Central quadrangles the main structural features have a nearly north-south trend—slightly west of north in the region west of Nome River, north or slightly east of north in much of the region east of Nome River. In a broad way this central part of the area under consideration is characterized by comparatively open folding, but this apparent simplicity of structure is not confirmed when the beds are examined in detail, for closely compressed minor folds are seen in many places. The three features just named suggest that the portion of the Nome group represented on the geologic maps has in general a shallow basinlike structure, the beds dipping at comparatively low angles from the north, west, and south sides toward the central part of the area, the fourth side necessary to complete the basin lying beyond the eastern limit of the quadrangles.

Reference has been made in the outline of the geology to evidences of two periods of folding that have affected the rocks of the Nome group. These evidences consist in the main of two sets of folds that have axes almost at right angles to each other, the one running north and south and the other east and west. A good example of these folds is seen in the limestone of Newton Peak east of Dry Creek. The limestone beds exposed on the south side of Newton Peak strike east and west and dip north, but when favorable exposures are examined carefully it is found that in many places the rock has been thrown into close minor folds whose axes pitch north and thus lie parallel to the principal dip of the limestone. These minor folds are subordinate, however, to the larger structural features, the principal difference between the two systems as they are seen in this region being that the folds with east-west axes are broad and open, whereas those with north-south axes are intensely compressed and in many places are so small as to be easily distinguished in a small outcrop. Such examples of the two systems of folds as that seen in the limestone of Newton Peak are found in the schists also and in places show the structure even better than at the locality mentioned. It is conceivable that the forces that produced the folds acted simultaneously, but it is believed that the east-west folds are connected with one of the later disturbances that affected the area, probably the intrusion and uplift of the Kigluaik Mountains, and that they were superposed on the folds of an earlier movement. One of the best evidences of this is that the axes of the minor north-south folds pitch in directions parallel to the dip of the east-west folds, a fact which seems to indicate that the north-south folds were produced first. A remarkable peculiarity of the north-south folds is that they were seen only in rocks of the Nome group and were not observed in the Tigaraha schist of the Kigluaik group, in which, if they ever existed, they must have been entirely destroyed by later metamorphism.

Another feature that should be mentioned is that changes from the original condition of the sediments have not taken place uniformly throughout the region. All the rocks have undergone alteration and all are more or less folded, yet neither the degree of metamorphism as expressed by changes in mineral composition of the rock nor the deformation of the beds (folding) is the same in all parts of the area. These differences may be due in part to differences in the original characteristics of the rocks, which led to diverse results when alteration took place. It is probable, however, that they are due in larger part to differences in intensity or in character of the forces that produced the changes. The effects of igneous intrusions are more localized than the changes brought about by mountain-forming movements, and both these agencies have been active in this area.

The rocks of the Nome group were last deformed under comparatively small load—that is, they were subjected to deforming forces while at a slight distance below the surface. The effect of this was that they accommodated themselves to the deformation, not by a rearrangement of material within the mass but by rupture and displacement, so that we now find them cut by numerous joints and fault planes. Most of this movement took place after the rocks had already reached an advanced stage of metamorphism and after the principal period of vein formation had been passed.

Displacements and jointing of this kind are perhaps most noticeable in limestone areas. Massive limestone beds show it especially. In many places the rock has the appearance of having been crushed. In one place the blocks have undergone little or no movement on one another; elsewhere they are distinctly faulted. Faulting has taken place in considerable degree throughout the Nome group, yet no general system of faulting was made out. Except in the small faults in which the displacement may be seen, it is rarely possible to tell how great the movement was. This is due to the absence of reference beds, which makes it difficult to correlate outcrops in one locality with those in another.

It was stated at the beginning of this section that the relation between the Kigluaik and Nome groups is somewhat in doubt, but that it appears to be one of conformity, although the possibility of an unconformable relation is admitted. One of the difficulties attending the supposition of conformity is that there seems to be too little space between the limestone south of Salmon Lake and the Tigaraha schist on the north to give room for any such thickness of schist as underlies the limestone of Mount Distin. The solution of this difficulty may be that faulting has taken place along the east-west valley south of the Kigluaik Mountains, giving rise to a displacement within the Nome group, or that there is an unconformity below the limestone that brings about the same result. Both these possibilities were recognized in the field, and evidence to support one or the other was sought without success.

Smith [1] has presented evidence for unconformity at the base of the Sowik limestone in the Solomon and Casadepaga region. The Sowik limestone extends north-northwest from Solomon River near the mouth of Big Hurrah Creek to Kruzgamepa or Pilgrim River, where it turns abruptly to the west along the south side of the Kruzgamepa Valley. Extensive faulting has obscured the relations of this limestone to the limestone south of Salmon Lake, but the field relations suggest their equivalence. If this proves to be the case, there should be, at the base of the limestone in the Nome region also, an unconformity which has not yet been recognized. It is hardly conceivable that sedimentary formations having so great a range in age as those of Seward Peninsula could have been deposited without repeated interruptions and periods of erosion, and it seems certain that if the

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, 1910, p. 55.

geology were worked out in detail over the whole area unconformities in deposition might be discovered of which we now have no knowledge.

HISTORICAL GEOLOGY.

The great age of nearly all the rocks of Seward Peninsula, the lack of fossil material in most places, and the exceedingly complicated structure produced by the deformation that the rocks have undergone have made it impossible so far to gain satisfactory knowledge of the geologic history of the region. It is possible, however, from the character of the sediments, the relative position of different formations so far as they are known, and the presence of intruded rocks in the sedimentary beds, to form an idea of the order in which some of the important geologic events took place, even if they can not be assigned to a definite place in the time scale.

It is believed that the first period of sedimentation of which a record remains in the Nome region is that during which the massive limestone in the lower part of the Kigluaik group was laid down. This limestone rests on gneiss, which is most intricately folded and probably is the floor on which the limestone was deposited, although it is not certain that the gneiss may not be a greatly altered igneous mass intruded into the limestone. It has already been stated in discussing the age of the Kigluaik group that there is reason for thinking that the massive limestone of Mount Osborn is one of the oldest sedimentary formations of Seward Peninsula, and that it probably was deposited early in Paleozoic time.

A change in the character of the material deposited by the ancient sea brought about the formation of the argillaceous and quartzitic beds of the Tigaraha schist, which constitutes the upper formation of the Kigluaik group. These schists were intruded by great masses of granitic rock and by sills and dikes of more basic composition. The intrusions took place in several different periods of time, as is shown by their relation to one another and by the different degrees of alteration they have undergone. It is not known that the Kigluaik group was deformed before the sediments of the Nome group were deposited, but there is some reason for believing that it was.

Possibly the Kigluaik rocks were folded and elevated above sea level, so that they underwent erosion before the Nome sediments were laid down upon them, but the resulting unconformity, if it exists, is either not prominent or has been obscured by later deformation affecting both the Kigluaik and Nome groups. Whatever the relation may be, it is believed that the deposition of the Kigluaik sediments was followed by that of the schists and limestones of the Nome group. These deposits were laid down in Paleozoic time and possibly in two or more periods of deposition separated by intervals of erosion, but of this no definite proof has been found within the area under consideration. Into them were intruded igneous rocks, for the most part dikes or sills of granite and diabase. The available evidence indicates only approximately the time when these intrusions occurred, but as in many places the diabases are entirely recrystallized it is probable that they are not younger than Mesozoic and perhaps are older. There is just as great uncertainty in regard to the granite intrusions, for it is not evident whether they are to be correlated with some of the granite intrusions of the Kigluaik Mountains or are more recent.

After the sediments of the Nome group had been invaded by the basic igneous rocks, or perhaps while these intrusions were in progress, there began the most profound and widespread movement that is known to have affected Seward Peninsula. By it the rocks were folded and given their north-south structural lines and in large measure their cleavage. This folding was accompanied by the deposition of quartz in veins. The greenstone intrusion and the movement that folded the dikes and sills began in post-Silurian, possibly post-Carboniferous time, and although it may have been interrupted during long intervals, was not ended till after the coal deposits and associated beds in the eastern part of the peninsula had been laid down unconformably on the older rocks and folded together with them.[1] The time when these younger sediments were deposited is not definitely known, but they are believed to belong in the upper part of the Cretaceous or possibly in the lower part of the Tertiary. Another dynamic disturbance then began, which gave rise to an uplift along the axis of the Kigluaik and Bendeleben mountains. It was accompanied by granitic and pegmatitic intrusions, possibly also by the deposition of quartz veins in portions of the schists of the Nome group. The relation of the quartz veins to the pegmatitic intrusions, however, has not been definitely established.

Movements of considerable magnitude continued after the granite was intruded and their effects are seen in both groups of metamorphic rocks. These disturbances must have taken place throughout a long period of time, for they have produced a schistose structure in some of the granite and have caused widespread faulting and fracturing throughout the Nome group at a time when the rocks were, it is believed, at or near the surface.

The events so far related may be considered as belonging to the ancient geologic history of Seward Peninsula, and they bring us to the time when the present topographic features began to take their form. These events were scattered through an immense range of time extending from earliest Paleozoic to the beginning of the Ter-

[1] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 247, 1905, p. 25.

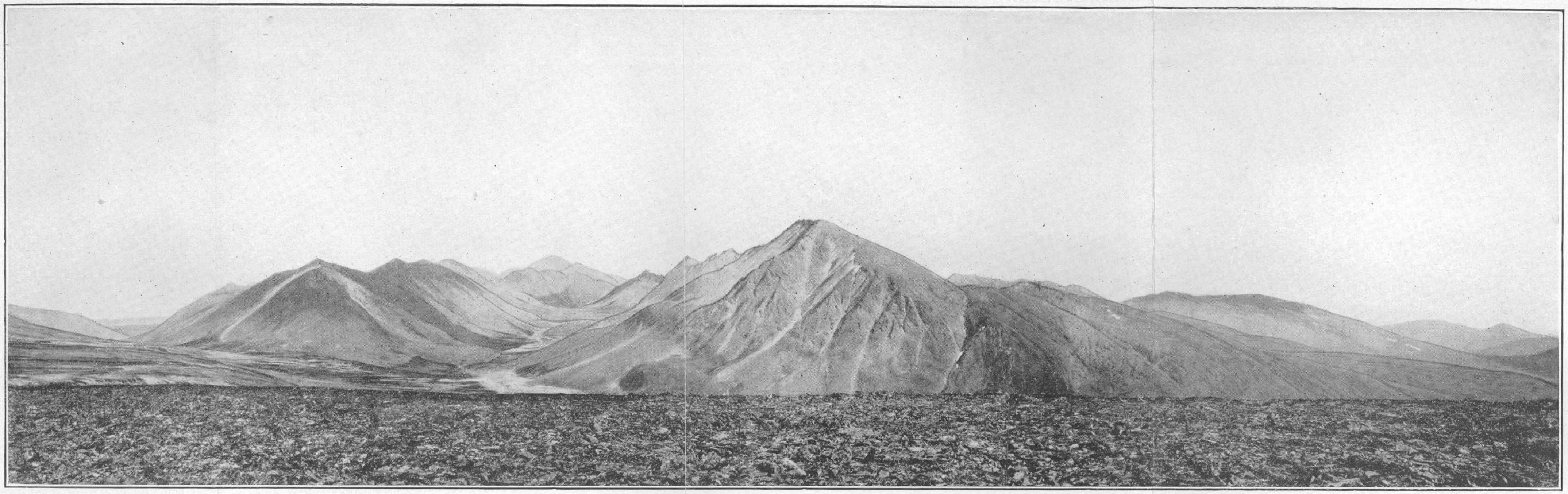
tiary, a period vastly greater than has elapsed since then. The records they have left are difficult to interpret, partly because the evidence of many important events is destroyed or undiscovered and partly from failure to understand the full meaning of the records that persist and are known.

At the time when these earlier events were brought to a close Seward Peninsula was an elevated land mass, on which streams had already begun to carve their valleys. There is reason to believe that this land mass had undergone long-continued erosion, during which whatever rugged features it may have had were removed and its inequalities of elevation were largely reduced. The evidence for this in the Nome region consists in a general accordance of summit levels to a plane sloping gently from the Kigluaik Mountains to the sea.

This land mass was attacked both by streams and by the sea. The rivers deepened and broadened their valleys and carried away the sands and gravel they produced to be scattered over the bottom of the ocean. At the same time the sea was cutting away the cliffs along the coast line and helping to form the rock floor extending back to the foot of the hills 4 miles from the present beach at Nome, on which the coastal-plain gravels were laid down. Changes in the elevation of the land relative to the sea took place. During the formation of the coastal-plain deposits there was a gradual subsidence, which carried the shore line considerably landward of the third beach and must have allowed the sea to enter the lower valleys of Snake and Nome rivers. The amount of this subsidence is uncertain, but it could hardly have been less than 300 or 400 feet. It was followed by a reelevation of the land and a retreat of the shore line to its present position. These movements were interrupted at times and may perhaps have been temporarily reversed, giving way to intervals of relative stability in which the buried beaches of the coastal plain were formed.

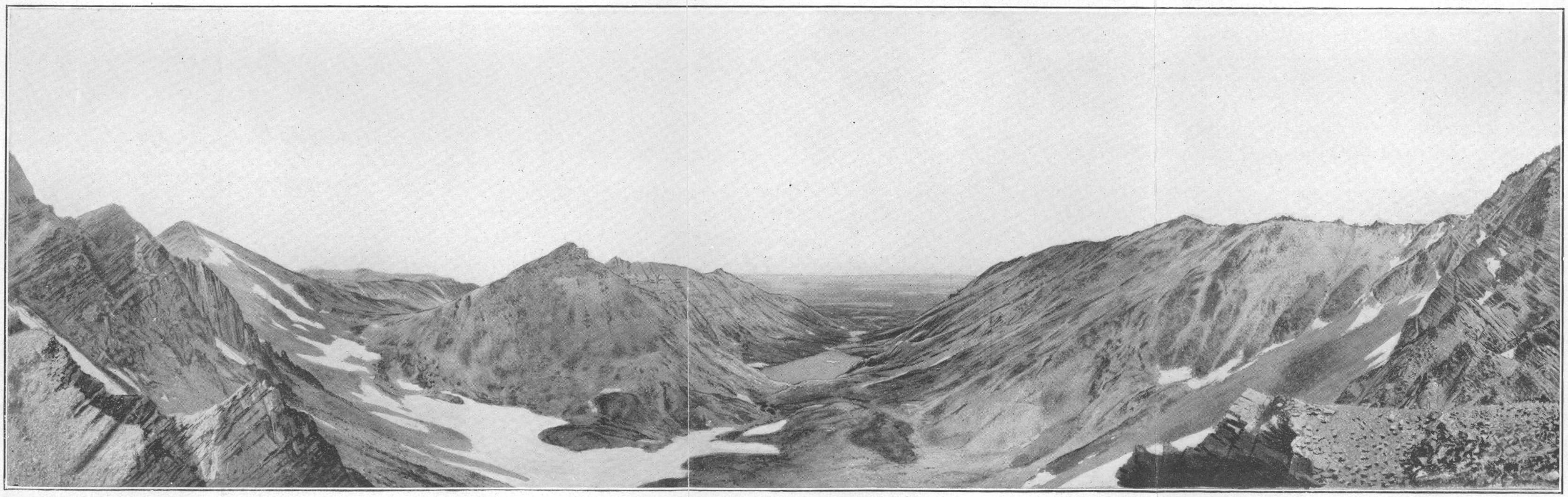
The oldest of the coastal-plain gravels give evidence by the fossils they contain of a climate milder than that now prevailing. (See p. 45.) This climate, however, did not continue throughout the time in which the coastal-plain deposits were accumulating, for the later deposits afford proof of glacial conditions existing in the mountains on the north. It therefore appears that a climatic change had taken place which brought about the accumulation of snow and the formation of ice streams that moved down the valleys from the interior highlands toward the coast. Accumulation was greatest in the high mountains of the Kigluaik region, where the ice remained long after it had deserted the lower valleys and where remnants of the former more extensive glaciers remain to the present day. It is in the Kigluaik Mountains that glaciation left its marks most conspicuously on the topography. All the usual evidences of mountain glaciation are found there—cirques, hanging valleys, U-shaped troughs, over-steepened slopes, glacial striæ, rock-basin lakes, and moraines. (See Pls. X and XI.) An excellent example of a rock-basin lake is found in the extreme northwest corner of the Grand Central quadrangle. (See Pl. VI, *B*, p. 14.) It lies in the cirque basin bounded on the south and west by granite walls that rise almost perpendicularly more than 1,000 feet. The open side is choked by morainic débris, but the lake occupies a true rock basin. Other examples might be named. The little basin represented in Plate XII, *B*, was once occupied by a lake, now almost destroyed by the cutting of a channel through the rock rim. To illustrate other glacial features, it may be said that nearly all the tributaries of Grand Central River flow in hanging valleys. Windy Creek and the upper parts of Sinuk and Grand Central rivers occupy typical glaciated U-shaped valleys. Furthermore, the valleys of these three streams contain the largest morainic deposits of the region, but such deposits are recognized in other valleys also, as those of Fox and Thompson creeks and Gold Run. Examples of modified drainage are numerous. Deposition of morainic material has had an important effect on the drainage in many places by damming the streams and producing lakes. Salmon Lake and the two small lakes on Windy Creek and Sinuk River were formed in this way. Over-steepened valley slopes are a common feature of all the larger streams within the high-mountain area. Glacial grooves and striæ, however, are not seen so frequently as the other features noted, because the rock surface, where not covered by gravel and other loose material, is rapidly broken down by frost and the surface markings are thus destroyed.

In that part of the Grand Central quadrangle south of the Salmon Lake and Sinuk River valley and in the Nome quadrangle the evidences of glaciation are less conspicuous yet no less conclusive than in the Kigluaik Mountains. This condition arises from two causes. In the first place, all the evidence so far collected indicates that glaciation was less severe, and in the second place, the ice deserted the valleys of this area long before it ceased to accumulate and began to melt away in the high mountains. There is evidence that ice masses originated in this southern area also. Christian Creek heads in a small lake in a cirque basin once occupied by a small glacier. Such examples are not numerous, however, and there is no doubt that the principal source of ice supply was toward the north. The ice moved southward from the Kigluaik Mountains through the valleys of Silver and Slate creeks into the valley of Stewart River and thence also to the heads of Goldbottom and Grouse creeks, although the principal movement of ice in the Stewart River valley was westward. In the upper part of this valley the ice must have maintained a fairly constant height at about the 800-foot contour for a considerable time, as



A. TOPOGRAPHY OF THE KIGLUAIK MOUNTAINS.

Cobblestone River on the left; Windy Creek near the center, with Mount Osborn at its head.

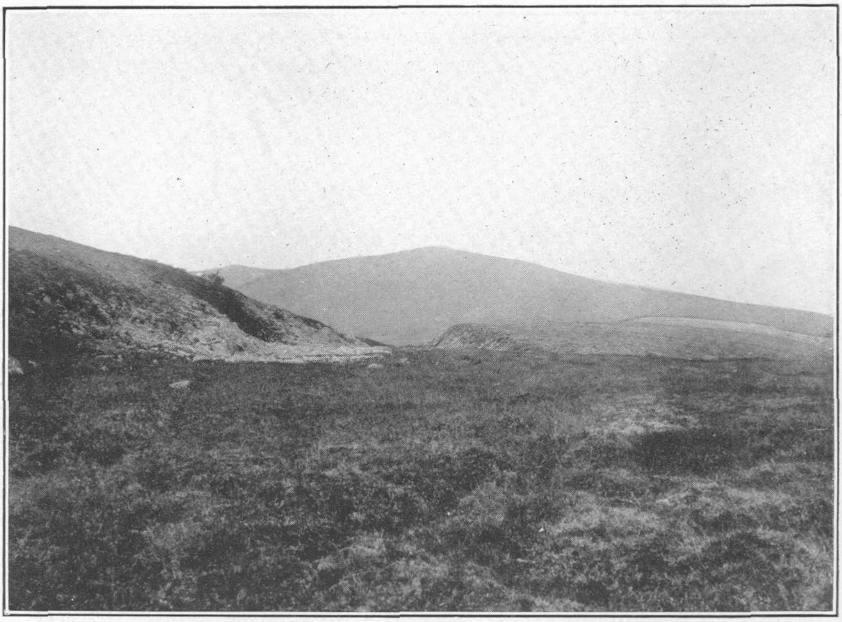


B. GLACIAL TOPOGRAPHY IN THE KIGLUAIK MOUNTAINS.

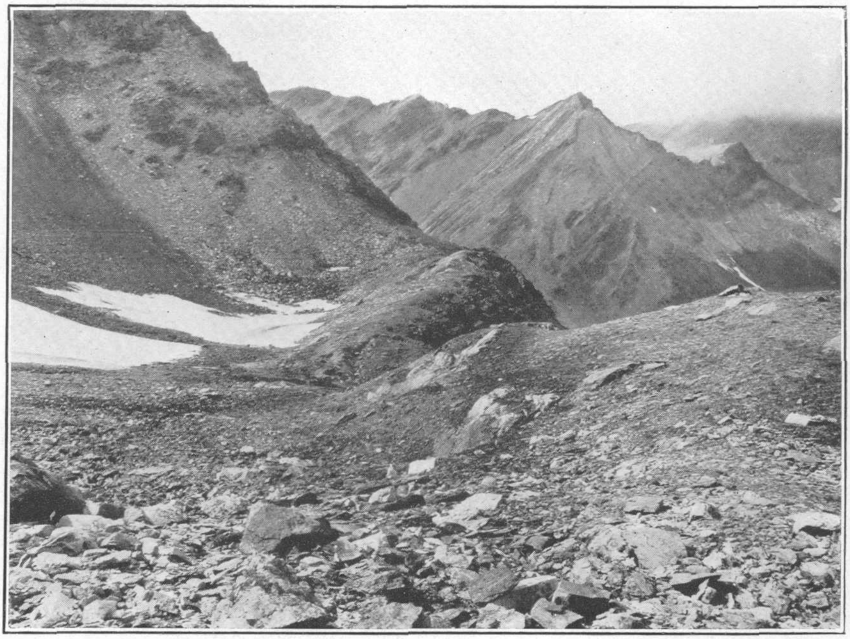
Lowlands east of Imuruk Basin in the distance.

GLACIAL CIRQUE ON EAST SIDE OF MOUNT OSBORN.

The lower half of the mountain is gneiss, which is overlain by limestone with interbedded schist or gneiss. A few hundred feet of biotite schist caps the mountain.



A. CHANNEL CUT BY A STREAM FLOWING ALONG THE EDGE OF THE GLACIER THAT FORMERLY OCCUPIED STEWART RIVER VALLEY.



B. SMALL CIRQUE ON SOUTH SIDE OF THOMPSON CREEK VALLEY, 500 FEET ABOVE THE STREAM.

The rock rim across the front ranges in height from 5 to 15 feet but has been cut through by running water.

is shown by the many granite bowlders brought from the Kigluaik area and laid down at this level on the mountain slopes. It is shown also by minor topographic features. One such feature is an abandoned stream channel on the north slope of Mount Distin. (See Pl. XII, *A*.) This channel crosses the axis of the ridge almost at right angles and was formed by a stream that flowed westward along the edge of the ice at the time when the deposits of granite bowlders just mentioned were laid down.

Another great ice stream flowed out through the Grand Central valley. This glacier probably discharged part of its ice into the head of the Nome River valley, although the greater part moved eastward. It originated on the east side of Mount Osborn and appears to have been the largest glacier within the area considered. It formed extensive morainal deposits in the valley below Salmon Lake and thus gave rise to the lake itself, as already noted.

