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GEOLOGY AND MINERAL RESOURCES

OF THE

SOLOMON AND CASADEPAGA QUADRANGLES

SEWARD PENINSULA ALASKA

BY

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PREFACE.

By Alfred H. Brooks.

The investigation of the mineral resources of Seward Peninsula from 1899 to 1906 was mostly of a reconnaissance character, the work having been done in accordance with the policy of learning as much as possible of the distribution of the larger rock groups and determining the general laws of the occurrence of the gold before attempting detailed surveys. Moreover, as the cost of detailed surveys is at least ten times as great as that of reconnaissance work, it was considered best to devote the inadequate funds available to reconnaissances, because these yielded results about larger areas and therefore benefited the greater number of prospectors. With the close of the field season of 1904, however, reconnaissance surveys had been carried over the entire peninsula; much had been learned regarding the distribution and occurrence of the placer gold throughout the mining districts; and the tin deposits had been a subject of special investigation. The reports on these surveys, though of a general character, have been of value to the mining interests.

It was early realized that in a field which is geologically so complex and which presents so great a variety of economic problems, definite results could be obtained only by the most detailed studies; and preparations for detailed work were therefore made in 1904 and 1905 by the topographic survey of certain areas on a scale of a mile to the inch, with 25-foot contours. Detailed geologic work was begun in 1905 and continued to the close of 1908, the results of these topographic surveys being used as base maps. Naturally, these studies were begun in the areas of greatest proved economic importance, and in the first two years a belt about 30 miles wide extending inland from Nome to the Kigluaik Mountains was covered. Unfortunately, it was found that this field was geologically so complex as to make it impossible to solve many important problems until more work had been done in adjacent areas, and the publication of the report on its geology was deferred until larger districts could be surveyed. For this reason the present report on the Solomon and Casadepaga quadrangles is published before that on the earlier work in the Nome and Grand Central quadrangles. Facts developed in this later investigation will necessitate some revision before the work in the Nome region can be presented in proper form.

As it is important to establish the geologic relations of the area here treated to the entire region, considerable space is devoted to a discussion of this subject. It is believed that this account of the general geology of Seward Peninsula may also serve a useful purpose by presenting concisely results of the work of the last decade, now scattered through a number of different publications. The field is of special importance because Seward Peninsula forms a link between North America and the easternmost part of Asia, from which it is less than 60 miles distant.

The most important result of Mr. Smith's geologic studies, as here presented, is the proof of great complexity of structure in the metamorphic rocks. Recumbent overturned folds and extensive thrust faulting, such as he describes, may have been suspected by the earlier workers in this field, but no proof of such complexity was obtained. Mr. Smith's work removes this province from the tectonic field of simple local close folding and regional metamorphism, to which it had been assigned, to one of Alpine complexity of structure. This fact throws a doubt on the stratigraphic sequence as established by the earlier reconnaissance surveys, and final judgment on the succession of terranes must await further investigations.

The results here presented confirm the suggestion previously made that the contacts between heavy limestones and schists are in many places loci of mineralization—a conclusion which may have far-reaching economic importance. Of perhaps greater importance for the special area under discussion is the proof that a certain formation, made up of quartzite and quartz slate, is very generally mineralized. It is in this formation that the quartz vein of the sole productive gold lode mine (1908) of Seward Peninsula occurs.

GEOLOGY AND MINERAL RESOURCES OF THE SOLOMON AND CASADEPAGA QUADRANGLES, SEWARD PENINSULA, ALASKA.

By Philip S. Smith.

INTRODUCTION.

Reconnaissances in Seward Peninsula.—With the close of 1903 the first period in the geologic study of Seward Peninsula came to an end. This period has been devoted to the reconnaissance of the region, which up to that time was but vaguely known. In the fall of 1899 Brooks and Schrader[a] spent a few weeks in the region around Nome and laid the foundations of the subsequent work. In 1900 Brooks, Collier, Richardson, and Mendenhall,[b] working in different areas, covered practically the whole southern part of Seward Peninsula.

In 1901 the reconnaissance studies were continued by Collier,[c] who devoted the field season to the northwestern part of the peninsula. During 1902 no further work was undertaken in Seward Peninsula, but in 1903 Moffit[d] visited the northeastern part and thus completed the preliminary study of the 20,000 square miles of the peninsula.

Each of these geologic parties was associated with a topographic party, so that each season's work resulted in the publication of maps for the areas covered, on the scale of 4 miles to the inch and with a contour interval of 200 feet. The 1900 map of the southern part of the region was made by E. C. Barnard, W. J. Peters, J. G. Hefty, and D. L. Reaburn; the 1901 map was prepared by T. G. Gerdine and D. C. Witherspoon, and the topographic work of the 1903 expedition was done by Mr. Witherspoon. Although containing slight errors,

[a] Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region, Alaska, a special publication of the U. S. Geol. Survey, 1900.

[b] Brooks, A. H., Richardson, G. B., Collier, A. J., and Mendenhall, W. C., Reconnaissances in Cape Nome and Norton Bay regions, Alaska, a special publication of the U. S. Geol. Survey, 1901. The Solomon-Casadepaga portion of this work was done chiefly by G. B. Richardson.

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

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

these maps are the standard maps of the region, and so far as is warranted by the scale show its principal features.

In 1903 a special investigation of the placers of the southern and northwestern parts of Seward Peninsula was undertaken by Collier and Hess, and the results were published[a] after considerable delay, with the addition of notes on other parts of the region by Brooks and others. This publication is the most authoritative one on Seward Peninsula geology and mineral resources.

Detailed surveys.—With the close of this initial stage of geologic and topographic mapping there arose a demand for more detailed information about the wonderfully rich placer camps which were yielding each year millions of dollars in gold. To meet this need, detailed topographic mapping of the Nome and Grand Central quadrangles on the scale of a mile to the inch and with a contour interval of 25 feet was done in 1904 and was followed in 1905 and 1906 by detailed geologic studies.[b] In 1905 the Solomon and Casadepaga quadrangles were surveyed on the same scale by T. G. Gerdine and W. B. Corse, and it is the geology of the area delineated by these maps with which the present report deals.

The geologic field work was done in the summer of 1907, when practically the entire area was covered. The scientific corps of the party consisted of the authors, F. J. Katz, and G. I. Finlay. The active work commenced on June 20 and continued uninterruptedly until October 1. Unfortunately one of the members of the party was slightly injured during the season and withdrew a month or so before the close of the field work. On account of this decrease in the party a small portion of the work was unfinished and it was necessary to visit the region again during the field season of 1908 to complete the geologic mapping. The party was able to move freely with wagons along the larger streams, so that none of the rigors of the early explorers were encountered and no more hardship was experienced than in field work in the States.

Location of the quadrangles.—The Solomon and Casadepaga quadrangles cover a land area of about 470 square miles, extending from latitude 64° 30′ to 65° north, and from longitude 164° to 164° 30′ west. Figure 1 shows the location of the two quadrangles with reference to the rest of Seward Peninsula.

Names.—The name of the Solomon quadrangle is derived from the river which nearly bisects its area. This river, it is said,[c] was originally named by Pierce Thomas, who staked the discovery claim

[a] 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.

[b] Moffit, F. H., Hess, F. L., and Smith, P S., The geology and mineral resources of the Nome and Grand Central quadrangles: Bull. U. S. Geol. Survey. In preparation.

[c] Collier, A. J., Hess, F. L., Smith, P. S., and Brooks, A. H., Bull. U. S. Geol. Survey No. 328, 1908, p. 223.

on it in June, 1899. Brooks and Schrader[a] state that it bore its present name in September, 1899, and was the seat of small mining operations. In the 1900 report Brooks gives the native name as Ongutuk, although he uses the name Solomon in his text.

The mouth of Solomon River affords as good a location for a town as any other place in the immediate region, for boats can discharge their freight from lighters on the beach and the broad gravel-floored valley of Solomon River gives a good pathway into the interior. In consequence, a town bearing the name of Solomon has sprung up there. In 1902 this place was made a post-office and at present has a semiweekly mail service to and from Nome. Stores have been

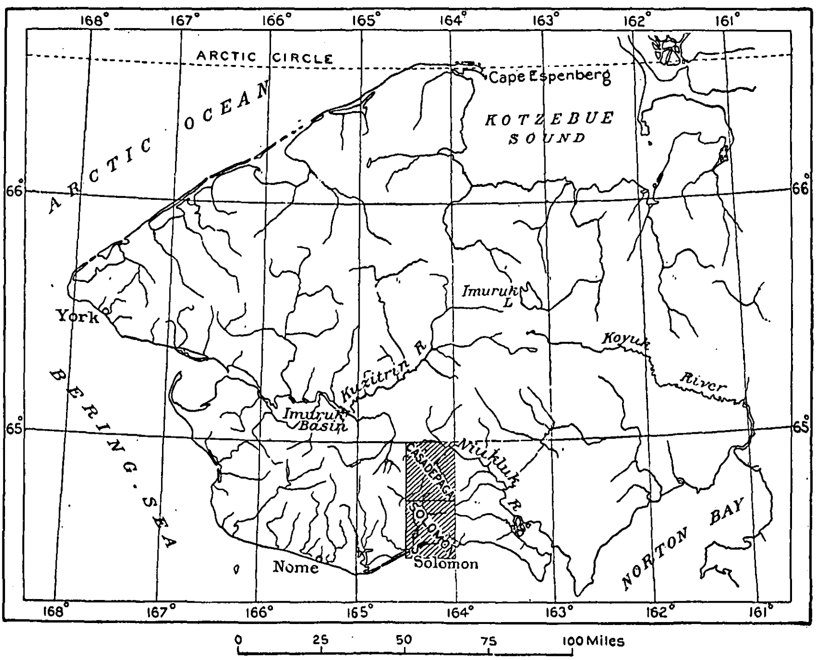


FIGURE 1.—Outline map of Seward Peninsula, showing location of Solomon and Casadepaga quadrangles.

opened, at which supplies of all kinds can be purchased. The town has been more or less deserted lately, and probably not more than fifty people were living there during 1908.

The only other town in the area is Dickson, which was named for T. Warren Dickson, of New York. It is directly opposite Solomon, on the east bank of the river. Dickson is the coastal terminus of the Council City and Solomon River Railroad, and all of its industries and inhabitants are connected with the railroad. Its entire population does not exceed 50 persons. This settlement was established in 1903.

[a] Brooks, A. H., and Schrader, F. C., Preliminary report on the Cape Nome gold region, Alaska, a special publication of the U. S. Geol. Survey, 1900.

The Casadepaga quadrangle owes its name to the river which flows from its extreme southwest corner diagonally across it to the northeast corner, where it joins Niukluk River. On the map accompanying the 1899 report of Brooks this river is vaguely indicated and named the Koshotok; but on the map in the report for 1900 it is called the Koksuktapaga. This was eventually softened into Casadepaga by the United States Geographic Board. The word is undoubtedly of Eskimo origin, but its true meaning has not been determined. It is suggested, however, that the last part of it means "mouth of the river" and the first part "loon," so a free translation would be "the river with a loon at its mouth."

Acknowledgments.—To those who have contributed to the work, either directly or indirectly, acknowledgments are due. To the miners who have facilitated the studies of the mineral wealth of the area the writer desires to express his thanks. To his geologic predecessors, who, in the face of great difficulties, have left such enduring records of their persistent endeavor and penetrating insight, the keenest appreciation and respect is paid. Although some of their conclusions may be questioned, it is always with admiration that one scrutinizes their work and notes how closely they have outlined the broad general features of the district.

In the field work and in the compilation of the data in the office the observations of F. J. Katz have been of great assistance. He made all the microscopic studies of the different rocks and supplied the description of many of the productive placers from his field notes. His contributions to the geologic maps can not be specifically defined but consisted of daily traverses and observations in all parts of the region.

GEOGRAPHY AND GEOLOGY OF SEWARD PENINSULA.

In order to gain a correct idea of the problems involved in the study of the small area which forms the subject of this bulletin it is important to see this region in its relation to the whole of Seward Peninsula. It is therefore desirable to point out the large features of the whole province before taking up the details of the special area. In the following review it is not intended to revert to the various chronologic stages by which the present interpretations have been reached, but rather to set forth the present beliefs concerning the geology and geography.

GEOGRAPHY OF SEWARD PENINSULA.

The main outlines of Seward Peninsula are well shown on the map previously referred to (fig. 1), so that further reference to these characters is unnecessary. But the relief of the surface is not shown, and it is proposed to devote some space to a description of the various geographic provinces which are noted.

There are three distinct provinces: The first a lowland skirting much of the coast; the second an elevated region with a relief up to about 2,000 feet; and the third a belt of mountains with maximum elevation of 4,200 feet. Although presenting these three different types of land forms, Seward Peninsula as a whole may be referred to the Central Plateau Province of Alaska, which lies between the Alaskan or Pacific mountain system on the south and the Endicott or Rocky Mountain system[a] on the north.

COASTAL PLAIN PROVINCE.

The lowland province, which forms a girdle around almost the whole of Seward Peninsula, shows by the character of the material of which it is composed that it was made by the deposition of river and marine gravels on the floor of the sea and was subsequently uplifted, forming a coastal plain. The coastal-plain province shows but slight relief, nowhere rising more than 300 feet above the sea. Its continuity is here and there interrupted, as at Topkok Head, Cape Nome, and Cape Prince of Wales, where the second province forms the shore line. It is of recent origin, for as yet but little dissection has been effected by the various streams which extend across it. The surface is covered with a rank growth of grass, but trees or even bushes are entirely wanting on the interstream areas, while stunted willows and alders form only a narrow fringe along the watercourses. Its width varies much, but nowhere is it more than 20 to 25 miles.

The coastal plain in different places shows different stages of growth and of destruction, and it has been affected by different amounts of uplift, depression, and erosion. On the whole the northern coast seems to have been quite recently depressed, as is shown by the drowned lower courses of Serpentine, Goodhope, Kiwalik, and Buckland rivers. Evidence of this recent depression is, however, wanting on the south shore, and the suggestion is made that an opposite direction of movement is indicated. The difference, however, in the strength of the eroding agents is such that no positive statement can be made. The southern coast shows in its more smoothly swinging coast line and absence of offshore reefs a later stage than the northern coast; but in the northern area the force of the waves is much less, owing to the smaller size of the water surface, so that erosion ought to be less. It is, therefore, impossible to determine without closer study than has yet been practicable, whether the less eroded form of the north coast is due

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

to the more recent disturbance of that district or to the lesser efficiency of the eroding agencies.

In a few cases the land form preserves a trace of past conditions so that one may reconstruct in part the former sea level. Such a feature is presented near Nome by the low sea-cut cliff at the base of which occurs the "second beach." Again, the terraces or beaches which occur along some of the streams, as for instance Hastings Creek, allow of no other interpretation than arrested or revived stream cutting. In the main, however, the past history of the coastal plain is better read from the materials of which the plain is composed than from the surface form, for it is known that many of the earlier episodes have been effaced by subsequent depression and the deposition of new material.

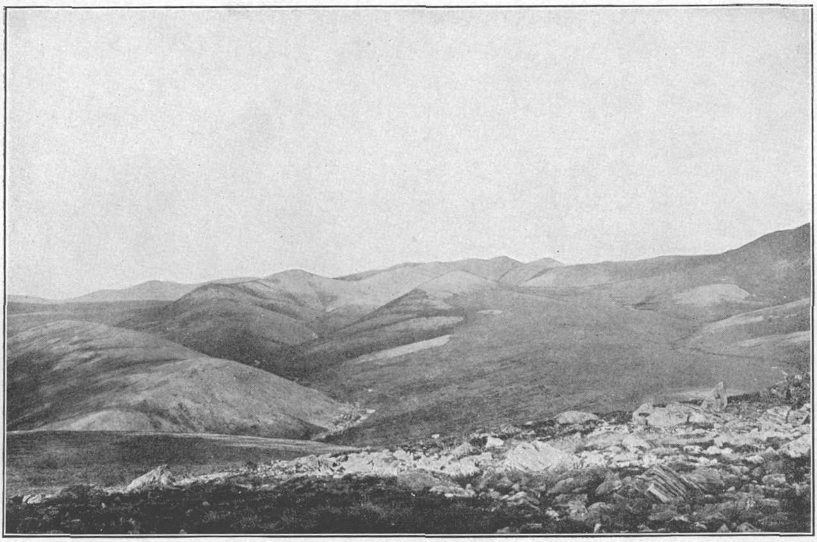
The fact that the coastal plain forms a fringe around almost the whole peninsula has had an important bearing on the commercial development of the region, for it is characteristic of coastal plains the world over that they afford no harbors for ocean-going vessels save under very special conditions. With the exception of Port Clarence Harbor, there is no place where large vessels may lie in safety and discharge their cargoes. In consequence, the cost and danger of marine communication is great and every year records new losses of property and life.

PLATEAU PROVINCE.

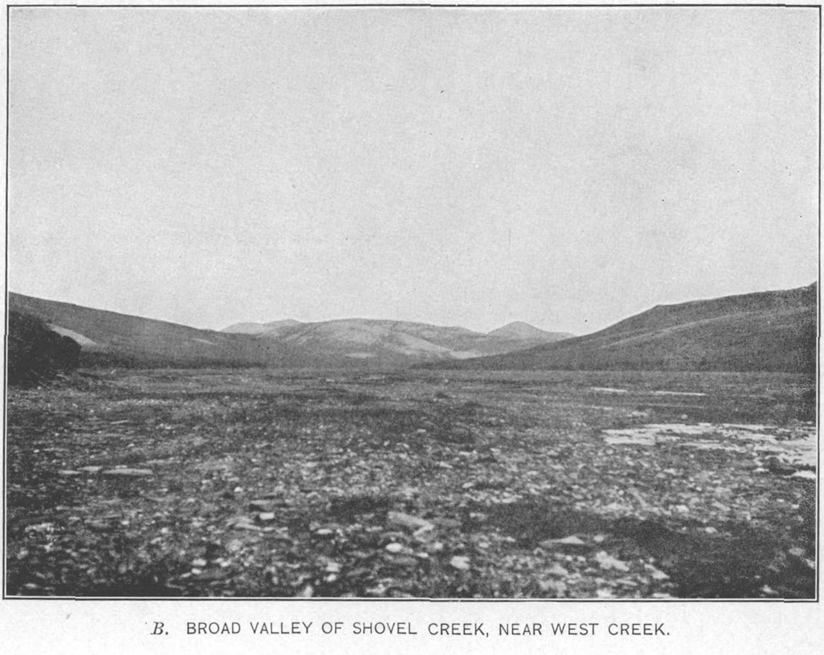
By far the larger part of Seward Peninsula falls into the second physiographic division, the plateau province. It is characterized by more or less elevated country, much dissected by streams, so that only a small portion of the upland is preserved. Collier has divided the plateau province into two portions, one lying north and the other south of the mountain axis of the peninsula. The southern portion he described [a] as follows:

> To the south of the mountains is, as already stated, a highland mass whose summits range from 800 to 3,000 feet in elevation. The slopes of this upland are in many places broken by well-marked benches which up to an altitude of 800 feet are plainly due to stream erosion. * * * This highland area is essentially one of irregular topography with no well-defined system of ridges. The water courses flow in broad deeply cut valleys whose slopes ascend gradually to the divides. The summits are rounded, but are broken by numerous rocky knobs, many of which are carved into fantastic shapes. These castellated peaks are very characteristic features of the topography and their preservation plainly indicates the absence of regional glaciation * * * . The general trend of the larger valleys is north and south, and these block out broad ridges whose margins are scalloped by the minor tributaries.

[a] Collier, A. J., et al., Gold placers of parts of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, 1908, p. 46.



A. SOWIK LIMESTONE ON SHOVEL CREEK, NORTH OF KASSON CREEK.



B. BROAD VALLEY OF SHOVEL CREEK, NEAR WEST CREEK.

The northern plateau province is described by Collier[a] as follows:

This upland, like the similar one to the south, is characterized by flat-topped ridges and hills rising to altitudes ranging from 600 to 2,500 feet. Here, too, the monotony of the summit level is broken by numerous minor peaks of irregular form.

Collier has identified three different stages in the development of this upland portion, and has named them the Nuluk Plateau, the Kougarok Plateau, and the York Plateau.[b]

In the plateau province there are numerous large lowland areas whose mode of formation is in doubt. A typical basin of this sort is found on the central part of Fish River, where there is an elliptical lowland 30 miles long and 12 miles wide, surrounded by hills rising from 1,000 to 2,000 feet above its level. The stream has cut a narrow outlet with a floor not more than a few hundred yards in width leading from this basin. There are perhaps half a dozen similar basins distributed through different parts of the peninsula. These have been called "basin lowlands" by Brooks and attributed to local deformation.

Throughout the province the general features are the same, although the details vary widely; and while three erosive intervals have been deciphered in the western part of the peninsula, other workers in other portions have not been able to trace such a number with so much assurance. It is, however, a point which will be treated in more detail in the later chapters on the special area with which this report is most directly concerned.

MOUNTAIN PROVINCE.

In the description of the plateau province it has already been stated that several of the so-called mountains of Seward Peninsula are simply portions of a plateau surface that have acquired some isolation and relative relief by the processes of erosion. Thus the York Mountains would appear to mark by their summits the former elevation of the Nuluk Plateau and to have been carved from it by streams. Such remnants of a plateau can not rightly be considered mountains. If, therefore, this class of mountains be excluded, there appear to be only three distinct mountain ranges in Seward Peninsula, and possibly this number should be decreased to two. The two ranges which appear worthy of the name are the Kigluaik-Bendeleben Range and the Darby Range; the third comprises the highlands which form the divide between Kiwalik and Buckland rivers. The elevation of the last named, however, nowhere exceeds 2,600 feet, and it probably averages considerably less than 2,000 feet.

[a] Loc. cit.

[b] Collier, A. J., Reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, pp. 35-37.

The Kigluaik-Bendeleben Range, although bearing two names and although trenched across by the Kruzgamepa, is presumably one continuous range from a genetic standpoint. This range has an average height of 3,000 to 3,500 feet, the highest points being somewhat over 4,000 feet. The forms are very rugged. On the northern side of the Kigluaik Mountains the steep face overlooking the Kruzgamepa Flats suggests by its abruptness a fault scarp. If it be such, the history of these mountains has been more complex than has generally been believed. The continuation of this fault, however, appears to be wanting along the flanks of the Bendeleben Mountains. The range seems to be characterized by a single main ridge; that is, the slopes culminate in a continuous divide containing all the highest points, with no other equally elevated ridges running more or less parallel with it. This ridge line is fairly straight and exhibits but few irregularities. Near the heads of the larger streams the divide has been pushed over into the territory of the smaller streams on its opposite side, as, for instance, at the heads of the Grand Central River, Cobblestone River, and Canyon Creek. The amount of ground gained in this way by the streams is slight, so that no captures of any large amount of drainage area have been effected. In general the range is unsymmetrical, with the culminating points nearer the northern abrupt side than the southern more gentle slope. This is particularly noticeable in the Kigluaik Mountains, and is not as well marked in the Bendeleben Mountains. In the latter, the position of the line joining the highest points is nearly symmetrically placed; however, the information available concerning the geography of the Bendeleben Mountains is much less complete than that concerning the Kigluaik Mountains.

In the Kigluaik Mountains in the recent past glaciers occupied the existing stream valleys. So numerous were these valleys that they were separated only by narrow ridges. In consequence, the wasting of the walls by glacial erosion and by the general processes of weathering has produced a series of knife-edged divides which preserve practically no trace of the preexisting topography, and has rendered the reconstruction of the earlier stages in the topographic development of these hills practically impossible.

The knifelike character of the ridges is perhaps the most striking feature of the mountains from the traveler's standpoint. Often there is not even a flat area wide enough to walk on, and sometimes progress can be made only by walking astride the crest line as one would the ridge of a steeply sloping house roof.

In the greater portion of the Kigluaik-Bendeleben Range no trees are found. The temperature, the steepness of the slope, the absence of soil, and the strong winds prevent extensive growth of vegetation. In the valleys, especially those with flat floors, some bushes and plants are found. In the western range the bushes consist exclusively of willows and alders which never exceed 10 feet in height. Farther east, however, in the valleys of the Bendeleben Range, some stunted spruce add variety to the view by their spire tops. The spruce, however, are generally small, being seldom more than 20 feet high.

The second distinct range is the Darby Mountains. This is one of the least known parts of Seward Peninsula. Brooks in 1900 was inclined to consider it as the continuation of the Kigluaik-Bendeleben Range, but the data on which this determination was made were acknowledged to be insufficient. Moffit has, moreover, in a later report based on a study of the Fairhaven district,[a] thrown some doubt on this interpretation. In this report it is stated that the period of east and west folding marked by the Kigluaik-Bendeleben Range preceded a later period of folding in which the prevailing direction of folds was north and south. The general direction of the Darby Mountain structure runs north and south, and from this fact it was argued that the Darby Mountains belonged to later date than the Kigluaik Mountains, which mark the earlier deformation. It is a question how far this argument will hold, for it has not been definitely shown that both foldings are present in the supposedly older range and that only one is shown in the range which is assumed to be younger.

From the present meager information concerning the Darby Mountains it is believed that they present no remarkable topographic features. They seldom rise to over 3,000 feet, and their average height is considerably less. Occurring as they do much farther east than the Kigluaik-Bendeleben Range, their valleys have more timber but their ridges are bare and rocky. Glaciation of the valley type has sharpened the mountain features and produced rugged forms even in this relatively low range.

GEOLOGY OF SEWARD PENINSULA.

KIGLUAIK GROUP.

The oldest rocks of Seward Peninsula are gneisses which were formerly included in the so-called Kigluaik "series." Moffit,[b] who has most recently studied this group in detail, has worked out the following succession:

> The Kigluaik group as seen in the region of Mount Osborn comprises three principal members—a basal gneiss, an overlying heavily bedded limestone, and an upper member consisting of a great thickness of schists and a few thin limestone beds. The lowest member is found at the base of Mount Osborn, and consists of a biotite gneiss cut by

[a] Moffit, F. H., Fairhaven gold placers of Seward Peninsula: Bull. U. S. Geol. Survey No. 247, 1905, pp. 36–37.

[b] See Moffit, F. H., Hess, F. L., and Smith, P. S., Geology of the Nome and Grand Central quadrangles (in preparation) for further details.

many intrusive masses. These rocks are mingled together in a most intimate way. The light-colored granitic portions especially are drawn out and folded and show a well-developed flow structure. The gneiss is a dark, coarse-grained rock with a large amount of biotite and forms more than half the vertical section of Mount Osborn.

The coarsely crystalline limestone overlying the gneiss has a thickness of 800 to 1,000 feet and is well seen on the east side of Mount Osborn, where its full thickness is exposed. In the central mountain mass it lies in a horizontal position, but on the south and east and possibly on the west and north it dips under the schists.

The limestone gives 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 schist mass still remains; and it caps the lower summits to the north where its white cliffs stand out prominently. Exposures are always much weathered, the crumbling débris falling in small talus slopes at the base of the ledge. While this limestone has been subjected to alteration in various ways and is entirely recrystallized, it does not show the secondary minerals found in some of the thinner limestone beds of the (overlying) series.