A long glacier moved down the valley of Nome River. It probably received most of its ice from the Kigluaik Mountains, but doubtless acquired further material from small glaciers along its course. This glacier discharged some of its ice into the head of the Stewart River valley and probably spilled over also into the Flambeau and Snake valleys, for erratic granite bowlders are numerous on the divide between Darling and La Spray creeks and in Grub Gulch. It is difficult to determine whether the Nome River glacier extended to the sea. There is no question that part of the coastal-plain deposits contain glacial material, and it seems certain that some of this material was derived from the Kigluaik Mountains. The glaciated limestone and schist bowlders could be of local origin, but this is not true of the granite. Cape Nome is the nearest source of granite material, and although floating ice might be able to distribute granite bowlders from this source over the coastal plain, it would not be capable of placing the granite in the Nome and Snake River valleys. Possibly glacial ice and stream currents together are the causes accounting for the distribution of granite fragments in the Nome coastal plain. There is no evidence at hand suggesting that Seward Peninsula has been subjected to regional glaciation.

So far as present knowledge goes, the belief seems to be warranted that glaciation began after the first of the coastal-plain gravels were laid down, that it reached its maximum long ago, and that it has only recently been ended. Thus there have been at least two changes in the conditions that control glaciation, the first allowing ice to accumulate and the second causing it to disappear. During this time there were at least two principal changes in elevation of the land. Depression carried the shore line back to the slopes of Anvil Peak and the elevation that succeeded this depression advanced the shore line to its present position.

Such changes are trivial in comparison with the long line of unknown events that must have taken place during the earlier geologic history of this region. We recognize them because they are recent, the evidence of them having not yet been destroyed, but we should not fail to remember that they are only a very small part of the story. Yet these changes are of great importance in one way, for they are closely connected with the processes that have made Nome important as a placer-mining district.

ECONOMIC GEOLOGY.

INTRODUCTION.

Nome and the region adjacent to it gained economic importance because of their placer-gold deposits. No valuable minerals besides gold have yet been mined there in a commercial way, and no other source of gold than the gravels of the streams and benches and the ancient beaches has contributed materially to the great quantity of precious metal that made the name of Nome familiar. Probably Nome will always be thought of as a placer region, for even if important lodes of gold or other metals should be developed there in the future the vast quantity of auriferous gravels will be productive as long as improvements in methods of mining keep pace with the demand for gold; or, to state the matter in a different way, the life of Nome as a gold-placer camp will depend on success in keeping the cost of mining below the recoverable gold content of the gravels rather than on the quantity of gravels to be exploited. This statement is not made to raise doubt concerning the possibilities of lode mining in this district, but rather to emphasize the importance of Nome's placer-gold resources.

The gold production of Seward Peninsula from 1897 to 1911 is given in the following table and is represented graphically in figure 7.

Gold and silver production of Seward Peninsula from 1897 to 1911.

Year.	Gold.		Silver.	
	Quantity.	Value.	Quantity.	Value.
	Fine ounces.		*Fine ounces.*	
1897	725	$15,000	65	$39
1898	3,628	75,000	326	190
1899	135,455	2,800,000	12,190	7,262
1900	229,790	4,750,000	20,681	12,683
1901	199,831	4,130,700	17,984	10,600
1902	220,686	4,561,800	19,861	10,358
1903	216,032	4,465,600	19,442	10,391
1904	201,470	4,164,600	18,132	10,374
1905	232,209	4,800,000	20,898	12,611
1906	362,827	7,500,000	32,654	21,808
1907	338,639	7,000,000	20,952	13,828
1908	247,690	5,120,000	20,477	10,852
1909	208,118	4,302,000	20,608	10,716
1910	170,770	3,530,000	20,317	10,971
1911	151,661	3,135,000	17,996	9,718
	2,919,531	60,349,700	262,583	152,401

The silver is computed from the purity of the gold, the figures given being based on a comparison of assay returns.

It is not possible to give figures that will represent the gold produced at or near Nome separate from that of the whole peninsula, but the output of Nome is so large a proportion of the whole that the form of the curve in figure 7 probably represents with considerable accuracy that for the Nome district alone. The curve brings out clearly some of the important facts in the development of mining there. From the discovery of gold in 1898 there was a rapid rise in production during the first two years, while the rich gravels of Anvil Creek, Snow Gulch, and the present beach were the most important producers. From 1900 production remained relatively constant at a little more than $4,000,000 a year till after the third beach was dis-

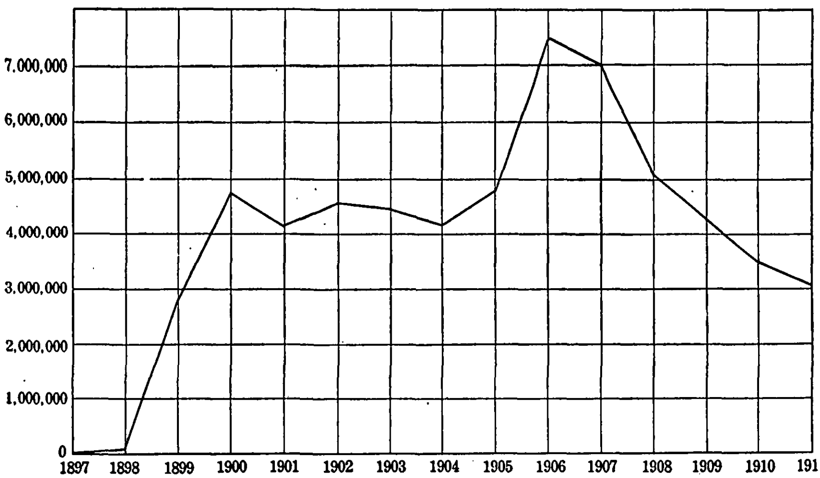


FIGURE 7.—Diagram showing gold production of Seward Peninsula from 1897 to 1911.

covered in 1905, when a rapid rise took place, and a maximum of over $7,000,000 was reached. This high production was maintained for two years, but it was followed by a reduction in gold output, due to the approaching exhaustion of the third-beach placers, and in 1910 the yield fell below the yearly average of the five-year period from 1900 to 1905. Some well-informed mining men at Nome believe that the gold output for 1911 is below the average of what may be expected under present conditions, and that with the installation of new dredges now projected and with continued success on the part of those already in operation an average yearly production of approximately $4,000,000 will be maintained.

HISTORY OF MINING.

A somewhat detailed account of the development of mining on Seward Peninsula has been given by Brooks[1] in a recent publication,

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 13–39.

and brief statements have been made in earlier reports. It is not necessary to present all the facts anew, but a summary of the important events is desirable here.

Placer gold has been known on Seward Peninsula since about 1865, when the Western Union Telegraph Co. began the construction of a telegraph line to connect the United States with eastern Asia. The route chosen across Seward Peninsula was along Niukluk River to Kruzgamepa River and thence west to Port Clarence and Cape Prince of Wales. Portions of the line were constructed, but the project was finally abandoned because of the successful laying of the Atlantic cable. It is believed that the first white men who had knowledge of placer gold in this part of Alaska were members of parties sent out by the telegraph company to carry on this work. They are said to have found fine gold on Niukluk River.

Gold was mined in the Council region several years before it was known at Nome, and from this vicinity the prospectors set out who made the Nome placers familiar to the world.

Placer gold was discovered on Snake River in 1898 by a party which started from Golofnin Bay to prospect the gravels of Sinuk River. It is said that this party included N. C. Hultberg, J. J. Brynteson, H. L. Blake, and J. L. Haggalin. They worked their way westward along the coast in a small boat, but were storm bound for several days near the present site of Nome and spent the time in prospecting the gravels of Snake River. The results were not encouraging to a majority of the men, and they pushed on to their original destination, but, not having success on Sinuk River, finally returned to Golofnin Bay.

One member of the party, however, Brynteson, was sufficiently impressed with the prospects on Snake River to make another visit to the region. With two companions, Jafet Linderberg and Eric O. Lindblom, he returned to Snake River and on September 20 found rich placers on a stream which they called Anvil Creek from a peculiarly shaped rock on a neighboring hill. They also prospected and located claims on Snow Gulch, Glacier Creek, Rock Creek, and Dry Creek as well as the original claims on Anvil Creek. These streams have since proved to be the greatest producers of the region.

A rush to the region took place immediately after the news reached the miners about Golofnin Bay, and on October 18 the Cape Nome mining precinct was formed and Dr. A. R. Kittleson was elected recorder. It was then too late in the year for mining, but claims on some 7,000 acres were filed by about 40 men.

By the spring of 1899 rumors of the new gold field reached the outside world and started a movement in the Nome direction which progressed during the summer till the population of the camp, then called Anvil City, was increased to nearly 3,000. A great proportion of this number was composed of disappointed gold seekers from the Yukon country. They found on arriving at Nome that most of the region had already been staked and that their opportunities for sudden wealth were as poor in the new camp as they had been in the camps they had recently left. An attempt was made by them to have all the claims staked up to that time invalidated so as to permit a general restaking of the creeks. This was defeated through the intervention of the military authorities, yet there was scarcely a claim that was not "jumped"—many of them several times.

One of the important events of the season, important not only because it made known a new source of gold to the camp, but because it helped in great measure to relieve the unrest and dissatisfaction felt by the disappointed late comers, was the discovery of gold in the Nome beach. It was free to anyone who had the means to dig up the sand and wash it, and the shore was soon lined with a great crowd, each one at work on his little patch of ground. Although only the most primitive means were employed, over a million dollars was taken out in a period of about two months, and the richest deposits of the beach were practically exhausted.

In this year also the first newspaper was started, a mayor and town council were elected, a post office was established, and a United States commissioner was appointed.

The great rush to Nome took place in 1900. At the end of the previous summer many of the miners returned to the States, and the reports concerning the wealth of Nome were confirmed. A stampede comparable to that of the Klondike set in, and by the middle of the summer probably more than 20,000 persons had been landed on the Nome beach. Jumping of claims and litigation over mining properties continued during the year. One of the most important events was the discovery of deep gravels at the head of Dexter Creek, leading to the beginning of winter mining. Another event having a significant bearing on the future of the region was the construction of a short railroad from Nome to Anvil Creek.

In the following year, 1901, the Miocene ditch was begun. This ditch, the first of the system now bringing water from the upper Nome River to the placer ground near Nome, was originated by two experienced placer miners—W. L. Leland and J. M. Davidson—who were quick to recognize the importance of such a project and lost no time in carrying it out. Important extensions of the ditch were made in 1902 and 1903. The year 1901 also witnessed the installation of the first pumping plants for hydraulic mining.

Hydraulic elevators were introduced in 1903, and since that time improvements in mining methods have consisted chiefly in a reduction of costs by the use of labor-saving machinery.

The third beach, 3 miles north of Nome, was discovered late in the fall of 1904, and although there had been mining on the second beach for two or three years the discovery first turned the attention of most of the mining men toward the possibilities of the Nome tundra, which since that time has held chief place in the minds of the Nome public.

The summer of 1905 at Nome was a season of ditch building and experiment. The Seward ditch and the Pioneer ditch, both taking water from Nome River for use near Nome, were begun. The Wild Goose pipe line, to divert water from the head of Grand Central River to the Nome River valley, was also started. A large dredge was built on Nome River and a steam scraper was installed on the beach.

The most important feature of the winter of 1905–6 was the extension of mining enterprises along the third beach, eastward from Little Creek to a point near Nome River. This was followed in 1906 by the greatest production for a single year that the region has known, and by great activity in prospecting over all parts of the Nome tundra. In 1906 the railroad, which, during the previous year, had been extended to the low saddle north of King Mountain, was pushed forward by way of Nome River and Salmon Lake valley to Lanes Landing, now called Shelton, on Kuzitrin River. Another event of importance in 1906 was the construction of a public road from Nome to the head of Dry Creek, the first road built in the region outside the limits of the city of Nome.

Since 1906 the important events that have taken place include the discovery of several other buried beaches, notably the "intermediate" and "submarine" beaches, and the increased use of dredges in exploiting the coastal-plain gravels. The successful application of dredges to mining in the Nome region is of great importance, for it makes available for working much low-grade gravel from which the gold can not be extracted economically by any other means in use there at present. There were in 1911 nine dredges in the vicinity of Nome.

ECONOMIC CONDITIONS.

Nome is more fortunately situated than most of the other gold-producing camps of Alaska. Its location on the sea gives it great advantage over the interior towns, even those that are reached directly by the Yukon. Six or eight steamships make trips with passengers and freight between Seattle and Nome from the beginning of June until the end of October or the middle of November. A considerable amount of freight also is carried by sailing vessels, one or two of which may be seen at almost any time at anchor off the Nome beach.

The cost of living at Nome in summer is now very little higher than in some of the Pacific coast cities of the United States, and the accommodations are nearly as good.

During the early days little work other than the carrying of supplies was done in winter. The lack of roads and other difficulties of travel made it exceedingly expensive to haul freight in summer, and consequently preparations for mining were made while the snow was on the ground. A great many claims were staked in winter, because traveling was easy and rapid. No prospecting was done, of course, but a man with a sled load of lath or willow sticks could lay claim to more ground in a week's trip than he could hope to stake in a month during the summer. The mining season, or rather the sluicing season, probably did not average over 70 days, although if the days of preparation were added to this the number would be increased to about 90, which is generally given as the length of the working season.

With the discovery of the deep gravels and the beginning of underground mining conditions were much changed. It was no longer necessary for a man to be idle during half or three-quarters of a year, as a force of miners could be kept at work throughout the winter as well as the summer. Winter work is less expensive than summer work. Winter wages usually have been not more than half as great as those of summer, for the supply of labor is larger, there being less work to be done. The gravel mined in winter is piled in a " dump " near the shaft, and is ready for sluicing with the melted snows of early spring, thus further reducing the cost and making it possible to exploit gravels in many places where no other water supply is at hand, or where the cost of ditch water is high.

The transportation of supplies from Nome to the creeks has always been one of the great items of expense in mining. Even on the streams near Nome, such as Anvil and Glacier creeks, the freight charges were high, because until 1906 there was no good road across the tundra, and the railroad practically controlled the freighting. The wagon road to the head of Dry Creek now makes it possible to reach Nome River, at the mouth of Dexter Creek, without great trouble, and from that point northward to the Kigluaik Mountains the river bars furnish good going for freight wagons. Freight charges by wagon to the head of Nome River in 1906 were about $60 a ton. Snake River is less satisfactory for wagons than Nome River, and is more difficult to reach, so that it is not used much as a highway. The Seward Peninsula Railway follows the valley of Anvil Creek to the Dexter Creek divide, and then passes into the Nome River valley. By its extension in 1906 all points in the upper Nome River valley could be reached, but freight rates are not likely to fall appreciably below the cost of freighting by wagon.

A second large item of expense in mining is the cost of fuel. Underground mining made it necessary to have a much greater and better supply of fuel than the region afforded. The gravels are frozen, and must be thawed before they can be removed. Power also is required to hoist them from the shafts. Water must be pumped to keep some of the mines dry, or for sluicing. Coal and oil now furnish heat and power for all mining operations in the Nome region. Attempts were made to utilize the coal resources of Cape Lisburne, but did not meet with success, so that now a large part of the coal burned comes from British Columbia or the Pacific coast of the United States. The price to the consumer averages between $17 and $20 a ton. Crude oil, distillate, and gasoline are employed generally for power. The cost varies greatly and depends largely on freight rates from Nome to the place where it is used.

The question of water supply is of great importance to placer miners. When mining began on Anvil and Glaciers creeks water for sluicing was obtained from the creeks themselves. The drainage areas of the streams are small, and their run-off[1] varies greatly in different parts of the season, so that the supply was uncertain. Thus the amount of gravel that could be handled depended on the summer rainfall, as sluicing did not begin till after most of the snow was melted.

Two methods have been employed to overcome this unfavorable condition. The first and most satisfactory is to bring water from a reliable source and deliver it at an advantageous elevation by ditches. The second, which has not proved economical, is to pump water to the required elevation. There are, as has been said, three large ditches drawing their supply principally from the Kigluaik Mountains that deliver water within a radius of 6 miles of Nome at elevations ranging from 200 to 400 feet above sea level. Besides these there are smaller ditches in several parts of the area that supply water to individual claims.

These ditches removed in some measure the uncertainty regarding water supply, but they are constructed and maintained at a considerable expense. Ice beds on the hill slopes offer one of the greatest obstacles to construction, for the water melts out the ice and undermines the banks. During the first year of use a large amount of water is lost from a ditch by seepage. This difficulty, however, diminishes as the fine sediment in the water fills the cracks and small openings through which the seepage takes place. The critical time for a ditch each year is when the water is first turned into it in the

[1] During the summers of 1906–1909 stream measurements and records of rainfall were made by J. C. Hoyt, F. F. Henshaw, and C. C. Covert. The data collected by them are published in Water-Supply Papers U. S. Geol. Survey Nos. 196 and 218; in Bull. 379, pp. 370–401; and in Bull. 442, pp. 372–418.

spring. Frost loosens the ground and leaves it porous when the thaw comes, so that until the ground settles constant vigilance is necessary to avoid breaks in the embankment. All the large ditches are patrolled regularly throughout the working season.

Water for power, one of the most valuable resources of the region, has not been used up to this time, although two projects for its use have been proposed and may be carried out in the future. One of these contemplates a 50-foot dam across the outlet of Salmon Lake, which would give both greater storage capacity and greater fall than can now be obtained. It is proposed to transmit the power by electric current to those places on the coast that require it.

The purpose of the other project is to generate power by the water of several streams south of Imuruk Basin, on the north side of the Kigluaik Range. Both projects are feasible, and it is perhaps strange that they were not proposed earlier and carried to completion.

Water supply is a function of weather conditions, as are also the length of the working season and in some measure the efficiency of labor.

Abbe[1] places Nome in the Bering seacoast province, one of the eight climatic provinces into which he divides Alaska. It is characterized by temperature ranges and precipitation intermediate between those of the more southern coast provinces and the provinces of the Arctic coast and the interior. He says:[2]

In the Seward Peninsula, which forms the north shore of Bering Sea, June, July, and August can be counted the summer months. The snow has usually disappeared by the 1st of June and does not begin to fall again till September. In some years June and July are delightfully dry and pleasant months, but the colder rains, which are apt to begin in August and practically continue until snow flies, often accompanied by severe winds, are exceedingly trying. During 1901 the average temperature was 44° in July and August and 40° in September,[3] the number of rainy days during these months aggregating 66. At Port Clarence two years' records[4] showed a mean annual temperature of 22°, with a minimum of —38° and a maximum of 77°. The precipitation of the only year in which a record was kept amounted to 5.58 inches. The ground is usually frozen a foot or two below the surface throughout the year. * * * While the temperatures of the northern Bering Sea coast lines are usually not so low as those of the interior, the greater humidity of the atmosphere makes them harder to resist.

Ice covers Bering Sea in the neighborhood of St. Lawrence Island from early November till the end of April, but does not leave

[1] Abbe, Cleveland, jr., Climate, in Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 141.

[2] Idem, p. 146.

[3] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 7.

[4] Brooks, A. H., and others, Reconnaissances of the Cape Nome and Norton Bay regions, Alaska: Special publication U. S. Geol. Survey, 1901, p. 163.

the mainland shore till later. In some seasons ice stays on the Nome coast till the last part of May, and even after it has moved away from the beach prevents the approach of boats except those of light draft that can follow the shore line closely.

The growing season for plants in the Nome region is about 100 days or perhaps less, for the late spring frosts end in the later part of May and the early winter frosts come by the middle of September.

A table of the monthly precipitation at Nome from July, 1906, to December, 1910, as given by Henshaw and Parker,[1] is here presented, together with a summary of meteorologic observations covering the period 1907 to 1910, inclusive. A much more extended account of temperature and precipitation at Nome is given in the paper from which this summary is quoted.

Monthly precipitation, in inches, at Nome, Alaska, for 1906 to 1910.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Period.
1906	......	......	......	......	......	......	2.38	2.50	1.02	0.93	0.32	1.91	9.06
1907	2.64	1.46	3.37	0.10	1.12	1.31	2.08	2.68	1.41	.16	.06	.30	16.69
1908	.43	.76	1.19	.02	.19	.90	2.10	2.92	.52	1.13	.26	.75	11.17
1909	.37	.13	.21	45	.15	.88	.82	1.66	.96	1.45	1.16	1.22	9.46
1910	.94	.32	.23	.49	1.03	1.59	3.57	2.61	4.06	1.08	.99	.56	17.47
Mean	1.10	.67	1.25	.26	.62	1.17	2.19	2.47	1.59	.95	.56	.95	13.78

Summary of meterologic observations at Nome, by years, 1907 to 1910, inclusive.

Record.	1907	1908	1909	1910	Mean of period.
Total precipitation, rain and melted snow ....inches	16.69	11.17	9.46	17.47	13.70
Total snowfall ....do	76.65	62.50	44.25	39.40	55.70
Maximum temperature ....degrees F	69	78	70	62	....
Minimum temperature ....do	−32	−32	−33	−38	....
Mean of daily maximum temperatures ....do	30.42	31.55	30.13	28.79	30.22
Mean of daily minimum temperatures ....do	17.64	18.88	17.17	15.87	17.40
Mean barometer ....inches	29.86	29.78	29.87	29.82	29.83
Number of clear days	148	122	163	150	146
Number of partly cloudy days	47	49	55	40	48
Number of cloudy days	170	195	147	175	172
Number of days with rain or snow	103	84	70	114	93

The Nome and Grand Central quadrangles contain no timber. There are willows along the streams and scattered clumps of alders on hill slopes, but spruce does not extend west of Niukluk River—that is, not within 25 or 30 miles of the eastern boundary of the quadrangles. (See fig. 8.) Some species of willow in this district attain a thickness of 4 inches and a height of 15 to 20 feet. Trees of such size are not numerous and probably require the most favorable con-

[1] Henshaw, F. F., and Parker, G. L., Surface water supply of Seward Peninsula, Alaska: Water-Supply Paper U. S. Geol. Survey No. 314, 1913, p. 28.

ditions for growth. Most of the willows seen along the stream courses do not exceed the height of a man nor have a greater thickness than about 2 inches, yet they have made it possible to prospect many parts of Seward Peninsula where no other fuel is to be found. In the early days at Nome driftwood from the beach served as firewood and even as material for cabins, but no such source of supply was available to the miners on the creeks. At present all fuel (coal and oil) is shipped to Nome from outside points.

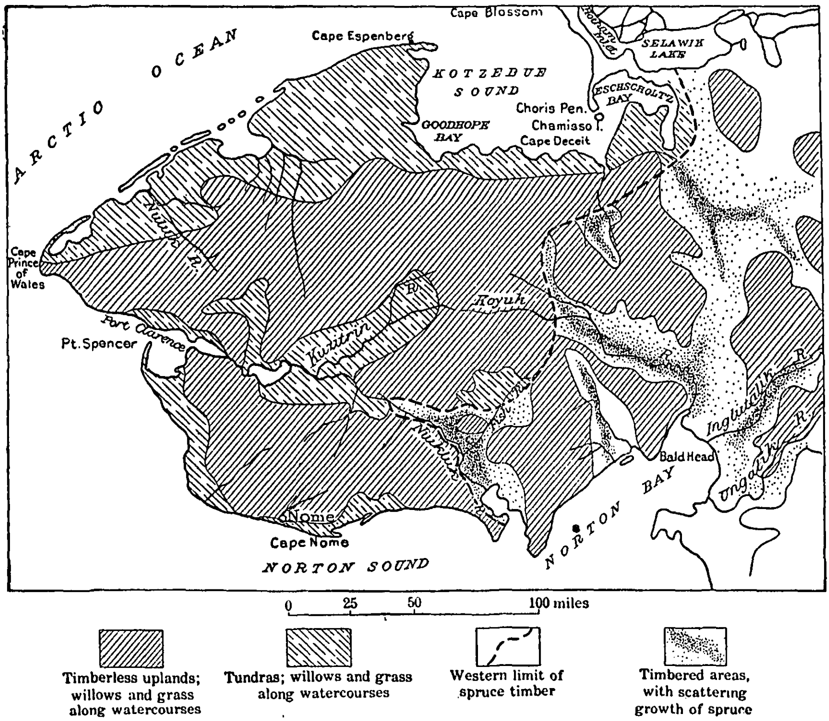


FIGURE 8.—Map showing distribution of vegetation on Seward Peninsula.

The Nome district, except the higher hilltops, is covered for the most part with a mat of vegetation, made up chiefly of various kinds of moss, but including a great variety of small plants and in places dwarf willow, dwarf birch, and grasses of several kinds. This vegetation has formed many deposits of peat, some of which have been used as fuel. The peat is cut into blocks and stacked to dry for a considerable time before it is burned; and although the proportion of ash is great, very satisfactory results are reported.

Grass is plentiful on most of the lower slopes of the hills and valleys. It serves as food for horses, but must be supplemented by grain or hay when the animals are doing heavy work.

MINERAL RESOURCES.

METALLIFEROUS DEPOSITS.

It has been stated herein that the mineral wealth of the Nome district, so far as present development shows, lies in its deposits of placer gold. Many gold-bearing veins and mineralized zones cutting the schist bedrock have been discovered, and on several of them development work has been conducted for a number of years. The results, when compared with the great production of the gold-bearing gravels, are disappointing, yet the very rich placers of Anvil Creek, Dexter Creek, Snow Gulch, and the beaches derived their gold from a near-by source; and although the original deposits may have been widely disseminated in bedrock and became valuable only after repeated concentration, the placers furnish reasonable grounds for the hope that lodes may be discovered. Other valuable metals and minerals, including bismuth, antimony, copper, graphite, and scheelite, are found in the Nome district, but, like the gold lodes, the deposits of these minerals have not yet reached notable commercial importance. It thus appears that the gold-bearing gravels rank first in a consideration of the mineral resources.

The study of placer-gold deposits involves a study of the bedrock source of the gold as well as of the manner and conditions of their occurrence. When these things are understood they serve as guides in the search for gold-bearing gravels and supply valuable information for the exploitation of such deposits when found. It would thus seem proper to consider the bedrock source of gold before taking up the placer deposits, but because of their present far greater commercial importance the placers are described first.

PLACER DEPOSITS.

KINDS OF PLACERS.

A description of the Nome placers at this time, long after most of the observations were made, necessarily deals with many things that are now only history to the men who have been active in developing the field. The richest deposits of some of the creeks and benches and even of the third beach are nearing exhaustion. Other bonanzas have not been found to take their places, and only by the use of new and better methods of mining is the present production maintained.

It is fully recognized that the following descriptions of placers lack much to make them complete and that the critical reader will find occasion to raise questions, yet it is worth while to assemble in one place the records of observations, most of which have already been published,[1] although they are not new nor exhaustive, for they

[1] Accounts of placer mining at Nome since 1905 will be found in the several volumes of Mineral resources of Alaska, Bull. U. S. Geol. Survey No. 284, 1906, pp. 132–144; No. 314, 1907, pp. 126–145; No. 345, 1908, pp. 206–216; No. 379, 1909, pp. 267–283; No. 442, 1910, pp. 353–359; No. 480, 1911, pp. 40, 52; No. 520, 1912, pp. 339–344; also in Bull. 328, 1908.

thus become conveniently available for the use of the thoughtful prospector as well as the geologist. The writer's own observations have been supplemented by those of earlier and later workers in the field, particularly Smith and Henshaw, both of whom collected data on the Nome placers during the course of other work. An excellent paper by T. M. Gibson[1] on the Nome beaches should be read by all those interested in this subject.

The principal placers of the Nome vicinity may be grouped under the four following heads, which are not intended to represent a classification of gold placers but are used mainly for convenience in description: 1, Residual placers; 2, stream placers; 3, bench placers; and 4, beach placers.

These headings are descriptive and refer only secondarily to the origin of the deposits. As a further help in description and to avoid confusion, the placers are here grouped according to the drainage systems of which they are members.

RESIDUAL PLACERS.

Origin.—Residual placers are produced by the decay of gold-bearing rock and the removal by solution or by water and wind transportation of the lighter products of decomposition, the heavier minerals remaining in a natural concentrate. The process is common and is of economic importance where the residual minerals are valuable and occur in sufficient amount to return a profit in mining.

Such concentrated minerals, when compared with those found in streams or on the beach, are seen to have moved relatively short distances from their original bedrock positions, and the movement may be considered as downward rather than horizontal. It is evident that accumulations of this kind are favored by very long continued weathering and are the result of subaerial rather than of stream activities. Gold placers, in which the accumulated gold represents residual material, are known at a number of localities, and some of them have been mined with profit.

Rock Creek.—Gold occurring as a residual concentration is found on the hill slope between Rock and Lindblom creeks. The bedrock is schist, cut by many small veins and stringers of quartz in which pyrite is abundant. These stringers also carry gold. The slope of the hill is gentle, and an accumulation of débris consisting chiefly of angular schist and quartz fragments and ranging in depth from 3 to 6 feet is present. Without doubt a considerable portion of this débris came from the upper slopes of the hill, for its character indicates that it has not traveled far. The gold occurs near and on bed-

[1] Gibson, T. M., Pay streaks at Nome: Min. and Sci. Press, vol. 102, 1911, pp. 424–427, 462–467.

rock and is associated with a great deal of iron-stained quartz and with schist equally or more stained. Sluicing is attended with some difficulties, chief among which is that of obtaining water, so that mining has been carried on only on a small scale and the production is not large. Attempts have been made to exploit the bedrock source of the gold, but with what success is not known to the writer.

A peculiar association of minerals, including the sulphides of lead, antimony, arsenic, and a little copper is found here, and for a time was thought to be possibly a new mineral.

Pioneer Gulch.—Residual gold deposits are mined at Pioneer Gulch, on the west side of Snake River just below the forks. The deposits here occur near a small gulch on a hill slope much steeper than that of the Rock Creek locality just described. The bedrock is schist, cut by small veins of quartz containing iron pyrite, and stained with the oxide resulting from decomposition of the pyrite. Neither the veining nor the mineralization is as notable here as at Rock Creek.

Part of the gold and of the fragmental material, although it is not rounded nor waterworn, has probably moved some distance down the slopes, but some of it appears to be almost in place. Gold may be seen free and in some of the quartz fragments. The free gold is coarse and angular.

Water for operating a hydraulic plant is provided by a ditch having its intake at the mouth of Waterfall Creek and drawing an additional supply from Dewey Creek and Surprise Gulch.

Boer Creek.—Boer Creek is a small southern tributary of Hudson Creek, which joins Buffalo Creek near the head of Nome River. It flows in a steep, narrow valley cut chiefly in black graphitic schist in which are a few interstratified limestone beds. There is little gravel in the creek, but a small hydraulic plant near its mouth is operated for recovering gold from the decomposed graphitic schists, from which nearly all the gold present appears to come. These schists are silicious and thinly laminated. Near them is a dark-blue limestone.

Nekula Gulch.—A claim on Nekula Gulch, commonly known as "Caribou Bill's claim," probably lies near the border line between residual deposits and stream deposits. The gravels were of extraordinary richness and occupied a great hole in limestone. The gold evidently must have traveled more or less to reach its resting place, but its condition indicated that the movement had not been great. This deposit may be compared with some of the rich potholes in limestone on Ophir Creek, in the Council district, and will be described more fully in the account of stream placers on Nekula Gulch. (See pp. 83–84.)

STREAM PLACERS.

PRINCIPAL CLASSES.

Stream placers in the Nome region are of two kinds. Most important are those whose gold seems to be a first concentration resulting from weathering of gold-bearing rock and accumulation of the gold in the channels of streams that carry away the products of weathering. To placer deposits of this nature belong the greatest number of the stream concentrations.

The second kind of stream placers comprises those whose gold is concentrated from gravels of a previous period of deposition. Such placers are well represented on those streams that arise within the coastal plain and on the lower portions of streams that cross the coastal plain. The gold of this concentration is not derived directly from the bedrock source but from a supply disseminated throughout the gravels in which the stream is cutting.

A common variation of stream placer deposits is found in the gold-bearing sands and gravels of river bars, but such placers have no importance yet in the Nome region, although the bars of Nome and Snake rivers are known to carry a small amount of gold.

The most important and productive stream placers of the Nome area were found on Anvil Creek, Glacier Creek and its tributary Snow Gulch, Dexter Creek with its tributary gulches (especially Grass Gulch), and Dry Creek. (See fig. 9.) With these may also be named Bourbon Creek, Newton Gulch, and Hastings, Osborn, and Dorothy creeks. A considerable number of smaller streams complete the list of creek placers of the region, for neither Nome River nor Snake River has reached importance as a gold producer. The writer is indebted to the reports of Brooks and to the notes and unpublished manuscripts of Collier for a large part of the data on the stream placers, collected prior to the year 1905. This material has been incorporated with the results of observations made during the two years in which the field work for this report was carried on.

SNAKE RIVER BASIN.

Snake River.—Snake River heads in the region adjacent to Mount Distin, but the name Snake is applied only to the lower part of the stream beginning at a point 15 miles from the coast. The length of this lower part is much greater than 15 miles, however, for the river follows a winding course through a broad valley in the upland region, and, after crossing the coastal plain to a point within about a mile of the coast, turns abruptly eastward and flows nearly parallel with the shore for about 5 miles before joining the sea. Its elevation at the mouth of the North Fork is 170 feet, giving a gradient of not over 7 or 8 feet to the mile.

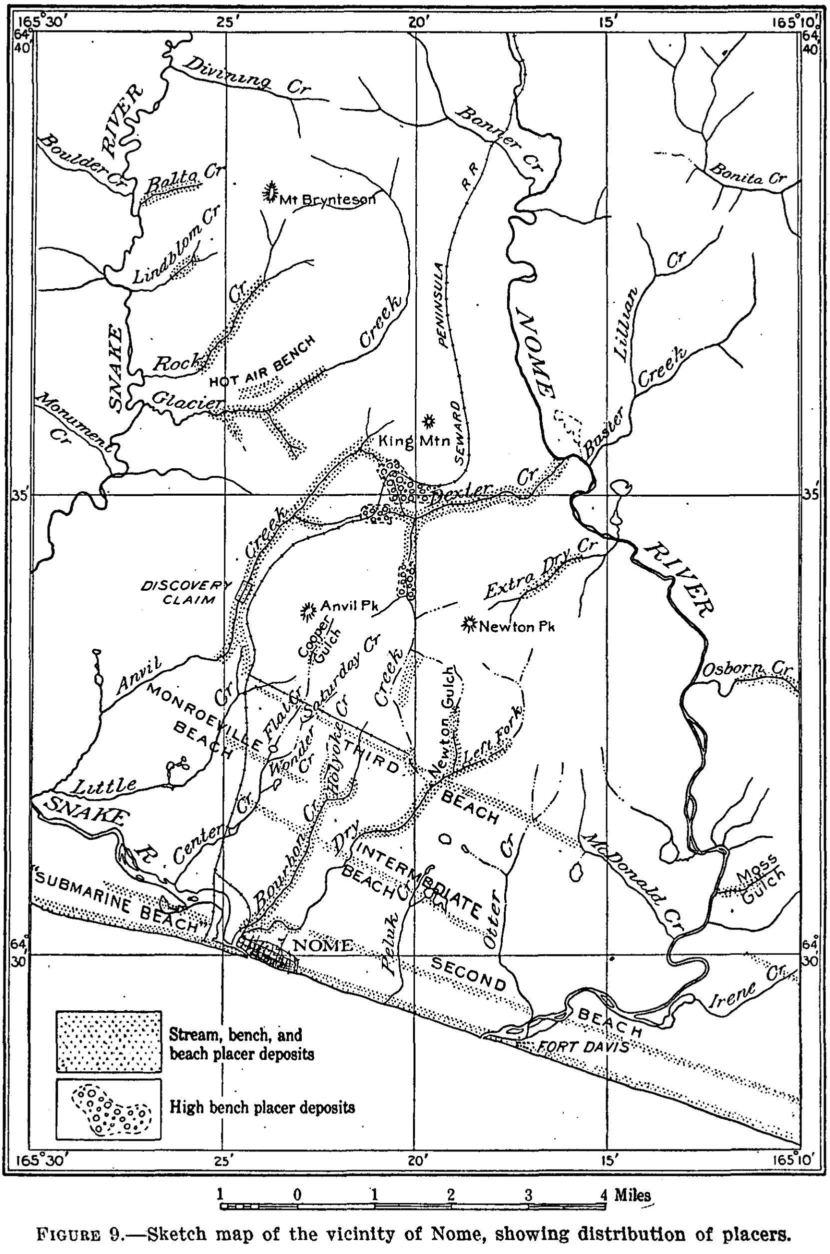


FIGURE 9.—Sketch map of the vicinity of Nome, showing distribution of placers.

Low marshy ground borders the river and forms a valley floor whose width varies between half a mile and 1 mile, and from which the lower hill slopes rise gently on either side. The river swings back and forth across this low land in a succession of meanders, whose complexity suggested the name Snake to the first prospectors.

The Snake River valley has a deep gravel filling, but has been very little prospected. Gold is found on some of the bars. The deposits, however, are not rich enough to pay for working on a small scale and offer little encouragement to prospectors.

The Snake River basin, however, includes some of the richest creeks of the Nome region, such as Anvil, Glacier, and Dry creeks, and other less important streams.

Anvil Creek.—Anvil Creek is the most widely known stream of the Nome region, both because it is the stream on which the first great discovery was made and because of its gold production, which during the first five years of mining amounted to $1,000,000 a year.

Anvil Creek is nearly 6 miles long. The lower 2 miles lies within the coastal plain, but the upper part flows through a broad valley in the upland plateau. About 3 miles of the stream has been productive. This part extends from the vicinity of Moonlight Springs to Nekula Gulch.

Moonlight Springs has an elevation of 100 feet above sea level. The elevation of Nekula Gulch at its mouth is almost 400 feet, so that Anvil Creek between these points has an average grade of very nearly 100 feet to a mile. The drainage basin is small, and scarcity of water for sluicing was frequent in the early days.

Anvil Creek flows in a valley whose rocks are chiefly chloritic and graphitic schist of the Nome group. In the vicinity of Discovery claim, which is situated near the point where the creek leaves the hills to cross the tundra, the bedrock for about half a mile is black graphitic schist. Above that for another half mile is chloritic schist and beyond comes a succession of chloritic and graphitic schist beds, some of which are calcareous. Many of these schist beds are faulted and in places, as near Discovery claim, show small veins and stringers of quartz with pyrite.

Anvil Creek cut its present channel into the schist of the valley floor and is confined on the east by an escarpment not over 15 to 20 feet high in most places. A low bench, with surface sloping gently toward the stream, is thus formed along the east side of the valley. It does not appear on the west side, however, for the creek flows close to the valley's western slope, which here rises rather steeply. The flood plain has a width of approximately 300 feet at the lower end of the productive part of the creek and narrows gradually toward the mouth.

Gold-bearing gravels were first found along the present stream channel and later on the rock bench east of the creek. The gravels of Anvil Creek consist chiefly of material like the rocks of the surrounding hills, and are doubtless derived in large part from sources within the drainage area of the creek, yet rounded granite bowlders from the size of cobblestones up to 2 feet or more in diameter are found in the valley, especially along its east side, and it is, therefore, evident that the surficial deposits are not entirely of local origin.

Gravel deposits ranging from 3 to 5 feet in thickness have been exposed all along the present channel by mining operations. The surface deposits on the bench east of the creek reach a thickness of 25 feet, but the thickness is much more irregular there than along the creek, as the bench gravels have been partly eroded and in one or two places persist only as isolated patches.

All the claims from the tundra to Nekula Gulch have yielded a profit. Some were far richer than others, for the gold is not evenly distributed throughout the length of the creek. Discovery claim, together with the ground above and below for a short distance, proved to be the most valuable part of the creek. The richer deposits of the present channel were in part a secondary concentration of material brought by Anvil Creek and tributary streams from those places where they attacked the auriferous gravels of the bench on the east and especially where they cut into the gold-bearing gravels of

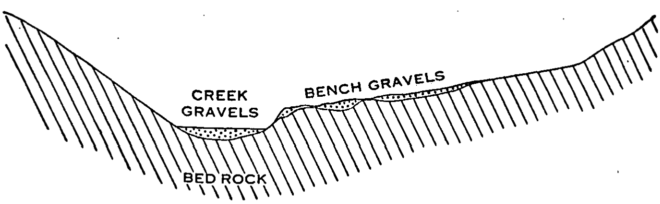


FIGURE 10.—Diagrammatic section of Anvil Creek valley, showing bench gravels.

an old channel of Anvil Creek. In a larger way the great difference in concentration between the auriferous gravels of the upper end of Anvil Creek in the vicinity of Nekula and the gravels found 2 or 3 miles below, near Discovery claim, appears to depend on a difference in gold content of the rocks from which the placers were derived. Collier[1] says on this subject:

> The rich placers on the upper part of the creek, for example, can be attributed partly to the reconcentration of high bench gravels washed down by Nekula Gulch, and the richness of the placers near Discovery claim is in all probability due to veins in the local bedrock, for it is there that all the phenomenally large nuggets have been found, and these could not have been transported far. The facts necessary for estimating with any degree of exactness the gold tenor in the Anvil Creek placers are not at hand, but the average for all the gravels mined along the creek can not have been less than $5 a cubic yard. In the richer spots much of the gravel contained more than $50 to the cubic yard.

The gold-bearing gravels on the bench east of the creek (fig. 10) are found chiefly in well-defined channels cut in bedrock by Anvil Creek and its tributaries at a much earlier stage of their history, but

[1] Collier, A. J., The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 188.

the auriferous deposits are not confined entirely to these channels, as in a number of localities they extend beyond the channel rim. The channels are not indicated by the topography, and their presence was not known till mining began on the bench gravels. What seems to be the principal old channel lies at a distance of 300 to 600 feet east of the present stream and although not exposed continuously can be traced with a considerable degree of certainty from a point about a mile above Specimen Gulch as far south as Discovery claim. Its greatest width so far as known is about 120 feet, and at one place it has a depth of 20 feet. It has been cut by tributaries of the present stream, and its rim is in some places destroyed on one side. A short distance above Specimen Gulch the main channel lies about 400 feet east of Anvil Creek. Between it and the creek a smaller rock-cut channel was exposed in mining. It is about 20 feet wide, is 12 feet deep, and where exposed has the form of a letter S.

From observations in the workings on the bench it is seen that there is no uniformity in the character of the gravels present. Fifteen feet of gravel is exposed in an old channel half a mile above Specimen Gulch. The channel is here 60 feet wide and lies from 200 to 300 feet east of the creek.

Just north of Specimen Gulch a channel 70 to 120 feet wide was exposed in a pit 20 feet deep and 200 feet long. The east rim is steep, but the west rim has a gentle slope. A graphitic schist bedrock is overlain by 7 feet of auriferous gravel, which in turn is covered by 12 feet of sandy clay. Pebbles and bowlders of schist, greenstone, and a few of granite are seen in the clay.

At Specimen Gulch where it intersects the old channel the following section was exposed:

Section in old channel at Specimen Gulch.

	Feet.
Moss and muck	1
Coarse gravel	8
Clay	1
Bedrock, graphitic schist.	

Half a mile below Specimen Gulch not less than 500 feet of the main channel was uncovered, also a small tributary channel about 7 feet deep and 8 feet wide entering from the west. The section showed the following beds:

Section in old channel half a mile below Specimen Gulch.

	Ft.	in.
Light-brown sand and angular gravel	6	
Brown clay		1
Gravel with large bowlders, mostly flat, some measuring 18 inches in longer dimension, but most of those at the bottom of the bed much smaller	15–20	
Schist bedrock.		

About a mile above Discovery claim the old channel was exposed. It is bounded along most of its length by well-marked rock rims but is smaller than the present channel of the creek and about 20 feet higher. There appear to be a number of channels rather than a single one. At the south end the working faces show:

Section in old channel 1 mile above Discovery claim.

	Feet.
Brown clay and soil containing a few angular pebbles	3
Fine gravel with sticky clay sediment	6
Coarse gravel, flat, 4 to 6 inches across, and sand	3
Bedrock not exposed.	

Gold is distributed through the 9 feet of gravel, both in the upper 6 feet of fine clayey material and in the underlying coarse gravel and sand.

About three-fourths of a mile above Discovery claim a remnant of the old channel deposits was discovered 300 feet east of the escarpment and 50 feet above the creek. It occupied a depression bounded by rock walls and was only about 100 feet long, but the gravel was very rich.

The rock bench on the east side of Discovery claim stands about 10 feet above the creek at its lower edge and slopes gently for 500 or 600 feet to the foot of Anvil Mountain. Gold-bearing gravel of unusual richness was discovered on this bench. Its thickness ranged from 4 inches to 4 or 5 feet, and as in most other places the greatest concentration of gold was in its lower part. Gold was present also in the bedrock beneath. The gravel was overlain by 12 to 14 feet of yellowish clay, which contrasts sharply with the more usual covering of about 3 feet of peaty "muck." The bedrock at this place is graphitic schist with an irregular surface but is not cut by any well-defined channel. One of the old channels of Anvil Creek, however, extends south from Discovery claim in this vicinity to Little Creek, where it was at first mistaken for the "third beach." This channel, according to Gibson,[1] is incised into the schist bedrock to a depth ranging from about 4 feet to 12 feet. It has been buried in delta and beach deposits, and the auriferous gravels, besides filling the channel, overflowed its rims both to the east and to the west. Near the old shore line the gravel was mined to a width of 500 or 600 feet, although the channel itself was not more than 150 feet wide. The gravel ranged from 20 to 25 feet in total depth and was overlain by 12 to 15 feet of ice, "muck," and surface vegetation. Coarse creek wash, quartz, schist, and limestone filled the channel depression in bedrock. This material was overlain by cross-bedded delta and beach deposits of similar composition and character, but including also a small amount of interbedded beach-worn pebbles and sand.

[1] Gibson, T. M., Pay streaks at Nome: Min. and Sci. Press, vol. 102, 1911, p. 464.

As has been stated, bench gravel containing sufficient gold to yield a profit on mining is not confined to the old channels of Anvil Creek. In many places the gold-bearing deposits extend beyond the channel rims, especially the western rim, and spread out upon the bench below. Many of the Anvil Creek claims have been worked over twice, and one or two have been worked three times. All the gravel is put through the sluice boxes, and from 6 to 18 inches of the bedrock is broken up with the pick and washed. The gold is now nearly exhausted on the present channel floor, but work is still carried on in a number of places, and on the bench much gravel remains that with cheaper methods of mining will yield a profit.

Anvil Creek gold as a rule is chunky rather than flat. Two nuggets worth approximately $1,500 and $1,700 were found on Discovery claim, and a third nugget, the largest ever brought from Alaska, was discovered on the bench east of Discovery claim. This nugget with its contained quartz weighed 182 ounces. The gold in it was calculated to be worth $2,660. Many smaller nuggets were found, and pieces worth several dollars were common.

The richest gravel of Anvil Creek was that on Discovery claim and in its vicinity, where also the coarsest gold was found. From that locality the average size of the placer gold decreased downstream, as would be expected, for the lighter particles would be transported farther by the water, and probably the particles that traveled far were more or less reduced by abrasion.