Directly over the limestone of Mount Osborn is a great thickness of brown weathering biotite schist which has a southerly dip and forms the whole northern slope of the east-west ridge south of that mountain. A thickness of not less than 2,500 feet is there exposed.

The schist is usually fine grained and with rather a smooth cleavage. Biotite is the conspicuous mineral. Large red garnets are not infrequent. Locally graphite is developed in numerous small flakes. 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 frequent, and larger masses of fine-grained granite have been intruded.

Above the brown weathering schist comes more biotitic schist which is usually highly siliceous and may possibly represent altered sandstones or quartzites. Still higher, forming the upper part of the series, 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 series 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. The black graphitic schist is a hard, siliceous rock with platy cleavage, and is entirely distinct from the graphite-bearing schist overlying the heavy limestone. In the former the carbonaceous matter is present as fine dust throughout the rock, while 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 given the name Kuzitrin "series." 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 biotite 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[a] 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.

Thin limestones appear in places in the schists of the Kigluaik group, but are not so numerous as they are in the Nome group. 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 little brown mica. These min-

[a] Reconnaissance in the Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the United States Geol. Survey, 1901, p. 29.

erals were found in limestones which have been highly folded, and were associated with granitic intrusives. Limestone beds in the upper part of the Kigluaik group are less altered than in the lower part, and the secondary minerals mentioned above were not seen.

From the foregoing statements the following column of the Kigluaik group may be deduced:

Kigluaik group	Schists (2,500 feet)	Black graphitic schists. Staurolitic schist. Highly siliceous, very biotitic schists. Brown-weathering biotite schists.
	Limestone (800 to 1,000 feet)	Heavy crystalline limestone.
	Gneiss (200 feet)	Gneisses with many intrusives very intricately folded and "kneaded."

There seems to be without any doubt an unconformity between the gneiss and the limestone, and there may be an unconformity between the upper two subdivisions of the schists. Although it has been stated that the two are conformable in the eastern part of the area studied by Moffit, the fact that the black schists are not found so abundantly developed in the western part of the same area suggests the possibility of an erosion interval either before or after the deposition of the black graphitic schist, or possibly two erosion intervals. This is a point, however, which can only be determined by further detailed studies.

Although nowhere else in the peninsula has the work been carried on in such detail as in the Mount Osborn–Grand Central area, it seems possible to delimit the region occupied by the Kigluaik group. The geologic map (Pl. II) shows that the Kigluaik group forms a belt about 15 miles wide stretching from near the coast between Tisuk Creek and Feather River in a nearly due east direction. About 50 miles east the range which forms the topographic expression of this group is breached by the Kruzgamepa, and the gravels of this stream cover the country to such a depth that no exposures of the bed rock are afforded. Beyond this water gap the Kigluaik group continues to form the country rock for a distance of over 60 miles—as far as the head of Tubutulik River.

Beyond this point the continuation is not obvious, for the surveys have been very hasty. It has been suggested, however, that the Kigluaik group bends southward and forms the country rock of the Darby Peninsula. Mendenhall[a] has definitely stated that:

Northwest of the Darby mass [of granitoid rocks], but separated from it by a broad belt of schistose rocks and alluvium, is another big granitic area lying south of the upper Koyuk Valley. Only the borders of this mass were touched at one or two points, but here it does not exhibit the dioritic phase which marked the Darby mass, but appears as a simple biotite granite.

[a] Reconnaissance of the Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the United States Geological Survey, 1901, p. 204.

It would seem safe, therefore, to consider that the eastern end of the Kigluaik group does not connect with the rocks at Cape Darby, and on the map the two areas are disconnected.

The topographic expression of the Kigluaik group is almost always mountainous. The highest points in the peninsula, Mount Bendeleben and Mount Osborn, are formed of this group of rocks. These mountains, although in few places rising to more than 4,000 feet, have been the seat of past glaciation and have very rugged forms, practically their entire surface being made up of ledges. In consequence vegetation is even more scanty than in the other parts of the region. Owing to their remoteness and seclusion, wild animals are more abundant in the hills than on the lower ground to the north or south.

NOME GROUP.

GENERAL DESCRIPTION.

According to both Moffit and Collier, the next overlying rocks are the Nome group. The description of this group by the former [a] is as follows:

> The Nome group consists mainly of schists, but limestones are present in most of the area, and are important in several parts of it. Calcareous schist or impure schistose limestone is locally well represented, and it is frequently of such a character as to leave one in doubt whether it should be mapped as limestone or as schist.
>
> The different kinds of schist may be broadly classified as chloritic schist, feldspathic schist, and siliceous graphitic schist, but all these present numerous variations.
>
> Chloritic schist is the most common of all. In fact, chlorite is rarely absent in any schists except the siliceous graphitic varieties, although the amount is sometimes very small and may not be sufficient to give any marked greenish tinge to the rock. In such less chloritic phases of the schist the quartz becomes a more prominent material, and with the mica gives a gray color to the fresh specimen. Contrasted with such types are those in which chlorite is the most prominent mineral to be seen and the rock takes on the marked green color characteristic of it. Such schist in places grades into the least feldspathic of the feldspar-bearing schist, which carries the albite crystals in amounts readily seen without the microscope.
>
> The feldspathic schist is so called from the presence of small albite crystals commonly not over an eighth of an inch in greatest dimension, though at times reaching one-fourth 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 in all cases and usually more or less quartz may be recognized. The schist is green or greenish gray in color, due to the chlorite constituent, but in certain instances the color may also be due in part to a considerable amount of epidote and hornblende.
>
> The siliceous graphitic schist is characterized by the two minerals used in describing it. The schist is black or dark gray in color. Quartz is the chief constituent, and the fresh surface is often covered with a fine black dust, like soot, which soils the hands when touched or rubbed. The rock is hard, weathering into angular platy fragments

[a] See Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska, Bull. U. S. Geol. Survey (in preparation) for further details.

which ring under the feet like cinders when one crosses the shattered outcrops. As far as external appearances is concerned it 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. It occurs irregularly in many parts of the region.

The black schists of the Nome group are usually thin, rarely reaching a thickness as great as 50 feet.

Limestone beds are interstratified with schist in all parts of the Nome sedimentary beds. They are generally light gray or bluish gray in color. Occasionally they are dark gray, owing to the presence of carbonaceous matter. The limestone is always metamorphosed in some degree; often it is entirely recrystallized.

A careful examination of beds which at first glance appear to be little altered may show them to have been intensely folded and to have had their overturned portions compressed until the limbs of the folds lay parallel with the bedding. Many small limestone beds not of sufficient importance or too poorly exposed to be separately mapped occur throughout the Nome group. These vary in thickness from a few inches or feet to possibly 50 feet or more.

BASAL SCHISTS.

These schists and thin limestones form the base of the Nome group and occupy by far the largest portion of the peninsula. Nowhere, however, do they contain fossils; so the only determination of their age is based on their relation to the next overlying horizon, which in places carries Ordovician fossils. The dominant structure in the lower part of the Nome group is cleavage, so that precise determination of the attitude of the rocks in different places is often impossible. The topographic forms produced are not striking, except in those places where the schists form the summit of a ridge. Under such circumstances the pinnacled character is remarkable. This part of the group forms the bed rock of most of the important placers, and its delineation has been of considerable importance in the study of the loci of placer formation.

PORT CLARENCE LIMESTONE.

The Port Clarence limestone, which is the next higher member, has nowhere been subjected to the minute study which has been given the rocks already described. It is typically developed in the Port Clarence region and is there fossiliferous. Although different writers have extended its areal distribution to places far removed from the type locality, it seems desirable to quote the description of Knopf,[a] who has recently published a report of geologic observations in the original Port Clarence country.

The Port Clarence limestone was so named by Collier on account of its typical exposure north of Port Clarence, where it occupies an area of 1,400 square miles. Here it comprises a thick volume of thin-bedded limestones of dense texture, generally

[a] Knopf, A., Geology of the Seward Peninsula tin deposits: Bull. U. S. Geol. Survey No. 358, 1908, pp. 12-13.

unaffected by metamorphism. Four types of rock can be discriminated, an ash-gray variety, a dark lead-gray variety, magnesian and tremolitic phases, and an argillaceous banded variety. The first two are the commonest types and occur together in interstratified beds. The dark lead-gray limestone forms massive beds up to 6 feet thick, while the ash-gray variety, which is fine grained like lithographic stone, is thin bedded and commonly breaks into large, thin slabs whose surfaces are covered with fucoid fragments. Some beds of fine-grained dolomite occur in the Port Clarence formation. Occasionally strata occur interbedded with the normal Port Clarence limestone which shows numerous small prisms of tremolite in random orientation. This is the highest degree of metamorphism displayed by the formation, except for the purely local manifestations surrounding granitic intrusives.

The basal portion and lower horizons of the Port Clarence formation consist of an impure banded limestone, the banding being produced by laminæ of argillaceous material. This phase is commonly in a highly contorted condition.

In the Lost River region the Port Clarence has a thickness of 2,000 feet.

As exposed along the western flank of the York Mountains, the basal argillaceous schistose limestones of the Port Clarence formation merge imperceptibly into members of the slates, the transitional zone being several hundred feet thick. The transition zone has been a zone of weakness and exhibits more or less severe dynamic deformation. As already indicated, the lower horizons of the Port Clarence are acutely crumpled, locally passing into a brecciated condition. Viewed in the large, however, this phase maintains the appearance of undisturbed and simple structure, characteristic of the Port Clarence as a whole.

Farther east, in the vicinity of Bay Creek, the Port Clarence limestone gives place to the graphitic, chloritic, and calcareous schists characteristic of the Nome region. The exact relations are, however, obscure.

The age of the Port Clarence formation, according to Collier,[a] is either Ordovician or Silurian. The writer found a few poorly preserved fossils from the head of Cassiterite Creek, which, as identified by Kindle, appear to belong to the two genera *Raphistoma* and *Liospira*, indicating an Ordovician age.

In 1908 the typical Port Clarence region was revisited by E. M. Kindle and collections of fossils made. The result of his work has been to extend the age of the Port Clarence beds so as to include the passage beds between the Cambrian and Ordovician through the Silurian. A description of the Port Clarence limestone, prepared by Kindle for publication elsewhere, gives a list of the fossils upon which this age determination of the horizon is based.

Moffit, in the Nome and Grand Central region, has noted a limestone which appears to have the same stratigraphic position as the Port Clarence limestone, although it is unfossiliferous. He says:[b]

Mount Distin is a mass of interbedded limestone and chloritic schist cut by greenstone dikes, the limestone being much the most important 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 occasional brown-weathering impure (limestone) beds. The limestone forming the north front of the hill south of Salmon Lake shows a thickness there of not less than 800 feet, but

[a] Bull. U. S. Geol. Survey No. 328, 1908, p. 79.

[b] See Geology of the Nome and Grand Central quadrangles, Alaska (in preparation), for further details.

toward the southwest interbedded schists appear and faulting is so frequent that the structure and thickness are uncertain.

The areal distribution of the Port Clarence and the rocks which have been provisionally correlated with this member are shown on the general geologic map of Seward Peninsula (Pl. II). From this map it will be noted that the limestone forms the greater part of the Port Clarence region, and that there are numerous scattered areas in the Fairhaven precinct south of Kotzebue Sound. South of the Kigluaik Mountains it forms a nearly continuous belt stretching from near Cape Rodney to near the mouth of Casadepaga River. Another large area is represented as occurring in the hills north of Council and extending to White Mountain. The White Mountain region is important, as fossils have been found there. Concerning this place, Collier [a] says that certain collections which were examined by Doctor Schuchert were reported on as follows:

The limestone of this locality is much metamorphosed, shattered, and squeezed, so that one hesitates to state what genus the white calcite sections in the rock represent. However, they appear to be a large bivalve, and as the strata not far away from this locality seem to be certainly of Silurian age, the suggestion is arrived at that *Megalomus* may be represented. This suggestion would not have offered itself if we did not know of a similar occurrence on Drake Island, Glacier Bay, Alaska. At this locality, the natural sections indicate that they belong to a thick-shelled bivalve like *Megalomus*, and as there are associated with them unmistakable Silurian fossils the fact is established that a horizon of about the age of the Silurian Guelph is present on the Drake Island.

Near this place another fossiliferous locality has been found of which Doctor Schuchert reports:

Lot 3AH 103 (Black Mountain near Fish River, 6 miles above White Mountain) has a *Diphyphyllum* quite unlike the other Seward Peninsula species.

A short distance away *Cladopora* are found, and it is probable the *Diphyphyllum* from Black Mountain belongs also to the Silurian.

It is a significant fact that the limestone at White Mountain is so dolomitic that it will not effervesce, while the limestone at Black Mountain and also in the original Port Clarence area contains little or no dolomite. The Silurian throughout Alaska is usually dolomitic, whereas few of the other known limestones have this character.

UPPER SCHISTS.

According to Collier and Moffit, there is a series of schists, included by the former in the "Kugruk group" which appear to overlie the Port Clarence limestone in the area east of Kougarok River. Furthermore, Moffit has stated that in certain parts of the Nome region the heavy limestone is overlain by schists. In the latest report on these schists they are supposed to form the top of the Nome group.

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[a] Bull. U. S. Geol. Survey No. 328, 1908, pp. 77.

There is, however, some doubt expressed even by those who have advanced this idea as to their true position, and it was felt that in the absence of more detailed observations they could not be sufficiently differentiated to be separately mapped. Plate II therefore includes under "Undifferentiated schists" all the rocks which have been classed as the Nome group with the exception of the Port Clarence limestone (included in "Heavy limestone") and the areas which have been provisionally referred to that horizon. As the Port Clarence in the type locality is certainly Silurian or Ordovician, it follows that the lower part of the Nome must be of Siluro-Ordovician age or earlier, while the schists above referred to may be younger.

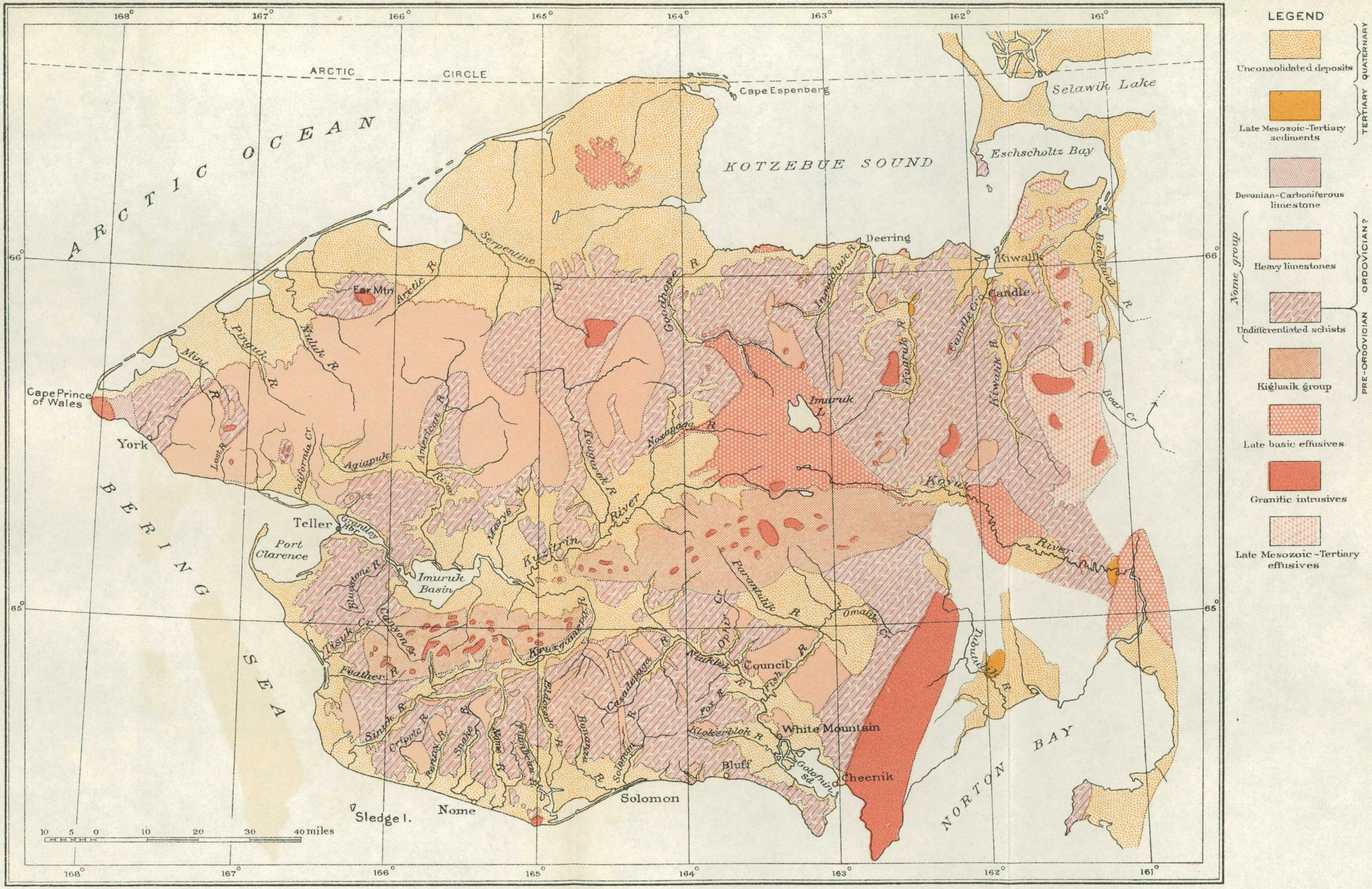
GREENSTONES.

Throughout the Nome group there are numerous greenstone intrusive rocks which seem to be practically limited to that group. Some of the areas, especially in the southern part of the peninsula, are so large that they have been mapped as separate from the rest of the group, and undoubtedly many other areas would be delimited if all the sheared intrusives of basic character which occur in the Nome group were included. While noted in all portions of the Nome group neither these greenstones nor the schists derived from similar igneous rocks are abundant in the northeastern part of Seward Peninsula.

DEVONIAN OR CARBONIFEROUS LIMESTONE.

In the westernmost part of the peninsula, separated from the rocks just described by a fault of indeterminate throw, there is a heavy crystalline limestone from which Carboniferous or Upper Devonian fossils have been obtained. On the basis, therefore, of the paleontologic collections, it has been possible to assign them to a higher position stratigraphically than any of the rocks so far described. The descriptions of the limestone state that in the contact region with the granite which forms Cape Prince of Wales the limestone is very crystalline, and that there is no lithologic difference between it and the Port Clarence limestone or even between it and the limestone of Mount Osborn. For this reason it is strongly suspected that in many places where, because of metamorphism, fossil evidence is lacking, certain of the heavy limestones which have been placed in the Port Clarence would rather have been referred to the same age as the limestone near Palazruk, described by Collier[a] as "a belt of crystalline limestone and interbedded dark mica schists or phyllites * * * exposed along Bering Sea coast for about 5 miles between the native village of Palazruk and the granite outcrop

[a] Bull. U. S. Geol. Survey No. 328, 1908, pp. 81.



A. HOEN & CO. BALTIMORE.

GEOLOGIC MAP OF SEWARD PENINSULA, ALASKA of Cape Mountain. Near Palazruk they are intensely crushed and probably faulted." In his remarks Collier gives several notes from different paleontologists, giving the names of the species found by them in the collections brought home from this locality. He then sums up the position of this limestone as follows: "From this evidence the correlation of the limestone exposed near Palazruk with the Mississippian limestone of Cape Lisburne seems well established."

PRE-TERTIARY EFFUSIVE SERIES.

In the extreme eastern part of the peninsula, forming the divide between the Kiwalik and Buckland drainages, there is a series of andesites and allied rocks which according to Moffit are younger than the schists of the Fairhaven district. Although their relation to the limestone near Palazruk is not determined, it seems probable that they are younger and so would be post-Mississippian. These andesites are described as follows:[a]

> They are of a dark-gray or greenish color, and on an exposed surface have a spotted appearance due to the alteration of the feldspar phenocrysts. Both hornblende and pyroxene varieties were seen, the latter showing considerable olivine in addition to pyroxene, and showing the secondary mineral iddingsite. Alterations of pyroxene to hornblende were also observed. The feldspar is a basic variety, labradorite or sometimes anorthite, giving as alteration products chlorite and epidote. Andesite breccias were found at various localities.

This type of rock is unknown in other parts of Seward Peninsula.

GRANITIC INTRUSIVE ROCKS.

Later than the andesites of the Buckland-Kiwalik divide are granites and allied granular rocks. In the limestone near Palazruk there are also granitic intrusives. In the Kigluaik and Bendeleben mountains, as well as in other places, there are recent granites. While it is impossible to state conclusively that all these granites are of the same age, there is probably sufficient ground for grouping them all together on such a generalized map as that accompanying this general description of the geology of Seward Peninsula (Pl. II). In topographic expression these granites usually form sharp prominent peaks surrounded by much frost-riven talus at their base. In the Fairhaven country, however, there are apparent high-level terraces which have been carved on the granites, and the usual pinnacled appearance is wanting.

LATE MESOZOIC OR EARLY TERTIARY ROCKS.

The next higher formation affords some fossil evidence as to its age. It seems to be Tertiary or Mesozoic, but its exact position has not been determined. The rocks which form it are in general less

[a] Moffit, F. H., Fairhaven gold placers, Seward Peninsula: Bull. U. S. Geol. Survey No. 247, 1905, p. 31.

metamorphosed than those of the other series and are frequently of economic importance because of the coal beds which they contain. These more recent beds occur in widely separated areas and probably represent either local basins or infolded remnants which have been preserved by their slight elevation above base level. The most northern of these areas on the Kugruk River was described by Moffit[a] in 1903 as follows:

Sandy and shaly sediments interbedded with thin limestones were noticed at several localities in the valley of Kugruk River, especially in the vicinity of Chicago Creek, where they are associated with deposits of lignitic coal. These beds are folded and much jointed, but have not been altered to the same degree as have the neighboring schists. They have the same north-south strike and high dips common in the highly metamorphic rocks, and when weathered their altered surfaces present an appearance very similar to that which would have resulted had they been burned. Such outcrops were noticed on Kugruk River near the mouth of Chicago Creek, and for several miles to the south. Also on Chicago Creek one-half mile above the Kugruk. Other smaller coal deposits are found on French Creek in the upper valley of the Kugruk.

In the eastern part of the peninsula Mendenhall[b] found evidence of the same general series, which he described as follows:

Eleven or 12 miles above the mouth of the Tubutulik some bluish and shaly sandstone and fine quartz conglomerate entirely unaltered but dipping NE. 50° or 60°, outcrop along the river bank. Two or 3 miles above this exposure is another of soft brown sandstone and fine conglomerate with blue clay shales. The beds are very soft and do not resist weathering and erosive agencies, so that the exposures are poor, but sufficient to determine the presence of a small area of sediments more recent than the schistose rocks and deposited apparently in a basin in them.

On Koyuk River about 26 miles above its mouth a similar series is exposed, but it is here much better shown. Shales, coarse loose sandstones, fine quartz conglomerates, and impure limestones alternate in thin strata that strike N. 15 W. and dip S. 70° W.

The third area of late Mesozoic or Tertiary sediments has been described by Collier[c] as follows:

In the Nome precinct a small area of unaltered sediments, including some coal beds, occurs on Coal Creek, a western tributary of the Sinuk about 14 miles from the coast. The most prominent outcrops consist of a conglomerate containing pebbles of schist and vein quartz and some large, well-rounded bowlders of greenstone that has been slightly sheared. In addition to the conglomerates, the coal-bearing formation contains finer sediments made up largely of schist pebbles that are very much decomposed. These beds have been slightly crushed and sheared subsequent to their deposition, making it difficult to distinguish the clastic material from the schists which are in place. The formation also contains a number of seams of finer material in the condition of fire clay. The beds strike nearly northwest and dip to the southwest at an angle of about 30°. These sediments were probably deposited in a fresh-water basin that was of small extent. Subsequent to their deposition they have been folded

[a] Op. cit., p. 25.

[b] Brooks, A. H., Mendenhall, W. C., and others, Reconnaissance in the Cape Nome and Norton Bay regions, Alaska, a special publication of the U. S. Geol. Survey, 1901, p. 205.

[c] Bull. U. S. Geol. Survey No. 328, 1908, pp. 83–84.

with the older rocks and eroded to base level with them, so that the original extent of the basins can not be determined.

LATER BASIC EFFUSIVE ROCKS.

In addition to the rocks already enumerated there are several igneous rocks represented on the map which are difficult to treat systematically. These rocks seem to have been formed at different times, but all are probably later than the coal-bearing sediments just described. The facts concerning these rocks have been recently summarized by Collier, who says:[a]

> Typically they are dark-gray or nearly black lavas, usually very cellular or even spongy in appearance, but in some places compact and without amygdaloidal cavities. They are diabases and basalts, both rich in olivine. In the basalts especially olivine phenocrysts are abundant and are noticeable even in the hand specimen. Rocks of this type find their greatest development in the Fairhaven precinct, where Moffit reports that there has been a succession of outbreaks of lava occurring through a considerable period of time. In the region about the head of Kuzitrin River the most recent outpourings of liquid rock occurred at no very distant date, for the ropy surface and irregular margin are still preserved. Caverns or tunnels produced by the cooling of the surface and the continued flow of the still liquid rock beneath are numerous. * * * On Noxapaga River the writer found these lavas overlying Pleistocene or late Pliocene gravels that were indurated near the contact and contain pebbles of basalt derived from an older flow. Along Koyuk and Tubutulik rivers Mendenhall reports the occurrence of several masses of basalt of similar character. On the upper Koyuk the lava has a relation to the unconsolidated gravels similar to that seen by the writer on the Noxapaga. * * * Basalts occur in small flows and volcanic necks at a number of localities north of Port Clarence and Grantley Harbor. * * * There are no criteria for age determination of the basalts north of Grantley Harbor except the amount of erosion which they have suffered. They antedate the formation of the Kougarok Plateau, which is certainly older than most of the Pleistocene sediments.

Although it has not been possible to differentiate all these various diabase and basalt flows and dikes on the small-scale map of the peninsula, it is believed that the grouping together brings out the essential fact that soon after the deposition of the late Mesozoic-Tertiary coal-bearing sediments a period of volcanic activity ensued which extended with some interruptions down to nearly historic times.

UNCONSOLIDATED DEPOSITS.

Preceding, concomitantly with and later than the volcanic effusions, gravels were deposited on the sea floor and on the land surface. The accumulation of the gravels took place under varied conditions, owing to the diverse physical features of the region from which they were derived and of the surface on which they were laid down. Some of the gravels were deposited on the sea floor and by waves and currents were modeled into characters appropriate to that agency.

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[a] Op. cit., pp. 101-102.

In other places the land waste was transported by streams and deposited under fluviatile conditions. In still other places valley glaciers transported fragments, eroded their beds, and, melting, left débris in forms producible only by ice action. Sometimes the same deposit has been worked upon by two or more agents, and in this way complex relations have been developed. With this great variation of loose unconsolidated material it has been thought advisable not to attempt differentiation but to group them all under the head of "unconsolidated deposits."