With the gold were concentrated a number of heavy minerals, of which magnetite, garnet, and scheelite are most common. These minerals, however, do not cause great difficulty in cleaning the gold. Dr. Cabel Whitehead, formerly of the Alaska Bank & Safe Deposit Co., at Nome, has given the fineness of Anvil gold as 0.89, or $18.33 an ounce. The Anvil Creek placers have averaged probably not less than $5 to $6 to the yard of gravel and locally have yielded 10 times that amount.

Specimen and Nekula gulches.—Two small tributaries of Anvil Creek, Specimen and Nekula gulches, may be described in connection with it. Nekula Gulch is one-third of a mile long and heads near the saddle at Dexter station. The bedrock is graphitic and chloritic schist, calcareous schist, and limestone. The stream gravel averages about 3 feet in thickness and consists of schist, quartz, and some limestone. The gold in this gravel is largely or perhaps wholly derived by secondary concentration from the high-bench deposits near Dexter station.

A short distance north of Nekula Gulch and about 50 feet lower than the saddle between it and Deer Gulch very rich gravels, previously referred to as "Caribou Bill's claim," were discovered in a hole, which seems to be a cavern or sink in the limestone bedrock. The pit made in the gravel was about 30 by 50 feet in area and 20 feet deep. This auriferous deposit was probably a part of the high-bench deposit and has been described as such by Collier. Calcareous schist inclosing a bed of limestone forms the country rock. The sink, if such it is, was shown by a shaft to have a depth of nearly 90 feet. It is filled with gravel consisting of rounded schist fragments and limestone in yellow clay probably carried into it by running water. The gold mined here was coarse and angular and appeared to have traveled only a short distance from its bedrock source. The gravel was remarkably rich; its gold content has been estimated as not far from $1,000 a cubic yard.

Auriferous gravel was found below this claim on Nekula Gulch, but none had so high a value as the deposit just described. Most of the gravel was shallow, averaging about 3 feet deep. The gold was most concentrated on bedrock and is reported to have reached about $1.50 to the yard.

Specimen Gulch heads near the high-bench gravels between Anvil Creek and Grass Gulch and, like Nekula Gulch, received some of its gold from these older deposits. At its lower end part of its gold was doubtless received from the bench deposits east of Anvil Creek. The bedrock is graphitic schist. The gravel has a thickness of 8 feet on the Anvil bench and reaches 10 feet in other places. Near the old Anvil channel the gravel rests on 1 foot of clay, and here the best pay was found. The gold does not show much wear and probably has not traveled far.

Glacier Creek.—Glacier Creek is another of the streams staked by the discoverers of the Nome placer field. It has a length of 5½ miles and joins Snake River 6½ miles north of the coast. The upper 4 miles of Glacier Creek lies in a broad upland valley with gently sloping sides, but the lower part crosses the lowland of Snake River, into whose gravels it has intrenched its bed. The productive part of the stream extends from a point just below the mouth of Bonanza Gulch to Snow Gulch. Some mining, however, has been carried on above and below these points. From Snake River to Bonanza Gulch the grade of the creek averages 50 feet to the mile. This stretch includes that part of the stream crossing the Snake River lowland, which is the part of least grade. Above Bonanza Gulch the grade increases to 75 feet to the mile.

Most of the gold of Glacier Creek has been taken from four localities, the bed of the stream from Snow Gulch down to the Snake River flats, Snow Gulch, Hot Air bench north of the most productive portion of the main stream, and Bonanza Gulch.

Glacier Creek above Bonanza Gulch flows through a rock-walled channel from 100 to 300 feet wide, incised in schist belonging to the Nome group. The bedrock consists, for the most part, of chloritic schist, in which are local limestone beds. The schist in a number of places carries a considerable percentage of pyrite and is cut by veins of quartz containing pyrite and a small amount of gold. One selected specimen of such vein material assayed half an ounce of gold to the ton.

Below Bonanza Gulch the flood plain of Glacier Creek has a width of 200 to 500 feet. Prospect holes have been dug along the lower part of the creek, and the gravels there are known to carry gold, although, on account of the small content of metal and the low grade of the creek, little effort has been made to recover it. The test pits show a depth of gravel ranging from 5 to 20 feet. One mile above the mouth (whose elevation is 40 feet above sea level) a section showed 10 to 12 feet of gravel resting on schist bedrock and overlain by 2 to 3 feet of muck. The gravel carries fine bright gold that has evidently traveled a considerable distance.

Near the mouth of Snow Gulch 6 feet of gravel, made up of schist and quartz, rested on schist bedrock. The lower third of this gravel carried considerable gold.

Little mining has been done on Glacier Creek above the mouth of Snow Gulch, and most of the operations on the creek proper have been confined to the part between Bonanza and Snow gulches. Most of the gold is fine and worn. Garnet and scheelite accompany it.

Snow Gulch.—Snow Gulch was formed by a small stream about three-quarters of a mile long, heading in the divide between Anvil and Glacier creeks. The stream flows directly across the bedding and cleavage of the schist, whose upturned edges form the riffles that caught the gold. In its lower and less steep portion this gulch has a grade of 150 feet to the mile, but the upper quarter mile has a much steeper grade. The bedrock is schist, in which are a few limestone beds, some reaching 12 feet in thickness. Faults are numerous, and the rocks are cut by many small quartz veins. Veins of quartz and of calcite carrying free gold are seen on the ridge at the head of the gulch. Owing to the steep grade of the stream, deep gravels did not accumulate. The deposits averaged 3 or 4 feet in depth near the lower end, but the gulch is now swept almost clean by mining operations, and the gold supply is exhausted. Considering its size, Snow Gulch was one of the richest streams discovered in the Nome region, more than a million dollars' worth of gold having been taken from it. Most of the gold was fine and rounded, but it is not believed to have traveled a great distance; part of it, at least, was probably derived from gold-bearing veins in the immediate vicinity.

Hot Air bench.—Northwest of the mouth of Snow Gulch, nearly 100 feet above Glacier Creek, auriferous gravels were found along an old channel once occupied by the creek. The north rim of the Glacier Creek channel rises in a steep bank that limits a southward-sloping bench on which the old channel gravel lies. There was no topographic indication of the presence of a channel, but mining operations disclosed one. It is cut in the schist bedrock and extends nearly parallel with Glacier Creek for 400 feet or more. Its east end turns toward the creek, but its west end is less well defined. The channel has a depth of approximately 20 feet and a width of 100 feet. Both rims are seen except in one or two places. Schist forms the bedrock and is cut by quartz veins, which opposite the mouth of Snow Gulch reach a thickness of 6 inches and carry considerable pyrite. Pyrite is abundant also in the schist itself. A section of the surface deposits included 4 to 5 feet of vegetable matter and clay overlying the same thickness of gravel, which rested on the schist bedrock. Schist and quartz with some limestone and a few granite pebbles compose the gravel. It is estimated that the pay streak carried nearly $50 in gold to the cubic yard. The gold is believed to have been derived from the mineralized schist and quartz veins found in the immediate vicinity.

Bonanza Gulch.—Bonanza Gulch is a shallow depression, less than half a mile long, on the hillside south of Glacier Creek. It joins Glacier Creek where that stream leaves the upland valley to cross the Snake River lowland. A small stream flows in this depression, but except in spring does not carry enough water for use in mining. The bedrock is highly folded and much-decomposed schist. At the lower end of the gulch 2½ feet of gold-bearing gravel was overlain by 5 to 6 feet of sandy clay and 1 foot of surface "muck" containing much vegetable matter. The gold was fine and worn by travel. All the richest gravels so far as known have been mined out.

Rock Creek.—Rock Creek is a small stream, which rises on the south slope of Mount Brynteson and joins Snake River about half a mile above Glacier Creek. The productive part of the stream extends from a point 1 mile above Snake River to a point nearly half a mile farther up the creek. Rock Creek flows in a channel 25 to 30 feet deep cut in bedrock consisting of schist with some limestone beds. Many small quartz veins are present.

The gravel deposit averages about 5 feet in depth, and ranges in width from 50 to 100 feet, according to the width of the rock channel. A few nuggets have been found, but most of the gold is rather fine, and is recovered by the use of mercury. Associated with the gold are considerable scheelite and less magnetite, limonite, and garnet. A vein of scheelite 3 to 4 inches wide is reported to have been uncovered on the creek.

Lindblom Creek.—Lindblom Creek is about 1 mile long and flows down the west slope of Mount Brynteson. It has cut a narrow gulch in the schist of the mountain and for part of its length flows in the gravel floor of Snake River. The gravel is shallow, and only a small amount of gold has been found in it. Little mining has been done there.

Balto Creek.—Balto Creek joins Snake River directly west of the summit of Mount Brynteson. It flows in a narrow gulch cut in the schist. A small quantity of gold was obtained from its shallow gravels.

Boulder Creek.—Boulder Creek has produced a small amount of gold, but its productive portion lies outside of the area under consideration.

Bangor Creek.—Bangor Creek joins Snake River near the southern boundary of the Grand Central quadrangle, but only 3 miles of it is represented on the map. It flows in a narrow V-shaped valley and through most of its course has a grade of nearly 90 feet to the mile. The bedrock is schist, with which a few limestone beds are interstratified. The gravel consists chiefly of schist and quartz. Many large bowlders of quartz, also bowlders of granite, are seen in the stream. A hole 11 feet deep was sunk at the mouth of Bangor Creek without reaching bedrock, and another near by on Snake River was put down 22 feet with the same result.

Mining has been carried on near the mouth of Butterfield Canyon. The gravel here has a depth of 14 feet and is said to yield $2.50 to the cubic yard. The gold is fine, but nuggets worth $15 or $20 are found. Scheelite and hematite occur with the gold. Pieces of scheelite weighing half a pound have been found in the concentrates.

Last Chance Creek.—Last Chance Creek, a small tributary of the North Fork of Snake River, flows in a deep, narrow valley and supplies sufficient water for such mining operations as have been carried on. The bedrock is chloritic schist in which are graphitic and calcareous beds. Limestone beds are not uncommon. These same rocks supplied material for the stream gravel.

A small amount of gold has been found, but mining was not very profitable. Just above Dewey Creek the heavy concentrates from the gravel contained, besides the gold, scheelite, hematite, magnetite, and pyrite. The gold was rough and iron stained. Nuggets worth $2 were found.

Goldbottom Creek.—Goldbottom Creek flows around the west and south slopes of Mount Distin. Its bedrock is partly schist and partly limestone, and its gravel consists of the same materials, but a considerable quantity of granite bowlders appears along the stream, especially near its mouth. The stream has produced a small amount of gold, most of which was obtained by pick and shovel. A small hydraulic plant was set up, on the upper part of the creek in 1905, but whether the undertaking was profitable or not was not learned. Stream tin is found in the gravel at a number of places along the creek.

Steep Creek.—Steep Creek, a small tributary of Goldbottom Creek, has had a small gold production for a number of years. The creek cuts the schists and limestones of the Mount Distin mass and its upper portion is a series of waterfalls. The gravel lying along the lower part forms a deposit from 18 inches to 4 feet deep and from 60 to 70 feet wide. It is coarse, though it includes no bowlders not easily handled, and contains little fine sediment. The gold is smooth, bright, and coarse. No large nuggets have been found, the largest being worth only about $2. A little magnetite occurs with the gold.

Grub Gulch.—Grub Gulch heads in a low saddle between Nome and Snake rivers and flows in a channel bounded by rock walls of greatly sheared schist. The gravel is schist and quartz, but many granite bowlders are also found. A pay streak said to average about 40 feet in width and between 5 and 6 feet in depth, carrying $3.75 to the cubic yard, has been worked out. The gold was coarse and rough, but no pieces of greater value than $1.75 were found.

Grouse Creek.—Grouse Creek is 4½ miles long. The lower half of the stream occupies a north-south canyon-like valley, but the upper half of its valley does not have this feature so well marked. A large part of the water comes from springs at the base of Mount Distin.

The bedrock on the lower part of Grouse Creek is chiefly schist, but above Cold Creek the limestone beds of Mount Distin outcrop in many places. The surface deposits consist of limestone and schist with quartz, smaller amounts of greenstone, and scattered granite bowlders.

Mining has been carried on near Cold Creek and for some distance below. The gravel averages approximately 5 feet in thickness. About a mile above the mouth of Grouse Creek a pay streak 40 feet wide and from 1 to 3 feet thick, containing a large amount of limestone, was worked. The gold is bright and rough and rests on limestone bedrock. Near Cold Creek smooth-worn gold is found. It has worked down into cracks in the limestone, so that considerable labor is required to get it out.

There has been some prospecting also in the bench gravels between Grouse and Cold creeks, but the results were not especially encouraging. The gravel is well washed, and the deposits are from 4 to 24 feet thick.

Center Creek.—Center Creek and its tributaries, Flat, Wonder, and Saturday creeks, lie within the coastal plain. Their placers are of the type of reconcentrated stream placers, but their gold production is small. A claim on Saturday Creek where mining was carried on in 1900 showed 3 feet of gold-bearing gravel resting on a false bedrock and covered by 3 feet of "muck." Some of the gold was worn and bright, some rough. Most of it was rather coarse. Nuggets worth from 25 cents to several dollars were common, and one nugget worth $14.50 was found. Magnetite, garnet, and a small amount of scheelite were the heavy concentrates accompanying the gold.

Cooper Gulch.—Cooper Gulch is a deep gash in the limestone mass of Anvil Mountain, but it also trenches some schist beds. Whether its waters flow into Flat Creek or Little Creek is difficult to say, for the stream spreads out upon the low fan-shaped deposit at the base of a rock bench through which it cuts and is lost on the tundra. A small area near this bench yielded good returns in gold, but in general mining has been conducted with little profit, and for several years nothing has been done on the stream.

Bourbon Creek.—Bourbon Creek empties into Snake River at Nome. It is 3½ miles long and has one principal tributary or branch, Holyoke Creek. Its gold deposits are a concentration from the tundra gravels and are not derived directly from a bedrock source.

Bourbon Creek flows in a broad trench cut in the coastal-plain gravels. This trench in its southern part has a width of several hundred feet and a depth of 12 to 15 feet. Toward the north it disappears, and the two branches flow through broad, shallow depressions in the coastal plain.

A section of gravel 1 mile from the head of the creek shows the following beds:

Section on Bourbon Creek 1 mile below head.

	Feet.
Moss and muck	2
Rock and blue clay	6
Gravel	1
Blue clay	½
Schist gravel with gold	1
Clay "bedrock."	

A second section half a mile farther north showed:

Section on Bourbon Creek one-half mile below head.

	Feet.
Blue and red clay	4
Gravel with gold	2
Sand.	

At the head of Bourbon Creek a small area of gravel mined in winter and piled in a dump yielded $12 a cubic yard when washed in the spring. Another claim a short distance lower on the creek had a gold-bearing gravel deposit 10 to 12 feet wide and 5 feet deep, which yielded $4 a cubic yard. The figures given represent a gold content probably somewhat larger than the average, and although considerable gravel sufficiently rich to yield a profit when worked by the usual and more primitive methods has been mined, a much larger portion must be handled more cheaply.

Nearly all the claims on Bourbon and Holyoke creeks are now under the control of one company, which has installed machinery for dredging the gravel adjacent to the stream as well as the stream gravels themselves. The difficulty to be overcome is found chiefly in the frozen condition of the gravel away from the stream channel. The gravel near the creek is thawed in summer, but where "muck" and tundra vegetation are present it is frozen. Drill holes have been put down to bedrock on all the claims and show that gold is present in the lower marine gravels as well as in the upper creek deposits.

DRY CREEK AND NEWTON GULCH.

Dry Creek heads in the mountains north of Nome between Dexter Creek and the coastal plain and owes its name to the fact that during a month or so of a dry summer its upper half contains little or no running water. It has an average grade of 95 feet to the mile for the 6 miles of its length. About three-fourths of the creek lies within the coastal plain, so its placer deposits are partly a primary and partly a secondary concentration. The most productive portion is in the vicinity of the boundary between the plateau and coastal plain, but the concentrated deposits on the lower part of the stream are of importance also.

About a mile north of the present beach auriferous gravels from 3 to 5 feet thick were found resting on a slightly undulating clay bed. This pay streak is said to be 150 feet wide, and where mined to have an average value of about $5 a cubic yard. The gold is chunky, but pieces of the value of a dollar are rare. The pay gravel rests on the clay and is not found in or below it. Hematite, scheelite, and pyrite accompany the gold. Magnetite is present in the concentrates on the upper part of the creek.

North of the coastal plain Dry Creek flows through a V-shaped valley between Anvil and Newton Peaks. Little bedrock is seen along the channel, but the creek crosses the edges of schist and limestone beds exposed in the mountains on either side. Gravel extends from the coastal plain to the bench deposits at the saddle. The present creek bed, however, has produced little gold, although considerable work has been done on it near the mouth of Bear Creek.

An old channel of Dry Creek about 600 feet east of the present stream and 50 feet above it has been an important gold producer. This channel has been traced for three-quarters of a mile and has almost the same grade as the present Dry Creek. Its pay streak is from 20 to 60 feet wide. Partly rounded schist fragments, together with quartz and a few pebbles of greenstone and granite, constitute the bulk of the auriferous deposit, which is covered by 50 feet of gravel, angular schist fragments from the neighboring hills, and "muck." Part of the pay gravel is cemented with iron oxide. The north and south continuations of the channel have not been discovered. At the north end a pay streak 4 feet thick and 60 feet wide rested on the schist bedrock and was covered by 20 to 60 feet of loose material. This claim is said to have yielded from $9 to $12 a cubic yard.

A short distance south of this locality the pay streak was 20 feet wide and was found in a well-defined rock channel. The shaft furnished the following section:

Section in shaft on old channel of Dry Creek.

	Feet.
Muck and silt	45
Fine sand	5
Pay gravel	½–2
Schist bedrock.	

It is reported that 6,000 eight-pan buckets from this place yielded $16,000. The gold of the old channel is coarse and not much worn. Many of the larger pieces contain fragments of quartz. Besides gold, the concentrates contain magnetite, ilmenite, scheelite, and garnet.

Newton Gulch joins Dry Creek about 3 miles from the coast. The stream rises on the south slope of Newton Peak, and is thus partly within the plateau region. Its branch known as the Left Fork has cut a deep V-shaped valley in the massive limestone forming the south slope of the mountain, but the only rock exposed in the gulch itself, except at the very head, is schist.

The auriferous creek gravels do not lie on schist bedrock, but for the most part rest on a bed of clay. The following section was measured near the mouth of the Left Fork:

Section near mouth of Left Fork of Newton Gulch.

	Ft.	in.
Sandy clay	3	6
Schist gravel with cross bedding		6
Sand	2	6
Gravel		7
Sand and gravel		3
Pay streak of schist gravel	3	
Clay bedrock.		

Another section still farther up the creek showed:

Section on Left Fork on Newton Gulch.

	Feet.
Moss and muck	3
Sandy clay	3
Gravel consisting of schist and limestone—the pay streak	8
Clay bedrock.	

In each of these localities the gold-bearing gravel lay on clay that was in turn underlain by other gravel of unknown depth. A prospect hole near the second locality mentioned was sunk 92 feet without reaching bedrock.

Along Newton Gulch the creek gravel disturbed in mining has a width of 30 to 150 feet and a thickness ranging from 2 to 27 feet. Near the mouth of Newton Gulch the deposit of pay gravel had a width of over 100 feet and was from 2 to 6 feet thick. Bedrock is 27 feet below the surface. The deepest pay gravel was located about a mile farther north, and rested on a clay seam 10 feet below the surface. It is thus seen that there is considerable variation in the occurrence of the gold-bearing gravel as well as of the other stream deposits accompanying it.

Auriferous gravels were discovered on the west side of the gulch three-fourths of a mile north of the forks, and mining has been carried on there for a number of years. The pay gravel lies above the stream, and the section exposed in mining is:

Section in Newton Gulch north of forks.

	Feet.
Tundra vegetation and peat	2
Sandy subangular gravel	6–8
Blue clay, false bedrock.	

This deposit does not appear to be directly connected with the stream placers. There is no defined channel, and the limits of the auriferous gravel are indefinite also. The gold is bright, and most of it is smooth. It is said that the average gold tenor of the gravel is $2 a cubic yard.

At the mouth of Newton Gulch the gold is coarse and bright, and as a rule the pieces are not much worn. In this locality the gold content was probably not less than $15 a yard, but the valuable deposits are very unevenly distributed along the stream.

NOME RIVER BASIN.

Nome River.—Nome River rises in the Kigluaik Mountains and follows a winding course southward to Bering Sea. The point where Buffalo and Deep Canyon creeks join, which is regarded as its head, is 26 miles north of Nome. Its valley is wide and is floored with a deep filling of gravels into which the river channel is incised to a depth ranging from 5 to 50 feet. In several places between Osborn and Darling creeks the river flats reach a width of a mile without attaining an elevation more than 50 feet higher than the top of the river banks. North of Darling Creek the valley narrows decidedly and below Osborn Creek it enters the coastal plain.

The elevation of Nome River at Dexter Creek is less than 50 feet, which allows the river below that point an average grade of 4 feet to the mile. From Dexter Creek to Hobson Creek the river level rises 107 feet, or at the rate of 8 feet to the mile, and from Hobson Creek to the mouth of Deep Canyon Creek it rises 393 feet, or at the rate of 44 feet to the mile.

No gold placers of consequence have yet been discovered on Nome River itself, although its tributary, Dexter Creek, has been one of the most important gold-producing streams of the region. Fine gold is found in the bars of the river, and a first-class modern dredge was built about 2 miles below the mouth of Banner Creek to exploit the river gravels, but the venture was undertaken without properly prospecting the ground and proved a failure. This is one of the few attempts yet made to work the gravels of Nome River in a truly commercial way.

In addition to Dexter Creek, a number of other tributaries have either produced important amounts of gold or hold possibilities for the future. In the first rank among these may be named Buster, Osborn, and Dorothy creeks. Colors of gold, however, may be found on almost any stream in the region.

Dexter Creek.—Dexter Creek, which joins Nome River 7 miles from the coast, is the one very rich creek near Nome that was not staked by the discoverers of gold on Anvil Creek in 1898. Mining began in 1899, and during most of the time since then the creek has been a large producer, although at one time its supply of gold was thought to be exhausted. At present, however, only one or two claims are being worked.

The creek is formed by the union of two small branches, Left Fork and Grass Gulch. These streams, together with Deer Gulch, a tributary of Grass Gulch, none of which is more than half a mile long, head in the three saddles between Dexter Creek on the one side and Nekula Gulch, Specimen Gulch, and Dry Creek on the other. From the forks to Nome River the length of Dexter Creek is 2¼ miles and its grade is 128 feet to the mile. The grade of the tributaries, however, is much greater. One other small branch, Grouse Gulch, should be named here, as gold has been mined in it.

Dexter Creek has cut a channel averaging 20 or 25 feet deep in the floor of the valley between King Mountain and Newton Peak. The walls for nearly a mile within the Nome River valley are made up of gravel, but above that portion they consist of schist and limestone of the Nome group. Limestone forms a large part of the bedrock. Its surface is deeply fissured, and underground streams flow through it. Gold-bearing gravel was extracted from some of the cavities to a depth of 30 feet.

The gravel consists essentially of schist, limestone, and quartz, but with these rocks are associated rounded granitic pebbles from 1 or 2 inches to 10 inches in diameter.

Most of the auriferous deposits that have been exploited were situated in the stream channel, yet two or three valuable placers were found on the benches above the creek. On the benches gold-bearing gravels still remain that will probably yield a profit when mining conditions, such as water supply and freight rates, are more favorable.

Gold was found near the mouth of Dexter Creek at a depth of 5 feet below the surface, resting on a false bedrock of blue clay, which continues up the stream half a mile. The pay streak had a thickness of 3 feet and consisted of schist, quartz, limestone, and a small amount of greenstone. The gold was comparatively fine. Half a mile above this point the gravel reached a thickness of 6 feet, but the gold was found in the lower part. Large bowlders of limestone occur in the deposits, and a sticky yellow clay is abundant. A nugget worth $22 was discovered here.

About 1 mile from the mouth of this creek the pay gravel had a thickness of 7 feet and a width of 30 feet. It consisted chiefly of limestone fragments.

A short distance above Grouse Creek the loose deposits on the north side of Dexter Creek have a thickness of 20 feet. At the surface is 5 feet of yellow clay, which overlies 15 feet of angular and rounded fragments of schist, limestone, quartz, and granite. Mining here extended north into the gravel deposit, which may perhaps indicate the west end of the channel mentioned on page 103.

Near the forks of Dexter Creek the gravel accumulations widen. Their depth, too, is greater than on the central part of the creek. One pit 60 feet wide and 250 feet long showed from 6 to 10 feet of gravel resting on limestone and schist bedrock. The schist is slightly decomposed, allowing the gold to penetrate it for several inches; hence its upper part must be removed in mining. The limestone is much fissured and its surface is rough.

Gravel accumulations in the fissures were of great richness in places but required much labor to remove them. The gold was smooth and worn. Underground passages through the limestone are sufficiently large to carry away the natural flow of the streams as well as ditch water brought from other sources.

Bench gravels carrying gold were mined on the south side of Dexter Creek a mile from the creek's mouth, also on the north side a short distance farther west. On the south side of the creek a small area of gold-bearing gravel rested on limestone bedrock about 10 feet above the creek bed. The gold was taken in large part from crevices in the limestone.

On the north side of the creek the auriferous deposits were collected in a rock-cut channel 200 feet from the creek and 75 feet above it. Gold was found on the bedrock. The channel is nearly parallel with the present stream and was doubtless occupied by it at one time.

Grass Gulch.—Grass Gulch from a point near its mouth westward for a distance of about one-fourth of a mile has proved to be the most valuable of the Dexter Creek placers. Its gold deposits are partly of the elevated-bench type and partly of the reconcentrated creek-deposit type. The stream is slightly more than one-third of a mile long and has a grade of about 450 feet to the mile. Deer Gulch joins it from the north 100 yards above its mouth. There is little or no running water in it during a part of the summer, and nearly all the water used for sluicing or hydraulicking is brought by the Miocene ditch.

A large amount of gravel has been taken from a pit that extends west from Left Fork for one-fourth of a mile, or nearly the full length of the gulch. The bedrock is a rough fissured limestone, from whose cavities and crevices the gold-bearing gravels frequently have to be removed by hand, as they can not be reached by the stream or by water from the giant.

Near the west end of the pit 25 feet or more of gravel, nearly all of which contains gold, is exposed. The section shows:

Section in pit on Grass Gulch.

	Ft.	in.
Moss and soil	2	
Brown gravel with well-rounded pebbles and clay	6	
Dark gravel streak		3
Brown gravel with well-rounded pebbles and clay	9	
Limestone bedrock.		

Schist, limestone, and quartz make up most of the gravel, but many granite pebbles and bowlders also are seen in it.

The greatest concentration of gold is found on bedrock. In general the gold is well worn and shows the effects of travel. Several nuggets of considerable size have been discovered, the largest of which was valued at $412.

Deer Gulch.—Deer Gulch heads near Dexter station and joins Grass Gulch a short distance above the mouth of that stream. The bedrock is schist and limestone. These same rocks make up the gravel deposits that occupy the gulch and join the bench gravels at Dexter. A small amount of gold was obtained from these gravels.

Left Fork.—Left Fork heads in the saddle between Dry and Dexter creeks. Its length is about half a mile and in that distance it falls 200 feet. The lower part of the stream flows in a channel cut in schist and limestone to a depth of 15 to 20 feet. A pay streak in this channel is 50 feet wide near the south end of the best ground, which extended up the creek for a quarter of a mile from Dexter Creek. One nugget worth more than $50 was found.

Grouse Gulch.—Grouse Gulch heads near the southeast end of the upper channel of the Dexter bench gravels. It is only one-fourth of a mile long and falls 200 feet in that distance. Its bedrock is schist and limestone, the limestone being limited to the lower end of the gulch.

Near the upper end of the gulch a section exposed on the east side showed:

Section in Grouse Gulch.

	Ft.	in.
Moss		6
Yellow clay	4	
Stratified sand and gravel	6	
Decomposed schist bedrock.		

In the lower part of the gravel bed a layer of quartz pebbles and many large angular pieces of schist contained some gold.

A short distance above this point a tunnel was driven from Grouse Gulch toward the Dexter Bench channel, and a small amount of gold was taken from it.

Buster and Lillian creeks.—Buster Creek flows into Nome River one-third of a mile below the mouth of Dexter Creek. It is 3½ miles long and has an average grade between its mouth and Good Luck Gulch of 100 feet to the mile.

Buster Creek forks 1½ miles above Nome River, the western branch being called Lillian Creek and the eastern branch retaining the name Buster. Above the forks Buster Creek occupies a narrow V-shaped valley cut through schist and limestone. Below the forks the valley broadens, and for the last half mile of its length the stream flows over the gravel floor of Nome River.

Buster Creek has been productive since mining began in 1899, and mining is still carried on, although nearly all the creek bed has been worked over. The gravel was shallow and the pay streak narrow. The richest portion of the creek lies between Davis Gulch and Good Luck Gulch. Schist, quartz, limestone, greenstone, and a small amount of granite made up the pay streak, which in some places rested on limestone and in others on chloritic and graphitic schists. The gold was coarse, and where the pay gravel rested on schist was found to have penetrated it to a depth of 18 inches. A nugget worth $18 was discovered.

Union Gulch, a steep, narrow gulch on the north of Buster Creek, is occupied by a small stream, which cut its channel in schist and limestone. The lower end of the gulch has a gravel deposit ranging from 10 to 20 feet in width and having a depth of less than 3 feet. The gravels here, which are like those of Buster Creek, yielded from $3 to $4 a cubic yard. The gold is coarse and iron stained. One nugget worth $16 was found.

A deposit of auriferous gravel was discovered near the mouth of Union Gulch, on the hill south of Buster Creek, 100 feet higher than the stream and at an elevation of 300 feet above sea level. Two pay streaks are present, on above the other. The upper one is 10 feet thick, but carries only a small amount of gold. The lower one is much richer. It is 3 feet thick and lies in a well-defined rock-walled channel, which has been traced for about one-eighth of a mile. At the west end the northern channel rim disappears and the gravel spreads over the hillside. Eighteen feet of fragmental material, consisting of schist and quartz with bowlders of greenstone and granite rocks, is present in the channel, but below the channel the thickness of this deposit diminishes to 4 or 5 feet. A section of gravel a short distance east is as follows:

Section in Union Gulch.

	Feet.
Muck and slide rock	18
Low-grade auriferous gravel	10
Muck (probably frozen-slide deposit)	10
High-grade auriferous gravel	3
Iron-stained decomposed schist bedrock.	

A gold deposit of similar character was found on Grace Gulch, east of this place, at the same elevation and is possibly its continuation. The gold of the bench is like that of Buster Creek; it is coarse, but large nuggets are rare, and most of it is smooth and worn. Average pans from the lower pay streak are said to have contained from 10 to 18 cents in gold.

Lillian Creek occupies a shallow channel in a broad valley with gently sloping sides. Schist with occasional interstratified limestones form the bedrock. The gravel deposits are from 3 to 10 feet thick, and are in places covered by several feet of "muck." The gold is unevenly distributed, and the total production is small.

Osborn Creek.—Osborn Creek joins Nome River 5 miles from the coast and is its longest tributary. That part of the stream called Osborn Creek is about 10 miles long, but if the upper end, which is known as New Eldorado Creek, were included the length would be 14 miles. Osborn Creek flows in a broad upland valley, once deeply floored with gravel that has since been partly removed. Gravel benches are present along much of the stream, especially on the right side, and are prominent above St. Michaels Creek. The channel now occupied by Osborn Creek is intrenched in the valley floor to various depths in different parts of its course. At one point the valley walls have a height of 75 feet, but this is exceptional. The stream is confined by gravel banks in much of its upper course, but along its lower part the channel walls are schist with a few included limestone beds and have a height ranging from 10 to 20 feet. The width of the flood plain ranges from 100 to 200 feet, increasing at one locality, about 2 miles above St. Michaels Creek, to nearly 1,000 feet.

75778°—Bull. 533—13——7

Schist, quartz, and greenstone are the most common rocks in the gravel deposits. Limestone also is present but in smaller amount than the three rocks first named. Granite bowlders are numerous on the benches and in the stream for several miles above Nome River. The great quantity of greenstone pebbles and bowlders is accounted for by the presence of the greenstone area west of Osborn Creek. Large greenstone bowlders are especially numerous along the lower 4 or 5 miles of the creek.

Little mining has been done on Osborn Creek, and that was confined to the middle portion. The gold-bearing gravels were there found to have an average width of 100 feet and to consist of 5 to 6 feet of rather coarse material resting on a clay bedrock. The gold is coarse and bright, and most of it is smooth and well rounded. Nuggets worth $1 to $20 were common. It is reported that a yield of $2.50 to $4 a cubic yard was obtained.

Gold is found on St. Michaels Creek about three-quarters of a mile above its mouth, and a small amount is taken out each year.

Washington Gulch.—Washington Gulch is about 1¼ miles long and joins Nome River 3 miles north of the coast. It drains part of the south side of Army Peak, but most of the stream lies in the lowland bordering the river. Gold is recovered from a deposit of fine sand resembling beach sand, which rests on bedrock and averages about 10 inches in thickness.

Dorothy Creek.—Dorothy Creek is a western tributary of Nome River and joins it 24 miles from the coast. The stream is less than 3 miles long; it flows in a steep, narrow V-shaped valley, which broadens slightly near its head and has a grade of about 290 feet to the mile.

The bedrock of Dorothy Creek includes schist, limestone, and a little greenstone. Mineralized quartz veins are numerous. These rocks, together with a small proportion of granite pebbles and bowlders from the Kigluaik Mountains, make up the gravel deposits. At a point little more than a quarter of a mile from Nome River Dorothy Creek leaves the narrow canyon-like part of its valley, and its gravel load is spread out in a broad fan-shaped deposit from 3 to 4 feet thick, in which most of the auriferous gravel is found.

Mining has been restricted to the lower mile of the creek and has proved very expensive, so that the profit, it is said, has been small. The gold is of lower grade than much of the gold from the Nome region and assays less than $15 an ounce.

Extra Dry Creek.—Extra Dry Creek rises on the north side of Newton Peak and joins Nome River 1¼ miles from Dexter Creek. It is 2 miles long and has a very steep gradient. The productive part of the creek occupies a narrow gulch cut in chloritic and feldspathic schists that include a few limestone beds. A section of the gravel here showed:

Section on Extra Dry Creek.

	Feet.
Muck	1
Sandy clay	1
Gravel consisting of schist and quartz	6
Schist bedrock.	

The gold was coarse in this portion of the creek, but became finer downstream. One nugget had a value of $13. The creek appears to be exhausted at present, as little work has been done for several years. It is probable that the total production is less than $20,000.

Banner Creek.—Banner Creek joins Nome River 3¼ miles north of the mouth of Dexter Creek. It is less than 3 miles long and carries only a small quantity of water. The lower half mile of the creek is within the valley floor of Nome River. Above that part the creek has cut a deep channel in the schist of its valley. The rock exposed is chiefly schist, but much limestone is also present. The schist and limestone have been faulted and are cut by quartz veins.

Mining operations on a small scale, yielding a correspondingly small production of gold, have been carried on below Slate Creek.

Basin Creek.—Basin Creek is 3 miles long and joins Nome River 14 miles from the coast. The lowest half mile of the creek lies in the Nome River valley floor, but above that part the stream flows for a mile through a narrow valley, which broadens out toward the east near the point where the creek forks. There has been some mining on Basin Creek between the forks and Nome River valley.

The bedrock is schist and limestone. Several limestone beds outcrop along the lower part of the creek, and a much heavier bed extends across the valley near the forks. Heavy limestone beds are also seen in the mountains on either side.

Schist, limestone, and a small amount of greenstone constitute the gravel deposits, in which an unusually large proportion of bowlders is present. A section of the gravel exposed in mining is as follows:

Section on Basin Creek.

	Feet.
Soil	2
Rounded creek gravel	3
Coarse angular material with clay (the pay streak)	12
Bedrock.	

At this locality the pay streak had a width of nearly 150 feet. The gold was coarse, bright, and rough, and was associated with ilmenite, hematite, and scheelite. Nuggets worth $2 were found, some of which still showed their crystalline form. It is estimated that the richest gravel carried not more than $6 a cubic yard, and that the total production did not exceed $30,000.

The drainage basin is small, yet water was obtained to operate a small hydraulic plant. A much larger supply, however, would be necessary if mining were done on an extensive scale. A gradient of about 150 feet to the mile along the lower half of the creek gives considerable advantage in the disposal of tailings over many of the other streams described.

Divide Creek.—Divide Creek is a small stream slightly over 1 mile long, heading in the saddle between Stewart and Nome rivers. During the construction of a ditch to carry water to Dorothy Creek gravel deposits were discovered in this saddle and along the hill slope on the Nome River side. Quartz with free gold was found, and one nugget of quartz and gold weighing nearly three-fourths of a pound was uncovered. This gold is thought to have come from the slopes of Boer Mountain on the north and might perhaps be classed with the residual deposits. No attempt has been made to exploit the gravel in a systematic way.

Boer Creek.—Boer Creek has been partly described in connection with the residual placers (p. 76), so that now only its creek gravels need be considered. It was seen that the creek flows in a steep, narrow valley cut in graphitic schists and limestones. The stream gradient is about 500 feet to the mile; but there is not sufficient water for mining purposes, as the entire gathering ground of the drainage basin is not more than 1½ square miles.

Although part of the placer gold taken from Boer Creek is residual, another part owes its concentration to stream action. Gold-bearing gravels are confined to the narrow creek channel and range in thickness from 18 inches to 8 feet. These deposits consist of schist and limestone, with a large amount of granite from the mountains on the north. In the channel near the head of the stream is a recent conglomerate made up of schist and quartz fragments cemented by iron oxide. A similar deposit was noticed on a number of small streams in the Stewart and Sinuk river basins. Two grades of gold were obtained from this creek; one assays $18 an ounce, but the other is lighter colored and assays only $16 an ounce.

STREAMS NOT INCLUDED IN NOME AND SNAKE RIVER DRAINAGE.

Placer gold has been mined on several streams not belonging to the Nome and Snake River drainage systems. These streams, however, have yielded only small amounts of gold.

Hastings Creek.—Hastings Creek is about 3 miles long and flows into Bering Sea 3 miles west of Cape Nome. Its important placers belong to the "second beach," described on page 41. A small quantity of gold, however, has been taken out near the head of the creek and some from its lower part south of the old beach line. Hastings Creek lies within the coastal-plain deposits, and its gold is a reconcentration from the tundra gravels. That taken from the lower course of the stream was doubtless derived largely from the old beach, which it has partly removed.

Fred Gulch.—Fred Gulch is a small tributary of Stewart River rising on the north side of Mount Distin. Its upper portion trenches the heavy limestones of the mountain, but the lower portion has carved its channel in schist and the gravel floor of Stewart River. A small amount of gold, probably little more than wages for the man working, has been taken from the stream gravels below the main limestone mass.

Hazel Creek.—Hazel Creek, 2 miles long, is a tributary of upper Flambeau River. Its upper valley is narrow and steep, but for the last half mile of its course it crosses the valley floor of Flambeau River. Gold-bearing gravels are found near the place where the creek leaves the hills, and a hydraulic plant supplied by a ditch with water from the head of Flambeau River was installed to exploit them but was not completed when the Survey party visited the vicinity.

HIGH-BENCH PLACERS.

Character and distribution.—High-bench placers are stream deposits that differ from the stream placers already described chiefly in their position relative to the neighboring stream courses. They are remnants of deposits laid down by a former drainage system and now in large part removed by later stream erosion, including that of the present-day streams.

Elevated gravel deposits are known to be present in several localities within the Nome and Grand Central quadrangles. Only a few of them, however, have been producers of gold. The elevated gravel deposits in the three saddles at the head of Dexter Creek have been described. (See p. 39.) They appear in the divides between Deer and Nekula gulches, between Grass and Specimen gulches, and between the Left Fork of Dexter Creek and Dry Creek. All these localities have considerable economic importance, although the deposits at the head of Dry Creek now appear to be practically exhausted. It is worthy of note that the presence and the probable importance of the high-bench placers at the head of Dexter Creek, like that of the buried beaches of the Nome coastal plain, were predicted by Schrader and Brooks[1] before these placers were discovered.

Dexter station.—Dexter station, in the divide at the head of Deer Gulch, has an elevation of 594 feet and is practically in the lowest part of the saddle between King Mountain and Dexter Hill. The

[1] Schrader, F. C., and Brooks, A. H., A preliminary report on the Cape Nome gold region, Alaska: Special publication U. S. Geol. Survey, 1900, pp. 12, 16, 20.

watershed is only 100 or 200 feet north of it. Placer gold was discovered in the gravels near this point in 1900, and mining has been carried on ever since, some of the ground proving to be very rich.

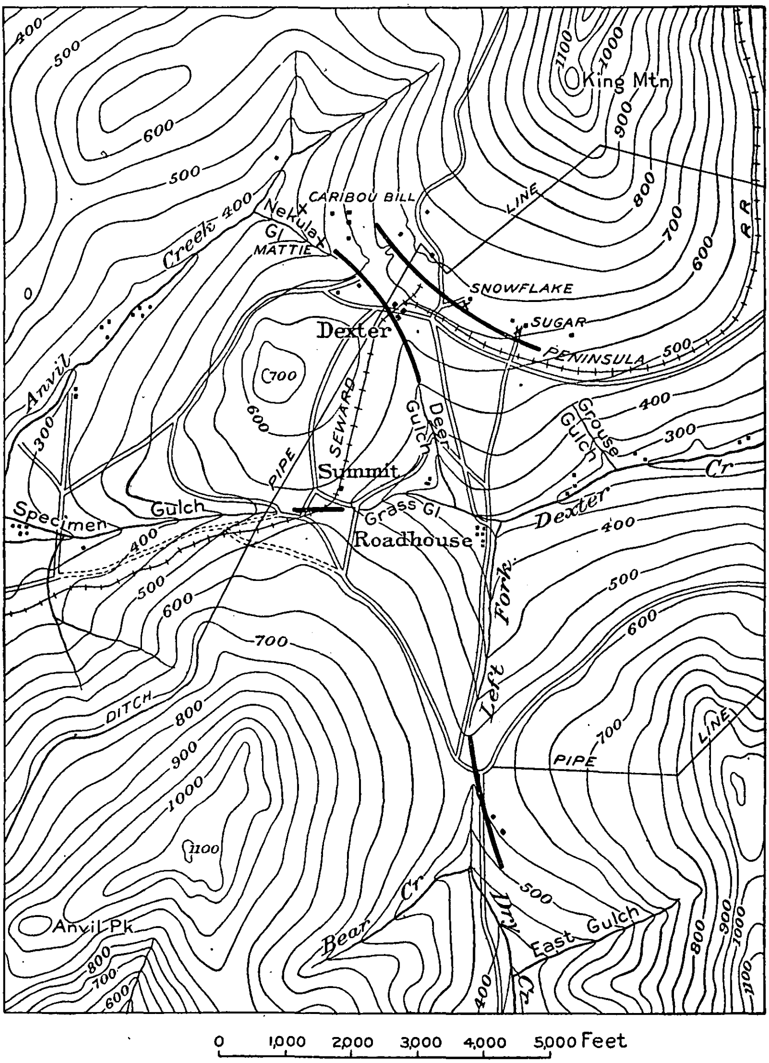


FIGURE 11.—Sketch map showing (by heavy lines) the position of pay streaks or old channels in the high-bench gravels at the head of Dexter Creek.

At Dexter station divide the thickness of the gravel is about 135 feet. The bedrock divide, however, does not correspond with the surface divide, but lies several hundred feet north of it, as a consequence of which the gravel deposit thins out in that direction. Gravel extends northeastward on the slope of King Mountain to an elevation of 650 feet above sea level, or about 50 feet above the saddle. It also extends southeastward toward Grouse Gulch, near which it finds topographic expression in a broad, low bench, and southward toward the head of Grass Gulch, but it is not seen on the slope west of the saddle.

The bedrock is schist, which includes several beds of limestone. These rocks are much disturbed, faulting has taken place, and the structure is uncertain. Schist, quartz, and limestone form the gravel deposits. A few rounded granite bowlders are found, but it is probable that they occur chiefly near the surface. The fragments are angular. Flat pieces of schist a foot or more in greatest diameter are numerous, and the deposits have the characteristics usually found in stream wash or in rock waste that has not traveled far.

The rich gold-bearing gravel at Dexter station comprises two distinct pay streaks in old stream channels (fig. 11).

The lower streak lay upon bedrock and extended from the head of Nekula Gulch to Deer Gulch, sloping toward the south. It was practically at the surface on Nekula Gulch, but is 135 feet below the surface at Dexter station. The workings have exposed it continuously from Nekula Gulch to Deer Gulch. Unfortunately, mining began at the north or higher end of the old channel, and although the work was carried on from a number of shafts all the gravel had to be hauled up the slope before hoisting. The slope in places is so steep that two men were required to push the cars.

The lower pay streak comes to the surface on the Mattie claim, north of the station and just east of the head of Nekula Gulch, and was worked in an open cut about 30 feet deep. This is the place where the high-bench placers were first found and is the north end of the pay gravels passing under the divide at Dexter station.

The upper pay streak lies north and east of Dexter station. At a point 500 or 600 feet northeast of the station pay gravel was reached at a depth of 100 feet, or 75 feet above the level of the nearest part of the lower pay streak. From this place the upper pay streak extends northwestward toward Anvil Creek and southeastward across the south slope of King Mountain toward Grouse Gulch, in which direction the thickness of overlying gravel deposits increases.

The principal claims located on the upper pay streak are, from north to south, the Mattie, which includes the north end of both pay streaks; the Lena and Gambrinus, whose common boundary line cuts the upper pay streak lengthwise; the Snowflake; and the Sugar. Collier visited these workings in 1903, and his notes have been used freely in the following descriptions of the bench gravels and the placers.

On the lower or west end of the Mattie claim 30 feet of gravel was exposed in a pit measuring 50 by 150 feet. The bedrock consists of much-faulted chloritic and graphitic schist with some limestone. Small quartz veins cut the schist and have been found from assays to carry traces of gold. Bedrock outcrops on the claim near the head of Nekula Gulch. The loose deposits exposed in the cut comprised 5 or 6 feet of light sandy wash underlain by 25 feet of gravel, which rested on schist bedrock. This gravel in places was well stratified and of brownish color but toward the east contained considerable clay and was less well bedded. A few granite bowlders were found at the surface. Gold was found on bedrock and in the upper 2 feet of the decomposed schist. It was bright and waterworn, averaging about 10 or 12 colors to the cent.

On the east end of the claim a shaft was sunk 65 feet through gravels to schist bedrock, which at this place is 50 feet higher than at the open cut.

Pay gravel was found in a channel ranging in width from 15 to 150 feet and was traced into the pay streak of the Lena and Snowflake claims, thus proving it to be a part of the upper pay streak. The following section was exposed by the shaft:

Section in shaft on Mattie claim, near Dexter.