In age these deposits vary greatly. Certain of the tundra gravels have been provisionally assigned to a Pliocene age, while some of the gravels are in process of formation at the present time. Concerning the Pliocene gravels, the following excerpt from a letter by W. H. Dall relating to the fossils on which this age determination was based is of interest not only on account of its identification of the particular horizon of the fossils but also on account of the suggestion it contains as to past climatic conditions: "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."

So far as has been definitely proved, these Tertiary gravels are the oldest unconsolidated deposits in Seward Peninsula, but it is a question whether some of the high-level channels which have been uncovered may not antedate them.

CONCLUSIONS IN REGARD TO THE SOLOMON-CASADEPAGA QUADRANGLES.

From the preceding abstracts the beliefs which have been published concerning the small area of the Solomon-Casadepaga quadrangles by the earlier workers may be summarized as follows (see Pl. II):

The area belongs to two geographic provinces, namely, the coastal plain and the plateau. The geologic formations described as occurring within its borders are at the base the Nome group, which is said to cover about three-quarters of the entire area and to show both a basal schist member and an upper limestone member—the Port Clarence. This limestone was mapped as a belt running along most of the western border of the quadrangles and swinging eastward across Casadepaga River to the head of No Man Creek. A few small scattered patches of limestone at the heads of Big Hurrah and East Fork creeks were also correlated with the Port Clarence. No other consolidated deposits were described as occurring within the Solomon and Casadepaga quadrangles, the next highest deposits mapped being alluvium, probably ranging in age from Tertiary to Recent. The alluvium was said to cover about a quarter of the total area of the quadrangles and to be more extensive in the coastal-plain province to the south than in the plateau province to the north, although occurring as a broad belt along the lowland which marks the northern margin of the Casadepaga quadrangle.

TOPOGRAPHY OF SOLOMON AND CASADEPAGA QUADRANGLES.

RELIEF.

From the general position of the quadrangles with reference to the whole of Seward Peninsula it is evident that within the Solomon-Casadepaga area the forms belong to the coastal-plain and plateau provinces. In the following paragraphs many of the descriptions will be more easily understood by reading the text and detailed topographic maps, Plates III and IV, together. These maps show all the larger features that will be described, but, since it is not always possible for one unfamiliar with topographic maps to correctly interpret them, a verbal description may be permitted in addition.

The amount of relief relative to sea level or local base level is rather slight, the highest point being only a little more than 2,000 feet above the sea. Twenty per cent of the area represented on the two sheets is less than 300 feet above the sea; 35 per cent is between 300 and 600 feet; 33 per cent is between 600 and 1,000 feet, and only 12 per cent, or an area of less than 60 square miles, is more than 1,000 feet above the sea. As more than two-thirds of the area lies between 300 and 1,000 feet, it may be described as one of rather low relief. When viewed from a distance it presents no great diversity in elevation, except between the coastal-plain and the plateau provinces. These two divisions seldom merge one into the other, there being generally a more or less abrupt transition. Thus, though the boundary may not be delineated topographically by a line, the junction may be placed within an error of an eighth of a mile.

From a consideration of the way in which the two provinces were formed it is evident that the coastal-plain province is the younger. It will be convenient to describe its forms first, but such description must be prefaced by a statement of its origin as a whole, as in that way the separate features may be best understood.

COASTAL PLAIN PROVINCE.

The coastal-plain province is believed to have been formed by deposition of material in water and to have been subsequently raised with reference to sea level until after many oscillations it attained its present position. Its relief is so slight that to one standing on its surface it appears flat, and there are few points which interrupt the evenness of its surface.

FORM.

The upland or surface of the plain is but little dissected by streams. It is nearly smooth and rises gently from the sea toward the north at a rate never exceeding 100 feet to the mile. As the surface is so little dissected the upland surface corresponds more or less closely with the original surface of the sediments that were deposited on the sea floor when the region was submerged. It does not precisely correspond, however, for deposits of land waste and slide have in places mantled the original constructional forms and thus masked the true form that the surface originally had. Then, too, vegetation growing and dying on the upland for long periods has built up deposits of peat which obscure some of the earlier forms.

On the upland there are few forms which can be interpreted as remnants of the earlier history of the region. Few of the ancient stream valleys can be recognized except from the character of the gravels which are found in different parts of the plain. Cliffs, such as that which marks the "second beach" at Nome, are wanting, except inland, near the foot of the hills which belong in the plateau province. The absence of cliffs of this sort strongly suggests that this region has undergone a different history from that made out for the Nome region, and for this reason the attention of prospectors should be turned to the examination of these points. Not only does the region lack many of the surface forms that might result from the destructional action of the sea as it retreated when uplift took place, but practically all constructional forms, such as beaches and deltas, are also unrecognizable.

SOILS.

The soil over most of the province is thin and is not well adapted for any but the more hardy forms of vegetation. The upper 12 or 18 inches is general bluish muck, abundantly filled with vegetable fibers. The subsoil is generally frozen from the surface downward to as great depths as have been reached by mining (100 or more feet). As a result of this nearly perpetual frozen condition, decomposition goes on but slowly, and the various chemical constituents necessary for abundant plant life are not available. Winds blowing over the nearly unbroken surface of the coastal plain have great strength, and probably deter plant life on the upland. As it is, the vegetable covering is mainly a mat of hardy plants in few places more than 6 or 8 inches in height. Over the undissected upland no trees at all are found. Dwarf willows 3 or 4 inches high flourish with rank grasses. During the short summer season myriads of flowers, belonging to a relatively small number of genera, give color and brilliancy to the tundra.

DRAINAGE.

VALLEYS.

The valleys of the coastal-plain province are as a rule separated from each other by rather large interstream areas. Their dominant trend is north and south, or parallel to the slope of the plain. The valleys are more or less straight and have few side gulches. All of the streams that originate in the coastal plain are small and are little more than wet-weather streams. The valleys of the streams, however, that head well within the plateau province and flow thence across the plain (for instance, Solomon River and Spruce Creek) are often of good size, and their streams have therefore accomplished more work than the creeks that do not extend into the plateau. From the mere question of size, then, the valleys may be divided into those which extend well into the plateau and those which do not extend much beyond the limits of the plain. The latter class are generally shallow and have hardly been sunk below the level of the upland.

The larger valleys, such as that of Solomon River, are more deeply intrenched and therefore present a different character. The Solomon Valley shows evidence that a larger volume of water formerly passed through it, and that its present stream is only a shrunken remnant which wanders in rather irregular manner across its broad flood plain. The greater volume of water and the consequent flatter slope on which it is possible to flow has allowed the river in places to cut the floor of its valley below the bottom of the deposits which form the coastal plain. For this reason, in the lower part of the valley of Solomon River, as for instance, at Manila Creek, ledges of hard rock form bluffs along the valley sides. These bluffs are rather striking forms, for where the rivers are flowing over the unconsolidated coastal-plain sediments the walls cave rapidly and the slopes are rather gentle and smooth.

The position of valleys wholly within the plain is that imposed by the original depositional surface of the tundra. The surface of the plain formed by the laying down of sediments under water was not a perfectly smooth surface, but showed slight depressions here and there which allowed streams to form in them when the region was lifted above the water and subjected to the present day climatic conditions. On the other hand, the longer streams which head within the plateau province must have antedated the shorter coastal-plain streams and have had their mouths at the coast line when the sea stood at the inner (northern) margin of the coastal plain. Later, when uplift occurred and the shore line receded toward its present position, these streams were forced to extend their courses across the coastal plain that was thus in process of formation. In this extension all of the irregularities of the surface, such as depressions, influenced the course of the streams. Owing, however, to the slight amount of these inequalities in proportion to the dominant southward slope of the plain, the extended streams acquired a more or less straight course, dependent on surface slope and entirely independent of lithology. Lithology exerted no control, because in the unconsolidated condition of the gravels all parts of the plain were equally advantageous for the production of valleys, and slope was the determining factor.

As the valleys of the streams completely within the coastal plain have been carved almost entirely by the streams which now occupy them, there is seldom any appreciable discordance between the size of streams and size of valleys. This indicates that there has been no decided climatic change since the coastal plain emerged, and that there have been few captures of drainage. The larger streams, however, are older and have been effective for a longer time, and therefore present somewhat different features. As has already been pointed out, Solomon River does not satisfactorily fill its valley floor, and therefore some change which affected the amount of water it carried in the past must be postulated. The evidence is not clear as to the nature of this change, but it is tentatively suggested that it was climatic.

STREAM ROBBERY.

Though captures are not pronounced within the coastal-plain province, the course of Uncle Sam Creek is best explained by assuming that a diversion of this sort has taken place. Uncle Sam Creek heads on the north side of Uncle Sam Mountain and flows, in general, westerly. Its upper valley seems to be a direct continuation of Quartz Creek, a tributary of Solomon River, but lower down it makes an abrupt turn and flows south into Pine Creek, which enters the lagoon about 4 miles east of Solomon. At the present time, as there is need of water for mining purposes near the mouth of Quartz Creek, a ditch has been built to divert water from Uncle Sam Creek to Quartz Creek, so that the old condition is artificially reproduced. The reason of the diversion is not clear, for the cause of the greater efficiency of Uncle Sam Creek is not evident. It is believed that greater erosive power was furnished by warping, which gave the advantage to the coastal-plain stream. Since this warping took place, erosion has been proceeding headward in both streams. In this renewed activity, Quartz Creek has an advantage over Uncle Sam Creek, because its average gradient from the point where the diversion has taken place to the mouth of Quartz Creek is nearly 100 feet per mile, while from the point of diversion to the lagoon the fall is only a little more than 50 feet to the mile. With the greater slope, the erosive ability is greater, and it might be expected that in the geologic future, if the present processes are allowed to continue undisturbed, Quartz Creek will be able to recapture from Uncle Sam Creek the headwaters drainage which formerly belonged to it. Figure 2, showing the profile of the two streams, may make this point more evident. Further evidence of this earlier course is afforded by river gravels and flood-plain deposits at an elevation of nearly 50 feet above the mouth of the present stream.

FIGURE 2.—Profiles of Uncle Sam and Quartz creeks. *a*, Profile of Uncle Sam Creek; *b*, profile of Quartz Creek on the same plane; *c*, hypothetical earlier course of Quartz Creek.

STRUCTURAL FEATURES.

In the valleys of the coastal plain there are few evidences of constructional or destructional forms of an earlier cycle. Terraces and benches are practically wanting. Some constructional forms, such as alluvial fans of recent origin, have been built by the streams as they passed from the steeper slopes of the plateau to the gentler ones of the coastal plain. This has, in a measure, obliterated the junction of the two provinces, so that the line between them can seldom be drawn with precision. Other constructional forms, such as deltas, are almost wanting. This is in part to be explained by the slight amount of erosion that has been effected by the streams and the consequently small amount of waste that has been brought down by them, and, in part, to the recency of the uplift which produced the coastal plain. Even those streams which enter the quiet waters of the protected lagoons have built no deltas.

THE COAST.

The coastal-plain province, as may be seen from the topographic map, Plate III, is terminated to the south by the waters of Norton Sound. It is probable, however, that the same general surface slope is prolonged under water, and that if further uplift should take place a new strip of land in all essential respects similar to the present-day surface, except where the sea floor has been modified by wave and current action, would result. Such modification is well shown by the reefs and lagoons which extend almost the entire length of the coast of the Solomon quadrangle. The building of the reefs is due to the on and along shore action of the waves and currents, sand being derived from the sea floor. In the early stages such reefs are often a mile or more off the coast. As the destructive attacks of the sea finally exceed the repairs that can be made from the floor of the sea, the reefs retreat inland until they become attached to the coast. Such a condition is shown at Taylor Lagoon. As the onshore building by the waves exceeds the scouring action of the rivers as they flow seaward, the rivers may become so blocked that instead of flowing directly into the sea they are forced to parallel the beach for considerable distances before discharging. Spruce, Lillian, and the smaller creeks between the two are good examples of the obstruction of rivers by the constructive activities of the sea. These streams are forced to flow nearly 8 miles parallel to the coast, although at the point where they are deflected they are less than 200 yards from Norton Sound.

The seaward side of the reefs is smooth, owing to the currents which flow parallel to the coast, but the inland side is frequently irregular because the erosive activities along this face are weak. While many of the smaller streams have been obstructed by the currents, the larger ones have not suffered so much deflection. It is evident that a force strong enough to overcome a small stream might not be able to affect a larger one. Solomon River, because of its size, has been able to enter the sea directly and shows no lateral deflection. In times of strong onshore winds, however, or of high tides, even this river is so checked and ponded back that its water is brackish for 2 or 3 miles upstream.

POPULATION.

Few people live in the coastal-plain province, but even this small number constitutes the larger part of the population of the two quadrangles. Of the few there are three main classes, namely, townspeople, miners, and natives. The townspeople are employed in various enterprises that have sprung up as a result of the roadstead, and more particularly as a result of the easy path into the interior. The low gradient into the more remote districts has, as already noted, been taken advantage of by a railroad, which employs many of the inhabitants. The miners are a more or less floating population at present, owing to the fact that no profitable gold-bearing gravels have been discovered and that the work is mainly prospecting. They number only a score or so and live widely separated from each other during the summer, returning to one of the towns in the winter. The third and last class are the natives, numbering only a few families within the coastal-plain area. They live mostly along the seashore, where fishing and sea hunting can be carried on easily. Some also congregate near the towns, remote enough to live in their own fashion, but near enough to take advantage of the rejects of their white neighbors. None of these classes can in any sense be regarded as agriculturists, although a few of the people raise in frames some of the more hardy and quickly-growing vegetables. Game is almost lacking, although ducks are numerous among the reeds and on the quiet waters of the ponds and lagoons. Fish are plentiful, not only in the waters along the coast but in many of the streams of the coastal plain.

PLATEAU PROVINCE.

Forming nearly three-quarters of the area under consideration is the plateau province. As is indicated by its name it is a region of considerable elevation above the sea and above the neighboring coastal-plain province.

FORM.

The plateau has been so thoroughly dissected that it by no means everywhere presents a flat table-topped sky line, with the valleys forming narrow notches below that surface. Looked at in a broad way, however, it is seen that the uplands are more or less uniform in elevation. Furthermore, when the structure is studied in detail, it is seen that the surface in no wise corresponds to the attitude of the rocks, which are usually beveled by the upland. From the fact that no known process, except that of long-continued subaerial erosion, is capable of producing a widespread uniform level on rocks of different resistances, it has been more or less tacitly assumed that to such a process is due this upland surface.

When, however, the observer tries to construct wide erosional plains, differing from each other by only a few hundred feet, the errors introduced are too great, owing to the obscurity of the forms, to warrant the attempt. That there are such levels can not be doubted, for the region must have undergone a long period of geologic activity in the past, but their positions can not be ascertained at present. Little or no flat upland is preserved, and, as has already been stated, only about 12 per cent of the entire area is above 1,000 feet in altitude, so that the amount of surface at any elevation between 1,000 feet and 2,000 feet (the highest point in the quadrangles) must be very small.

As the upland seems to consist of rocks of nearly the same resistance to weathering, and as there are few of the characteristic features of an old surface of subaerial erosion, it seems unsafe at present to attempt to account for its present topographic form. That this must be due to long-continued subaerial denudation can be of but slight doubt, but whether the denudation gave rise to a peneplain or to subequal accordance of summit level is uncertain. If, then, the origin is in doubt, it is not appropriate to attempt to correlate the upland surface over the entire area, as having been formed at one time or by one process.

There seems to be no ground for assuming any particular direction of slope for the upland. The highest points occur in the divides between the larger streams, but if they are considered as a whole, it can not be shown that there is a constant direction of slope, although it would appear that the divide along the eastern margin of the areas is relatively higher than on the western. The upland on the western margin is narrower and appears to be formed by the meeting of two erosional plains on opposite sides of the divide—that is, with no original upland surface remaining. On the eastern margin, however, there seems to be more upland preserved between the slopes on opposite sides of the divide, so that possibly some of a more ancient surface is preserved. If such is the case it is manifestly unsafe to correlate the old surface preserved to the east with the surface which may be the result of recent degradation to the west. It is, therefore, believed not to be feasible to make any statement as to the slope of the upland.

Although a statement of the direction and amount of the slope of the upland is out of the question, it is evident that the surface is in no sense due to constructional forms, such as folds or original planes of deposition. Many of the various rocks that compose the crust are standing at high angles, and yet are terminated abruptly by the surface. The lithology of the different members, however, exerts a considerable control over the surface features. Thus, the limestones, which, in more humid regions, are the weak or valley-making rocks, are here the resistant members and often hold up the ridges. The greenstones also are resistant, so that they form the upland over large areas. This is the more striking when it is remembered that relatively small amounts of such igneous rocks are present.

Constructional forms of an earlier cycle are wanting on the upland, and in practically no instances are deposits of fluviatile or marine origin observable. In one case only were well-rounded pebbles found near the upland surface, and these occurred in such a position that their mode of origin was not determinable. From the character of the frost-riven fragments that cover the major part of the upland, and the absence of waterworn deposits, it is unsafe to venture a suggestion as to the original history of the upland. Destructional forms, such as benches, monadnocks, etc., are also wanting. It is true that here and there rocky knobs rise to heights of several hundred feet above the average level of the upland, but their form and distribution is not such as would be characteristic of monadnocks.

SOILS AND VEGETATION.

On the uplands the soils are rather thin and consist mainly of angular broken fragments of undecomposed bed rock of local origin. No trees or bushes grow on the upland and the only vegetation consists of grasses, hardy flowery plants, and mosses and lichens. The local origin of the soils has had a decided effect upon the character of the vegetation. This is perhaps most strikingly shown in those cases where limestone forms the surface rock. In such places vegetation is practically absent and a careful search must be made to find even a blade of grass. Where the limestones are cut by other kinds of rocks, the latter may often be traced by the band of vegetation which follows them and does not occur on the limestone itself. This condition seems to hold true only with the more massive, thicker limestones and is not the case with the thin limestones interbedded with and merging into the schists.

DRAINAGE.

STREAMS.

The valleys of the plateau province present many different features both as regards form and arrangement. The original surface on which the drainage of the region was effected is too completely obliterated to allow a satisfactory statement as to the early stages of the stream development that determined the major valley lines. The map, figure 3, shows that the drainage of the plateau discharges either into the Niukluk (and thence into Golofnin Bay) or into Norton Sound directly. Of these two divisions the Golofnin Bay drainage carries off considerably more than half the precipitation from the two quadrangles. The streams belonging to this system drain the entire northern part of the area and also a small amount along almost the entire eastern margin of the quadrangles. Niukluk River with its branches is the largest member of this group of streams. Its tributaries within the quadrangles commencing with the most northwestern, are: American Creek, several small unnamed tributaries between this creek and the Casadepaga, Casadepaga River, Alice, Elkhorn, Camp, Richter, and Bear creeks. Only about 4 or 5 miles of the Niukluk itself is within the limits of the quadrangles. Of the tributaries named the Casadepaga and its many side streams drain by far the greater area.

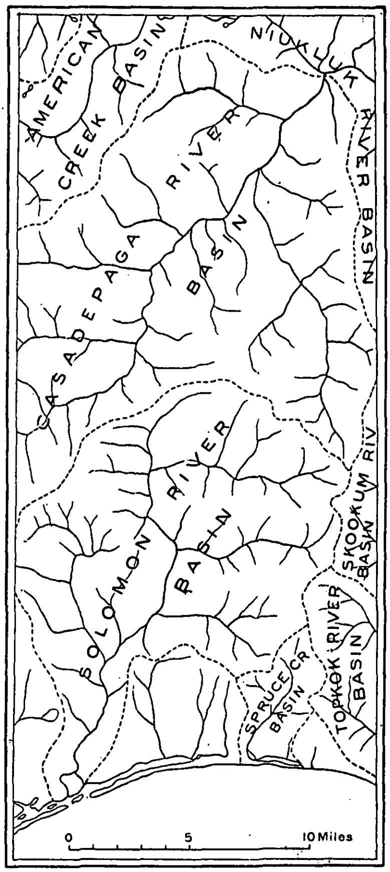


FIGURE 3.—Diagram showing drainage basins of Solomon and Casadepaga quadrangles.

The Niukluk is a tributary of Fish River, and the latter stream has one large tributary, Fox River, which heads within the quadrangle, although the area it drains is only a square mile or two in extent. The position of this stream is, however, of considerable importance, for at its head there is a low pass which allows easy communication between the coast and the productive part of the Niukluk River gold fields, near Council City.

The most southern rivers that empty in Golofnin Bay are the streams which form Klokerblok River. The more important of these streams that head within the area under consideration are Skookum River, Boil, O'Brien, and Kentucky creeks. Their entire drainage area, however, does not exceed 15 square miles.

Solomon River is the most important stream of this region that enters Norton Sound. Together with its many long branches, it drains the larger part of the Solomon quadrangle and also receives some water from the area to the north. Practically its entire drainage basin is shown on the detailed maps, Plates III and IV. From the relation of this stream to Casadepaga River to the north it would appear that the former had gained some territory from the latter. This conclusion is based mainly upon the way in which the divide of the two streams bows toward the Casadepaga. This point will receive some further attention later.

Besides Solomon River there are several other streams belonging to the Norton Sound drainage. Some of them, such as Pine, Lodestone, and Lillian creeks, have been already discussed in the description of the coastal-plain province, and further mention of them may be omitted.

Two other streams east of Solomon River, namely, Spruce Creek and Topkok River, each drain small areas of the quadrangles. The former lies wholly within the mapped area, but the latter has only its headward portion, Rock Creek, west of the margin. Neither of the basins of these streams, however, drains an area of more than 8 or 10 square miles. West of Solomon River a small amount of the surface is drained by streams belonging to the Bonanza River system; the largest within the quadrangles is Jackson Creek. Its mapped basin has an area of only 3 or 4 square miles, and is therefore insignificant.

VALLEYS.

In most of the valleys, especially in the larger ones, such as those of the Casadepaga and Solomon rivers, the slopes of the valley walls, in the lower part, show distinct benches which mark old erosion and construction levels. This interpretation is borne out not only by the form, but also by the character of the material of which they are composed. Higher up on the sides of the valleys, and also in the headward portion, benches are rather uncommon. This absence is perhaps to be accounted for by the destructive effects of the downhill creep of material under the influence of gravity. As a rule the shape of the valleys is not broadly flaring. An understanding of the general character may perhaps be best gained from the various illustrations that accompany this report. The usual cross section of a valley from the divide toward the river is shown diagrammatically in figure 4. At first the slope is gentle, but it steepens notably a short distance below the divide. Then it flattens until a few score feet above the stream, when it becomes still more gentle. Usually this is followed by a steep descent of 10 to 20 feet, and this cliff is succeeded by the nearly flat valley floor.

In ground plan none of the valleys show any marked sinuosities on a large scale. Bends, indeed, do occur, but they are seldom arranged with any regularity. Though this is true of the streams in general, it does not hold for that part of Casadepaga River between Curtis and Canyon creeks, where numerous swings occur with rhythmic order intrenched below the bench, which stands 20 to 30 feet above the water. The arrangement of the streams with reference to each other may be best gathered from the sketch map, figure 3. It will be seen that, as a rule, the streams of two opposing drainages do

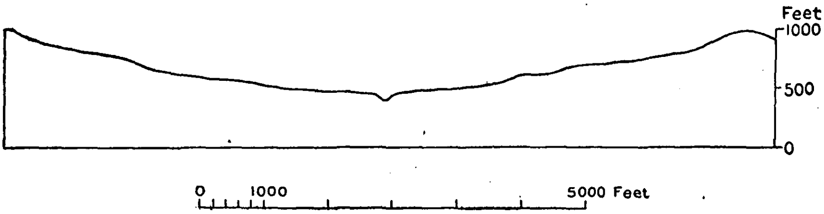


FIGURE 4.—Cross section of a plateau-province stream, Castle Creek.

not interlock to any marked extent, and that as a result the divides between the two are not very irregular. This would suggest that active headward erosion by the different streams is not now in progress. Such a condition may be due either to the fact that the drainage has had sufficient time to adjust itself to existing conditions or to a lessening of erosive ability caused either by a change in relation to local base-level or by a decrease in precipitation and accompanying run-off. The first suggestion is not believed to be correct, for in many places streams are found with essentially similar volume and yet with very different gradients. Although definite proof has not been adduced, it is strongly suggested that there have been climatic changes which may account for some of the features, and that others are probably due to rather recent movements of the crust.

The gradient of the valley floor often shows changes from steep to gentle slopes. This throws some light on the recent history of the region. It is common to find the lower half mile or so, especially of the side streams, showing a steeper slope than the middle portion. The flatter gradient of the middle part is succeeded, farther upstream, by steep slopes, which increase gradually toward the head. Such a condition can be best explained by supposing that the stream originally had a slope which decreased steadily from the head to the mouth, *ac* in figure 5. Subsequently uplift took place. As erosion proceeds headward, starting at the lower part of the stream first, it follows that the steep slope at the mouth, *ab*, figure 5, marks the attempt of the stream to erode its valley appropriately to the new conditions. Under such an explanation the junction between the steeper and gentler slopes, *d*, figure 5, would mark the limit to which headward erosion of the present cycle had proceeded. The gradient of the middle part of the stream would therefore nearly coincide with the course of the stream prior to the uplift.

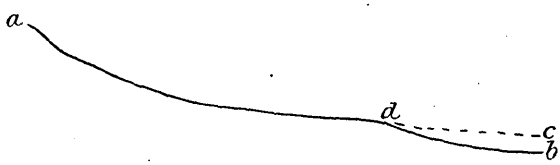


FIGURE 5.—Diagrammatic longitudinal section of plateau-province stream.

EFFECTS OF STRUCTURE ON DRAINAGE.

A region composed of rocks of varying resistance to erosion and with structures so diverse and pronounced necessarily shows many valleys which have been determined by these features. The larger valleys, such as those of Solomon and Casadepaga rivers, when examined on a small scale, do not seem to be directly controlled by the structural or lithologic character of the rocks, as they do not flow parallel with the strike. But when looked at in a broad way the north-south trend of the belts, interrupted though they are (see Pls. VI, VII), seems to have been the controlling influence which determined the direction of the streams. Where softer rocks occur the valleys of the main stream have often been opened out more widely than where the rocks are more resistant. Many of the local constrictions of the valley seem to have been caused by recent local uplift. There can be but little doubt that the main streams have had a long history, which is difficult to unravel.

In the case of the smaller streams, however, the number of interruptions are fewer because of their more recent origin. In many instances it is possible to show that the courses have been determined by structural features, such as faults, which have affected either the surface form or the resistance of the rocks and thus caused the location of streams in certain places. A study of the geologic maps (Plates VI and VII) will disclose many examples of streams that have had their position determined by faulting or other structural features. Lithology has also had a pronounced effect on the character and position of streams and therefore of the valleys. The contacts between different rocks are often zones of weakness which have permitted the location of streams. Dixon Creek, in the Casadepaga quadrangle, is a good example of this feature, and others may be found in many parts of the area. In many places the contact was a plane of weakness, owing to movement along faults, and therefore the two types of control, structure and lithology, have often been exerted in the production of a valley.