	Feet.
Turf	1
Sand and gravel	60
Pay gravel	6–9

About one-fourth of a mile southeast of the Mattie claim and directly east of Dexter station is the principal opening of the Snowflake mine. A shaft 130 feet deep was sunk to bedrock, exposing the following gravel section:

Section in Snowflake shaft, near Dexter.

	Feet.
Muck and gravel with bowlders and pebbles of gneiss and granite	5
Silt and gravel	125
Quartz chlorite schist, bedrock.	

The gravel is nearly all of local origin and is made up of schist and quartz fragments showing little wear. Only a few granite pebbles were found, and they were at the surface. Most of the rock fragments forming the gravel have subangular edges and evidently have not traveled far. They are the wash of a small stream. From 3 to 9 feet of the gravel directly above the schist was gold bearing.

The pay streak at the foot of the shaft occupied a rock channel running S. 60° E. and averaging about 100 feet in width. This channel is shallow, the southern rim rising only a foot or two above the gold-bearing gravels.

Seventy feet east of the foot of the shaft, on the 130-foot level, the bedrock pitches below barren gravel, which underlies the pay streak at this place. A shaft was sunk here and reached schist bedrock at a depth of 100 feet, thus giving a total thickness of 230 feet of gravel. The lower end of this shaft followed a slickensided schist wall on the south for 15 or 20 feet. There is evidently a fault here extending from northwest to southeast, which is older than the gravel deposit, for it has not disturbed the gravel. Another pay streak lies on bedrock in this second shaft.

The surface deposit at the Snowflake claim is frozen to a depth of 90 feet. Below that the gravel is dry, practically no water entering the workings except from the shaft. Gold was found in all the gravel, but is not present in sufficient amount to be recovered with profit from any of it except the pay streak under the conditions prevailing at the time the mining was carried on. Only gravel averaging from $6 to $7 a cubic yard was hoisted, and doubtless much ground remains that would yield good returns if a suitable water supply were available, so that the gravels could be handled by hydraulicking.

The gold was bright and coarse. Its rough edges showed that it had not been carried far by the stream. The larger nuggets were porous, and many of them included pieces of quartz and calcite. One nugget weighing 9 ounces 9 pennyweights was found.

About 600 feet southeast of the Snowflake is the Sugar claim. Gold-bearing gravel of low grade was here reached at a depth of 100 feet; this rested on an older gravel deposit like that at the Snowflake. Drill holes showed that bedrock lies 205 feet below the surface. The lower deposits contain a small quantity of gold, but only those at the 100-foot level were exploited. This pay streak is here 70 feet lower than at the Mattie claim, 3,000 feet northwest, which gives it an average slope of 1 foot in 40 feet.

About 300 feet southeast of the Sugar claim a shaft was sunk, from which the following section was obtained:

Section in shaft southeast of Sugar claim, near Dexter.

Muck and silt	feet	4
Loose gravels with colors	do	25
Decomposed chloritic schist	do	51
Washed gravel and silt	inches	10
Schist	feet	20

The 10 inches of washed gravel was thought to be continuous with the pay streak of the Sugar claim, but it carried no gold.

Exploratory tunnels driven along bedrock to the north and to the south showed that the gravel pinched out in these directions. Tunnels were driven west and north also in the schist from the bottom of the shaft, and an upraise to the 75-foot level was made in the western tunnel without discovering important gold-bearing deposits, although a thin bed of gravel containing a little gold was revealed.

To summarize the foregoing descriptions, it may be said that the elevated bench gravels near Dexter station, except a small proportion of those found at the surface, are of local origin. These gravels occupy the saddle between King Mountain and the hill on the southwest and mantle the mountain's lower southern slope. In the saddle they are 135 feet thick, but about 1,000 feet east their thickness increases to a maximum of 230 feet. North of the divide the gravels thin out.

Two principal pay streaks have been developed and largely worked out. The lower one extends from the head of Nekula Gulch to Deer Gulch and has a southerly slope. The upper pay streak begins a short distance east of Nekula Gulch and extends southeastward to the head of Grouse Gulch, a distance of about 3,000 feet. These two pay streaks have a difference in elevation of 50 feet at their north ends, and east of Dexter station this difference increases to nearly 75 feet. The lower pay streak lies on bedrock, but the eastern one rests in some places on bedrock and in other places on older gravel. Gold is not confined to the main pay streak of the eastern claims, for in the Snowflake mine it is found also in another pay streak 100 feet lower—that is, 230 feet below the surface. It is not known whether there is any connection between the lower pay gravels of the Snowflake and those found in the saddle, but apparently there is none. In general the gold is angular and rough, yet at the north end of the lower pay streak smooth, waterworn gold was found.

Specimen and Grass Gulch divide.—The saddle between Specimen and Grass gulches is 3,000 feet south-southwest from Dexter station and is 50 feet lower, or about 540 feet above sea level. This saddle is crossed by the railroad tracks and by the wagon trail. It is occupied by gravels which fill a narrow rock cut running almost directly east and west. At the summit the gravel has a thickness of 106 feet. The total width of the deposit probably does not exceed 600 or 800 feet, and development work was carried on along an east-west line for about the same distance, although the gravel extends to the heads of Grass and Specimen gulches.

No section was obtained, but the dumps show fine sand and silt containing many bowlders of schist and granite. All the material is considerably waterworn. On the east side of the saddle, 150 feet from Grass Gulch and 500 feet from the railroad, the surface material shows 20 feet of yellow clay with some sand and rounded pebbles. Granite pebbles are abundant on the surface and appear all along the hill slope to the head of Dry Creek.

The gold-bearing gravel has a thickness of 6 to 7 feet. The fragments are waterworn and contain much granite, though the chief constituents are schist and limestone. The pay streak ranges from 50 to 80 feet in width and is overlain by clay in some places. The gold-bearing gravel lies on bedrock in a fairly well-defined channel running from east to west. All the deposits are frozen.

The gold obtained here was worn and smooth. Many nuggets were found and all showed the effects of travel. One nugget, valued at $138, was taken from this place. Some of the gravels were very rich, but the pay streak averaged probably about $7 or $8 a cubic yard.

Dexter and Dry Creek divide.—Between Dry and Dexter creeks is a broad saddle whose elevation above the sea is 570 feet. It is thus 24 feet lower than the saddle at Dexter station and about 25 feet higher than that at the head of Grass Gulch. This saddle, like the other two, is occupied by gravel deposits whose surface is nearly flat, but slopes slightly toward the south. The gravel is gold bearing, but the rich portion is now worked out.

Development work extended along a nearly north-south line for 2,000 feet, following a broad, shallow channel in bedrock, in which the best gravel lay. Near the summit the channel lies in the middle of the saddle; to the south, however, it is situated a little east of the head of Dry Creek. Its highest point is perhaps 1,000 feet farther south than the lowest part of the saddle. It slopes to the north and is 40 feet lower at the north than at the south end. The gravel deposits increase regularly in thickness from 35 feet in the most southern shafts to 70 or 75 feet in the northern ones. East and west from the channel line the thickness diminishes rapidly.

The gravel consists essentially of subangular fragments of schist. Much of it is feldspathic; it is all more or less decomposed and some is iron stained. There is a comparatively small amount of vein quartz, a large percentage of which is derived from quartz-chlorite-albite veins such as appear on the hill on the east and on Newton Peak. A little limestone also is present, and a very few granite pebbles and bowlders are seen. Whether the granite occurs in the deep gravels was not determined, but it is common on the hill slope to the northwest.

A shaft near the middle of the workings showed the following section:

Section in shaft on divide between Dexter and Dry creeks.

	Feet.
Muck and slide rock	16
Washed gravel with some gold	12
Soft sandy soil	2
Soil, peat, and slide rock	22
Stream gravel	10
Decomposed schist bedrock.	

None of the deposits are frozen. The bedrock in most places is schist, but toward the north schist gives place to limestone.

Gold-bearing gravel was found on bedrock in the broad shallow rock channel described. It has a thickness of 2 to 3½ feet and consists of light-brown sandy material containing pebbles of schist with some quartz and limestone. Gold was not confined to this channel, although the richest gravels were found there. Both on the east and west auriferous gravel was worked with profit. The gold was coarse and well rounded, yielding probably from $6 to $12 to the cubic yard of gravel. Some pans of $3 to $4 were obtained.

It is possible that the placers found in the old channel 400 or 500 feet east of the present bed of Dry Creek where it leaves the hills to cross the Nome tundra are a continuation of the gold-bearing gravel in the saddle at the head of the stream. No connection between them has been established, however, and if they were continuous, the intermediate portion has been cut through by the small easterly tributaries of Dry Creek. This old channel has been described in connection with the gold-bearing gravels of Dry Creek (p. 90).

A somewhat similar occurrence of high auriferous gravel appears on the south side of Buster Creek and has been described in connection with the Buster Creek placers (pp. 96–97). It lies at an elevation of 325 feet above the sea, or about 125 feet above the stream, hence it is somewhat lower than the high gravels already described. What relation, if any, there is between them is not known.

Summary.—The elevated gold-bearing gravels at the head of Dexter Creek are found in the three low saddles in the watershed between the Snake and Nome river drainage areas. These saddles have elevations ranging from 540 to 594 feet above the sea. The deepest as well as the most productive of the accumulations is that at Dexter station, where the greatest thickness of gravel measured was 230 feet. Next to the Dexter station gravels in point of thickness are those at the head of Grass Gulch.

The great mass of the material is made up of subangular fragments, apparently of local origin, consisting of schist and quartz with a small amount of limestone. Clays and sands are associated with them. Well-rounded granite and gneiss pebbles are found in the surface deposits at each of the localities and are abundant at the head of Grass Gulch and on the hill slope at the southeast. At the Grouse Gulch locality they are found also in some of the lower gravels.

Gold is present in all the gravels, but only a part of them were sufficiently rich to be mined with profit at the time when work was being carried on.

The most important gold-bearing gravel formed well-defined pay streaks sloping toward Dexter Creek. These pay streaks represent the beds of former streams, which in some places cut distinct channels in the bedrock but in others flowed over older surface accumulations. Such streams could not exist under present conditions, and it is evident that they were part of a drainage system that differed in considerable measure from the one we now see. The streams that deposited the gravel and gold must have carried much more water than collects in the present drainage areas. Moreover, the worn granite bowlders and pebbles give conclusive evidence that the top gravels are derived in part from a distant source, although the lower beds consist of material like the rock of the surrounding hills.

In themselves these high gravels give no conclusive evidence of land elevation, unless it can be shown that the granite bowlders were laid down when this area was below the sea or were deposited by a stream near sea level.

As the three old channels converged in the Dexter Creek valley, it is probable that the gold found in Dexter Creek was largely a reconcentration from the older gravels.

BEACH PLACERS.

General features.—The Nome beach placers are of two kinds—those of the present beach and those buried in the coastal-plain gravel deposits. They do not differ in origin, however. The buried beaches were once like the present one; they were beaten by the waves of Bering Sea, like the beach of to-day, and they were washed by shore currents such as now sweep along the coast. Their chief peculiarities are that they have been covered with a mass of later deposits and, with the exception of the "submarine beaches," have been elevated above sea level. Some account of the old beaches has already been given in the description of coastal-plain deposits (pp. 41–44), but it will be necessary to restate some of the important facts and consider them more particularly with regard to their economic bearing.

Five or six ancient beaches, more or less well defined, may be recognized in different parts of the coastal plain and have received local names. Many others are reported, and it is evident from a study of the way in which the coastal-plain deposits were formed that there may be a very considerable number, but it by no means follows that they are all economically important. Two of the beaches are of especial interest in a consideration of the placers, because the richness of their gold-bearing gravels caused them to be traced for long distances and to be studied with great care. They are known as the "second" and "third" beaches from the order of their discovery, the present beach being regarded as the first. Both are nearly parallel to the present coast line but converge toward it in the direction of Cape Nome, where all three come together. The "intermediate beach," the "submarine beaches," and the somewhat doubtful "Monroeville beach" are not so rich and are less well known. These beaches, essentially similar in most respects, form one of the most noteworthy features of the Nome placer district.

Present beach.—Sixteen miles of coast line is represented on the Nome map. The western half of this line is broken by the mouths of Nome and Snake rivers and includes the most productive part of the present beach. The eastern half is cut by a few minor streams, and only one or two small sections of it have been found to contain notable amounts of gold.

This coast line is slightly bowed toward the north, but is so nearly straight that one scarcely realizes the curvature as he looks along the shore. The beach varies in width from about 250 feet to 300 feet and has a southerly slope of about 1 foot in 10. This slope is greater in some places and is less in many places. On the north is a low escarpment of silt and tundra vegetation locally underlain by ice and having a height exceeding in a few places 8 or 10 feet, though in most places not greater than 3 or 4 feet.

The gravel on the beach surface is mostly rounded quartz associated with a considerable amount of schist and a little granite. The granite, like the quartz, is well rounded, but most of the schist fragments, although their edges are ground away, have one dimension very much smaller than the other two. A few bowlders are seen, but in general the pebbles do not exceed 2 or 3 inches in greatest dimension. Some of the bowlders were probably carried to the beach by floating ice.

Fine sands predominate near the water, but in the higher part of the beach, gravel is more conspicuous than sand. In places the surface material is almost entirely composed of red garnet, or "ruby sand," as it is called. It is especially common near Cape Nome, but is found in many other localities. The beds of ruby sand are commonly not more than a few inches thick and extend in a horizontal direction for short distances only. Where buried under other gravel they lie in lenticular beds exactly similar to those found in the buried beaches. This form is characteristic of all the beach deposits. The gravel beds are not continuous, like those laid down in deep water, but consist of overlapping lenses. Besides garnet, the minerals magnetite, ilmenite, scheelite, pyrite, and mica have been noted in the beach sand, but the great bulk of it is quartz.

A section of the beach placers shows from 1 to 6 or 7 feet of sand and gravel overlying a blue clay "bedrock." The clay bed or rather beds, for the clay is not known to extend continuously along the shore, slope toward the sea and are nearest the surface at the upper side of the beach—that is, their slope is greater than that of the beach.

Other thin clay beds or seams are distributed in the gravels above them.

Most of the beach gold was found to be concentrated in the sands overlying the blue clay, but in places more than one pay streak was uncovered. The principal pay streak ranged in thickness from 6 inches to 2 feet. In nearly all places where gold was found in quantity a large amount of ruby sand was present in the pay streak and usually some magnetite also, although magnetite constitutes but a small proportion of the concentrates.

The pay streak, like the other gravel deposits, was lenticular, its dimension parallel to the shore being greater than at right angles to it. Gold was much more highly concentrated in some localities than in others. The richest sands are said to have carried about $1 to the pan. That part of the beach adjacent to the mouth of Snake River yielded a major portion of the beach production, yet the whole coast line from Cape Nome to Penny River afforded valuable gold-bearing gravels. The gold averaged from 70 to 80 colors to the cent and was therefore regarded as fine gold. Coarser gold has been found in a few places, but nuggets worth a dollar were rare. On the sandspit between Snake River and the sea coarse gold with nuggets up to the value of $6 and $8, similar in character to gold found on the lower end of Bourbon Creek, was taken out. There still remains much gold in the present beach at Nome, and each summer a few men may be found washing the sands, but the most highly concentrated deposits have been removed, and the ground has been so thoroughly searched for rich spots that only by handling the gravels in a large way and with machinery for saving all the valuable content could mining be carried on with much profit. One curious feature of the beach gold is that much of it is now found to be amalgamated with mercury lost from the sluice boxes. There is so much mercury in the beach that one can hardly wash a pan of the lower gravel without finding the little white globules.

Second beach.—The second beach was the earliest of the ancient buried beaches to be discovered, but did not attract attention till two or three years after the gold deposits of the present Nome beach were found and was not itself thoroughly exploited till a year or more after its deposits became known. It extends eastward from a point about two-thirds of a mile north of Nome for 8½ miles to Hastings Creek, where its distance from the sea is about a quarter of a mile.

During the winter of 1904–5 many holes were sunk along the line of this beach between Nome and Hastings Creek and helped to determine more accurately than before the location and position of its pay gravel throughout the greater part of its extent. The pay gravel lies at the foot of a well-defined bench, which is continuous throughout much of the portion of the beach mentioned, except where it has been cut through and removed by some of the larger streams. The pay streak, as is well shown by the line of tents and cabins erected on the claims along its course, forms a nearly continuous deposit almost as constant in direction as the present beach, to which it is approximately parallel.

The gold-bearing gravel, which rests on a clay or in places a gravel "bedrock," ranges in thickness from 3 or 4 inches to 2 or rarely 3 or more feet and lies, as a rule, from 20 to 35 feet below the surface. On several claims its depth below the surface is about 40 feet and in a number of places it is less than 10 feet. The width of the gold-bearing deposit ranges from 25 to 100 feet, but averages between 35 and 40 feet. At three widely separated localities its altitude above sea level is 37 feet. It has also been observed that the pay streak has a dip toward the south amounting at one point to 4 or 5 feet in the width of the pay streak at that place, which was 50 feet. In some places—for example, on Peluk Creek, Otter Creek, and Nome River—the gold-bearing gravel is less regular in its longitudinal extent and appears to have been cut through or scattered by the streams. Possibly there were indentations of the shore line at the mouths of these streams interrupting its regularity, although there are none along the present beach, the mouths of streams being characterized rather by delta deposits.

The gravel from which the gold is taken is a true beach deposit and, like the beach material of to-day, contains a large amount of "ruby sand" and some marine shells. Walrus tusks and driftwood have been taken from several shafts.

All the deposits from the surface down are permanently frozen. The gold is fine, like that of the present beach, yet in one place near Otter Creek nuggets were found, and according to T. M. Gibson were probably derived from a near-by schist ridge slightly above the beach level. The gold deposits of the second beach were much smaller in amount than those of the present beach.

Third beach.—The third beach was discovered late in the fall or early in the winter of 1904. During the following summer operations on it were confined to the immediate vicinity of Little Creek, and not till the winter of 1905–6 was its eastward extent determined and the ground opened for mining. This old coast line skirted the hills back of Nome and extended in a broad arc, bowed toward the north, from Cape Nome on the east to Cape Rodney on the west—a distance of 27 miles. At Little Creek, where it was discovered, the third beach is 3½ miles from the present beach, but eastward from that point the two gradually converge. The third beach lies above present sea level at an elevation variously given as 70 to 79 feet, depending probably on the part of the deposit chosen for making the measurement. It is thus above the level of Nome and Snake rivers at the points where it intersects their courses. These two streams flow through valleys in the coastal-plain deposits that are younger than the third beach, and in forming these they removed parts of the third-beach deposits, making two important gaps in the beach within the area considered. A smaller gap, formed by Hastings Creek, should also be mentioned. The gap at Nome River is $2\frac{1}{2}$ miles broad; that at Snake River extends west from Little Creek at least as far as Sunset Creek.

The best-known and richest part of the third beach is between Little Creek and the head of McDonald Creek. East of Nome River the gold content is much smaller, and so far as is known at present the beach deposits are less well defined. The gold-bearing gravel lies at the same elevation above the sea wherever the elevation has been determined, but its depth below the surface depends on the surface topography. Where valleys are cut below the deposit it appears at the surface, and it lies at a maximum depth of 120 feet near the head of Bourbon Creek.

The beach deposits are of marine origin, yet some of the rich gold-bearing gravel associated with them and a great deal of the overburden are not. This is evident from the character of the gravel. The difference between marine and stream deposits is noticed in both their vertical section and their horizontal distribution and is well shown in the stretch of beach between Little and McDonald creeks. Near Little Creek stream deposits are intermingled with well-washed marine gravel and form a large proportion of the whole. Toward the east the amount of stream gravel decreases and marine gravel becomes predominant.

Mining operations and drilling[1] have shown that the third-beach deposits between Little Creek and a point about halfway between Newton Gulch and Otter Creek rest for the most on a bedrock of schist having small included beds of limestone. The bedrock dips gently below the third beach from the vicinity of Otter Creek to McDonald Creek, where it is 20 feet lower, then falls more steeply to a point below sea level near Nome River, rises within 12 feet of the third beach near Irene Creek, and finally pitches below sea level, not to rise again to the third-beach level till the hills of Cape Nome are approached.

A description of the unconsolidated deposits overlying the third beach has been given (pp. 41–42). They consist of a varied association of marine and stream gravel and sand overlain by and in places interstratified with "muck" and vegetation. The third beach de-

[1] The writer is indebted to the paper by T. M. Gibson previously cited for some of the facts concerning the Nome beaches, particularly the third beach.

posits resemble those of the present beach in most respects, except in the important one that they contain a greater proportion of stream gravel in certain places. They have a thickness ranging from 5 to 12 feet and a width, including the so-called "slough over," of 300 to 600 feet. The "slough over" is a minor line of marine deposits lying immediately south of the main beach and containing a pay streak of considerably smaller value. It is separated from the third beach by a narrow zone occupied in part by a bed of quartz cobbles and small bowlders. Its origin is not known with certainty, but it has been explained as an off-shore bar.

The third beach, like the present beach, has a slope of about 1 foot in 10, but is slightly steeper in the seaward than in the shoreward half. It is made up of elongated, lenticular beds of gravel and sand laid down by the waves, but at three localities the ancient streams that emptied into the sea along this beach have contributed quantities of débris that obscured the character of the marine deposits. These localities are at Little Creek, the old mouth of Anvil Creek; near the head of Bourbon Creek, the old mouth of Dry Creek; and near Irene Creek, where, with little doubt, Osborn Creek once joined the sea.

The placer deposits in the vicinity of Little Creek have been described as follows:[1]

> The gold deposits are deep. The average depth of the various shafts is between 30 and 35 feet, but this is exceeded in a few instances and reaches 50 feet. A heavy covering of muck and moss, with a thickness varying at different places from 12 to 23 feet, overlies the gravel, and all is frozen from the moss down. The gravels are not entirely similar at all localities, either in the thickness or in the character of the beds. Some deposits are apparently well-washed beach sand, others were without doubt laid down by streams. At a distance of 1,000 or 1,200 feet east of the railroad track beach wash with a thickness of 5, possibly 7 feet, rests directly on bedrock (mica schist), and is overlain by stream deposits. A short distance west of this the gravel lying on bedrock is probably of stream origin. Still farther west, near the railroad, thin beds of clean rounded gravel are interstratified with stream wash. Beds containing bowlders up to a ton in weight overlie the workable gravels in some places and are a constant source of danger in mining, especially during the summer months, when the roof is weakened by thawing. These bowlders are also present on the bedrock and are found not infrequently in the muck overlying the gravels.
>
> Nearly all the deposits from the surface to bedrock carry a certain amount of gold, but the rich gravels are found well down, in some places resting directly on the schist and in others at a height of 5 or 6 feet above it. The gold-bearing gravels of present economic importance have a thickness of between 4 and 5 feet, but in one instance, where the material removed formed a lenticular mass, the thickness was 16 feet. Thin elongated lenses or beds of reddish sand, called "ruby sand," whose color is due in some cases to small grains of red garnet and in others to iron oxide, occur throughout the pay

[1] Moffit, F. H., Gold mining on Seward Peninsula: Bull. U. S. Geol. Survey No. 284, 1906, p. 134.

gravel, many of which contain enough gold to be easily seen, even when hastily examined. Mica schist, in which occur occasional thin limestone beds, forms the true bedrock, but the so-called "bedrock" on which the gold lies is in some places the schist, in others a clay streak, and in one place gravel cemented with calcite deposited by circulating waters. Part of the gold is fine, bright, and flaky; part is coarser, containing many nuggets of 5 and 10 cents, with occasional larger ones, some of which are valued as high as $20.