Perhaps the most striking effect of the control exercised by lithology on the shape of valleys and streams is to be found in those regions where limestone forms the country rock. Owing to the solubility and the fissured character of the limestone, much of the water is carried by underground streams, which are not effective in modifying surface forms. Bonanza Creek is one of the most striking examples. For stretches of more than a mile no stream is found on the surface, and the river bed, which is occupied by water only in times of exceedingly heavy rain, looks like a roadway covered with angular fragments of glistening white limestone. In many of the valleys where limestone forms the bed rock no surface water flows and the turf has not even been cut through. Sink holes are common, and their circular funnels lead to underground channels. These conditions are found on many of the streams flowing in limestone areas. As examples may be mentioned Auburn Ravine, No Man, Moonlight, and Kasson creeks, and many of the streams at the head of Shovel Creek. In a few cases the underground channels of the limestone streams have been uncovered by erosion. Such a feature is seen on Fox Creek, a small tributary of Coal Creek. It is, however, of small size and not notable.

Not only is the effect of lithology seen in the case of the streams themselves, but it is also evident in the slopes of the valley walls. The heavy limestones practically always make steep slopes, which differ materially from those produced on the schists. This condition is particularly well shown in the sudden steepening of slope in the northwestern portion of the area, wherever limestones occur, and may be easily recognized by comparing the geologic and topographic maps. (Plates VI and VII, III and IV.) In places the interlamination of different kinds of rock makes benches on the valley sides, which in a measure resemble fluviatile terraces, but which are generally due to lithologic differences rather than to erosion by streams.

As a rule, the valleys, except in their lower portions, are free from constructional forms of water-laid origin. Fans, terraces, and flood-plain flats are recognizable, but only the last named are common. The flood plains show from their form that in many cases they are due to the building up of previous and more deeply incised valley floors rather than to normal developments in a single cycle.

The river has built up broad flats, covered with sands and gravels, and abruptly terminated by steep rock walls, in places a score of feet in height. These walls, in turn, are succeeded by gently sloping flood plains of an older stage in the river's development. The higher plains gradually merge with the slopes to the upland, although in places the transition is abrupt.

RELATIONS OF STREAMS AND VALLEYS.

The smaller streams generally are well proportioned to the size of their valleys, but this is not the case with the larger streams. Niukluk River, even in the more constricted portions of its valley, has a floor much too wide for its volume. Its irregular straggling course, which does not fit the swings of the valley, is well shown in the part northwest of the mouth of Casadepaga River. It is believed that the misfit character of this stream is due, first, to the former greater extent of glaciation in the mountains in which it heads; and second, to the probable diversions of drainage that have occurred in the divide between Niukluk and Kruzgamepa rivers. Although it is evident that no glaciers have entered the area under consideration, it is equally probable that the melting of the large body of ice farther up the valley once gave rise to a greater run-off than now exists. Deformation of the crust also has caused local filling or erosion, so that the Niukluk presents many small filled basins and narrow rock-cut gorges. Its relation to the other features in the district has, however, not been satisfactorily determined. The problem is one that requires study over a much greater area than that included in the quadrangles.

The Casadepaga, as has already been pointed out, is incised below the level of its old valley floor. In this later trench, however, the stream seems to be proportional to the size of the new valley, and there is but slight evidence of a change in the amount of discharge in recent times. The relation of the present stream to the earlier one, which flowed on the broader, older floor, is not determinable. A stream the size of the Casadepaga could make as large a valley, if time enough were allowed. The rather straight course of the older valley, on the other hand, suggests that it was not an old valley carved by a small stream but was a more youthful one formed by a large stream and subsequently filled, uplifted, and again dissected. If this is the case probably the older stream was a larger one than the present-day Casadepaga. Its larger size may have been due to a different climate or to the possession of other drainage, now diverted; speculation is useless until further evidence is obtained regarding the former size. It should be stated, however, that if there has been a climatic change, it could not have been one involving glaciation. A few scratches which might have been formed by the movement of winter ice along the sides of streams were seen, but from the form of the valleys and spurs it is certain that no glaciers have occurred in the region in sufficiently recent time to have left traces of their presence upon the topography. This conclusion is based, not only on the evidence afforded by the land forms but also on the character and distribution of the various deposits.

Solomon River, except in the coastal-plain province, shows in few places any decided discordance in size between the valley floor and the stream. Here and there local warping or some other cause has produced small gravel-filled basins, but these are relatively uncommon. Some of the tributary valleys, however, show floors that are much too wide for the existing streams. Shovel Creek affords a good example. Plate I, *B*, taken from a point near the mouth of West Creek, looking north, shows the broad gravel-covered floor of this creek with the stream but poorly shown in the middle ground. This view would also serve to show the character of Coal Creek above Boise Creek to a point beyond Offield Creek, or of East Fork near Matson Creek, or of the middle portion of Big Four Creek and its tributary, Birch Creek. The cause of this feature is not evident, but does not seem to be due to lithology, climatic change, or diversion. It is tentatively suggested that a part of the broadening may be due to the seasonal overflows during the closing months of winter. Many of these streams have large accumulations of snow and ice formed in them, and as thaws occur the water often overflows and freezes so that finally a body of ice, thickest near the stream, is formed which may last for weeks after the snow elsewhere has melted. The effect of the ice mass, therefore, is to cause the water formed by the melting snow to abandon its former course and flow down on either side. This process naturally tends to widen the valley floor where the obstructions occur, by holding the streams against the walls. As the gradient is not sufficient to cause downcutting, the energy is spent mainly in lateral erosion.

STREAM ROBBERY.

Diversions have occurred within the Solomon and Casadepaga quadrangles, but so long ago that most of their obvious traces have been obliterated. The low pass by which the railroad crosses from the Solomon basin to that of the Casadepaga, however, shows all the features of a gap carved by a stream, although now it is many feet above the neighboring creeks. This diversion, however, was effected so long age that the narrow gorge of the capturing stream has been widened; further uplift has allowed it again to incise its course, and a long period in the history of the rivers has become practically indecipherable from the surface forms. The existence of this pass, however, is of considerable importance in the development of the district.

Other low passes for which a similar history is suggested occur in the divide between the Solomon and Casadepaga drainages; one such is between the heads of Johnson and Doverspike creeks. Its greater elevation, however, would give some slight grounds for believing that its diversion took place earlier than the Ruby divide capture, although the basis for such a determination is inadequate when the subsequent amount of warping and dislocation is considered.

In the American Creek basin a striking example of a recent diversion is shown in that part of the stream below Crater Creek. Figure 6 shows the upper part of this basin and serves to supplement the

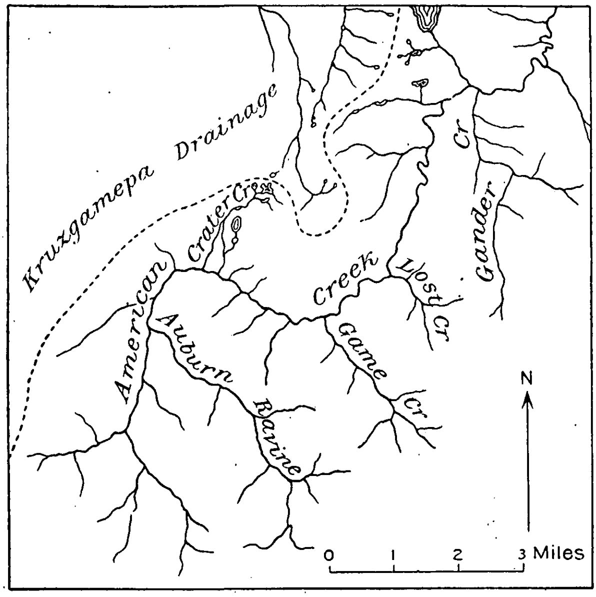


FIGURE 6.—Map of the American Creek basin.

detailed topographic map (Plate IV), on which only the part of the stream below Crater Creek is represented. At the head of Crater Creek is a low pass having an elevation of between 575 and 600 feet. There is good reason to believe that at one time all of the present American Creek drainage west of Lost Creek flowed out through this gap. An idealized diagram to show this condition is afforded by figure 7. (The apparent lack of symmetry of the eastern and western parts of the Kruzgamepa drainage in this diagram is due in large measure to the lack of adequate field mapping of the streams to the west.) At the time represented in figure 7 a ridge with an elevation of nearly 800 feet separated the tributary of the Kruzgamepa, *A*, from the headwater branch of American Creek, *B*. Subsequently, the outlet by the Crater Creek pass was blocked, sands and gravels were deposited, and a lake was probably formed. Gradually the surface of the lake waters rose until it overtopped the low divide between streams *A* and *B*, and the waters of the lake occupying a part of the Kruzgamepa basin discharged toward the northeast down American Creek. With the development of an outlet across the ridge the water began to cut the gorge now represented by the canyon of American Creek. This gorge is about 400 feet deep, and its steep slopes are well shown on the detailed topographic map (Pl. IV). The downcutting of the stream has proceeded headward until now the junction of American and Crater creeks is from 50 to 75 feet below the lowest part of the Crater Creek pass. It is not yet possible

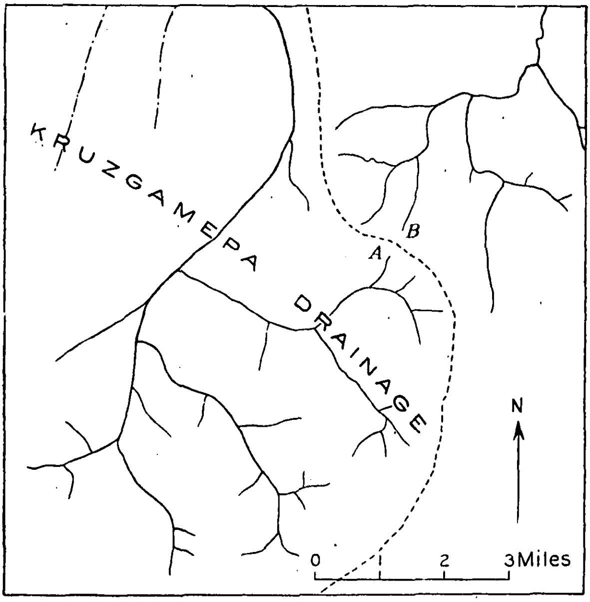


FIGURE 7.—Diagram showing earlier stage of American Creek drainage.

to state definitely the nature of the obstruction which caused the abandonment of Crater Creek pass, but the best evidence at hand indicates that it consisted of a tongue of ice which extended southward from the Bendeleben Mountains. Whatever it was it persisted for so long that when it disappeared the drainage to American Creek was established, and the stream continued to flow in the more recent channel.

SUMMARY.

When the valleys of the plateau province are considered in a broad way it is seen that they form a mature series of dissection lines, which have so ramified throughout the quadrangles that few remnants of a much earlier surface are preserved. Furthermore, the more mature valleys have been uplifted, so that the streams have been forced to degrade their floors, and therefore rock outcrops in the banks are common. A possible climatic change has taken place, for many of the more recent valleys incised in the older ones are gravel filled. Many of the smaller side streams have been formed in very recent times, and in many cases fail to show the features of streams that have been subjected for a longer time to earth movements. Nowhere, however, is there any proof that the valleys have been occupied by glaciers in the past, and there is strong positive evidence that such occupation has not occurred. This statement refers to the plateau province proper, and not to the Niukluk-Kruzgamepa Flats, where there are unmistakable evidences of ancient valley glaciers.

The soils of the valleys differ but slightly from those of the coastal-plain province, except that in places the material is entirely unsorted by water. This is particularly true near the higher parts of the divides, where angular frost-riven detritus, almost bare of vegetation, is the normal condition. On the valley floors tangles of willows, 6 to 8 feet in height, mixed with alders, are common. No coniferous trees are found in this province with the exception of a few stunted spruce, and even these stunted growths occur only in the extreme eastern part of the quadrangles; probably not more than a score could be found in the entire area. The most western spruce tree was found near the head of Gander Creek, and the most northern one was in the valley of the stream heading in the 1,770-foot limestone hill east of Gander Creek. Ten miles east of the eastern margin of the area, near Council City, spruce grows in sufficient abundance to supply local needs. The greater part of the valley slopes are covered with grass and mosses.

The northern termination of the plateau province does not appear within the mapped area, unless Niukluk River lowland be considered as such. As has been stated on page 18, the Bendeleben Mountains rise to the north, but the question whether they are formed by the dissection of the warped plateau surface is not within the scope of this paper. On the south the plateau is terminated rather abruptly by the coastal plain, and no outliers are found in the latter province. Near Topkok Head, however, the plateau province is cut off by the sea, and a steep cliff is formed. So vigorous is the attack upon this headland that no beach has been formed. It is entirely out of the question to walk around the base of the cliffs at sea level, and it is impossible except in favorable places to climb to the upland. The rather flat upland above the cliffs is at an elevation of about 600 feet, which coincides closely with the elevation of Cape Nome, and also of the York Plateau of Collier, but no gravels were found on its surface, and its mode of formation is not known. The local origin of the rock fragments, however, shows that for a long time it has not been affected by transporting agents.

DESCRIPTIVE GEOLOGY OF SOLOMON AND CASADEPAGA QUADRANGLES.

INTRODUCTION.

It has already been stated (pp. 30–31) that the formations which occur within the quadrangles belong to the Nome group and the unconsolidated alluvium. The Nome group, according to the earlier geologists, covered about three-quarters of the entire land area of the quadrangles and included the lower schist member and the upper limestone—the Port Clarence. Next above this group came the alluvium, ranging in age from Tertiary to Recent, and covering an area about one-third as great as that of the Nome group. These determinations were based upon reconnaissance surveys and were published on the scale of 4 miles to the inch, so they represent only the larger features of the geology. With the completion of the detailed geologic mapping, the field work for which was done on a scale of 2 inches to the mile, it has been possible to show more details and to subdivide the complex Nome group into units which have definite areal and stratigraphic relations. The results of these studies are shown on the geologic maps (Pls. VI and VII), and the basis for these subdivisions will be discussed and the various members defined and described in the following pages. The units will be described in geologic sequence from the base toward the top of the column.

Before describing the different members of the stratigraphic sequence, a statement concerning the kind of information afforded by the geologic maps is appropriate. To those familiar with similar maps no explanation is necessary, but to the others it should be noted that in drawing boundaries between highly metamorphic rocks a sharp line of separation between different members is not always possible. Much of the surface of Seward Peninsula is covered with muck and vegetation, so that outcrops are few in number; when it becomes necessary to draw boundary lines through such places, only approximations of the actual position are possible. Furthermore, where rocks have been so folded and contorted as these, transitional phases which might belong to either of two groups are common; in such cases the separation is based upon all the evidence obtainable but is at best often a compromise. Finally, when the scale of the map is insufficient to represent the actual conditions, it is necessary to generalize the observations and to show only such features as may be appropriate. Figure 8, which represents a portion of the Casadepaga River valley near the western margin of the Casadepaga quadrangle on a scale of 2 inches to the mile, illustrates the impossibility of showing all the data on a map on a smaller scale. For these reasons Plates VI and VII should not be interpreted as showing the exact lithologic character of specific small areas, but only as delineating the appropriate geologic groups and formations as far as is permitted by the area of the exposures and by the scale of the maps.

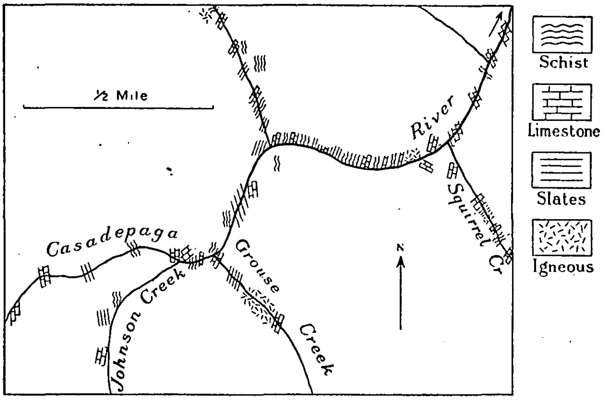


FIGURE 8.—Map showing outcrops on parts of Casadepaga River.

The various groups and formations which will be described fall into two main classes, namely, the consolidated and unconsolidated deposits. The consolidated deposits consist of three main types, sediments, igneous rocks, and veins. The unconsolidated deposits may be divided into marine and nonmarine sediments. Each of the divisions may be still further classified according to different topographic or physical features. In the present paper, however, it is purposed to treat the various consolidated or hard-rock members first and then to pass to the consideration of the unconsolidated deposits.

SEDIMENTARY ROCKS.

METAMORPHOSED SEDIMENTS.

In order to make the sequence of the various sedimentary members more evident, the following stratigraphic table is inserted here:

Section of metamorphic sedimentary rocks.

System.	Formation or group.	Lithologic character.
Post-Ordovician	Puckmummie schist	Dark slates and schists; little metamorphosed.
Post-Ordovician (?)	Hurrah slate	Carbonaceous quartzites and slate.
Ordovician (?)	Sowik limestone	Massive bluish-white limestone.
Unconformity.		
Pre-Ordovician (?)	Solomon schist	Highly metamorphic quartzose and calcareous schists.

SOLOMON SCHIST.

General description.—The lowest member recognized in the quadrangles is a series of schists with thin limestones, which exhibits a more or less uniform character throughout the area. It is proposed to call this unit the Solomon schist. Stratigraphically, its position is determined by the fact that it underlies all the other rocks. As will be shown later, however, this fact is not easy to determine in the field because of the extreme amount of deformation the rocks have undergone. Because of this extreme deformation, the thickness of this member can not be determined, but it is probably many hundred feet. The dominant structure shown by the outcrops is cleavage, whose planes usually stand at a low angle. Here and there, however, under favorable conditions, an earlier structure is preserved, which is probably bedding. The older structure may perhaps be best determined by noting the direction of the contacts between the schists and the thin beds of limestone associated with them. Even this criterion is open to doubt, for the junction between the two was often a plane of weakness on which movement took place. Because of the greater age of the Solomon schist, it is much more highly metamorphosed than any of the other rocks, and it is always more thoroughly recrystallized. Under the microscope earlier structures may sometimes be discovered. For instance, somewhat rounded quartz grains are now and then recognized as forming nuclei around which the later minerals have been developed. It is, however, only under exceptionally favorable conditions that these structures may be seen. From them, however, and from the relationship observed at places where interlaminated thin-bedded limestones occur with the schists, it is believed that the formation as a whole is a series of sedimentary deposits which have been more or less completely recrystallized and thus have lost their former characters and assumed a highly schistose condition.

Mineralogic character.—Lithologically, the Solomon schist shows a great range of character in different parts of the field. Some of the members are very quartzose; others are calcareous; and still others are mainly chloritic. Considered as a whole, however, the schists are usually quartzose and have abundant chlorite. For this reason they have a greasy appearance and are much contorted, with irregular stringers and lenses of quartz, probably of vein origin. Under the microscope it is found that few of the members of the Solomon schist show any considerable amount of feldspar, and in the hand specimens feldspar is practically wanting. No analyses of these rocks have been made. It should be noted that though muscovite is common in most of the schists, no biotite is found. The significance of this fact is not thoroughly understood, but it is believed that the absence of this mineral is due in part at least to the absence of granite in the neighborhood. According to this suggestion, many of the schists to the north and west, in which biotite forms a large part of the rock, have that character, because they are in the zone of contact metamorphism of granite masses, while the Solomon and Casadepaga region is devoid of this intrusive.

In addition to the more characteristic and easily recognized minerals, there are many others which can be determined only by the aid of the microscope. A characteristic specimen of one of the schists measured in thin section showed that nearly 80 per cent consisted of optically strained and recrystallized quartz. There was also a little muscovite in scattered flakes and an abundance of chlorite in thin parallel bands. A little zoisite was also found and a small amount of a dark pigment in small specks, probably carbonaceous material. The cleavage of the specimen was much wrinkled and the rock had a "woody" fracture. Another specimen showed about 70 per cent of quartz and nearly 30 per cent of pennine, clinochlore, and muscovite or sericite. Metallic minerals are sometimes present. Of these minerals magnetite of secondary origin is the most common, although sulphides are also frequently noted.

Interbedded limestones.—In the more calcareous schists calcite increases in amount until the rock may become almost a pure limestone. In a specimen of such a schist at the mouth of Canyon Creek, near the limestone contact, there is abundant carbonate which has associated with it iron oxides that appear to be secondary products resulting from its decomposition. In this schist there are a few secondary feldspars which show a distinct sievelike structure; that is, they have surrounded earlier-formed grains of quartz or other minerals. Some of the calcite is also of secondary origin, for it incloses some slightly rounded quartz grains. In addition to these more abundant minerals rutile in aggregates of minute needles is common.

It has already been noted that calcareous beds and lenses are found forming part of the sedimentary sequence of the Solomon schist. These beds have thicknesses ranging from a few inches to many feet. Some are distinctly interstratified with the schists, but the relations of others are not clear. On the geologic maps an attempt has been made to represent all the calcareous members that the scale of the map will permit, and although some have had to be excluded on account of their smallness, the maps give an idea of their general distribution. It should be stated in this connection, however, that the grouping as shown on the map probably includes some of the heavy limestones which really belong in the next higher division, but which, through faulting and complex folding, have had their relationship so obscured that their true position is not determinable.

The limestones of the Solomon schist are not dolomitic nor, indeed, are most of the interbedded limestones throughout the area. In a few places, however, dolomites do occur and form irregular patches whose relations to the other rocks is not clear, owing to structural deformation. One such dolomitic area is found on the upper part of Bonanza Creek a little west of the heavy limestone. Its relations are such that it is not certain whether it represents a dolomitised portion of the heavy limestone to the east or whether it is a distinct bed. In any event, it must be at least 250 feet thick. It occurs in the vicinity of a great overthrust fault, and so its relation to the schists is not evident. This dolomite can not be traced for more than a mile, and in that distance it does not appear to be continuous. Another dolomite was found at an elevation of about 700 feet east of the head of Crater Creek. Its exposed thickness, however, is not over a few score feet. Its entire extent is not visible, owing to the mantle of gravel-plain deposits that obscure the lower part. At this place it appears that the dolomite is interbedded with the schist. These two are practically the only places where dolomites are found within the mapped area. In neither case is it possible to demonstrate whether the dolomitic character is local or marks a definite stratigraphic horizon.

The limestone bands occur in all portions and are not limited to any particular part of the field. It seems clear, however, that the upper part of the Solomon has more of them than the lower part. It would seem, therefore, that the Solomon was deposited in the beginning under more or less stable conditions of rather shallow water, followed by more pronounced oscillations and a general tendency toward deeper water. It should be added, however, that the actual base of the schists is not determinable in the Solomon and Casadepaga region. No conglomerates which belong distinctly to this horizon have been found. Whether their absence is due to the fact that none were formed within the region, or whether it is due to the obliteration of the conglomeratic character by the great amount of deformation which the rocks have undergone, is not known. From the fact, however, that no lower member on which such a basal conglomerate might have been deposited is known in the region, it seems probable that none were formed, and that the near-shore deposits of conglomerates occur in other areas.

Metamorphism.—As regards the amount of metamorphism, there is slight reason to doubt that the Solomon schist has been subjected to more intense alteration than any other member of the stratigraphic sequence. Not only has cleavage been everywhere developed, but it is demonstrable at many places that this cleavage has itself been deformed, so that at least two marked periods of folding and shearing are indicated. With each of these periods new minerals were developed and new structures induced, which obscured the preceding characters. Therefore, when looked at in a broad way, the differentiation of the Solomon schist from succeeding horizons may be roughly made on the basis of the greater metamorphism of the schist.

SOWIK LIMESTONE.

General description.—Overlying the Solomon schist and covering an area of about 50 square miles in the Casadepaga quadrangle and probably a little less than half that extent in the Solomon quadrangle is a heavy limestone that forms one of the most striking topographic features of the region. This formation is most extensively developed along the western margin of the quadrangles, commencing near the mouth of West Creek on Shovel Creek and extending uninterruptedly in a northerly direction. It lies outside of the mapped area north of Wilson Creek, but may be traced continuously in the ridge separating the American Creek from the Iron Creek drainage. The northern end of this limestone is near the settlement of Sowik, from which the formation derives its name.

It will be noted that this is the belt of limestone which was previously correlated with the Port Clarence. Owing to the fact, however, that at least four different limestones, ranging in age all the way from the Cambro-Ordovician or earlier to Carboniferous, are known in Seward Peninsula, it seems inexpedient to correlate at such long range on lithologic grounds, and consequently a new name, which shall not in itself express too widespread correlation, is necessary. It is proposed to limit the term Sowik limestone to the massive limestone which immediately overlies the Solomon schist.

This formation consists essentially of a calcareous nondolomitic limestone with a thickness of 400 to 1,000 feet. At its typical exposures it is a limestone with practically no sedimentary schist beds. Where, however, metamorphism due to deformation and dislocation have affected the rock, micaceous minerals have been formed and a cleavage developed. In all parts of the field it has been subjected to some metamorphism and the component minerals recrystallized. The result of the recrystallization has been to destroy the original characters. If organic remains were originally in the rock, they have been mostly obliterated. In only two or three places within either of the quadrangles have fossils been found, and even in these places they are so distorted and absorbed that they are of little or no value in determining the stratigraphic position of the beds in which they occur. No fossils at all have been found in the western, longest belt of limestone; but farther east, near the head of Gander Creek, in beds which seem to be equivalent, a few fossils were found. Regarding a specimen from this place (8AS20 loc. 8AS94), E. M. Kindle, in an unpublished letter, says:

> It shows nothing that can be regarded as conclusive evidence of its age. The specimen shows an obscure corallite, a crinoid stem, and a cross-section of an undetermined

fossil. In view of the rarity, if not the entire absence, of crinoid stems from the lower Paleozoic faunas which I have seen in the Seward Peninsula, I am inclined, on account of the crinoid stem, to suspect that the specimen may represent a Carboniferous horizon. But I wish to register this opinion as being the best guess which I am able to make, and without weight if there is any evidence against it.

A comprehensive idea of the general field appearance of the Sowik limestone may be gained from Plate I, *A*, which was taken from a point near the top of the 1,160-foot hill south of Kasson Creek. The view is looking up Shovel Creek, and shows Topnotch Creek near the right or eastern margin. A comparison of this view with the geologic map, Plate VI, will make the distribution of the rocks more evident. The angular frost-riven fragments which cover the foreground show the characteristic method of weathering and partly explain why it is so difficult to obtain definite measurements of thickness and structure. All of the hills shown in the view have the same character as the foreground on which the camera was standing, and outcrops actually in place cover probably less than 1 per cent of the surface. Other views show other places where the Sowik limestone is well exposed. For instance, the limestone of Mount Dixon, which is correlated with the Sowik, is shown on Plate XV, *A*; the unconformity between the limestone and the Solomon schist and dolomite (see p. 56) is shown on Plate XIII, *B*; and an intrusion of the limestone by igneous rocks (see p. 77) is shown in Plate VIII, *B*.

Geologic relations.—It is impossible to state definitely what are the relations between the underlying Solomon schist and the overlying Sowik limestone, for the evidence seems to be contradictory. As has already been pointed out, the upper part of the Solomon schist is marked by more calcareous beds than the lower part. This would seem to suggest gradual submergence, and it is possible that the Sowik limestone marked the closing stage of this general movement. According to such an interpretation, the limestone would be broadly conformable with the underlying schist. On the other hand, it seems from the field evidence that the limestone is not as thoroughly metamorphosed as the underlying schists. This could not, however, be the case if the two were essentially conformable, since to bring about such a difference an intervening period of deformation must have occurred. It is, of course, unsafe to place much weight on the difference in the degree of metamorphism, especially when the rocks affected are so different in physical characters as the Solomon quartzose sediments and the Sowik limestone.

It might be asked by one unfamiliar with the region why the question of conformity is not settled by the observations on the structure of the two members. There are two main reasons why this criterion, applicable in most regions, is not conclusive in settling the problem in hand. In the first place, the original structure is so obscure that it seldom can be recognized. Bedding planes are ordinarily determined by the differences in lithologic character or texture on either side, but to take this as the dip of the rocks is necessarily to beg the question, as it involves the assumption that the beds are conformable. Nor does the secondary structure give any conclusive evidence, for divergence in direction of the cleavage may be due either to the decided differences in the physical characters of the rocks or to the fact that one of them has suffered two periods of deformation while the other has undergone but one. Thus it might easily be imagined that a deformation which would readjust the structure of a limestone might not be sufficient to destroy a schist or quartzite. Another reason that makes the determination of the relations difficult, if not impossible, is the amount of faulting that has affected the region subsequent to the deposition of the limestone. The junction between the schist and limestone was necessarily a plane of weakness, and this has permitted thrust faulting. In consequence of this movement the contact zone is almost always intensely brecciated, and seldom can any structure be determined in the limestone for several score of feet from the contact. Particularly good examples of this brecciated contact are afforded along the slopes of Mount Dixon, especially on the ridge north of the head of Dixon Creek. Here and there are distinct evidences of unconformity, but in every case that has been closely examined the unconformity is due to overthrusting and not to original deposition. An example of this kind is afforded by the 1,770-foot hill between Bonanza and the lower part of American Creek. (See p. 115, and Pl. XIII, *B*.)

Even if the relation between the Sowik limestone and the Solomon schist could be settled by the structure, the employment of this criterion would be difficult, owing to the absence of good exposures. Much of the country is covered with a mantle of vegetation and talus through which few outcrops appear. On the side of the exposures opposite the dip slope, the heavy mantle of frost-riven fragments from the limestone and from the weaker, more easily disintegrated schist cause the actual contact to be covered and even a thickness of a score or more feet may be completely masked.

For all these reasons, it may be seen that precise field observations on the structure are not feasible, and may lead to erroneous interpretations. When, however, the problem is looked at in a broad way and when the peculiar areal distribution and the apparently greater amount of metamorphism are considered, it seems most reasonable to believe that the Solomon and Sowik are not conformable.

Correlation of detached outcrops.—The areal distribution of the Sowik limestone is indicated on the geologic maps (Pls. VI and VII), but it is probable that some of the limestones which have been grouped on these as forming parts of the Solomon may be simply the infolded equivalents of the Sowik. This is especially true in the southeastern part of the Solomon quadrangle in the valley of Rock Creek. It is believed from rapid reconnaissance trips to areas outside of the region under discussion that the limestone here may connect with the massive limestone which forms practically continuous exposures along the coast from slightly east of Topkok Head to Bluff, a distance of 8 or 10 miles. According to the description of Brooks,[a] who visited Bluff in 1906, the limestone seems to be in general character similar to the massive Sowik limestone of the Solomon and Casadepaga quadrangles. Though it is not proposed to press the correlation of the limestone on Rock Creek with the limestone at Bluff, nor

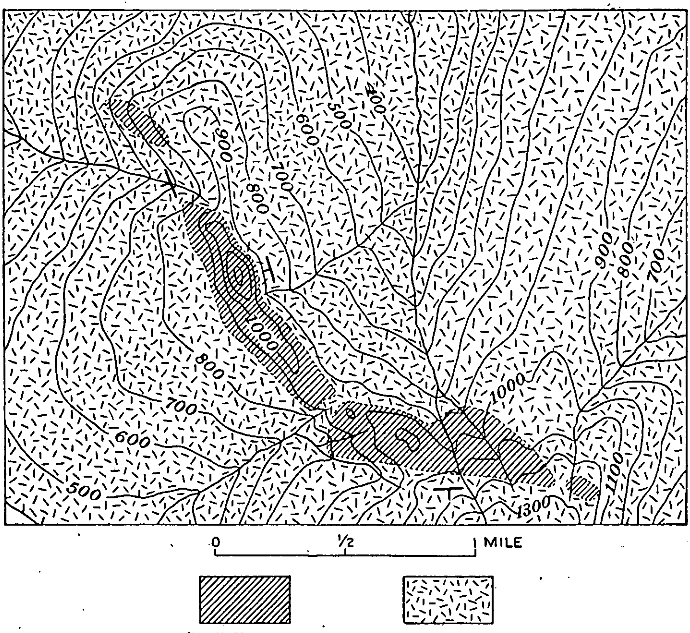


FIGURE 9.—Diagram showing relation of limestone and schist at head of Puckmummie Creek.

the correlation of the limestone at Bluff with the Sowik limestone, such an interpretation is not unlikely and may be warranted by further study. The point, however, which it is desired to emphasize by bringing up the question, is that with more numerous and better exposures, such as may be afforded later by mining excavation, it is probable that the areal extent of the Sowik may be slightly increased, even within the mapped area.

Ordinarily, the Sowik formation, where it appears, forms the ridges, but in many places it has been eroded to such an extent that it makes only isolated patches on the valley slopes. Such isolated areas are

[a] Collier, A. J., Hess, F. L., Smith, P. S., and Brooks, A. H., Gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, pp. 285–286.

often difficult to interpret, for the dominant structure—cleavage—would indicate a succession of strata that does not occur. Figure 9 shows an area of this sort on the ridge at the head of Puckmummie Creek. From this diagram it will be noted that the apparent dip is south to southwest, but through any of the little gulches which score the western face it is possible to keep continuously on the same schist that occurs underlying the limestone on the east. This would tend to prove that the limestone was either a lens in the schist or was cut off by a thrust fault, or that the observed structure is not the bedding structure. This last suggestion seems to be the correct one, although it is not definitely proved. Other examples may be found in the Solomon quadrangle, especially in the ridge west of Solomon River between Big Hurrah Creek and East Fork.

Metamorphism.—Silicification of the Sowik limestone has been noted at several places, being particularly characteristic of the base of the limestone near the contact with the schists. At these places a thickness of from 1 to 4 feet consists of limestone replaced by silica. All stages from nearly pure limestone to a quartzite showing no lime remaining can be found. In the replacement, cavities lined with perfectly terminated crystals of quartz of small size may be found. It is evident that the replacement took place at a much later date than the formation of the limestone, and was due to the comparatively recent presence of circulating waters, whose movement was made easy by the shattered and dislocated character of the rock. Owing to the fact that the Sowik is a limestone, it is readily soluble, but the cold water which prevails at that northern latitude is unable to dissolve the rock readily, so caves and caverns such as characterize limestone regions farther south are not abundant. Solution lines, however, may be found on the exposed surfaces and in places indicate solution under conditions different from those that now prevail.

Besides the replacement by silica, iron solutions have played a small part in altering the normal character of the limestone. This is especially the case on the hills east of Johnson Creek. Although examples of this replacement were not seen in place the slopes of the limestone hills, especially on the side toward Virginia Creek, were covered with numerous fragments of limonite. This mineral occurred in stalactitic and botryoidal growths of a porous texture, often apparently with unreplaced fragments of the limestone entirely surrounded by the limonite. Fragments up to a pound in weight were seen among the other blocks of the talus, and in places they were so abundant that they gave the slope a brownish color. This replacement, like the replacement by silica previously noted, seems to have been a recent one and probably did not take place prior to the last great metamorphism. From the distribution of the float limonite, it is suggested that its formation took place nearer the upper than the lower limit of the limestone.

HURRAH SLATE.

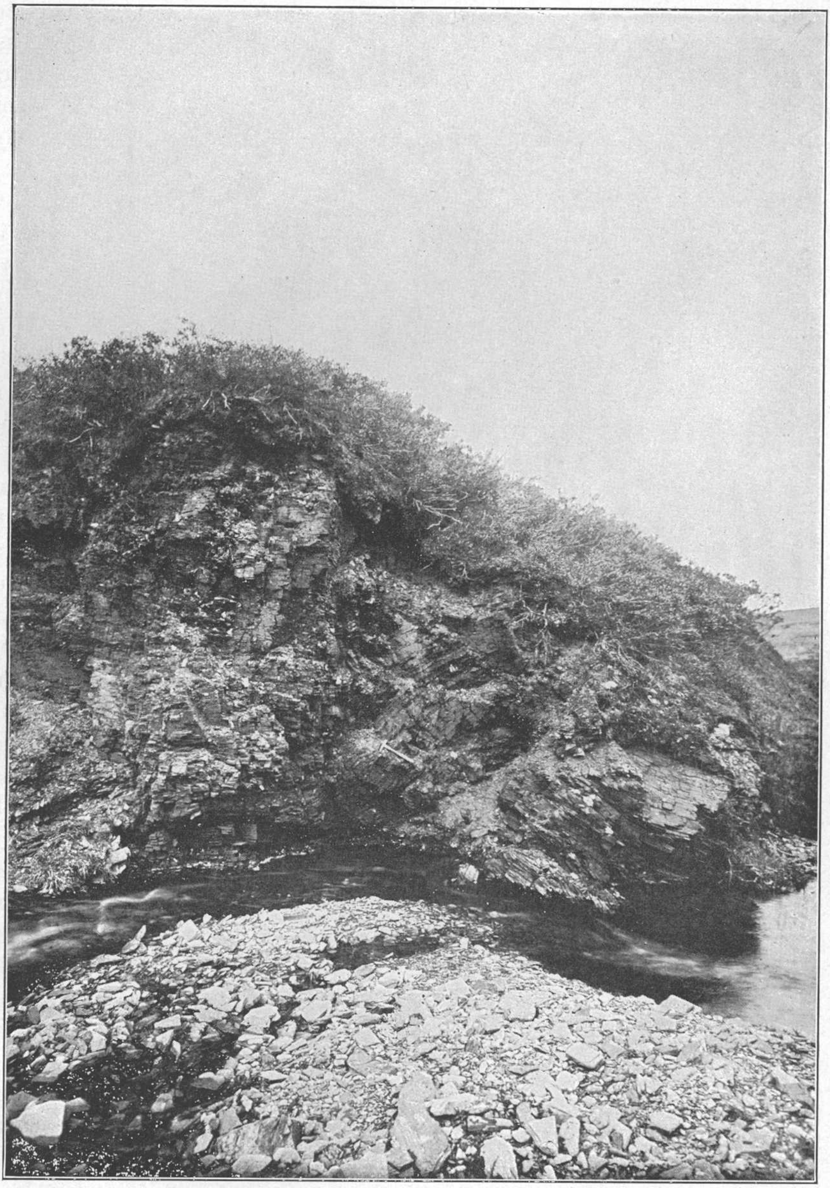
Character and distribution.—As Solomon is approached from the sea, one of the most conspicuous landmarks is a high hill 6 or 7 miles northeast of the town of Uncle Sam Mountain. This hill marks the southern limit of a black slate formation which is the next one overlying the Sowik limestone. Its areal extent is represented on the geologic maps (Pls. VI and VII). The largest area of this formation is roughly triangular in shape, having its base along the inner margin of the coastal plain and its apex near the mouth of East Fork. Its most continuous exposures are afforded by the lower 2 or 3 miles of Big Hurrah Creek and in the shafts and other mine developments of the Big Hurrah mine, located at the junction of Big and Little Hurrah creeks. For these reasons it is proposed to call it the Hurrah slate. It formed part of the Nome group of the earlier geologists, but the fact that over a considerable part of the field under discussion it may be traced with more or less continuity and preserves in the main characteristics of its own causes it to be placed in a separate subdivision from the rocks already described.

The Hurrah slate does not cover much more than half as great an area as that occupied by the Sowik limestone. This is to be accounted for by the fact that owing to its stratigraphic position it has been lifted higher above the planes of erosion and has therefore been removed over a larger area. There can be but slight question that originally the Hurrah slate was deposited practically uninterruptedly over the entire Solomon quadrangle and over at least the southern two-thirds of the Casadepaga quadrangle. The outcrops are now widely distributed, although the most extensive area, as has already been noted, is from Uncle Sam Mountain northward to the mouth of East Fork. In the drainage basin of Big Four Creek are many areas of a square mile or more where the Hurrah slates are the country rock. Outcrops also occur in the central portion of the American Creek valley near the mouth of Lost Creek and also near Game Creek, but they are much dislocated and can not be traced for any distance.

Along the western margin of the quadrangle the Hurrah slate is exposed in a discontinuous band roughly parallel to the Sowik limestone. Within the area covered by this report the slate is broken by numerous faults, so that it can not be traced continuously; but farther northwest, from the big bend in Lower Willow Creek a mile or so west of the junction of that stream and Wilson Creek, it can be traced northerly in an almost unbroken band, extending into the Iron Creek valley. From the field evidence in the western part of the quadrangle, it appears that the Hurrah slate is not so thick as in the central part. Though a thickness of over 200 feet is seldom indicated on the west, in the central part of the area the Hurrah slate is at least 400 feet thick and in some places may reach 800 feet; this, however, may be due in part to faulting. All of these estimates of thickness, however, are unsatisfactory, for in no place has the upper contact of the slates been seen, and therefore the amount that has been removed by erosion and the character of the overlying beds have not been determined.

At the base of the Hurrah slate in places where a normal sequence is indicated, a thin black limestone, in few places more than over 50 feet thick, occurs. This limestone is well exposed on Little Hurrah Creek, at the base of the slate on East Fork, and in various parts of the Big Four Valley. It is always calcareous and never dolomitic. The coloring matter seems to be carbonaceous material, which occurs sprinkled through the rock rather uniformly. Some of the carbon is in such fine particles that its character can not be determined even microscopically. When material of this sort, however, is heated in a bunsen flame, the carbon burns and leaves a white residue, thus showing that the material is not graphite. There are, however, some of the black limestones that show graphite instead of the other forms of carbonaceous material. Under the microscope the calcite of the limestone has been practically entirely recrystallized and the later crystals are much pressure twinned. Secondary minerals are developed and sometimes form as much as 10 per cent of the specimen. Of the secondary minerals, quartz and muscovite are the most common. In a specimen from the Big Four basin, however (spec. 7AS57, loc. 7AS208), garnet and amphibole were also recognized in thin sections. The amphibole was in colorless well-formed crystals. It is probable that the garnet and amphibole were introduced as a result of the igneous intrusions which have had such an important effect on the rocks of this part of the region. Sulphides are also found in the black limestone and were among the latest-formed minerals. The limestone is so thoroughly recrystallized that no trace of organisms have been found in it. Veins of calcite and sometimes quartz are abundant. Although thoroughly recrystallized, the limestone has seldom developed a good cleavage or schistosity.

Above the black limestone are from 200 to 800 feet of black quartzitic slates, which are the most characteristic portion of the Hurrah formation. Plate V shows a typical outcrop of the slates on the upper part of Big Four Creek 1½ miles southeast of the mouth of Surprise Creek. In this view the well-jointed character of the slates and the much-faulted condition are well shown. Although these rocks are much dislocated and practically everywhere show as much faulting as in the view noted above, they do not seem to have been



HURRAH SLATE NEAR HEAD OF BIG FOUR CREEK.

as much sheared as most of the rocks already described. Strong evidences of folding and even overthrusting are found, but seldom are the rocks schistose. A characteristic specimen shows that over 80 per cent of the rock is quartz. Associated with the quartz is usually some chlorite and muscovite, the amount of the latter minerals depending largely on the amount of metamorphism to which the rock has been subjected. The black color is due to fine dustlike particles of carbonaceous matter scattered nearly uniformly through the rock. In those places where metamorphism has been most extreme the carbon mineral is usually graphite. Where this is the case, the rock soils the hands and the graphite occurs mainly on the cleavage planes.

The structure of the rock in hand specimens shows incipient cleavages which look well developed, but the rock usually breaks along the joint planes, so that the exposures are a talus of more or less rectangular blocks from 1 to 5 inches in longest dimension. Sulphides in small amount are almost universally present and on weathering give the rock an iron-stained color on the surface. The alteration of the sulphides leaves little pits of somewhat cubical form filled with limonite. In weathering the rock sometimes takes on a whitish color, which completely alters its normal appearance. When pieces of the white-weathering Hurrah slate are broken open, an unaltered black core may often be found, showing distinctly that the material does not come from a particular bed but that the light color is simply an effect of alteration. No adequate explanation as to why the Hurrah slate weathers white in some places and not in others has been discovered. The light-colored phase of weathering is by no means so common as the other type.

Veins of quartz, sometimes showing drusy cavities lined with well-terminated quartz crystals, are so common in the Hurrah slates that they are characteristic of this member. Plate IX, *B*, shows a block of Hurrah slate with the network of such intersecting veins. In places the veins are so small that they are not distinguishable except on the weathered surface, where they form a perfect honeycomb of quartz ridges, between which the black slate has been removed by erosion. The veins usually occur as fillings along the joint planes, and are of recent origin. For a more detailed description see pages 89 et seq.

Fossils.—No fossils have been found in the slates of the Hurrah formation, and there are few indications that any will be found. At one place near the eastern margin of the quadrangle, near the little knob east of the 1,185-foot hill east of Big Four Creek, there is a small area of black slates which is the least-metamorphosed phase of the Hurrah that has been found. At this place the texture of the rock is pelitic. It consists mainly of quartz with the usual carbonaceous dust, which gives it a black color, and it contains also a little very fine chloritic or kaolinitic material. The rock shows no shearing at all and breaks with a shaly fracture, in places approaching a subconchoidal one. Probably this area affords the best chances for finding fossils in the Hurrah slate, but even here it must be confessed that the probability seems slight. It is necessary, therefore, to place the stratigraphic position of this formation purely on the field relations that exist between it and the other rocks and structures of the region. The results of this study will be set forth in more detail subsequently (see pp. 128–130), but for the present it may be said that the Hurrah slate forms the member of the sedimentary series next higher than the Sowik limestone.

PUCKMUMMIE SCHIST.

Character and distribution.—In the northeastern part of the Casadepaga quadrangle, exposed over an area of not more than 10 to 12 square miles, is a series of rocks which in the field appear to be different from any of those so far described. They are not only lithologically different, but their structures are not similar, and it is believed that they are younger than any of the sedimentary rocks, with the possible exception of the Hurrah slate. Field relationships are obscure, and the only fact of which one is sure is that they are younger than the Solomon schist. The region in which they occur is in large measure covered with alluvium, so that their outcrops are disconnected and impossible to trace areally. Their contact with the rocks to the south is in all examined instances marked by a fault. Owing to the inability definitely to determine the stratigraphic position it is impossible to make any statement regarding the amount of dislocation they have undergone, but from the fact that different series of strata are truncated or beveled by this formation it seems probable that this has been considerable.

The best exposures of these rocks are on the lower part of Puckmummie Creek and on the rocky knob to the east, in the low hill northwest of Post Creek, and in a few scattered outcrops along the ridge south of the Niukluk as far west as longitude 164° 15′ west. Owing to the especially complete development of these rocks on Puckmummie Creek and on the 1,150-foot hill to the east, it is proposed to call this member of the sedimentary sequence the Puckmummie schist. This formation is defined as consisting of more or less schistose rocks, possibly equivalent to the Hurrah slate, younger than the Solomon schist, and probably younger than the Sowik limestone. This formation should be differentiated, although its stratigraphic position has not been definitely determined, and can not be until more mapping in adjacent areas has been done. A tentative statement based on the best evidence now at command would place this formation as equivalent to the Hurrah slate.

Lithologically the Puckmummie schist presents two rather distinct types, which, however, in the field seem to occur interlaminated. The first is a dark-grayish, granular, slightly schistose phase, while the other is finer grained, nearly black, slightly graphitic or carbonaceous, and slaty. Limestone is practically wanting in the area occupied by this member. It seems significant that at the contact of the Solomon and Puckmummie on the first knoll south of the Niukluk, west of the mouth of Casadepaga River, black, coarsely crystalline limestone float indistinguishable from the limestone at the base of the Hurrah slate was found. No outcrops, however, were found, and the position of the float is such as to afford no positive information.

Schistose phase.—One lithologic type of the Puckmummie schist, as has previously been stated, is the dark grayish and schistose. In the field this rock breaks into more or less thin flags roughly parallel to the main structure lines. Schistosity, although noted, is not nearly so pronounced as in the Solomon schist. As a whole, the rock in hand specimens appears more like a slightly sheared sandstone with some chlorite and secondary minerals. The specimen from the locality on Puckmummie Creek about half a mile above the mouth (spec. 7AS64, loc. 7AS227) shows a dense rock with bands of different texture and composition, which give the rock a distinct bedded appearance. The rock appears to consist mainly of quartz with a little chlorite and some limonite. When examined under the microscope it is seen to contain over 60 per cent of quartz. A little albite in grains and in later-formed intergrowths is found. Chlorite, muscovite, or sericite form a small part of the slide. Limonite is abundant. The quartz occurs both in large and small fragments. It seems that the larger quartz and feldspar grains were formed later than many of the other minerals, and have formed around the small quartz grains, producing a "sieve" structure such as is diagrammatically represented in figure 10. The inclosed grains represent an earlier structure, which has been in places replaced by the later-formed minerals. In addition to this structure some of the grains show features which seem characteristic of rocks other than those in which they now occur and afford a clue to the history of the present rock. Other fragments of quartz associated with it are of different origin. From this fact it may be argued with a considerable degree of assurance that the rock in question is sedimentary, made up of grains of different earlier rocks and that some of these at least

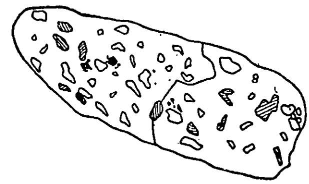


FIGURE 10.—Diagram showing "sieve" structure in Puckmummie schist.

were sedimentary. Another point brought out by the microscopic study of this specimen is that the banding so noticeable in the hand specimen is due to differences in the amount of quartz in the different bands. In the places where quartz is abundant chlorite and limonite are relatively unimportant, but where the amount of quartz is small the proportion of the other two minerals increases.

In the low knobs against which the Niukluk impinges west of the mouth of the Casadepaga, essentially the same features are found as at Puckmummie Creek. The hand specimens from the two places are practically indistinguishable. On the nearer knob the thin section shows chlorite and muscovite and consequently a little less quartz. At the further knob the amount of chlorite and muscovite is slightly less than in the locality on Puckmummie Creek, and the percentage of quartz is probably more than 70.

North of the Niukluk the only exposures of this first phase of the Puckmummie schist is on the ridge west of Post Creek, leading up to the 845-foot knob. The rocks here are similar to those south of the Niukluk. At the lowest exposure, which occurs at an elevation of about 400 feet, the rock is fine grained and slightly schistose. A specimen (7AS61, loc. 7AS223) from this place shows when studied under the microscope many structures of a previous stage that are characteristic of a sandstone or quartzite. As a whole the constituents are but slightly recrystallized. The larger grains appear to be original rock particles crushed rather than secondary. There are two arguments in support of this view—first, that the micaceous minerals wrap or feather around the larger grains and do not penetrate them; second, that although the grains sometimes include other minerals, these inclusions are not oriented according to the general structure observable in the rock but seem to be distributed at random. Such a condition would be expected if the so-called inclusions were fragments of quartzite and the whole grain a mass of these cemented together and then transported, probably by water, and deposited to form the rock in which they now occur. Other specimens from near this place but farther up the ridge show the same features.

Slaty phase.—The second type of Puckmummie schist which, as has already been pointed out, occurs interlaminated and inseparable from the one just described, is of black color and has a slaty cleavage. In hand specimen, this rock could not be distinguished from the typical Hurrah slate, except that it is more thinly laminated. On the north side of the Niukluk no outcrops of this kind of schist occur within the mapped area, although its float is abundant. South of the Niukluk, however, there are several places where ledges of the rock are exposed. In the rocky knob half a mile from the northern margin of the Casadepaga quadrangle, where the Niukluk is undercutting the cliff, a small area of not more than 20 feet square of the rock is found. It breaks into rather thin layers of a very black color. The powdered rock soils the hands as though it contained a good deal of graphite, but when it is subjected to the Bunsen flame it becomes white, so the material is probably some other form of carbon. Under the microscope about 70 per cent of the rock is seen to consist of quartz and muscovite. Of these two minerals quartz forms about 65 per cent, and muscovite only about 5 per cent. The remaining 30 per cent is made up of carbonaceous material and limonite. Owing to the small size of the dustlike particles of carbonaceous matter it is not possible microscopically to determine the relative proportions of the last-named minerals. The limonite is the result of the oxidation and hydration of iron pyrite. In fresh hand specimens pyrite may be recognized scattered throughout the rock in small crystals. Some of the quartz is secondary, filling the little cavities that are more or less numerous throughout the rock.

Another specimen (7AS73, loc. 7AS245) from the float east of the 845-foot hill north of the Niukluk also soils the hands, but burns to a white color at a rather low temperature. It shows excellent parallel arrangement of the grains. At least 75 per cent of the thin section consists of quartz. Grains of this mineral measure on the average from 0.1 to 0.05 mm. About 5 per cent of the rock consists of muscovite, which occurs in small scattered scales. The other 20 per cent is formed of carbonaceous material and limonite. Most of the carbonaceous matter is in lines parallel to the cleavage, although some is scattered irregularly throughout the rock and it is nowhere entirely wanting. Limonite is usually in square or roundish areas which from their form suggest strongly that they mark former pyrite crystals that have subsequently been weathered. A few small cavities are noted that are partly filled with quartz and have linings of well-formed quartz crystals.

Summary.—From the foregoing descriptions it will be seen that the Puckmummie schist is a much less sheared rock than the only other quartzose schist with which it might be confused. It is characterized in all parts by a considerable amount of dark, nearly black carbonaceous quartzite bands which are not found in the Solomon schist. It most nearly resembles the Hurrah slate and only differs from it in that it is somewhat more schistose. It is not calcareous, and therefore can in no way be regarded as the metamorphosed equivalent of the Sowik. Because of the lack of exposures its stratigraphic position with respect to the underlying and overlying rocks can not be definitely determined inside the area studied in detail, except in regard to the Solomon schist. Owing, however, to the fact that in near-by areas a rock in many respects similar lithologically has been traced by Brooks and others for long distances, it seems that this rock has a wide extent and is an important horizon in Seward Peninsula geology. It is a peculiar rock, and, like the Hurrah slate, probably represents a sandstone that has been formed of quartzose rocks with very little alumina and has had a large amount of vegetable matter buried with it and converted into carbon. It has subsequently been metamorphosed by mountain-building forces and has developed parallel slaty structure and secondary minerals, such as sulphides and muscovite.

UNMETAMORPHOSED SEDIMENTS.

The sedimentary rocks so far described have considerable areal extent and are of sufficient importance to be mapped separately and to show definite relations with the other rocks. Furthermore, all of these formations up to and including the Puckmummie schist have been affected by metamorphism. There remain, however, a few scattered outcrops which because of their small size can not be indicated on maps of the scale used, but which, nevertheless, deserve mention, because, although insignificant in amount, they throw light on the history of the region. None of them are metamorphosed and all must therefore have been formed later than the last period of metamorphism.