This description applies to a part of the beach where both the ancient stream placers of Anvil Creek and true beach placers were mined and at first were not clearly distinguished. Farther east there was no doubt about the origin of the gravel deposits, as the contributing streams were smaller and carried less débris to the sea. Beach deposits were there developed in characteristic form. In that part of the beach the pay streak had a width of 25 to 100 feet and rested in some places on bedrock, in others on gravel, and near McDonald Creek on fine sand. The upper streak is separated from the lower or "slough over" streak by a zone of barren ground, already referred to, 100 feet or more in width. It is invariably richer than the lower streak, which in places is absent. Gold is not evenly distributed throughout the old beach, for in contrast to the extraordinarily rich gravel of such claims as the Portland, May Fraction, Bessie, and others in the vicinity of the old Anvil Creek channel there are claims or parts of claims which are of little value at the present cost of mining, because although the deposits of beach gravel are continuous across them the gold is much diminished in quantity or is lacking. Such poor spots are locally known as blanks and are places where conditions were evidently unfavorable for the concentration of gold.

Blanks have been found in places where the ancient sea beat against a low cliff of bedrock and a considerable depth of water was maintained or the slope was too steep to permit the formation of the ordinary beach deposits. Places of this kind may be compared with the present shore line at Cape Nome, although no cliffs of such size as those on the cape were present along the third beach, except perhaps at its eastern end. Other blanks occur where the coastal plain was low and flat, permitting the tides and waves to sweep over a wide area. Each of these conditions is of a kind to prevent the milling and sorting of material such as goes on constantly along the present beach.

East of Nome River the third beach is only partly exposed and the auriferous deposits are of low grade compared with those west of the river. Some of it, including what was once probably the mouth of Osborn Creek, has been mined profitably. This better part undoubtedly owes its higher gold content to the presence of the stream that emptied into the ocean here. The beach deposits lie on other gravel, and true bedrock is nowhere present. Farther east drilling indicates that the beach is less well developed. Finer gold is found there than on any other part of the beach.

In addition to the major differences in concentration of gold along the third beach, such as are due to direct contribution by streams and such as are seen in the so-called "blanks," there are many minor differences. The gold is not evenly distributed through any of the gravel. The writer was informed that in the shallow indentations, which are found here and there along the beach, a greater concentration of gold took place on the eastern than on the western side, and that in one or two places where low ridges or rolls of bedrock reached the surface and projected slightly seaward from the beach, exceptional amounts of gold were found on their western sides (fig. 12)—a position of maximum concentration corresponding to that in the indentations just mentioned. This would indicate that the distribution of gold in the gravels was influenced largely by the prevailing direction of ocean waves and currents, although it is un-

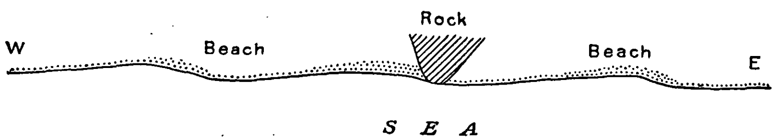


FIGURE 12.—Diagram showing concentration of gold in shallow depressions or on sides of cusps of the third beach.

doubtedly true that very rich deposits, such as occur at Little Creek and Bessie Beach between Holyoke and Bourbon creeks, are due to their nearness to the source of gold or to streams that brought it to the sea, as the character of both the gold and the gravel would point to this conclusion. On the western part of the beach the gold is on the average much coarser than at the eastern end, where it resembles in appearance and approaches in fineness that of the present beach.

The gravels of the west end, by their diversity in character and the large amount of coarse, angular stream wash they contain, show that the conditions under which they accumulated were less uniform than those prevailing farther east, and that at one time stream deposits were being laid down and at another time sea deposits.

In general, the gravel along the third beach is frozen from top to bottom, but in places there is no frost. These unfrozen areas are distributed irregularly, and their presence has never been satisfactorily explained. Their location is of great importance to the miners for two reasons. Mining can be carried on in frozen ground without such care and expense for timbering shafts, tunnels, and stopes as is necessary in unfrozen ground. Areas of unfrozen ground surrounded by frozen ground act as reservoirs for collecting surface water, which, when tapped in mining, can be prevented from flooding the workings only by the use of pumps, and thus greatly increase the cost of recovering the gold. On the Bessie claim, near the head of Holyoke Creek, the boundary line between thawed and frozen ground was located by drilling, and care was taken not to bring the workings too close to the unfrozen area. Thawed ground is in some places overlain by frozen ground, and in one or two places is known to be underlain by it also. The presence of thawed gravel appears to be due, in part, at least, to the circulation of water through the ground, hence it seems more probable that the thawed areas have been slowly encroaching on frozen areas than that the reverse is true.

The remarkable richness of some of its gravel was such as to distinguish the third beach above all the other coastal-plain gold placers. Probably not less than $6,000,000 was produced from it in the four years 1905 to 1908. It is stated that pans of gravel could be selected from the richest spots that would yield $500 or more, and that from the May Fraction in an area 100 feet long and 15 feet wide more than $330,000 was taken, 90 per cent of which came from the bottom 3 inches of the pay streak.

In summarizing the facts regarding the third beach, it may be said that the gold deposits lie at an elevation of 70 to 79 feet above sea level but are buried under a mass of later deposits—partly marine, partly laid down by streams—ranging in thickness from 25 to 120 feet. They dip toward the south with a slope of approximately 1 foot in 10 and in some places rest on bedrock, in others on gravel, and near Nome River on fine sands.

There is a marked difference between the west and east ends of the known portions of the beach, shown by a greater quantity of angular stream wash intermingled with marine gravels and sands at the west end and a correspondingly greater quantity of fine gravel and sand at the east end. This difference is shown also by the character of the gold, which at the east end is like the gold of the present beach, but in the vicinity of Little Creek is coarse and heavy with nuggets up to $20 or more in value.

Intermediate beach.—The intermediate beach was discovered near Center Creek in the winter of 1905–6 at a point 1¾ miles from the present beach. It has been traced eastward to Dry Creek, but beyond that point its course is not determined. The beach deposits rest on a bedrock of schist with a surface sloping gently seaward and have an elevation of about 21 or 22 feet above sea level. They are thus lower than either the second or third beach and give valuable assistance in determining the relative ages of those beaches.

The total thickness of coastal-plain deposits along the known part of the intermediate beach ranges from 30 to about 70 feet, of which the beach material constitutes from 6 to 12 feet and occupies a zone several hundred feet wide. Black graphitic schist is an important constituent of the pay gravel, which ranges from 1 to 3 feet in thickness, rests on true bedrock, and is characterized by so many fossil shells that it is sometimes called the "clam-shell beach." There is, however, considerable variety in the appearance of the beach deposits. In some places the rock fragments are not well rounded and are mixed with a large proportion of mud, in others fine sand is present, and in one place the gravel beds of the pay streak were separated by a layer of muck and were overlain by a bed of well-rounded bowlders, some of which were 2 feet long.

The gold of the intermediate beach is fine and is associated with small amounts of pyrite, arsenopyrite, and magnetite or ilmenite. Beds of ruby sand occur in smaller number than on the present and second beaches.

"*Submarine*" *beach*.—The "submarine" beach was discovered in 1907 at a point west of Snake River and nearly south of the pumping plant, where it is about one-fourth of a mile north of the present beach. It has been traced westward from that point for about 2 miles, and beach deposits thought to be its eastward continuation have been found at Dry Creek. This beach is 19 feet below sea level and forms the base of a coastal-plain section that includes from 50 to 55 feet of gravel overlain by 10 to 15 feet of muck and vegetation. The auriferous gravel has a thickness ranging from 1 to 3 feet. In some places it rests on schist bedrock; in others on older gravel deposits that fill the depressions of the undulating bedrock surface. All the deposits are frozen. This condition is a great advantage in mining, but is partly offset by the treacherous character of the roof resulting from the fact that the contact between the sand and gravel layers is a plane of weakness and permits masses of gravel to scale off and drop into the stopes. The gold is coarser than that of the other beaches and is more uniformly distributed throughout the pay gravel. Nuggets with a value as high as $10 to $12 have been found. Sulphides accompanying the gold are more abundant than in the other beaches. They include both pyrite and arsenopyrite and are associated with a little magnetite and ilmenite. Beds of ruby sand are not present in the beach, yet garnet is found in the concentrates.

The character of the gold deposits of the "submarine" beach where first discovered leads to the belief that they are not typical of concentration due to the action of surf alone, but, like those of the third beach in the vicinity of Little Creek, are in part the contributions of an old stream, possibly Anvil Creek, which have been distributed by the waves and shore currents prevalent at the place where they reached the sea.

Another so-called submarine beach, very little known as yet, is present 300 to 1,000 feet south of the one just described and 15 feet lower, or 34 feet below sea level. It lies on a false bedrock a few feet above true bedrock and 60 to 70 feet below the surface of the coastal-plain deposits. There has been no gold production from this beach, as the gold content of the gravel is small. The gold is fine and is associated with a considerable amount of heavy concentrates, consisting largely of well-formed crystals of arsenopyrite. Pyrite and chalcopyrite also are abundant, and magnetite and ilmenite are present. Garnet, just as in the inner "submarine" beach, appears in the concentrates but does not form an important part of them.

Monroeville beach.—The deposit of auriferous gravel usually referred to at Nome as the "Monroeville beach" is not a typical beach, and there is doubt as to its exact character. It lies about halfway between the intermediate and third beaches, extending in a nearly east-west direction parallel to them, and has been traced for nearly a mile between Little and Holyoke creeks. It thus lies immediately south of that part of the third beach which intersects the old channel of Anvil Creek. The pay gravel rests on bedrock at an elevation of 33 feet above sea level. It has a width from north to south ranging between 300 and 500 feet, is little more than a foot thick, and is overlain by 50 feet of frozen gravel and muck. It contains much coarse material, probably of stream origin intermingled with beach wash. This composition, together with the lack of ruby sand and of stratification, which are found in the typical beach deposits, account for the questions that have been raised concerning its character.

The gold is present in the gravel pay streak and in the 2 or 3 feet of schist underlying it, both of which are removed and put through the sluice boxes. In the richest part of this beach the gold is coarse, containing a large proportion of nuggets, but both to the east and to the west the coarseness decreases till the gold takes on the character of that usually found in the beaches. It is associated with a large amount of pyrite and arsenopyrite and a little magnetite.

There seems to be little reason to doubt that the peculiarities of this beach are due to the fact that its gold deposits are situated, just as on the third beach, at the place where beach deposits and stream deposits were intermingled and neither was developed in its usual form. Another explanation that may have some validity, although no definite evidence for it is available, is that some of the gold may be concentrated very near to its original bedrock source.

Origin of the beach placers.—It has been seen that the buried beaches differ only in minor ways from the present beach, and it is probable that all were formed in essentially the same manner. It is also probable that the causes leading to the concentration of gold in one beach were those leading to its concentration in the others, and that the immediate source or sources of the gold were the same. There is room, however, for difference of opinion as to the manner in which the concentration took place.

Three explanations for the origin of the beach placers may be considered—(1) that they are due to concentration, by wave action, of gold widely distributed in small quantity through the tundra gravels; (2) that the gold was brought to the coast from its bedrock source by streams and then carried along the beach by waves and ocean currents; (3) that the concentration results from both the causes just mentioned acting together.

Gold is found in all the tundra gravel deposits wherever they have been tested. The amount, however, except where concentration has taken place, is too small to pay for mining under present conditions and by the methods now in use at Nome, unless dredging proves to be sufficiently economical. The gold is fine, is present in the muck as well as in the gravels, and is even reported to have been found in or on some of the ice beds. Because of the small quantity in the gravel other than the pay streak of the beaches or streams and the fact that it can not be recovered economically, few if any attempts have been made by prospectors to determine the amount present. It is estimated, however, by some of those who have put down shafts along the beaches and elsewhere that the average content is about 10 cents to the cubic yard. In places it is several times as great. These estimates were based on panning tests and may be too large, but they indicate that the tundra gravels must be considered as a source of part of the beach gold deposits.

An explanation for the concentration of gold from the coastal plain was proposed by Schrader and Brooks and was later elaborated by Brooks,[1] from whom the following is quoted:

> In the "Preliminary report" Mr. Schrader and the writer advanced the theory that the gold was concentrated from the coastal plain gravels by the wave action which cut the seaward escarpment of the plain. The diagrammatic sketch which we published to illustrate this point is here reproduced [fig. 13]. In this sketch the edge of the coastal-plain escarpment is marked, and the position of the beach placers in reference to it is shown. During high storms the waves even now reach the margin of the escarpment and cut away the base of the bluff. The materials which go to make up the coastal plain are sorted by this wave action, and the heavier particles, such as the gold, sink into the sand. It is a well-known fact that this fine gold will make its way through sand for some distance, provided its passage is not interrupted by any impervious layer. This downward movement is brought about near the surface of the beach by the constant motion which is given the sand by the waves. The percolating waters

[1] Brooks, A. H., and others, Reconnaissances of the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 89.

will also help to carry the grains of gold downward. It should be noted here that the beach sand, being well drained, is not frozen in summer. In the course of its downward passage the gold finally reaches a clay layer and here becomes concentrated as it is found. There is another factor which may have accelerated the downward movements of the heavier particles. In the spring months southerly storms frequently pile up the ice on the Nome beach to a great height. When large floes are driven ashore on the shelving beach they must cause considerable movement in the underlying sands, and this motion is probably transmitted to a depth of several feet, and causes a disturbance among the grains of sand. A sort of sifting process would take place by which the heavier particles would always descend and eventually be concentrated beyond the line of movement or on impervious layers which they could not penetrate.

If we assume from our knowledge of the width and slope of the present beach that the gold in it was concentrated from a prism of gravels whose cross section is a right triangle with sides of 15 and 300 feet—that is, with an area of 250 square yards—and that the gold content of the gravels is 10 cents to the cubic yard, we get a value of

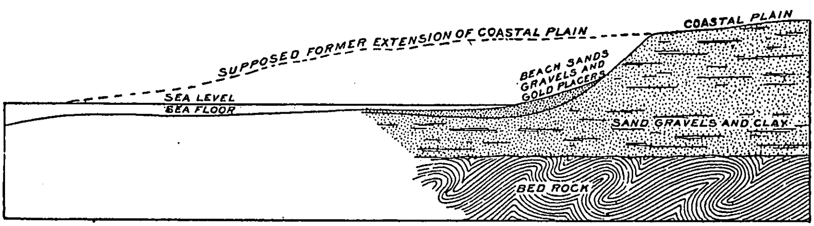


FIGURE 13.—Diagrammatic section of beach placers.

$25 to a linear yard or $43,000 to a linear mile of the beach. The gold production of the beach is over $1,000,000, all of which was obtained within a portion 20 miles long and most of which came from a portion less than 10 miles long. The valuation of $43,000 a mile is thus too small for the beach. This deficiency may be accounted for in several ways—too small a prism of gravel was used, or too small a gold content was assumed, or gold has been contributed to the beach in some other way. Finally any two or all of these variables together may have helped to produce the difference.

Again, there are places along the beach where the pay streak is said to have produced $1 to the pan or about $150 to the cubic yard. Assuming that the width of this pay streak was 20 yards, or less than one-third the average width of the beach, a value of $3,000 to a linear yard of beach is obtained. It was a matter of common observation that the gold was not distributed in anything like regular manner along the beach, and it is evident that if the beach gold were all derived from coastal-plain gravels their gold content was not disseminated at all uniformly through them, or else some other cause has operated to move the gold horizontally along the beach, so as to give the very rich concentrations and the intermediate stretches of smaller value that exist.

The streams reaching Bering Sea near Nome—for instance, the two tributaries of Snake River, Dry and Bourbon creeks—cross the richest portion of the tundra. If with these are included Anvil Creek and Newton Gulch the list comprises the important gold-producing streams flowing south from what is known to be the chief area of mineralization of the region. These streams, more especially those crossing the tundra, derived their gold from two sources. Part was received from the bedrock of their upper portions and part is a concentration from the tundra gravels. They have fairly well-defined pay streaks corresponding more or less closely with the present stream channels. To what extent gold is carried downstream under such conditions it is perhaps impossible to state, but it is certain that much of the gold of the tundra gravels near the beach must have traveled south at least 4 miles before reaching its present resting place, and it is reasonable to suppose that streams may carry gold in their channels equally far. There can be little doubt that part of the gold, although possibly a small part, was not liberated from the inclosing quartz or schist until the fragments containing it had traveled far from their original source. Grinding by pebbles in the streams and milling by the surf may be confidently referred to as two processes by which gold is freed from the rock, and it is evident that nuggets or heavy particles of gold could be transported by water more easily as parts of pebbles or bowlders than as free metal. Fine gold is readily carried by currents of water, and its presence at a distance from its source is more easily explained than is that of coarse gold. It is possible to account for coarse gold on the present beach without proving the ability of a stream to transport nuggets in the form that they have when found, and it is believed that part of the beach gold was carried to its place directly by streams. The gold found on the sand spit between Snake River and the beach and on the lower end of Bourbon Creek bears evidence of this. It is heavy and coarse like stream gold and is altogether different from that usually found on the beach.

It has been urged that if the gold of the Nome beach had been brought to the sea by streams and then distributed along the beach by waves and ocean currents, the concentration would have taken place on only one side of the stream. It is true that there is a prevailing current along nearly all coasts, and that the mouths of the streams entering Bering Sea give evidence of such a current here that would carry material in one direction, yet we know from observation that currents set both ways along the coast at Nome and that although there is now a prevailing westerly direction of movement it is not the sole one. Aside from this consideration, it is certain that the waves are far more effective in moving the sands and gravel of the present beach than the ocean currents, and that the direction in which they move the material depends on the direction of the winds. An interesting fact connected with this question is that fine gold and mercury are found in the top sands of the bars off the Nome beach. The mercury and possibly the gold also were carried there since mining began on the beach.

A second objection to the supposition that gold has been brought to the beach by streams is that little gold is found on the river bars. Although this is true, it is also true that both Bourbon and Dry creeks are gold bearing within a short distance of the beach, and that coarse as well as fine gold is found in Snake River only a short distance from its mouth. Part of this gold is much coarser than any found on the first or second beaches and resembles gold from such a stream as Anvil Creek far more than that from the beaches, except some parts of the third beach.

Finally, it is urged that the gold is too coarse to be carried by ocean currents, but this objection holds equally or better against the original distribution of gold through the tundra gravels, which near Bering Sea are chiefly marine.

The richest part of the present beach corresponds in position with the richest parts of the old beaches so far as they are known, also with the most productive streams—that is, it lies directly seaward from the area from which the gold is believed to be derived. It is certain that the gold of a part of the third beach, especially in the vicinity of Little Creek, was deposited near the mouth of a stream or the mouths of several streams. The character of both the gold and the gravel indicates this. On most of the third beach, however, the gold is like that of the present beach and was probably concentrated in the same way.

It seems a fair conclusion, therefore, that the beaches, both ancient and modern, have derived their gold from two immediate sources, a part having been brought to the sea by streams and a part concentrated from older gold-bearing gravels. Yet even the stream gold, it must be remembered, has been repeatedly concentrated from older deposits, the whole process forming a cycle of events which it is now impossible to trace.

GRAVEL-PLAIN PLACERS.

A number of less important placer deposits that have yielded gold apparently do not belong under any of the headings given. They do not occur as well-defined concentrations, such as are found in the stream-bench or beach placers, but as irregular accumulations disseminated through gravels, which in some places do not appear to be connected with streams or the sea. These deposits have been called gravel-plain placers by Brooks[1] and unconcentrated placers by Collier.[2]

At some places on the coastal plain they may result from simply a local increase in the amount of gold disseminated through the gravel, yet there is a question as to whether they may properly be called unconcentrated deposits, and it seems probable that former streams may account in part for their formation. It is possible, also, that some of them may be the scattered remnants of a previous concentration similar to those found in a number of places where bench deposits or old benches have been destroyed by later streams.

Placers of this kind are small, and although one or two have yielded considerable gold, no very rich ones have yet been found. It is probable that if the origin and subsequent history of the coastal plain were fully known, these placers might be found to have an origin similar to that of the other placers of the vicinity.

About 2 miles from the coast, near the head of Peluk Creek, several thousand dollars has been taken from the coastal-plain gravels. The following section was exposed:

Section near head of Peluk Creek.

	Ft.	in.
Gravel and clay	1	6
Sandy clay and muck, with some angular gravel	5-6	
Angular gravel with clay	4	
Clay seam, "bedrock"	2	

The gold-bearing gravel rests on the clay seam and consists of angular fragments of schist with clay. Gravels under the clay were also found to carry gold but were not exploited. The gold was coarse, rough, and stained with iron. A nugget worth $1.25 was the largest found.

An attempt was made to dredge gold-bearing gravels near Cooper Gulch, about half a mile from the foothills. The largest accumulations of gold were found on clay streaks in the gravel, although a small amount is present throughout the gravel from the surface down. This locality is near the third-beach line, but its gold deposits are probably the result of stream action and not of the sea.

Gold-bearing gravels of similar character are found along the eastern slope of the Nome River valley at two or three places, but have not been visited by the writer.

DREDGING.

The scope of this paper does not include methods and costs of mining, the value of reserves, and related subjects, which belong

[1] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, p. 81.

[2] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 166.

in the province of the mining engineer, yet so much attention has been given within the last five or six years to dredge construction, and dredging promises to play so important a part in the future development of the Nome district, that it is desirable to give a brief statement of the number of dredges now in operation and the conditions under which they work. This subject has been treated more fully from the engineer's standpoint by Gibson [1] and by Janin.[2]

The following table, giving the more important facts concerning dredges at Nome, is taken from a table compiled by Smith: [3]

Dredges built in the Nome gold field from 1905 to 1911.

Company.	Creek.	Date built.	Type or builder.	Size of buckets.	Bucket line.	Source of power.	Fuel [oil] used per day.
				Cu. ft.			
Gold Beach Dredging Co.	Osborn....	1905	I. B. Hammond.......	5	Open.	Crude oil....	18 bbls.
Nome Consolidated Dredging Co.	Bourbon..	1908	E. L. Smith-Linderwood.	9	Close.	Electricity [a]	(?)
Do............	Wonder...	1908	.....do................	7	...do..	.....do......	(?)
Plein Mining & Dredging Co.	Otter.....	1910	Risdon................	3½	Open.	Crude oil....	13 bbls.
Saunders Dredging Co.	Saunders..	1910	(?).....................	3½	Close..	Distillate....	200 gals.
Arctic Gold Dredging Co.	.....do....	1910	Union Iron Works....	2½	...do..	.....do......	160 gals.
Sioux-Alaska Mining Co.	Moss......	1910	.....do................	2½	...do..	.....do......	Do.
Julien Dredging Co.	Osborn....	1911	Union Construction Co.	2¾	...do..	.....do......	190 gals.
Nome Consolidated Dredging Co.[b]	Wonder...	......	....	10	....	Electricity..	

[a] Power generated from oil. [b] In course of construction.

Dredging in the Nome district and in Alaska generally is conducted under adverse conditions not encountered in warmer climates. The working season is a little longer than that for the simpler surface methods of mining, as the machinery can be protected against the cold to a certain extent. Experience at Nome has shown that dredging can begin in the later part of June and continue till late in October or even into November. The efficiency of the dredge is less in the early part of the season, however, than at the close, as the frost is not all out of the ground when operations begin. Frozen ground is one of the chief obstacles to dredging in the North, for a dredge will not work in such ground, and in order that mining may be carried on some means must be provided for thawing the gravel. Steam points are used for this purpose in the Yukon region but have not been employed at Nome, where all the dredging has been done in unfrozen gravel. Thawing would add to the cost of dredging, for

[1] Gibson, T. M., Gold-dredging industry on Seward Peninsula: Min. and Sci. Press, vol. 104, 1911, pp. 45–48.