Such rocks are found in four localities, viz, on Birch Creek near the mouth of Shea Creek; on No Man Creek; on Topnotch Creek; and at the head of Fool Creek, a tributary of the Casadepaga. In all these places the rock is a conglomerate or breccia entirely unsheared.

At the locality near Shea Creek (loc. 7AS196) float apparently nearly in place was found. It could not have traveled far, for its distribution is distinctly local. A specimen showed that it was made up of more or less well-rounded fragments of at least four kinds of rock characteristic of the neighboring area. It was thoroughly consolidated, so that on breaking it fractured across the pebbles rather than around them. It had none of the characteristics of a very recent conglomerate such as that frequently formed by spring deposits, but was cemented not only chemically but also by pressure.

The pebbles were seldom over 2 inches in longest dimension, and in general were from one-half to three-fourths of an inch long. They comprised a schist, two different limestones, and a slate. The schist was much crinkled and contorted, with chlorite and quartz as the most abundant constituents. It was such a schist as might easily be duplicated by many specimens from any part of the Solomon schist. Some of its pebbles were reddish-brown where stained with the decomposition of the iron minerals, while others had the greasy, shiny luster of schists low in iron but high in chlorite. The limestone pebbles were of two kinds, a light-colored rock and a dark-bluish one. The light-colored weathered to a dirty yellowish tint which strongly resembled the usual character of the dolomitic limestones associated with the Solomon schist, but so far as determined none of its pebbles were dolomitic. The other limestone was a dark slaty blue, and was similar to the Sowik limestone. Only one or two pebbles of the fourth kind of rock were found. This material was a black quartzose rock which strongly resembled the Hurrah slate. While it is not intended to assert definitely that these fragments have been derived from the rocks to which they bear such strong resemblances, the similarity is suggestive. Furthermore, the absence of all shearing in the rock as a whole, though the individual pebbles are made up of sheared rocks, would substantiate the interpretation that the conglomerate was formed later than any of the other sedimentary rocks previously described. It is to be regretted that the exposures of this interesting rock are not more widespread. The absence of the conglomerate over most of the quadrangle rather suggests that the beds were laid down unconformably on top of the other rocks and, being higher, were more completely removed by subsequent erosion.

Another place where conglomerate is found which may be equivalent to the one just described is on one of the headward branches of No Man Creek, at an elevation of about 600 feet (loc. 7AS191). The information afforded at this place is not clear, and it is possible that the rock in question is a silicified limestone breccia and not a conglomerate. The fragments of which this rock is composed do not show the lithologic diversity that was noted at the locality near Shea Creek. Drusy cavities lined with perfectly terminated quartz crystals are common, and the rock has a more or less porous texture between the different fragments. Some calcite is found in the groundmass between the fragments and in places is abundant. The pebbles, or brecciated fragments, as a rule consist of limestone, quartzite, or limestone replaced by silica.

A much more obvious conglomerate than the one from No Man Creek occurs on Topnotch Creek a short distance above Kasson Creek. Pebbles of vein quartz slightly rounded are common, and black quartzitic slates like the Hurrah formation are abundant. The cement seems to have been calcareous, but it is now quite thoroughly replaced by silica. The exposure of this rock was not in place, but from the extremely localized distribution of the float it seems evident that it could not have been carried far. Owing to the absence of outcrops, it is of course impossible to determine the relation of this conglomerate to the other rocks of the region, but from its unsheared condition it seems probable that it unconformably overlies them. Under the microscope the conglomeratic character is even more evident than in the hand specimen. Large fragments of quartz comparatively free from inclusions are surrounded by finer material, consisting of small quartz grains, with some muscovite and limonite. The groundmass appears to be in part secondary quartz which has replaced an earlier limy cement.

The fourth and last locality where conglomerate or conglomeratic breccia has been found in the area covered by the two quadrangles is at the head of Fool Creek, at an elevation of about 750 feet. This is within the area shown on the map (Pl. VII) as limestone. A heavy talus covers much of the surface, so that areal relations are not well shown. The pebbles, or fragments, do not as a rule show good water rounding, so that some doubt is thrown upon the mode of formation. Several, however, do seem to have been rounded, and the conclusion would appear to be justified that the rock is water deposited, but that its individual fragments were not transported far by this agent. The larger part consists of quartz grains and crystals in which pebbles and fragments of a black quartzose slate are embedded. No black slate is known in the immediate vicinity of the outcrops, so the probability of the rock being a breccia is rather remote. So compact is the rock that it breaks across the pebbles and never around them. From a microscopic examination it seems clear that the groundmass was originally a calcareous cement which has subsequently been replaced by quartz. Although the replacement has gone far, it is possible to detect the presence of a considerable amount of calcite by its effervescence with acid. Only a few fragments of schist were found.

From the foregoing description it will be seen that little of definite value can be said concerning the conglomerates. In two of the four localities the observations were made on float material, and in the other two the exposures were too poor to give satisfactory evidence of the relations. The localities are too far removed from each other to allow any attempt to reconstruct their former distribution, and their known areas are too small to be indicated on the map. In one or two places subsequent investigations carried on with better exposures might show that the so-called conglomerates were really breccias due to faulting. In the Shea Creek locality, however, there seems no way of escaping the conclusion that the rock is really an old water-laid deposit which is in no way to be confused with brecciation, and it is believed that further work in other areas might show similar rocks to have a rather wide distribution.

CALCAREOUS SPRING DEPOSITS.

The latest consolidated deposits in the Solomon and Casadepaga quadrangles, if the recently cemented gravels are excluded, are calcareous deposits formed by springs. These deposits do not form any notable part of the surface and are not indicated on the geologic maps, Plates VI and VII. One of the largest deposits of this material, although covering only a few square yards, is on the slopes of Mount Dixon, near the branches of Dawson Creek. Here fragments of quartz and other detrital material have been held together by a spring-deposited cement and have formed a calcareous tufa. This tufa is cellular, with the cavities filled with crystals of calcite. Wherever seen, it was entirely unsheared and must have been formed at a very recent time. From its mode of origin there is no reason to believe that the deposits were ever much more extensive than they are at present.

IGNEOUS ROCKS.

CLASSIFICATION.

The igneous rocks of the Solomon and Casadepaga quadrangles may be divided into two classes, according to their age. The second period of metamorphism, which had such an important effect on the physical character of all the sedimentary rocks up to and including the Puckmummie schist, forms a good time marker to which the igneous rocks may be referred. Those in existence prior to this period of deformation may be conveniently termed ancient igneous rocks, and those that show by their lack of metamorphism and by their relations to that structure that they were formed later than that period may be called recent. The igneous rocks of the quadrangles have, as a rule, a basic character; and acidic rocks, with minor exceptions (see pp. 83–84), are wanting. The older igneous rocks show a rather wide range of composition and are so much metamorphosed that their original component minerals are often indistinguishable; those of the younger group are typical basalts. The two classes are distinguished by different colors on the map, and their areal distribution may thus be studied. It will be seen that the ancient igneous rocks predominate, and the recent ones form but a few scattered outcrops throughout the area.

ANCIENT IGNEOUS ROCKS.

TYPES.

As has been pointed out in the preceding paragraph, the ancient igneous rocks were intruded before the metamorphism of the region, and therefore all of them show shearing and the development of new minerals. The rocks, because of their age, have been much altered, so that in the majority of cases the original composition is undecipherable. Though the rocks have been metamorphosed, they have not been subjected to the same amount of deformation that has characterized the Solomon schist.

Not only are the igneous rocks of the region divisible into two main groups according to their age, but the older is also divided into two parts, for one shows much greater metamorphism than the other. Each type has been represented on the geologic maps by a separate symbol. The more intensely metamorphosed and consequently the more schistose rock will be called the Casadepaga schist; no specific name will be applied to the other subdivision, but the rocks belonging to it will all be treated under the term "greenstones." Owing to the metamorphism which they have undergone, it is practically unavoidable, where the Casadepaga schist and the Solomon schist occur together, that the line of separation should be poorly defined.

CASADEPAGA SCHIST.

Distribution.—The rocks included in this group are widely distributed and form large areas not only within the region studied in detail but also in many other parts of Seward Peninsula. Within the quadrangles the Casadepaga schist is most extensively exposed in two belts—one along the eastern and the other along the western margin of the quadrangles. An idea of the general distribution may be gained from the geologic maps, Plates VI and VII. The belt which passes out of the mapped area north of Rock Creek is practically in direct continuation with the schists near Bluff described by Brooks.[a] (See pp. 73–74.) So also the northeastern continuation beyond the mapped area can be traced for a considerable distance and has been recognized by the writer on the Niukluk above Council City. Similar schists have also been found in the Nome and Grand Central regions. They also occupy large areas in the upper part of the Casadepaga River basin and to the west of Iron Creek and have been recognized in other parts of Seward Peninsula. It is believed that a more careful search in outside areas would greatly extend their known occurrence. From the large area known to be occupied by them the intrusions that they mark must have had widespread effect upon the history of Seward Peninsula.

The Casadepaga schist covers an area of about 100 square miles and over this surface maintains features which renders it distinct from the other rocks. Although its lithology does not definitely prove its igneous origin, this criterion, when coupled with its structure and field relations, lends strong support to that interpretation.

Mineral character.—Lithologically the Casadepaga schist is characterized by a much higher per cent of alumina than any of the rocks with which it might be identified. It is much lower in silica and in typical specimens seldom contains more than 25 per cent of quartz. The alumina content is represented by the minerals muscovite, chlorite, and feldspar. So characteristic is its high percentage of feldspar that it has been possible in the field to differentiate these schists,

[a] Bull. U. S. Geol. Survey No. 328, 1908, pp. 285–286.

where other criteria were lacking, on the basis of the presence or absence of this mineral. Although in many regions the presence of feldspar has little or no significance in determining the original character of the rock, yet in the Solomon and Casadepaga area, whenever evidence is afforded by other means, it has been found that schists of clearly igneous origin are always feldspar bearing. From this fact it has been assumed in the absence of other evidence that the feldspathic schists are different from the other schists and are usually of igneous origin. It is relatively easy to separate the Casadepaga schist from all the other rocks except the Solomon schist. Where these two rocks are in contact, however, the contact is more or less obscure because the igneous rock undoubtedly penetrated the sedimentary schist and developed minerals more common to intrusive than to clastic rocks. Where this relation is further complicated by strong dynamic metamorphism, it is evident that the relations become obscure and often undeterminable.

A typical specimen of the Casadepaga schist was taken from the 1,750-foot hill in the extreme northeast corner of the Solomon quadrangle (7AS223, loc. 7AS219a). This rock is light greenish and highly schistose. Abundantly scattered through it are small, nearly square cross sections of feldspar which give the rock a distinctly speckled appearance. When studied under the microscope the various grains appear to have a well-developed parallelism. Quartz forms about 17 per cent of the specimen. Most abundant of the minerals are chlorite and muscovite, which together form about 55 per cent of the thin section. Of these two, muscovite is about 5 per cent in excess of the chlorite. The soda-rich plagioclase feldspar, albite, forms about 20 per cent. The remaining 8 per cent is made of epidote, zoisite, and magnetite. Of the three, epidote is the most abundant, forming about 4 per cent of the entire rock. Zoisite only forms about 1 per cent, and magnetite makes up the other 3 per cent.

It is not intended to set up the foregoing analysis as representing fixed ratios which prevail throughout this member. For instance, another specimen (7AS19, loc. 7AS74) from the upper part of Chicken Creek, shows the following percentages of the different minerals: Feldspar 30, quartz 10, muscovite 25, chlorite 20, zoisite 5, epidote 8, magnetite, rutile, and hematite 2. Another (7AS484, loc. 7AK134) from the ridge south of Adams Creek, shows only 10 per cent feldspar, 20 per cent quartz, and 60 per cent muscovite and chlorite, the other 10 per cent being made up of from 1 to 2 per cent each of the following minerals: Garnet, zoisite, rutile, magnetite, and tourmaline. The rutile occurs abundantly as inclusions, which are especially numerous in the garnets.

The rock has been recrystallized so that but few of the pieces can be regarded as original in the form in which they now occur. As has been pointed out, however, there is reason to believe that there has been but little introduction of material from outside sources. It is probable that the feldspar is the recrystallized representative of earlier-formed aluminum and soda-rich minerals which were in part, at least, feldspars. Clarke[a] has stated that in the zone of deep burial of the earth's crust the amount of transfer of material becomes relatively slight, and therefore it follows that the chemical and physical changes due to metamorphism take place in rocks that have more or less nearly their original chemical composition. The writer desires to assert distinctly that most of the feldspar in the Casadepaga schist is secondary but believes it to have been derived in part at least from earlier-formed feldspars. Proof of the igneous origin of the schist rests on its structure and field relations rather than on its chemical composition, for, save for the higher soda-alumina and lower silica content, analysis shows it to correspond with the least calcareous phase of the Solomon schist. Beside the highly feldspathic schists which are characteristic of this group, there are schists of a silvery-gray color flecked with isolated and irregularly distributed flakes of chlorite, which give the rocks a distinctive appearance in the field. Feldspar is practically lacking in many of the representatives of this type, but its place is taken by epidote or zoisite, which show an increase over the amount of those minerals normally found in the feldspathic schists. A typical exposure of one of the nonfeldspathic, epidote schists in the Casadepaga schist is afforded by outcrops on the 1,025-foot knob west of Big Four Creek, 1½ miles north of Surprise Creek. A specimen from this place (7AS438) shows a decidedly schistose grayish-green rock with abundant mica scales and with the peculiarly distributed dark-green chlorite. Under the microscope the individual minerals show well-developed parallel arrangement. Quartz forms about 35 per cent of the rock. Epidote and zoisite form 27 per cent, of which the former makes up at least nine-tenths. Muscovite and clinochlore together form 35 per cent, the muscovite making 25 per cent and the clinochlore about 10 per cent. The remaining 3 per cent is composed of magnetite, limonite, calcite, garnet, rutile, and a very little tourmaline. Of the minor constituents the iron oxides form the greater part, and calcite and tourmaline are so small that they may be neglected. From the general distribution it seems that the feldspathic and zoisitic phases of the Casadepaga schist occur very closely associated and were of essentially the same original composition, but differ in their present mineralogical characters because of differ-

[a] Clarke, F. W., The data of geochemistry: Bull. U. S. Geol. Survey No. 330, 1906, p. 505.

ences in amount and nature of the metamorphism that they have undergone.

Origin.—Since, as has already been pointed out (p. —), the determination of the igneous origin of the Casadepaga schist rests more upon its areal and structural relations than upon its chemical composition, a study of these relations is of importance.

So far as the feldspar schist proper is concerned it is known to cut all the sedimentary rocks of the region up to and including the Sowik limestone. It has not been definitely proved to cut the Hurrah slate, and it is still a question whether it was not developed prior to the deposition of this formation; certain it is that it has been much more thoroughly sheared and metamorphosed. As will be noted later (see p. 84) in considering the younger division of these early igneous intrusives, some of the igneous schists appear older than the others, but exposures and field characters are not such as would permit differentiation at the present time. From present information concerning these rocks it appears that the larger part were formed after the Hurrah slate. (See p. 131.)

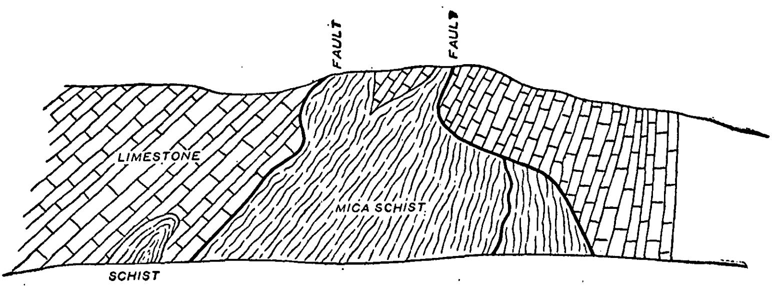


FIGURE 11.—Diagram showing relation of schists and limestones at Bluff.

Perhaps the most definite information concerning the relation between the Casadepaga schist and the other rocks is afforded where that member is in contact with the Sowik limestone. With rocks of such different character the contacts can be much more closely followed, even where actual outcrops are wanting, by the distribution of the float. In his report on the Bluff region, Brooks publishes a text figure, here reproduced (see fig. 11), showing relations similar to those found in many parts of the Solomon and Casadepaga region. Concerning the schists at this place, Brooks says:[a]

Mica schists occur as irregular masses within the limestone belts, and although they do not differ lithologically in any very essential way from the schists believed to be of sedimentary origin, their mode of occurrence strongly suggests that they are altered intrusives. The most striking example is seen in the cliff exposures just east of the mouth of Daniels Creek. [See fig. 11.] Here an irregular mass of mica schist is inclosed in limestone walls. Lines of faulting have obscured the original relation of the two rocks, but the outline of the schist mass is very suggestive of an

[a] Bull. U. S. Geol. Survey No. 328, 1908, pp. 285-286.

> intrusion. The schist, whatever its original character, has been intensely deformed, and at this particular locality has been intruded by many quartz veins. * * * Further evidence of the intrusive character of some of these schists is found in the fact that at various localities the limestone walls are more or less metamorphosed. These facts, together with the irregular distribution of the schist, indicate an igneous origin, though it must be confessed that the evidence is by no means conclusive.

This is one of the first references to the probable igneous origin of the schists that has been made. Evidence of the igneous origin of the schist is also afforded by its areal distribution. Figure 12 shows a part of the area around Moonlight Creek. (See Pl. VII for a more generalized geologic map of this region.) Figure 12 shows generalized conditions, but it serves to bring out clearly the irregular

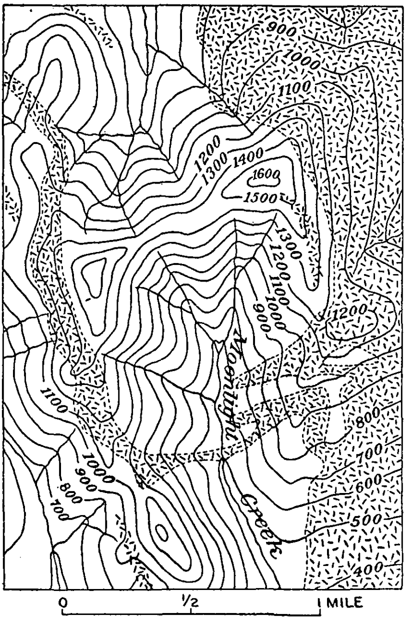


FIGURE 12.—Map showing distribution of Casadepaga schist near Moonlight Creek.

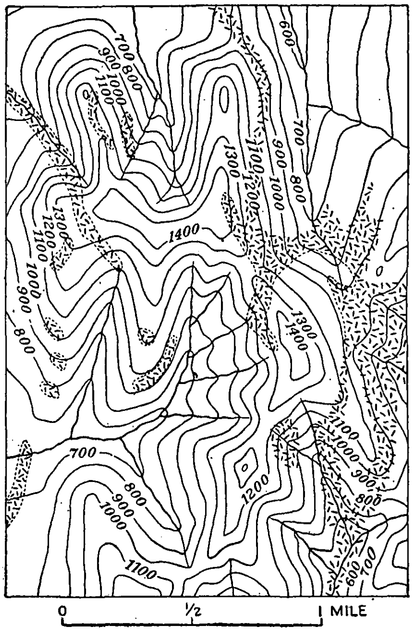


FIGURE 13.—Map showing distribution of Casadepaga schist west of Johns Creek.

contact of the larger mass on the east and the narrow dikes and apophyses that intersect the limestone, which forms the unshaded area in the diagram. It is practically impossible to assign other than igneous origin to rocks thus irregularly distributed. All these rocks show the peculiar feldspathic characters already noted in the preceding lithologic descriptions.

The intrusive character of the schist is also shown by the manner of its distribution in many other places. Figure 13 shows a portion of the divide between Shovel and Johns creeks and the tributaries of the Casadepaga. Here the areal distribution has not been fully worked out, owing to the heavy talus covering, but enough is clear to bring out the irregular distribution which even on superficial examination is seen to resemble igneous dikes and stocks rather than beds of clastic origin.

Both the occurrences cited are from regions where limestone forms the country rock, but there are many other localities where the same relations exist between the Casadepaga and Solomon schists; in these, however, the distribution can not be so thoroughly worked out unless the exposures are exceptionally good. It is believed, however, that the fact that these igneous schists cut the limestone which overlies the Solomon schist is sufficient proof that they also cut the underlying member.

Further proof of the igneous origin of the Casadepaga is afforded by the fact that some of the schists may be traced by gradual stages from the typical feldspathic schists into the greenstones which form the later group of the older basic igneous rocks of the region. This proves definitely that the feldspathic schists have been derived in part from the shearing of previous igneous rocks through mountain-building movements. It should be stated, however, that although some of the feldspathic schists were undoubtedly formed from rocks similar in composition to the greenstones, a part of the greenstones are later than these schists, for they show but slight evidences of having been subjected to the same amount of metamorphism. This interpretation, however, raises the question as to the conditions under which the greenstones were formed, and it will be considered later (p. 82).

Summary.—The arguments on which the subdivision of the Casadepaga schist from the other members of the sedimentary Nome group is based, are as follows. These rocks have not been derived from any of the rocks of the sedimentary sequence by shearing, for their composition, as far as can be determined by microscopic investigation, is more or less different. The difference is such that it can not be explained by the normal changes which usually accompany metamorphism under the conditions indicated by the physical character of the schists. Furthermore, these schists have an extent which proves that the presence or absence of certain minerals is not a local feature but is widespread. This distinct mineralogical character is preserved whether the schists are in contact with quartzose schists, limestones, or carbonaceous quartzites and slates. Therefore, it is not a condition attributable to the particular environment in which they occur but seems to be an inherent character of the rock itself. All these facts would show that these schists are not the equivalent of any of the other rocks. From the character of the contacts and from the areal distribution of the Casadepaga schists, it has been determined that they are of igneous origin.

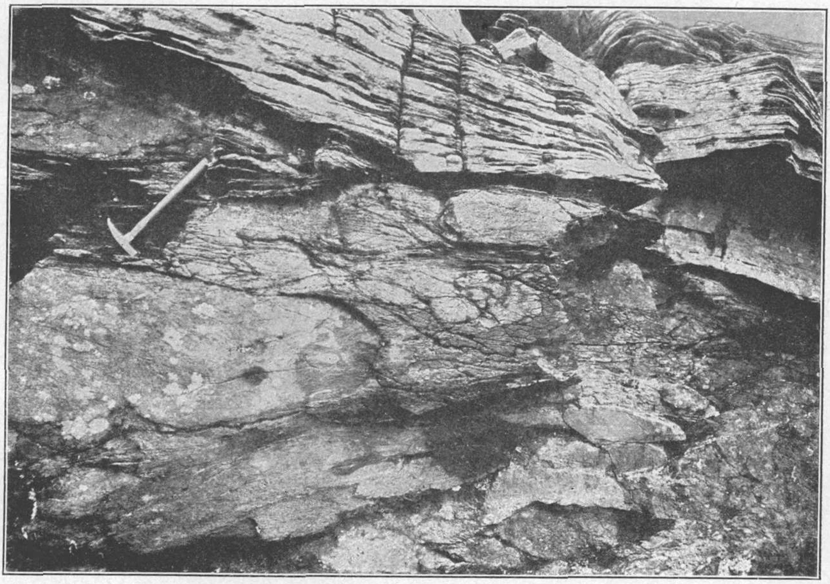
GREENSTONES.

Composition.—Typically the greenstones are composed of amphibole, feldspar, and a little quartz, but there is no evidence that any of these minerals are original in the sense that they have been formed in the same condition in which they now appear. It was early recognized that in places the composition of the rock varied but slightly from that of the contiguous rocks and that often one or more of the characteristic minerals was missing or its place was taken by a mineral more characteristic of the schists than of the greenstones. In fact, there is strong reason to doubt that a chemical analysis of the greenstones would give more than a clue to the original composition. However, although much of the material has been recrystallized, and although additional material may have been acquired from and certain elements may have been transferred to the wall rocks, there is still a sufficient amount of the original material remaining to warrant a guess as to its composition. When attacked in this way, it may be said that the original character was not far from that of a diabase.

Structural relations.—From the field study it was learned that the greenstones were later than a part of the metamorphism and yet earlier than the later deformation. Instances were found where the greenstones cut one structure but are cut by a later one. This condition is illustrated in Plate VIII, *A*, which shows one of the less metamorphosed greenstones cutting across the cleavage of the schist. This outcrop is situated on Victoria Creek, a short distance above the mouth of Coal Creek. The schists shown in the right-hand part of the view are so intensely metamorphosed that their original structure is not determinable, but their secondary structure, cleavage, is nearly flat. The greenstone dike, however, dips at an angle of about 60° NE. and strikes N. 30° W. In this illustration the dike seems less sheared than is actually the case. When the actual contact is studied in the field, it is evident that the dike is much sheared and metamorphosed. A slight impression of the intrusive character of the contact is afforded by the nose of schist in the greenstone near the middle part of the illustration.

A curious thing, when the general basic character of the greenstone is considered, is the amount of quartz which seemed to mark the closing stages of the intrusive activity. The quartz occurs as filling of the contact zone and also as strings in the midst of the greenstone. It all shows considerable crushing and nowhere has complete crystal form. Often the ends of the apophyses sent out along the cleavage planes of the schist are more quartzose than the central part of a dike, but this is not universally the case. The relation of the quartz to the greenstone seems to be in all essential

A. GREENSTONE AND SCHIST CONTACT, VICTORIA CREEK.



B. LIMESTONE HORSES IN GREENSTONE.

respects similar to the pegmatitic stage of granitic intrusions. The acidic material may thus represent the residue left at the end of the period of basic intrusion. In no sense are these later quartz strings comparable to any of the series of metalliferous veins described on pages 89–90.

In the field the greenstones have been found cutting all the other rocks with the exception of the feldspathic schists, and the relation to these rocks is, as already pointed out (p. 75), uncertain. The Victoria Creek locality will serve as a good example of the relation of the greenstones and the Solomon schist which form the lower part of the Nome group.

In the divide between the head of Daisy Creek and the first tributary of East Fork west of Lime Creek a limestone, possibly belonging to the Sowik but tentatively assigned on the geologic map (Pl. VI) to the limestones associated with the Solomon schist, is definitely cut by a greenstone. This occurrence is particularly interesting, for there are horses of limestone, much resorbed, it is true, in the greenstone. These horses may be recognized in the light-colored areas in Plate VIII, *B*, near the spot marked by the end of the hammer handle. The layered rock in the upper part of the view is limestone, and the more massive lower member is intrusive greenstone, which in this particular portion of the outcrop is nearly conformable with the limestone. When the illustration is hastily examined, the greenstone appears to be a massive, practically unsheared rock, but when it is studied with more care it becomes apparent that it is much sheared, and that a cleavage, coincident with the main cleavage in the limestone, has been developed. This conclusion is even more strikingly demonstrated by a study of the actual outcrop or of the rock specimens under the microscope.

The only place where greenstones have been actually seen cutting the black slate is in the southeastern part of the Casadepaga quadrangle on the small knob at an elevation of 1,225 feet, near the head of the tributary of Big Four Creek above Surprise Creek. At this place a greenstone similar in all respects to the greenstones found elsewhere throughout the region forms a dike cutting the black schists, which are here but slightly metamorphosed. The structure is complex, and there is strong evidence of pronounced faulting. It is suggested that here the greenstone occupies a fault plane. The absence of metamorphism, in spite of the small amount of regional or dynamic metamorphism, is a feature the reason for which is not apparent. At this place the dark, nearly black limestone, which usually forms the base of the slate series, is intersected by pipelike strings of igneous material of fine texture and small cross section. These intrusives give a brecciated appearance to the limestone.

The green feldspathic schists, which cover such a large area in the eastern part and form patches in other parts of the field, in places grade into the greenstones. (See p. 75.) This raises the question as to whether the Casadepaga schist has been formed by the shearing of the greenstones or whether the latter have been produced by the complete recrystallization of the schists under deep-seated metamorphic conditions. From evidence afforded by other fields either interpretation is possible. In this area, however, the second suggestion does not seem to be as likely as the first and seems to be refuted by several lines of evidence. In the first place, the greenstones in many parts of the field are definitely in dikes and sills. Descriptions of one or two such localities have already been given and illustrated. (See Pl. VIII, *A* and *B*.) In the second place, the small area occupied by the greenstones would of itself seem to indicate that these could not have been produced by recrystallization under great pressures, for under such a condition the distribution would show either a marked relation to the lines of great deformation or would be of much greater areal extent. According to either of these conditions it is presumable that the greenstones would show a more or less systematic arrangement and would not be scattered throughout the region so irregularly as is represented on the geologic maps, Plates VI and VII.

On the other hand, if the feldspathic schists have been derived from the greenstones by shearing, dikes and sills of the latter would naturally remain. Furthermore, in those places where the greenstone does not occur in dikes and sills, it would follow, if the supposition that the schists are the sheared equivalents of part of the greenstone is correct, that the distribution of the unsheared rock would be very irregular. It would also follow that the area of the unsheared rock would depend on the degree of the metamorphism. If the deformation was intense the small size of the greenstone areas would be explained by this mode of derivation, whereas it would not be on the theory that the greenstones were recrystallized from the Casadepaga schist.

Partly from these two lines of argument, but primarily because rocks of the same general character are recognized in narrow dikes and sills, it is concluded that in this area the greenstones have not been formed from the schists but that the reverse process is true.

Mineral constituents.—Some additional light is afforded by petrographic study of the greenstones and associated rocks. In almost all cases the amphibole, which is a common constituent, is bluish and is closely allied to the soda-rich hornblende, glaucophane. The glaucophane rocks are of widespread occurrence in the countries around the Pacific Ocean, from South America, through California and Alaska, and in eastern Asia and Japan. Glaucophane is a mineral which is found in both sedimentary and igneous rocks which have been subjected to metamorphism. It can only be formed, however, in those places where soda is present. This point is of some importance in considering the geology of Seward Peninsula, for with the exception of albite no other soda-bearing minerals are known. Although much of the amphibole has recrystallized and is not, therefore, in the original condition, it becomes significant, when it is remembered that the only other soda-bearing rocks in the area belong to the feldspathic schists of the Casadepaga formation. Either, then, the material of which the glauc-amphibole is formed was introduced by igneous activities, or albite feldspar has been metamorphosed so that it has yielded up its store of soda. No glaucophane could be produced except by one or the other of these actions. In either case the amphibole becomes a diagnostic feature of certain kinds of rocks and of those kinds only.

The reason for introducing the subject at this point, as was stated, was to throw some light on the origin of the greenstones. In the case of the rocks just described the field evidence seems too strong to be controverted by laboratory deductions, but in many areas the evidence is not so conclusive and it becomes necessary to treat the subject on purely theoretical grounds. In such cases the student needs as much information concerning other areas as is possible. If considered with this necessity in mind, the greenstones of Seward Peninsula are valuable as showing intrusive rock masses, similar in physical character to eclogites, which have not been formed by static metamorphism at great distances below the surface. Proof of this lies in the fact that in many places the greenstones which cut the cleavage of the schists are in bands so thin that static metamorphism could not have produced them without an impossible intensity of localization. The same reasoning suggests that the shear structures in the schist would become more and more obliterated as the region of static metamorphism is approached. Furthermore, the eclogite-amphibolite condition should affect all kinds of rocks and not simply those with a composition capable of yielding soda. Therefore, both from the results of the field examination and from theoretical considerations, the statement seems justified that in this area rocks resembling eclogites and amphibolites have been formed which in no sense owe their physical condition to enormously deep burial but must have been produced at a relatively slight depth below the surface. The necessary conditions for the formation of these rocks are believed to reside in the processes of igneous intrusion. Although the evidence seems conclusive in this case, it is realized that there may be other areas where such an interpretation is not permissible.

In addition to the amphibole minerals found in the rock there are many others which deserve mention and description. Plagioclase feldspar is a common constituent in the greenstones, but it is not always present. Where this mineral does occur it is practically always as a triclinic feldspar. In only one slide was the presence of orthoclase suggested, and its occurrence then was not at all certain, as the absence of much decomposition indicated that even this questionable material was not the potash feldspar. Albite is one of the most common plagioclases present, though others higher in their percentage of lime are sometimes found. The feldspars have been broken and reformed by the dynamic metamorphism the rocks have undergone, so that it is often a question as to what was the original character and distribution of this mineral. From the evidence now at hand it would seem that the amount of feldspar decreases more or less in proportion as the amphibole increases. If this be the case it would seem as though some of the soda required for the production of the glauc-amphibole was derived from the albite or vice versa. No definite proof of this suggestion has been obtained.

Garnets are present in the greenstones. They are always pink or red and never of the colorless lime varieties. Their outlines are frequently sharp and show that they have been among the later-formed minerals. Their number and distribution vary greatly in the different greenstones, but they are practically never entirely absent. It is on the strength of these well-formed garnets and amphiboles that Moffit[a] in his work on the region to the west has referred similar rocks to the amphibolite-eclogite series. Such a determination is perhaps safer than to refer them to the more ancient rock from which it is believed they were derived. It seems, however, that the more numerous observations which have been made since Moffit's study would warrant their reference to the diabase group.

In some of the greenstones garnet is abundant and forms large-sized crystals. On Coal Creek a greenstone was found with garnets over half an inch in diameter. Owing to weathering the garnets stood out on the surface as knobs. When the rock was studied under the microscope it was seen that the garnet was so filled with inclusions that over a third of it was formed of other minerals. The spaces between the large garnets were filled with other minerals, such as quartz and amphibole. The amphibole had recrystallized and appeared to be nearly fresh, but the quartz had been much strained optically and appeared to belong to a stage earlier than the metamorphism which produced the garnet and amphibole. This was further substantiated by finding frequent pieces of quartz in the midst of the garnet.

The larger part of the garnet or so-called "ruby," which is so common in the beach sands of the coastal plain and in the creek and bench placers throughout Seward Peninsula, is undoubtedly derived from

[a] Geology of the Nome and Grand Central quadrangles (in preparation).

areas of greenstone, these being the only rocks which carry any considerable amount of this mineral. Some is also found in the Solomon and Casadepaga schists and in the granite of the mountain province to the north, but the amount occurring in any of these is relatively insignificant. There is undoubtedly more of the greenstone present in the region than is realized, for float is found in practically all the creeks.

It has already been noted that quartz forms a small part of the greenstones. Its occurrence, however, is not such as to point clearly to its time of introduction or mode of origin. In some cases it is undoubtedly older than the formation of the amphibole and garnet and also older than a certain amount of deformation. In spite of this it is still a question whether the quartz was an original constituent of the greenstone in the form of quartz or whether it may not represent the separation of quartz due to the breaking down of complex silicates in an earlier period of metamorphism. The importance of this determination is the bearing it has on the original character of the rock, for free quartz indicates a more acidic variety of magma than the silicates do. It is a question, however, for more minute petrographic investigation than is warranted by the scope of the present report.

Chlorite is almost universally present in the greenstone as a decomposition product. It has been derived mainly from the ferromagnesian minerals. As is usual, it is found in irregular aggregates, sometimes forming a halo around the amphiboles and at other times entirely isolated from all minerals from which it could have been derived, so that its origin is in doubt. In such cases as the last the chloritic material has undoubtedly been transported while the rock was as yet unconsolidated. No attempt has been made to determine definitely the exact members of the chlorite group represented in these rocks, but both pennine and chlinochlore have been recognized.

The epidote group of minerals is represented by epidote and zoisite. Both are usually present together, and if one is absent the other, as a rule, is also wanting. As the amount of epidote or zoisite increases the amount of feldspar decreases. The zoisite often occurs in crystals with perfect crystalline outline, showing that it was probably one of the earlier-formed minerals which resulted from the recrystallization of the former igneous rock. Frequently there are aggregates of plagioclase and zoisite, which seem to have been derived from the decomposition of the feldspars. In almost every case the group of epidote minerals is fresh and shows but slight effects of chemical decomposition.

From the standpoint of amount, mica and sericite are among the less important minerals occurring in the greenstones. The most common mica, muscovite, is sometimes sparingly present. The mica is in well-formed blades arranged nearly parallel with the secondary structures in the greenstones and seems to have been formed later than the period of metamorphism. The plates are not frayed or bent and therefore could not have been subjected to any considerable degree of deformation. It is not easy to account for the potash of which the muscovite is formed, unless it was originally present in the form of orthoclase or muscovite.

Iron oxides and sulphides are everywhere present in this group of rocks. Magnetite is perhaps the most common of the oxides, but ilmenite, with its accompanying coating of leucoxene, is frequently to be recognized. Undoubtedly much of the magnetite forming the "black sand" of the placers has been derived from the weathering and disintegration of the greenstones. Sulphides are not abundant, but have been recognized in many places. (See p. 93.) Those found are usually iron pyrite, accompanied in a few instances by specks of copper sulphide. These sulphides are in small amounts and might easily escape detection. Many of the iron minerals have become oxidized and hydrated into limonite. No heavy coating of gossan, however, is formed, and only when the rocks are exposed to humic acids by burial under vegetation does iron staining become noticeable.

Occurrence.—The usual mode of occurrence of the greenstone is in dikes and sills which take advantage of the cleavage planes and so appear parallel to the dominant structure. This feature is more pronounced because in the later metamorphism the dense massive rock formed a layer which influenced the direction of cleavage so that it was more or less parallel with the direction of igneous intrusion. It is possible, however, that some of the greenstone may have been originally a surface flow. The amount of deformation undergone since its formation and the fact that it is more or less thoroughly recrystallized prevents a positive unraveling of its earlier history, all the criteria by which the identification could be made being obscured to such an extent that they are unrecognizable. If, however, any of the greenstone was a surface flow, the dikes whose character has been definitely proved might be regarded as the fissures through which the igneous material was brought to the surface. Further, if some of the greenstone is effusive it must have been subsequently rather deeply buried to account for the metamorphic effects already described. In view, however, of the uncertainty which exists, speculation and the construction of involved hypotheses on the question seem to be inadvisable.

Because the greenstones are as a rule less thoroughly sheared than the schists of the lower members of the Nome group the fragments derived from the disintegration and weathering of the outcrops are usually larger and more resistant. Consequently bowlders of greenstone are more noticeable and tend to collect and give the appearance of a greater area of outcrop than actually exists. But while allowance must be made for the better preservation of the rock, it is evident that it is abundant throughout the area of the two quadrangles. Many of the smaller dikes have undoubtedly escaped detection, owing to the heavy mantle of surface covering, and the maps (Pls. VI and VII) should be interpreted as indicating only the larger, more prominent areas. In other places, however, on account of the gradual merging of the greenstones into the feldspathic schists, the boundary is so vague that often errors have been introduced in attempting to separate the two definitely.

RECENT IGNEOUS ROCKS.

ACIDIC INTRUSIVE ROCKS.

Within the Solomon and Casadepaga quadrangles there are practically no outcrops of rocks belonging to the granitic family. The only exception that has been found was on Willow Creek, near the mouth of Rock Creek. At this place a schist outcrops with a strike N. 50° W. and a moderately low dip to the southwest and is intersected by a number of small dikes of a much decomposed reddish-brown rock. The exposure is too small to be represented on the geologic maps. When examined in the field, this rock shows abundance of kaolinized feldspar and glittering white mica. The contact between the dike and the wall rock is clear cut and sharp, but apophyses of the igneous rock penetrate for short distances along the cleavage planes.

Under the microscope the rock appears to have a distinct granular structure and is essentially unsheared. The chief components are quartz and orthoclase. Muscovite is abundant, but it can not be definitely stated whether any of it is original. From the structure of the rock and from the primary constituents, the rock is a granite or an aplite. Besides the primary constituents, there are many later-formed minerals due to the decomposition of the granite; the most important are chlorite, calcite, kaolin, and sericite.

The rock is much decomposed, but it shows no shearing. Furthermore, the granite definitely cuts across the cleavage of the schist and the cleavage is not continued into the granite, so that its intrusion must be later than the main deformation of the schist series. This is of some importance, for it shows that the intrusion of the granite took place after the period of deformation by which the cleavage of the schists was produced. The merits of this determination will be discussed at greater length later. (See pp. 132–133.) Although the number of exposures of granite so far found within the quadrangles is small, and although probably few other areas will be found, the occurrence is significant.

Before passing from this subject a brief description of the microscopic character of the wall rock may be permitted. The schist consists essentially of quartz, chlorite, and muscovite. In addition there is a little calcite and iron oxides with some questionable zoisite. Tourmaline appears in minute crystals, and its presence in the contact zone is of some significance. Tourmaline is quite characteristic of igneous rocks and contact zones, and one might be justified in predicating igneous intrusion near those places where tourmaline is found; it occurs, however, in several places where no granite exists. Nowhere is tourmaline so abundant that it can be recognized with the unaided eye, but microscopic studies have shown that it is present in widely separated areas. In the Solomon quadrangle it has been recognized in the schists south of Adams Creek at an elevation of about 700 feet. North of this place it was found in schists occurring between Doverspike and Oro Fino gulches. In the eastern part of the quadrangle it was recognized in specimens from near the mouth of Boise Creek and on the hills near the head of the Klokerblok.

In the Casadepaga quadrangle tourmaline was found in the schists on the Casadepaga between Grouse and Squirrel creeks and also in the thin band of feldspathic schist which cuts the Sowik limestone on the western shoulder of the 1,515-foot hill at the head of Grouse Creek. The location of this belt is represented in the more detailed map, figure 13. Tourmaline is also found in the basin of Big Four Creek. A specimen of the schists associated with thin limestone bands west of the mouth of Birch Creek showed a few crystals of tourmaline, and other schists from the 1,025-foot hill west of Surprise Creek also contained microscopic particles of this mineral. As its presence can only be recognized in thin sections, probably a much more extensive distribution would be indicated if more specimens had been examined microscopically.

BASIC INTRUSIVE ROCKS.

Distribution and age.—Regarding the next series of igneous rocks, the recent basic intrusives, there is practically no evidence from the field studies to show their relation to the granites. They form but an insignificant part of the country rock of the quadrangles, and with so few exposures definite determination of their precise position is impossible. From their structure and from their relation to the surface, both at the time of intrusion and at the present day, it would appear that they belong to a later period than the granitic intrusions previously noted. There will be occasion to revert to this question later (pp. 133–134) and to discuss the light that these rocks throw upon the history of the region.

Basic intrusions are found in six localities: On Monument Creek; on the Johnson-Curtis Creek divide; on West Creek; on East Fork;

on the slopes of the 920-foot hill south of Winnebago Creek, and near Rock Creek, in the extreme southeast part of Solomon quadrangle. In only two of these places are the relations to the neighboring rocks clearly shown, and in both cases the rocks appear to be dikes. In all five places the rocks have similar characters, both as regards their structures and their mineralogical composition. They will be accordingly classed together, and an intrusive origin assumed for all, although, as noted above, the field evidence, of itself, is not always sufficiently conclusive.

Monument Creek.—The outcrop of the basic intrusive on Monument Creek is near the mouth of the stream. The schists in the neighborhood are of the quartz-zoisite type and show a predominantly flat cleavage, although in detail the cleavage is much wrinkled and contorted. The intrusion lies nearly parallel with the general flat cleavage, but the actual contacts are not exposed. Upstream and relatively higher geologically than the schists at the mouth are brownish-weathering impure limestones, which in turn are succeeded by quartzose schists, similar to those at the mouth and probably underlying the impure limestones. The predominant strike of the intrusion is N. 20° E., and the dip is toward the northwest at a low angle.

In hand specimen the rock is dark and medium-fine grained, with numerous amygdules, which are sometimes over an inch in length, and which show a slight elongation parallel to the contacts; this last, however, is not very marked. The rock breaks into large blocks, which are usually covered with a thin coating of iron oxide. The thickness of this decomposed layer is not more than one-sixteenth of an inch, and fresh material is readily obtained. The filling of the amygdules weathers more rapidly than the rest of the rock, causing the formation of numerous small pits.

Under the microscope, the rock appears to be a typical basalt. The structure is micro-ophitic. The most abundant mineral is feldspar of the plagioclase family. The optical properties indicate that the feldspars are closely allied to the labradorite-bytownites, or the more basic end of the albite-anorthite series. The feldspar occurs both as moderately large phenocrysts of determinable size and as fine needles forming part of the groundmass of the slides. Iron oxides are the next most important of the original constituents. These are usually in the form of magnetite. A little augite is sometimes present, but it is generally in small amounts. Its absence is to be accounted for mainly by the decomposition that the rock has undergone.

Secondary minerals are common, and form a considerable part of the slide. The pyroxenes, as already noted, have frequently broken down to form chlorite. Chlorite and serpentine are also formed from the mineral or minerals that previously occupied the interstices between the feldspar laths. What the original character of this material was is not definitely known, but it is presumed that a part, at least, was glass, which was formed by the rapid cooling of the rock. The amygdaloidal cavities have been filled with secondary minerals, of which quartz and calcite are the most abundant. In addition to the large amygdules seen in the hand specimen, there are a great number of smaller ones, about 0.25 millimeter in size, which under the microscope are seen to form a large part of the slide. The central part of these cavities is filled with calcite, which is usually surrounded by a ring of quartz made up of minute crystals. The small amygdules are irregular in outline and show no constant direction of elongation. In no case do the slides show that the basalt has undergone any shearing or deformation since its intrusion. This is important, as it gives a clue to the relative age of the rocks.

Johnson-Curtis Creek divide.—On the divide between the head of Johnson and Curtis creeks, cutting the heavy white limestone which forms the country rock, is a dike of a basic igneous rock. The general strike is N. 15° E., and the dip is apparently nearly vertical. This place is only about 2½ miles from the Monument Creek dike, just described, and is almost on the same strike. The dike, however, is so narrow that it is difficult to believe such a thin intrusive could have persisted for such a distance. This is not a conclusive objection, but as none of the rock was found in the intervening area, direct connection between the two is not indicated. Southward, however, the dike can be traced with almost no interruption for nearly 1½ miles. It is never over 3 or 4 feet wide, but its black float and the line of vegetation growing on it is in strong contrast to the bare white limestone that forms most of the surface.

In the hand specimen the rock shows a fine-grained porphyritic texture with some amygdaloidal cavities, which are filled with calcite. The constituent minerals recognized are feldspar and olivine. Some sulphides may also be detected. Decomposition has advanced to a very slight extent, and there is practically no iron oxide coating on the disintegrated fragments. This is perhaps due to the well-drained character of the adjacent limestone, which retards the decomposition usual in wetter places. No shearing has affected the rock, and dominant jointing is also normally absent.

When examined under the microscope the rock is seen to have a fine-grained granitic texture, some of the minerals being holocrystalline. Of the primary constituents, feldspar is the most abundant. This often occurs in crystals showing notable zonal growths. From the optical properties it has been determined that oligoclase often forms the outer portion around a central core of labradorite. All the feldspars are of the plagioclase group and show but slight alteration. Pyroxene is the next most important mineral, two different members of this family being found in the rock. One of a light brownish-pink color suggests titaniferous augite, the other of a nearly colorless aspect is probably allied to the malacolites. These minerals show but a small amount of alteration.

Biotite in brownish blades, now mostly chloritized, forms the next most important constituent. Olivine is also abundantly represented by large phenocrysts with perfect crystalline outlines. Most of the olivine has been badly decomposed so that but a small amount of the original material is preserved. The characteristic form, however, of the crystals, and the way in which the alteration into chlorite and serpentine has proceeded along the fracture planes is sufficient to warrant the determination. Magnetite is also abundantly scattered through the rock as an original constituent.

Most of the secondary minerals have already been mentioned in describing the decomposition of the minerals from which they were derived. Opaline silica, which has been introduced into the rock after it consolidated, is often found as the filling of the amygdaloidal cavities. This mineral is nearly colorless and has no diagnostic value. It is a common filling of cavities or fissures in rocks all over the world. Although this rock is in contact with the limestones, it seems to be entirely free of any calcite, either as an original or secondary constituent.

West Creek.—At the forks of West Creek, near the western margin of the Solomon quadrangle, almost in line with the two localities just described but apparently not directly connected with them, bowlders of some recent amygdaloidal rock have been found. These were not in place, but their character shows that they could not have traveled far. In the hand specimen the rock is of dark-grayish color, with aphanitic texture and numerous amygdules filled with chalcedony and calcite. The rock is so fine grained that few of the component minerals can be recognized in the field.

Under the microscope the rock appears to be a basalt consisting mainly of plagioclase feldspar and biotite. There is also a good deal of iron oxide present in the form of magnetite. Chlorite as a secondary mineral is abundant. It seems to be the result of the alteration of ferromagnesian minerals and possibly of some of the unindividualized material which forms the groundmass. No glass was recognized, although from the other characters of the rock it would seem probable that it was originally present but had been subsequently altered. This rock, like the other recent basic intrusive rocks, shows no evidence of shearing or deformation. The amygdules are often half an inch in length but show no constant direction of elongation.

East Fork.—Another locality where a recent igneous rock was found in such a position as to preclude the possibility that it had traveled far, but so situated that its relation to the other rocks could not be made out, was on East Fork, a quarter of a mile above the mouth of Matson Creek. At this place a string of angular fragments of unsheared basic rock was found at an elevation of about 15 feet above the level of the stream. The texture of the rock is fine grained, a few small feldspar crystals in the midst of an aphanitic groundmass being practically the only mineral except iron sulphide that can be recognized microscopically. When examined in thin section the rock is seen to consist of plagioclase feldspar, pyroxene, and olivine in well-formed crystals in the midst of a fine ophitic groundmass. The olivine is in large, perfectly formed crystals but is generally completely serpentinized. Pyroxenes, consisting both of the pinkish titaniferous variety and of a nearly colorless member of the malacolite group, are present and are but slightly altered. Iron oxides, both magnetite and ilmenite, form a large proportion of the slide. The groundmass consists of a mat of feldspar needles, pyroxene crystals, and chlorite. No glass is recognizable. The rock as a whole is fresh and entirely unsheared.

Winnebago Creek.—On the slopes of the 920-foot hill west of the mouth of East Fork and south of Winnebago Creek, at an elevation of 700 to 800 feet, there is a good deal of float of a dark porphyritic igneous rock (spec. 7AS108–109, loc. 7AS337). The country rock near this locality is a chloritic schist, which is much faulted and which has some limestone, apparently the Sowik limestone, inset by dislocation. In hand specimen this rock differs from any later basic intrusive previously described, for it has an abundance of biotite flakes all through it. Furthermore, it contains frequently crystals of a decomposed pink feldspar which are abundant near the weathered surface. The rock as a whole is compact and does not seem to be decomposed to any marked degree.

When examined in detail under the microscope the character of the feldspar seems very different from that of the other recent basic intrusives. Instead of plagioclase, orthoclase is the feldspar. It is so much kaolinized that its character can not always be determined with precision. The alteration into kaolin is much more characteristic of the decomposition of orthoclase in Seward Peninsula than of plagioclase. In many places the triclinic feldspars have been practically untouched by weathering, while much more recent orthoclase is entirely changed. The presence of orthoclase is of considerable interest, for, save in the granite already noted from Willow Creek, none of the other rocks show this mineral. Biotite in well-formed laths is common throughout the sections and shows no dominant direction of orientation. Magnetite and sulphides are also abundant as primary constituents. In thin section the rock appears to be much more decomposed than is indicated in the hand specimen.

As a result the original mineral constitution and structure is much obscured. Besides the primary constituents many secondary minerals are present, some of which are due to the breaking down of the original minerals and others to later additions from extraneous sources. The most abundant minerals derived from the decomposition of the earlier constituents are calcite, chlorite, sericite, and kaolin. The other class of secondary minerals are those filling the small amygdaloidal cavities, which are scattered irregularly through the rock. Epidote and calcite are the main representatives of this class; the epidote as a rule forms a ring around the walls of the cavities and the calcite forms the central part. Though the mineralogic composition of this rock differs from that of the basic intrusives previously described, it is believed to be more characteristic of the recent basalts than of any other type.

Near Rock Creek.—In the extreme southeastern part of Solomon quadrangle, on a small tributary of Rock Creek, a single piece of float of an unsheared igneous rock was found. It has a lighter-gray color than the other recent basic intrusive rocks and has certain other characters which would seem to distinguish it from them. As the rock was not seen in place, its relations have not been determined and its significance has not been made out. The rock has an ophitic texture and consists essentially of plagioclase feldspar and iron oxides with a much altered groundmass. Some small quartz particles were found on microscopic examination. This would indicate that the rock is somewhat more acidic than the other basalts and might be more closely akin to the greenstones, although different from them in that this rock is entirely unsheared. The original minerals are frequently decomposed, giving rise to chlorite, sericite, and kaolin in fine aggregates, which make up the bulk of the groundmass. Some vesicular cavities occur which are filled with quartz and calcite of secondary origin. From the field occurrences of this float it is strongly suggested that a more acidic series of moderately basic rocks of unsheared character may be found in the Topkok Head region, but owing to the heavy detrital covering their presence, except for float, may remain undetected.

VEINS.

CLASSIFICATION.

The character and distribution of the mineral veins is of interest, not only on account of the light they throw on the history of the region, but also because it is in them that the valuable minerals are found. The relation of the veins to the deposits of economic importance will in the main be treated in connection with the economic geology (pp. 139–140). There are, however, certain points which may be described in this place, because, although they do not show any metallic minerals, they afford an insight into the genesis of those veins which may return values.

Veins may be classified in many ways, but for the purpose of the present paper those within the area studied may be referred to three classes—older quartz veins, newer quartz veins, and calcite veins. By the adoption of this system emphasis is placed on the age of the veins and the composition of the most important gangue mineral. Each of these classes may in turn be subdivided into a number of smaller groups according to other characters, such as the nature of the most important metallic mineral or the relation to lithology and structure. These various points will be considered in the following paragraphs, but this amount of subdivision obscures in a measure some of the larger aspects of the problem. It is the intention here to describe some of the more important vein types with reference to their mode of occurrence, and later (pp. 126, 132), in connection with the historical geology of the region, to consider their formation as related to the other events recorded by the geologic evidence, and still later (pp. 139–140), in connection with the economic geology, to discuss their relations to the metalliferous deposits.