[2] Janin, Charles, Gold dredging in Alaska and the Yukon: Min. Mag., vol. 6, 1912, pp. 45–48.

[3] Smith, P. S., Notes on Seward Peninsula: Bull. U. S. Geol. Survey No. 520, 1912, p. 342.

it would increase the consumption of fuel, already a large item of expense.

Coal, crude oil, and distillate are the forms of fuel used in generating power for the Nome dredges. Even those driven electrically depend on an engine consuming fuel oil. No use has yet been made of water power in this district, although such power is at hand and would have been employed before this time if litigation over the water rights had not prevented.

One of the most important considerations connected with the installation of dredges concerns the character of the gravel containing the gold and the bedrock on which it lies. Gravels in which many large bowlders are present, such as are common in the highly glaciated areas of much of Alaska, are unsuited to dredging operations, as is also gravel resting on a hard, uneven bedrock where the gold is not distributed through the gravel but lies principally on the bedrock and in its cavities.

Some of the deposits of stream gravel at Nome are suitable for dredging and are being handled profitably in this way. The gravel of the larger streams, like Snake and Nome rivers, and of smaller ones crossing the coastal plain does not contain many large bowlders. The material composing it is such as can be handled by a dredge when it is not frozen. There are many bowlders in parts of the coastal-plain deposits and others are scattered over its surface. They are of glacial origin and were either deposited by the glaciers or brought by floating ice. Bowlders of this kind have found their way into the stream gravels and at times give some trouble, but they have not proved to be a serious obstacle in mining, although they undoubtedly will cause some difficulty if dredging is attempted in some of the coastal-plain deposits. In those stream deposits whose character is favorable to dredging probably more difficulty will arise because of frozen ground than because of bowlders.

The Nome region offered a new field for dredging and has attracted the attention of dredge builders. New problems were encountered, and some of them have been solved. The early attempts at dredging met with little success, because the conditions were not understood and dredge construction had not reached its present efficiency, but the success of the past few years has placed dredging at Nome on a secure basis.

LODE DEPOSITS.

GENERAL FEATURES.

The principal useful metals that have been found on Seward Peninsula are gold, silver, lead, tin, bismuth, antimony, tungsten, copper, and mercury. These metals, either in their native state or in combination with other elements, have been found in their bedrock source as well as in the gravel deposits resulting from rock weathering and erosion. Gold is the only one of them whose lode deposits have yet been mined profitably. Tin is found in the gravel deposits of many widely separated localities. Tin-bearing lodes that have attracted much attention from capitalists were discovered in the western part of the peninsula in 1903, but the mining of these lodes is not yet an established industry, although some small shipments of lode tin as well as of placer tin have been made. Silver-bearing galena was discovered many years ago on Omalik Creek, a tributary of Fish River, in a lode deposit usually referred to as the "Omalik mine." Although several attempts have been made to develop this property, they have so far led to no important results. Among the other metals tungsten, antimony, bismuth, and possibly copper have been found in sufficient amount to justify the expectation of some future development. There is, however, little reason to attach much commercial importance to the presence of mercury. It occurs as the mineral cinnabar in the gravel deposits of the Council region and in small veins in the schist, but its amount is not great. Besides the metals enumerated the mineral graphite gives promise of commercial importance. It is present at several localities in the Kigluaik Mountain area, and small shipments have been made from places on the north side of the range, not far from Teller.

All the metals named except mercury occur in the Nome and Grand Central quadrangles. Gold is, of course, the most important, and it is the most widespread. Bismuth and antimony have attracted some attention, and tungsten, in the form of scheelite, may, perhaps, take a more important place among the mineral resources than it has hitherto held.

GOLD.

There is scarcely a stream within the plateau area of the Nome and Grand Central region whose gravel deposits do not yield gold in quantities ranging from a few colors to amounts great enough to pay for commercial exploitation. This is true also of most of the other streams of Seward Peninsula and demonstrates the widespread distribution of gold in the metamorphic rocks. Few of the streams of the Kigluaik and Bendeleben mountains have produced gold, but the reason for this may, perhaps, lie in the conditions resulting from glaciation, the character of the surficial accumulations, and the difficulty of prospecting, as much as in the gold tenor of the gravel.

Two facts stand out before one who carefully studies the distribution of the gold-bearing surficial deposits—first, the widespread occurrence of gold in small amounts throughout the region; and, second, the comparatively small size and number of the areas producing placer gold in considerable amount. These facts appear to lead to only two conclusions—that gold is present in small quantity in practically all the older rocks, and that in a few places, for some unknown reason, this gold content was very greatly increased. The increase is relative, and does not necessarily imply that the original deposit was of extraordinary value, for it is evident that a very rich placer can be formed by the weathering of a large amount of rock, with small gold content. The quantity of material removed by the streams during the formation of the present topography of the Nome region is enormous, and the gold contained in even the richest parts may have borne only an insignificant proportion to the original mass of rock. Yet it is not intended to imply that the rich placers of the Nome region are derived wholly from original deposits, too low in gold content to be valuable as mining properties, or that no lodes of commercial importance will be discovered. Although such lodes may not be found, the experience of many other placer camps goes to show that rich placers are commonly situated in regions where lode mining is eventually developed.

In the Nome region deposits of gold in bedrock, as distinguished from deposits of placer gold, may be broadly classified as disseminated deposits and vein deposits. Under the first head should be included those deposits in which mineralization is not confined to well-marked fault, joint, or similar fracture planes, but has taken place in the schist as a result of the circulation of mineral-bearing solutions through it, principally in minute openings, along cleavage planes and elsewhere, produced during the processes of metamorphism and deformation. The vein deposits are those in which mineralization took place in or along fracture planes, most of which are fairly well defined. They are accompanied by a notable amount of gangue material, consisting chiefly of quartz, but locally including some other minerals, such as calcite. The distinction between the two classes of deposits is, in a measure, arbitrary, depending in some examples on size rather than on fundamental differences, for it can hardly be doubted that both classes may be produced by the same geologic processes, however unlike the form of the channels through which circulation takes place. The auriferous quartz veins might be further subdivided into those in which free gold is unaccompanied by other metals and those in which it is associated with various sulphides, as pyrite, arsenopyrite, molybdenite, and stibnite. This distinction has been made by Smith[1] largely as a result of his work near Solomon, but owing to the lack of detailed knowledge concerning many of the gold-bearing veins near Nome, it is perhaps undesirable to attempt to classify them on this basis.

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey, No. 345, 1908, p. 230.

Small gold-bearing veins have been found near many of the gold placers, where bedrock was exposed originally, or was uncovered during mining operations, but at present no veins of proved commercial value are known in the Nome district. An account of the occurrence and character of the veins has been given. (See pp. 34–36.) Quartz veins, calcite veins, and veins consisting of quartz, chlorite, and feldspar are those most common in the region. The quartz veins may be divided into at least two classes, which, however, are not entirely distinct from each other. One class includes small veins, the largest only a few inches thick, stringers, and lenses, which in most places conform to the cleavage of the inclosing rock, though in others they intersect the bedding and cleavage. These veins are of small linear extent, and are not uncommonly folded and crushed. Most of them were deposited either before the schists and limestones were folded, or, as is most probable, while the folding was taking place. They are the typical veins of the region, and in many places are well mineralized. They are seen on Anvil, Glacier, and Rock creeks, on Snow and Pioneer gulches, and in other localities.

The second class includes, besides many small veins, large veins, or irregular masses of quartz, most of which are found in localities that plainly have been greatly disturbed by later movements in the rocks. Although some such masses are 20 feet or more thick, nearly all are limited in longitudinal extent to a few times their thickness, and are much crushed and faulted. The weathered surface is milky white, and only on fracture planes that have not been exposed does a stain of iron oxide appear. The veins contain very little pyrite, so that cavities due to the decomposition of this mineral are not so common as they are in many of the smaller veins.

After a detailed study of the Solomon and Casadepaga district, only a short distance east of the area under consideration, Smith [1] summarized as follows his conclusions concerning the veins which he found there:

> The occurrence of veins has already been noted, and their division into three main classes has been made. These classes were called the older and the younger quartz veins and the calcite veins. The latter class is of no importance from an economic standpoint, and it therefore requires no further attention.
>
> The older quartz veins are sheared, squeezed, and in many places are recrystallized, so that all original structure has been lost, and the veins appear as lenses or knotted quartz bunches in the contorted schists. Some of these bunches are evidently older than the cleavage, for that structure has been forced to wrap around them. In these veins there are sometimes traces of metallic minerals, such as iron pyrite, and the presence of gold has been noted

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey, No. 433, 1910, pp. 139–140.

in assays made by earlier collectors. The veins, however, are so deformed that it seems hopeless to mine them.

The younger quartz veins are somewhat deformed, but are not so completely sheared and contorted as are the older ones, having been shattered and smashed rather than knotted and recrystallized. In some places these veins show but slight evidence of metallic mineralization, but at others they contain abundant sulphides. In some of these later-formed veins the metallic minerals are sulphides of copper, in others they are arsenopyrite, and in still others they are iron pyrite. Whether the veins show other metallic minerals or not, they almost always contain a little gold in the native state.

It will be noticed that in this summary no mention is made of quartz-feldspar veins. This omission is not due to the absence of such veins in that district, but to their subordinate importance. With this exception it is seen that the subdivision of veins given by Smith may be applied to the Nome and Grand Central region, the greater number of quartz-feldspar veins here being probably in considerable measure a local feature.

Brooks[1] has recently emphasized the importance of examining the vicinity of limestone and schist contacts for gold-bearing lodes and for placer-gold deposits. He points out that many contacts such as these are loci of weakness in the strata, where movement takes place and where there is greater opportunity for the circulation of mineral-bearing waters and consequently for the formation of veins. He also draws attention to the fact that most of the important placer areas are in regions where limestone and schist occur.

Massive limestones are found in the southern part of the mineralized area of Anvil and Glacier creeks, and thinner beds occur in the ridge between the two streams. To the northwest, however, their number decreases, and here some of the greatest mineralization is seen. It is not evident in this particular place that the presence of limestone was essential to the formation of mineral deposits, and, in fact, it would be difficult to prove that the limestone and schist contacts on the southeast are more highly mineralized than the schists away from the contacts, but the occurrence of nearly all the placer-gold deposits of the peninsula in areas where limestone is found suggests a relationship between the formation of such deposits and the limestone.

Gold can be seen in some of the quartz veins of the Nome district, and assays have shown its presence in many more. Gold is not confined, however, to quartz veins alone; free gold occurs in calcite veins also. Gold-bearing calcite veins are present on the divide between Anvil and Glacier creeks, where several shafts were sunk without revealing an important ore body. Near by, quartz veins in the schist carry a small amount of gold and a little molybdenite. Two or three veins of this kind are exposed near the wagon road leading

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 122.

over the hill to Glacier Creek. One of these varies in thickness from 1 to 2½ feet and is included between schist and a thin overlying bed of limestone. It can be traced for about 100 feet along the surface.

Northwest of this point, on Snow Gulch, a number of small iron-stained quartz veins cut the schist of the creek bed. Picked specimens from quartz veins on Glacier Creek near the mouth of Snow Gulch yielded about $9 a ton in gold when assayed. The inclosing schist is highly impregnated with pyrite and contains gold also.

Attention has previously been drawn to the mineralized area between Glacier and Rock creeks and the association of sulphides occurring there. The schist is filled with a great number of small quartz stringers containing pyrite and is itself impregnated with the same mineral to such an extent that the deeply weathered surface rock is strongly colored by the oxidation products. A mixture of the sulphides of lead, arsenic, antimony, and copper is associated with the pyrite and for a while was thought to be a new mineral. The quartz stringers carry free gold and are so numerous that some attempts have been made to mine them.

A large amount of highly mineralized quartz is present in schist exposures south of Good Luck Gulch. The quartz is much crushed and in general occurs as stringers, although at one place a mass 4 or 5 feet wide is exposed in a small outcrop. A prospect hole shows much rotten iron-stained quartz. The schist also is filled with iron oxide, in which some pyrite still remains. Panning shows the presence of gold.

Several quartz veins, the largest of which is about 5 inches thick, occur near the mouth of Boulder Creek. Assay values of $3 to $4 a ton in gold were obtained from samples taken here.

On Pioneer Gulch the best ground of the residual placers occurs just below a number of small quartz stringers cutting the schist bedrock. One of these stringers 3 inches thick showed considerable free gold. Similar occurrences are known in other parts of the region, but nowhere has the number or size of the mineralized veins been sufficiently great to constitute an ore body.

Near the head of Goldbottom Creek are auriferous veins, one of which has received more attention than most of those already mentioned. It is near the contact between the massive limestone beds of Mount Distin on the east and the schist underlying the limestone on the west. The country rock is black graphitic slate, much jointed and cut by veins and stringers of quartz belonging to the later system of veins. Movement in the slate, which took place during the adjustment to disturbing forces, gave rise to numerous smooth slickensided surfaces. The vein quartz is milky white to glassy, with darker bands here and there. Locally there is a little sulphide mineralization, but for the most part the veins appear to belong to that class in which the gold occurs free in the quartz. The property is equipped with a small stamp mill and machinery for crushing the ore. Water is provided by a ditch about a mile long. It seems probable that the shattered condition of the country rock would offer some difficulties to following the ore, but the results of operations during the last year or so have not been learned.

Mining operations along Anvil Creek have disclosed auriferous veins at several places. Near Perkinsville many small quartz veins, from 8 to 10 inches thick, cut black chlorite schist. Most of the veins follow the schistosity of the rock, but some of them cross it. They are slightly folded and much crushed. A little iron pyrite is scattered through them, and assays show a small content of gold.

Two small openings were made a number of years ago on quartz veins near the head of Anvil Creek. Both are in black quartzitic schist much crushed and fractured. The quartz is slightly iron stained, and a little gold is reported, but no work has been done on the veins recently.

All the localities that have been mentioned are within the Snake River drainage basin, the area that contains the richest gold placers discovered in the Nome region. The list of mineralized veins and zones includes, however, other localities. Such deposits are known at the head of Dry Creek and on Newton Gulch, where they have received some attention with a view to development. A quartz vein on Osborn Creek shows gold associated with iron and copper sulphides. The vein is near the contact of a greenstone intrusion in schist. Only a little work has been done on it. Gold-bearing veins are known also on Banner Creek, Stewart River, and Buffalo and Hudson creeks. Mineralized quartz veins have been found on an eastern tributary of Grand Central River, where they cut black graphitic schist and contain a small amount of pyrite.

Although none of the operations on gold veins of this district appear to be commercially successful, they nevertheless have lent some aid to an understanding of the types of ore bodies likely to be met with.

Experience so far points toward the probability that, if commercial ore bodies are found, they will be in the form of small veins and mineralized zones in the schist. No well-defined and continuous belts of this kind have yet been discovered. There are restricted areas, however, where auriferous deposits are more widely developed than in the remaining parts of the region, and in general these correspond in location with the placer-gold areas. It was this fact that early led the workers in this region to the conclusion that the placer gold has its source in veins and impregnated beds, which occur close to the present location of the placers.[1]

[1] Brooks, A. H., Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900; Special publication U. S. Geol. Survey, 1901, p. 142.

BISMUTH.

It has been known for a number of years that bismuth is present on Charley Creek, a tributary to Sinuk River from the south. It was first found in the sluice boxes at the lower end of the creek, and later the float was discovered farther up and traced to its source. On the east branch of Charley Creek at a point about 1,000 feet from the forks and at an elevation of 950 feet above sea level, two parallel quartz veins appear near the stream bed and have been found to carry the bismuth. These two veins are about 12 inches and 8 inches in thickness and are separated by 16 to 18 inches of schist. They occur in strike joints dipping 50° to 60° and may be traced on the surface for only a short distance because of the covering of loose slide rock. At one place they are offset about 8 to 10 inches by a small fault. The proportion of bismuth seen in the veins is small, but some bowlders found in the stream below show a larger amount. Up to the present time little has been done toward prospecting the veins.

ANTIMONY.

A quartz vein carrying the sulphides of iron and antimony was found on Manila Creek in 1905. It crops out on a hill slope west of the upper end of the creek, and as traced by surface float has a length of about 3,000 feet. Its elevation above sea level is approximately 800 feet at the southwest end and 1,600 feet at the northeast end. At the surface it appears to dip moderately to the northwest. The surface float is quartz containing bunches and irregular streaks of stibnite scattered here and there or running through it. It is stained with oxidation products from stibnite and pyrite.

A prospect-hole incline was started on the vein in 1906. In 1907 an adit 315 feet long had been driven cutting the vein and showing it to have a thickness of 3 feet at that place. Since then considerable work has been done, and shipments of ore have been made. The antimony content of the ore where the vein is crosscut is less than at the surface, but the decrease is compensated for by an increase in gold. Specimens of ore from the vein in the adit show a mixture of gray quartz and antimony containing a notable amount of free gold. The quartz is crushed, and the spaces between fragments are filled with stibnite. Furthermore, tiny veins of stibnite cut the larger pieces of quartz. The gold appears to be more closely associated with the quartz than with the stibnite, and may have been deposited earlier, but this inference requires further evidence before it can be stated positively. A number of other minerals are reported from this property, but do not appear in the specimens examined by the writer.

Veins carrying stibnite occur on the west side of Anvil Creek a short distance above Specimen Gulch and have been described by Smith.[1] The veins were prospected by a number of holes about 25 or 30 feet above the creek, and these showed that the schist had undergone much dislocating and shearing, which produced fractures that had later been filled with stibnite and other minerals. Some of the veins reach a thickness of 18 inches, but most of them are thinner. The stibnite occurs in rather massive aggregates for the most part but here and there appears as radiating and lath-shaped crystals of nearly perfect crystalline form, showing that it must have been deposited after the close of the period of dynamic disturbances that affected the country rock. The economic importance of this fact is that such veins give greater promise of freedom from the faulting and dislocation that detract from the value of the ore bodies.

Stibnite is reported also from Osborn Creek, Goldbottom Creek, and Last Chance Creek, but the deposits at these localities have not been examined by members of the Geological Survey.

TUNGSTEN.

Tungsten occurs in the Nome region in the form of scheelite, the tungstate of calcium. It is a heavy white mineral and is found in many of the streams. Because of its weight it remains in the sluice boxes or pan and causes some trouble in cleaning the gold. Scheelite is also found associated with quartz in small veins in the schist, but its principal source is the gold-bearing gravel. Until recently the market price of tungsten has been so small that the scheelite has not been taken from the sluice boxes, but the present demand for the metal is so great that even small quantities may be profitably collected.

Tungsten is used in the manufacture of tungsten steel, in incandescent lights, and for various other purposes.

COPPER.

Copper deposits have not attracted much attention in the Nome district, as those already known have not yet proved to be of commercial importance. Two localities where copper minerals have been found are described by Smith,[2] who furnishes the following account of them.

The most promising locality is on the ridge between Copper and Dickens creeks at the head of Nome River. It lies within the area occupied by schist and limestone of the Nome group, and the geologic relations of the rocks are obscured by complicated structure and by scarcity of outcrops. The rocks are principally schist but include thin beds of limestone. Two types of schist are present. One of

[1] Smith, P. S., Recent developments in southern Seward Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, p. 282.

[2] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull. U. S. Geol. Survey No. 345, 1908, pp. 240–242.

these is silvery gray and consists chiefly of quartz with which is associated muscovite and chlorite. The other is dark greenish and contains many crystals of feldspar together with a little amphibole. This second schist is believed to be an altered igneous rock of basic character. All these rocks have a low dip to the northeast. There is a small mass of intrusive granite in the schist about a mile north of this locality.

The copper minerals are found in a narrow belt of white limestone overlain by green schist and underlain by green and gray schists. An inclined shaft was sunk in this limestone and gives the best information concerning the ore body. Smith[1] described the occurrence of copper at this locality as follows:

> The character of the vein and the distribution of the metals in it are peculiar. All over the surface are numerous blocks of limestone stained with a little malachite, but in the upper portion the vein shows mainly galena. Specimens from this upper portion show numerous drusy cavities, and the appearance is that of a replaced limestone. In every fragment several small quartz veins are visible. The ore is almost entirely galena with only a small amount of copper carbonate and practically no copper sulphide. An assay of picked specimens made by the owners is reported to have yielded 15 per cent of copper and 20 per cent of lead, with a rather high silver and low gold content.
>
> In the breast there seems to be a nearly vertical fissure, which shows for some distance in the inclined shaft. From this fissure a good deal of bornite, practically unmixed with any other minerals except galena, has been won This vein seems to pinch out 2 feet or so below the roof, and the bornite is absent from the rest of the underground workings. Near the floor of the incline there is a quartzitic rock which looks much like a replaced limestone. This quartzite contains a band about 8 inches thick of copper sulphides and carbonates mixed with quartz. The sulphides are mainly chalcopyrite, and both the carbonates, azurite, and malachite are present. In addition to the main stringers already described, some ore is scattered throughout the breast, but it is too disseminated to allow profitable extraction.
>
> The sulphides in the lower part of the mineralized belt occur nearly parallel with the stratification of the limestone. Nowhere in the underground workings was schist seen, but from the evidence already cited it seems probable that the contact of the schist would be found a short distance below the floor of the incline.

Other prospect holes in the near vicinity show evidences of copper. About one-third of a mile above the mouth of Copper Creek an adit was run in 25 to 30 feet on some stringers of copper ore at a schist and limestone contact but was finally abandoned.

The second locality where copper minerals have been found is on Dexter Creek. Assays are reported to show the presence of 4 per cent of copper, but the ore is probably more valuable for gold than for copper.

GRAPHITE.

Graphite is abundant in some of the black schist beds belonging to the Nome and Kigluaik groups and gives them their characteristic

[1] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: Bull U. S. Geol. Survey No. 345, 1908, p. 241.

color but is not known in a form to make it of economic importance within the Nome and Grand Central quadrangles. Just north of the Grand Central area, however, in the headwater areas of Grand Central River and Windy Creek (Pl. VII, p. 20), especially in the vicinity of the divide between these two streams, are graphite deposits of considerable size. Their occurrence, as well as that of graphite on the north side of the Kigluaik Range west of Cobblestone River, has been known for a long time, but only recently have they received especial attention from prospectors.

A sharp ridge made up of biotite schist striking east and west and intruded by dikes and sills of coarse granitic rock or pegmatite rises on the south from the saddle between the Grand Central and Windy Creek. Some of the schist is highly graphitic, the graphite appearing as abundant small scales on the cleavage surface and much of it not being distinguishable on casual examination from flakes of biotite. Locally graphite is segregated in beds or much flattened lenticular masses that conform in direction with the schist cleavage and reach thicknesses of 6, 8, or even 18 inches. These beds include thin layers of schist containing numerous large garnets and much quartz. The raw graphite found at this place is heavier than the higher grades of graphite, owing to its included quartz.

The sills and dikes of pegmatite cutting the schist also contain graphite, which is associated with them in such a way as to suggest a close relationship between the intrusives and the graphite. Graphite appears to be an original mineral in the pegmatite as well as to be associated with it in the schist. At one place about 8 inches of solid graphite is included between a pegmatite sill and the overlying schist. The steep slopes of the mountain are strewn with graphite fragments, which, owing to the fact that they are much lighter in weight than either the schist or the pegmatite, appear more abundantly on the surface, especially in gullies where water has brought about a rough sorting. One block, with dimensions of approximately 7 feet, 6 feet, and 30 inches, consists of about equal thicknesses of schist and apparently almost pure graphite.

The graphite-bearing schist extends eastward beyond the east fork of Grand Central River and westward across Windy Creek and the head of Cobblestone River to the region south of Imuruk Basin, in which the graphite is even more extensively developed than in the locality described and from which a number of commercial shipments have been made.

INDEX.