OLDER QUARTZ VEINS.

Throughout the Solomon schist are bunches of quartz, often of lenticular form and individually of slight lateral extent, the origin of which is uncertain. A part, at least, have undoubtedly been formed by the deposition of silica in the schists wherever a sufficient open space occurred to permit such deposition. This action probably took place as a result of the metamorphism by which complex minerals were broken down into simpler ones and some of the material transferred from its original position. Such deposition can hardly be called typical of veins and even if it were the lenses thus formed would belong to the newer series of veins. But, besides these knobs of quartz, there are many which show by their distribution that they must have been in place earlier than the main period of deformation and have been so folded, shattered, and recrystallized that but slight evidence of their original condition is now preserved.

That there may have been several distinct times when veins belonging to the older series were formed is not open to doubt. This conclusion is inevitable when the different amounts of folding and shearing are noted. This difference may in part be accounted for by the different relations borne by the veins to the stresses and also to the character of the wall rocks. But while such factors have undoubtedly influenced the form and character of the veins, the explanation is entirely inadequate to account for the varied types seen in the field. It should be remembered that all the veins which make up the older group were not formed at the same time. Differences of form, differences of relation, and even differences in mineral filling are therefore to be expected. As a rule, the older the veins the less continuous are they. Presumably many of the veins in the Solomon schist were formed before the higher members had been deposited. Proof, however, of this is difficult to obtain, for the discontinuity of the older ones prevents their being traced for any distance.

An idea of the amount of deformation to which some of the older veins have been subjected may be obtained from a study of Plate IX, *A*, which shows one of the crumpled and folded veins found southeast of Uncle Sam Mountain. Although it is not entirely evident in the illustration, all the quartz (the white portion of the rock) belongs to one vein. In places the pressures have squeezed the quartz out so that the string is discontinuous, and in other places, owing to lesser pressure, the quartz is thicker from the transfer of material. The two ends of the vein are in the left-hand portion of the illustration; one in the upper [a] and the other in the lower corner. The quartz is much crushed and in part recrystallized. The insight which this view gives into the amount of deformation to which some of the older veins have been subjected is the main reason for introducing it, for it represents one of the later of the older series of veins. It must be evident from such a view that the form of the veins is irregular and discontinuous. Furthermore, in the metamorphism many of the vein minerals have been expelled or have been recrystallized in a new form.

The greatest number of veins of this class is found in the Solomon schist, in which they are often so deformed that their earlier history is indistinguishable. They usually consist almost entirely of quartz, with few other minerals. Now and then small amounts of sulphides, distributed especially along the walls, are present. Usually, however, the quartz is more or less iron stained and in selected localities shows some small specks of gold. Blades of muscovite of recent origin are common. The quartz is mainly recrystallized and no evidence of crusted arrangement or drusy cavities was seen. Needles of rutile (oxide of titanium) are sometimes found an inch in length in the midst of the quartz. Chlorite as a decomposition product is frequently present. It occurs generally along the walls of the veins where ferromagnesian minerals from the wall rocks have been sheared into the quartz.

In the heavy limestones there are frequently quartz veins which show that they have been subjected to a great amount of deformation, but which are still not so completely shattered and recrystallized as are those common in the underlying chloritic schist. These

[a] This part is indistinct, owing to the dark color due to staining by iron oxide. The oxidation is due to surface weathering.

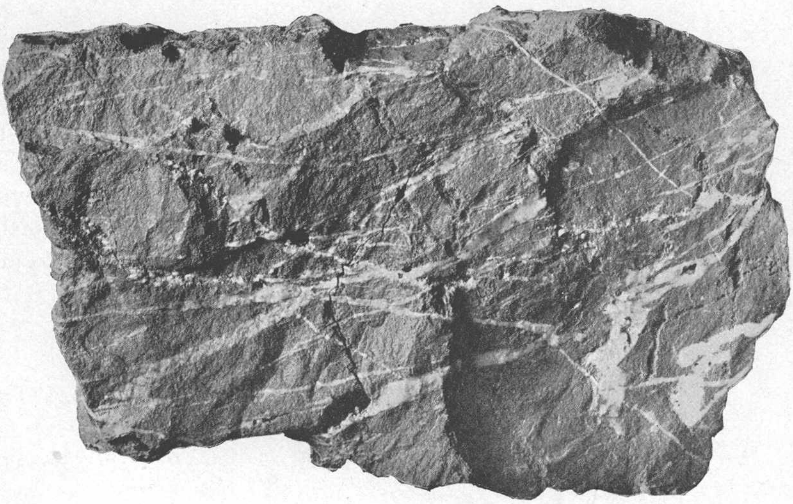
veins may be of the same age as the others or may be later. If they are of the same age, it is necessary to account for the smaller amount of deformation they have undergone. Such an explanation might be afforded by the different character of the wall rock. According to this view, the limestone, because of its slight resistance to pressure, would tend to rearrange itself by flowage to the strains and stresses, and therefore it, rather than the veins, would be acted on by the metamorphic processes. The condition would be similar to that of attempting to break a stick embedded in a ball of putty. On the other hand, it is of course possible that the veins which cut the limestones were formed later and therefore have not been subjected to the same amount of deformation. It has been stated (p. 55) that a long time may have intervened between the deposition of the different members of the sedimentary sequence, so that it is entirely probable that several series of veins of distinctly different ages could have been formed. Furthermore, the evidence of several periods of crustal movement is indicated by the structures, so the various periods of vein formation may easily have successively followed the different periods of movement and thus had different ages. The discontinuity of these older veins renders it difficult to trace them from one member into another, so that direct evidence from the field is wanting.

More detailed consideration of this question might be desirable from a theoretical standpoint, but, as will be shown later, the economic bearing of the problem does not justify the minute investigation necessary to definitely settle the point. It will be shown later that the veins belonging to either the older or to the younger series, in places, carry gold. Furthermore, some of the older veins in the limestone are auriferous, but so also are the possibly older ones in the chloritic schists. The main idea of importance to be gained is that the distribution of the older veins is widespread and is not characteristic of one particular horizon. All these veins were formed prior to the greater period of metamorphism, so that they are folded, bent, and discontinuous.

YOUNGER QUARTZ VEINS.

The main difference between the older and younger quartz veins is the amount of deformation. Neither group is entirely free from the effects of earth movements, but the latter are so little sheared that in treating the subject in a broad way the effects may be neglected. Just as there seems to have been more than one series of older quartz veins, so there were also at least two periods for the formation of the younger quartz veins. In many cases the younger show well-terminated crystals projecting from the walls of the fissure

A. FOLDED AND SHEARED QUARTZ VEIN.



B. NEWER QUARTZ VEINS IN HURRAH SLATE.

that was filled, forming a comb structure. Veins of this class are common and are the ones which give the best promise of economic returns. As they have been but little sheared they are more or less continuous. It should not, however, be imagined that they show no fracturing and dislocation, for faulting on a small scale is common.

Two distinct types of mineral filling are recognized. In one the main gangue mineral is quartz, with few other minerals. In the other there are frequent sulphides, not only of iron but also of antimony and arsenic. In the first type there is sometimes a little gold in a native state. Generally it is in such small specks that it can not be seen by the unaided eye, but at some places it has segregated so that it forms bunches an inch or more in longer dimensions. A good example of such a vein at the Big Hurrah mine is described in more detail on page 144; in this vein the quartz often shows a ribbon character, but open spaces in which well-formed crystals with terminations occur are rare.

In the other type of recent veins sulphides are commonly present. These sulphides are copper, iron, arsenic, and antimony. One such vein is found on West Creek, near the upper forks. At this place the quartz shows characteristic comb structure and is filled with perfectly formed crystals of the different sulphides. Fragments of the wall rocks are included in the vein, but these pieces have apparently not influenced in any marked degree the distribution of the metallic minerals. Undoubtedly much of the sulphide carried values in gold, but the particles are too small to be recognized by other than chemical means.

The distribution of the later quartz veins is as widespread as that of the older ones. They occur in all the members of the Nome group and show no distinct differences due to the lithology of the inclosing rocks. In the Hurrah slate, however, because of the more pronounced jointing, the veins frequently form a stockwork of intersecting strings of small size. Plate IX, *B*, shows a series of these small reticulated veins. In one hand specimen so numerous were these veins that twelve distinct and separate ones were counted in a linear inch. In some of these, combs of quartz with well-terminated crystals were evident. Where the veins are mere threads following joint planes, no minerals other than quartz are recognizable. Although the veins form a complex network owing to the fractured character of the country rock, the individual strings are evidently unsheared. The intricate pattern and great number of narrow veins is particularly characteristic of the Hurrah slate. It should not, however, be imagined that no larger veins occur in this kind of country rock, for the reverse is actually the case. Veins up to 6 feet thick have been seen and in all cases show the same features, but on a larger scale.

Contacts between the later veins and the wall rocks are always clean cut and well defined. There is no gradual merging between them and their boundaries, as is the case with the older veins. The veins seem to occur more often in the midst of the schists and slates than nearer the contacts. Although the veins are spoken of as occurring in the midst of the schists, it is not intended to convey the idea that they conform with the structure of the country rocks. In fact the later veins rarely are parallel to the direction either of the schistosity or of the bedding. Almost always they cut more or less directly across these structures and apparently are less influenced by them than by the jointing.

The difference in character of mineral filling is of considerable importance to the prospector. So far, however, the geologist can afford him but little help, for there is apparently no difference in age or in relation between the veins in which the sulphides occur and those which contain no recognizable metallic minerals. From the present observations it would appear that both rich and barren veins are of the same age and that their difference in mineral composition is to be attributed to a difference in the composition of the material below the crust from which the filling was derived. This would indicate distinctly local sources of supply rather than a single large homogeneous reservoir. The need of definitely settling the question is not acute, for samples taken from veins belonging to all the different classes and subdivisions show traces of valuable minerals. So the search for veins is not limited to those of any particular age or geologic environment, but rather to those in which segregation or concentration has gone on sufficiently to give commercial returns.

CALCITE VEINS.

A third class, veins in which the main gangue mineral is calcite, are distinctly specialized in their distribution and are never found at any great distance from limestone areas. They appear to be the result of the metamorphism of the limestone and the transfer and deposition of this material in adjacent fissures and crevices. Although the calcite filling is crystalline, it has never been observed to form well-terminated crystals arranged with comb structure, such as occur in quartz veins. It is believed that this lack is due, not to the subsequent metamorphism but to the small size of the open spaces and the different ability of quartz and calcite to crystallize. Calcite veins are practically free from all other minerals, a condition that would be expected if the method of formation suggested above is correct. So far as known, practically no deposits of economic value occur in this class of veins in Seward Peninsula. As a rule the veins are narrow, but at one place in the divide, near the head of Shovel Creek, a vein 6 to 8 feet in width was uncovered. In the vein was a horse of nearly black limestone very different from the bluish limestone which forms the wall rock, but similar to the black limestone frequently observed at the base of the Hurrah slate.

At no place were calcite veins much folded or otherwise deformed, so that it is believed all were formed subsequent to the major period of metamorphism. In few cases, however, the calcite veins were intersected by members of the later quartz vein series, so that their consolidation was earlier than the latest of the quartz veins. This, however, is not sufficient ground for stating definitely their relation to that group as a whole, for as has been pointed out (p. 92) the more recent quartz veins were formed at more than one period.

Almost always the calcite veins are distinct and do not form an intricate network of veinlets as, for example, the later quartz veins do in the Hurrah slate. This, however, is not always the rule, for stockworks of calcite veins are common in the nearly black limestone already described. In these places the general trend of the veins seems to be more or less closely parallel to the main structure of the limestone. In such a series of intersecting veins the country rock is generally softer than the filling and consequently depressions occur between the ribs of vein material.

On Bonanza Creek distinct evidence of two periods of calcite-vein formation was found. At this place a limestone occurs intersected by veins. One set was cut by faults and the veins were discontinuous. The amount of throw was slight, in some cases less than an inch. Later than the dislocation, because they filled the fault fissures, was another set of calcite veins. Whether any considerable time elapsed between these two series is not known, but it is believed that the two must have been distinctly separate. This is practically the only clear evidence of two periods of calcite veins that has been recorded within the two quadrangles, though the different characters of the veins in adjacent areas would strongly suggest that there was more than one such period. This question is of such slight importance from an economic standpoint that detailed consideration is unnecessary. In the case of the quartz veins consideration was unnecessary because all kinds carried some values, and the calcite veins do not warrant it, because practically none of them do.

UNCONSOLIDATED DEPOSITS.

There are two distinct types of unconsolidated deposits represented in the area under consideration. These may be briefly summarized as water-sorted gravels and non water-sorted deposits.

NON WATER-SORTED DEPOSITS.

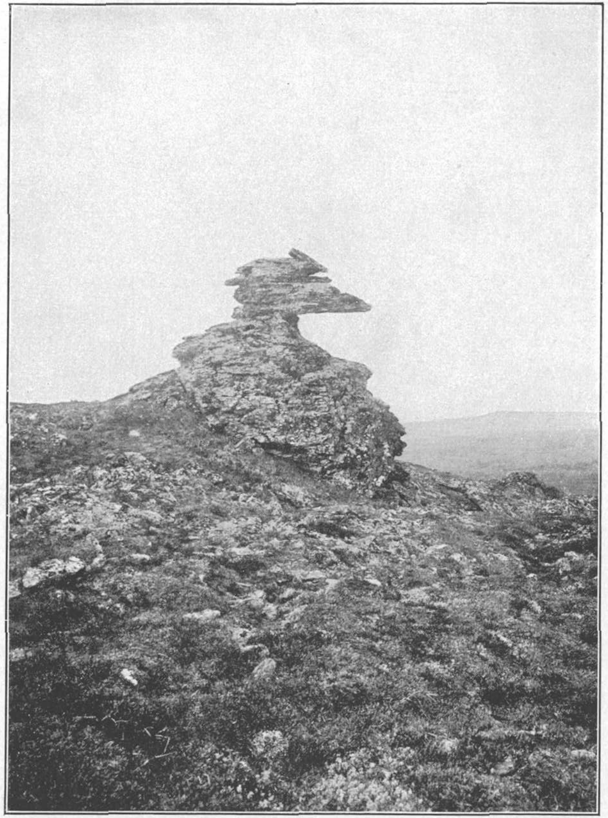
CHARACTER AND DISTRIBUTION.

Non water-sorted material is derived from the weathering of the rocks outcropping at the surface. It shows some sorting by the gravitative action which everywhere causes material to creep downhill. Although not economically important, it nevertheless in large measure determines the surface character of the country. On the geologic maps (Pls. VI and VII) it has been deemed inadvisable to attempt to separate it from the other unconsolidated deposits; and, indeed, where bed rock occurs within a short distance of the surface no unconsolidated deposits at all are indicated.

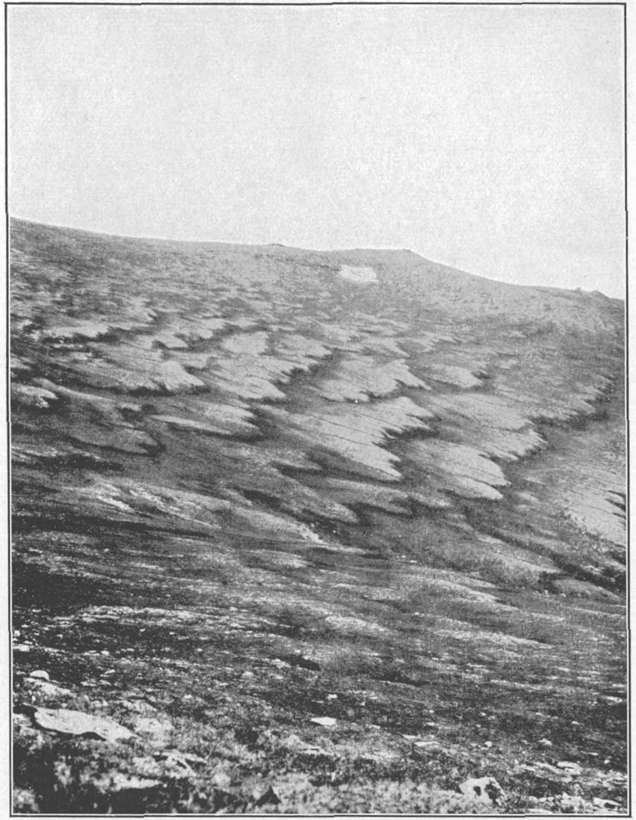
The extent of the waste covering has caused many miners to believe that the whole country has slid bodily into its present position, and from this they argue that none of the rock is in place. Such a belief is entirely untenable, for the various outcrops which appear at the surface, although somewhat shaken by frost action, are in reality in place and have not moved since the processes of weathering have been effective in the later stages of the development of the region. That this is true is shown by the way in which the waste from the ledges is distributed. Gravity tends to cause material to move down the hills along the lines of greatest slope. When the float or waste of the region is examined in detail, it is seen that its distribution is always downhill from the ledges from which it has been derived. This indicates the orderly development of the topography by processes which are now active rather than by some vague cataclysm of nature, credible only because it is beyond the range of any human experience.

The general tendency of the non water-sorted land waste is to move slowly down the gentler slopes and more rapidly down the steeper ones. When there is a cliff the waste tends to collect at its foot, forming a heap of angular fragments. Such a condition is shown at the foot of the pinnacle represented in Plate X, *A*. How this process of weathering is constantly weakening the rocks and allowing them to tumble down and so add to the mantle of waste may be imagined by considering the unstable character of the upper part of this ledge, which has now been so undermined by weathering that it looks almost as though a touch would dislodge the block and send it rolling down until the slope of the ground became sufficiently gentle to allow it to lodge. This feature is very characteristic of many places throughout Seward Peninsula, and is probably due, for the most part, to the great changes of temperature and the effectiveness of frost action.

Where the slope is gentle, the material tends to smooth over the irregularities so that the outlines of many of the hills are uncommonly free from benches or notable topographic features. On the gentler slopes the waste tends to move more slowly and it may take a long time to pass from the parent ledge to some stream as it becomes more and more comminuted. The breaking up of the larger blocks such as those shown in Plate X, *A*, is effected by the rolling and sliding of the material down hill and also by the same processes which separated



A. SCHIST PINNACLE AND TALUS, EAST OF MONUMENT CREEK.



B. EARTH RUNS AT HEAD OF CHICKEN CREEK.

the blocks of waste from the parent ledge. On the whole then the waste on the flatter slopes not only makes no positive topographic forms but tends to mask the forms produced by other agents.

EARTH RUNS.

Although the positive topographic expression of the non waterworn waste is as a rule lacking, there is a notable exception, which seems to be a direct consequence of the cold temperature which prevails in parts of Alaska for a portion of the year. The topographic expression here referred to is the lobate runs of waste which can be seen on almost any hill slope in the region. Plate X, *B*, shows these earth runs in somewhat greater numbers than is the case in the average view. Adequate scale is lacking, but the elevation of the hill above the camera is about 500 feet, and the distance from the camera to the pinnacle on top of the ridge is slightly less than half a mile. The earth runs are variable in size and irregular in outline. The front of each run is very steep and may be from 1 to 7 feet high. Because of the distribution of ground water, the foot of the frontal portion is generally the point of emergence of small springs. This has permitted vegetation to grow more abundantly at these places, and consequently the front is accentuated by the growth of small bushes. Such a darker belt of vegetation may be recognized in the view.

The origin of the earth runs is doubtful. It seems probable, however, that there is a slipping of the overlying burden of waste through the thawing of the ground ice in the summer time, and a consequent production of unstable equilibrium which finally causes movement. As the material flows down hill the tendency is constantly to decrease the angle of slope so that the lower angle arrests further movement. This movement of the material in some cases must be rather slow, for in some of the smaller examples the turf was not even broken. In one place a small earth run, not over 25 feet in width, was seen soon after its formation. At the rear of this run the turf had been broken by several gashes as though torn apart. The area outlined by these breaks was roughly semicircular. In front of these cracks the slope of the surface became less steep than that of the surrounding hillside. At the extreme front the slope was very steep and the turf had not been ruptured, but the inclination of the vegetation standing nearly normal to the slope of the front showed that the carpet of turf had been wrinkled by the movement of the mass beneath. A diagrammatic cross section of this earth run is shown in figure 14. This earth run had taken place so recently that the cracks in the rear of it had not become overgrown, and the bushes in front had not yet readjusted themselves to their new position with respect to gravity. While this movement is spoken of as being at times slow, it is probable that it is practically instantaneous in its application. It is believed that strains and stress accumulate, owing to the melted lower layers, until the mass of material is no longer able to stand the pressures, and then motion is set up. It is apparently a sort of avalanche process, but the material moves with much less violence. This slower motion is probably due to the relatively slight slope and the great resistance to be overcome.

Whatever may be the actual cause of earth runs, the fact that they do occur is of considerable importance in Seward Peninsula. It is important, because, with the bodily transfer of material by a more or less rolling motion, the waste becomes very much mixed and the original form of the surface tends to be so obliterated that it greatly increases the difficulty of unraveling its previous stages in detail. Because of it old stream benches, which must occur in places on the hillsides, find slight topographic expression. Furthermore, high-level gravels become so mixed with non water-sorted material that the prospector could not recognize the presence of stream gravels, and consequently deposits of value might be overlooked. Earth runs also impede the search for gold by scattering the metal that may have been concentrated in a previous high-level channel. The rolling and sliding of the material in an earth run evidently tends to rearrange the various parts in a more promiscuous way than that of material sorted by running water. As a consequence a placer deposit, which might have been profitable in the concentrated form imparted by water action, may, when affected by earth runs, become so scattered that it can not be economically handled.

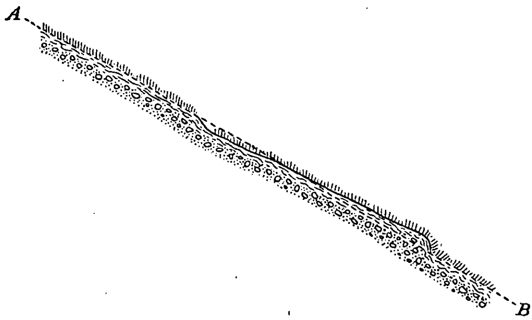


FIGURE 14.—Diagrammatic section of earth run.

MUCK.

Another kind of deposit, which has been but slightly, if at all, affected by water sorting, is the muck which forms the surficial covering of much of the lower ground of the quadrangles. The origin of the muck is in doubt because but little detailed work has been done upon it. From some slight microscopic studies of material collected in the Solomon region it would appear that most of it is very fine. In one specimen which was examined about 75 per cent of the grains were from 0.006 mm. to 0.065 mm. in diameter, 24 per cent from 0.065 mm. to 0.15 mm., and only 1 per cent larger than 0.15 mm.

The largest portion was made up of grains from 0.03 mm. to 0.05 mm. There is always a small amount of vegetable matter present, but whether it occurs as filaments of present-day plants which have extended down into the muck or whether the vegetable matter is comminuted plant fragments which were deposited contemporaneously with the mineral fragments of the muck has not been determined.

Most of the grains are angular, though a few are subangular. The muck from the coastal-plain province is in general so fine that no minerals other than quartz were recognized. In some muck, however, from near Penelope Creek, a number of the coarser fragments consisted of quartz or mica or small pieces of Hurrah schist. No limestone or calcite was recognized. From the specimens it would appear that the harder and more resistant minerals are preserved, but that the grains have suffered little attrition. Associated with the muck are frequently ice beds, sometimes several feet in thickness, in which gold has been reported to have been found, though the report could not be verified by personal inspection. The muck is generally of a dark-blue color, ranging toward gray when dry. It is somewhat plastic, but its cohesion is not strong. Remains of logs and land animals have been found in some of the beds.

Moffit [a] has summarized the more important conclusions regarding the origin of the muck as follows:

Brooks, in a recent publication on the hill slopes of the Dahl Creek region on Kougarok River, states the muck to be a subaerial accumulation, due in part to the decay of vegetable matter and in part to the deposition of silts during the rainy season. Against this hypothesis may be urged the fact that the silts sometimes occur at long distances from the hills and in places where it is difficult to see how under present conditions they could accumulate. The silts are not derived by decomposition from the gravels under them, for the line between the two is always sharply drawn, and the material is fresh and angular, containing little or no coarse material.

Another more general explanation of the silts (muck) is that they accumulated under water, either in the sea during a period of land subsidence, or possibly in fresh water. The character of the material suggests that part of it at least may be the rock flour ground up by glaciers, yet here again the widespread distribution of the silts seems to raise an objection to this explanation, since 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 on the area in question. The condition of the logs is such as to suggest that they are driftwood accumulations much like those seen on Nome beach when the region was first visited, and that may still be seen in a few places.

There are objections, however, to the supposition that the silts are of marine origin. If they were exposed to the force of the waves, it is difficult to see how 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 removing the vegetation they rapidly wear away.

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[a] See Geology of the Nome and Grand Central Quadrangles, Seward Peninsula (in preparation), for further details.

The organic matter present is another objection, since it is so widely distributed that apparently it must have been incorporated with the muck originally. It seems improbable that such an amount of organic matter would be found in marine sediments of this nature unless, perhaps, they were deposited in protected and possibly shallow waters. It is not improbable that each one of the factors mentioned may have had a share in the origin and distribution of the silts.

From the evidence at hand it seems clear that silts and muck of at least three different modes of origin have been recognized. In the Bluestone region stratified muck which must have been deposited under marine or lacustrine conditions has been noted a short distance above Alder Creek. The hillside muck noted by Brooks in the Kougarok region seems to be of subaerial origin. Some of the layers of muck near the surface of the coastal plain in which large angular blocks of detritus from remote drainage basins occur seem to have been formed as a result of glacial conditions in the more or less immediate neighborhood. So far the studies in the Solomon and Casadepaga regions have not thrown any additional light on the origin of the muck, and its history there is still an open question.

WATER-SORTED DEPOSITS.

CLASSIFICATION.

Unconsolidated deposits of the second type—those that have been sorted by water—are of greater economic importance than the non water-sorted type; and their general distribution has been delimited on the maps, Plates VI and VII. The water-sorted gravels may be roughly divided into three classes. First, gravels of the coastal plains; second, present stream gravels; and third, high-level gravels, generally deposited by former streams. Gravels of the first class are rather distinct, and although a minute inspection of any section shows great variety in the agents by which they have been formed they are best considered as a unit. Those of the second class are more or less completely described by the name present-stream gravels. In addition, however, it is intended to include in this class not only the gravels lying actually in the beds of streams, but also the lower-bench gravels which lie only slightly above the stream and which show such a definite relation to the stream that there can be no doubt but that they were formed by the stream at a date not far remote geologically. The third, or high-level gravels, present a much more diverse character and are much less well understood than either of the other two types. Each of the classes shows features requiring special description, and the following paragraphs will be devoted to noting the distribution and characteristics of each.

COASTAL-PLAIN DEPOSITS.

The coastal-plain sediments form the surface deposit over an area of about 40 square miles lying adjacent to Norton Sound. In the western part of the region this belt is between 4 and 6 miles wide. From this width it decreases more or less regularly toward the east, until at Topkok Head it disappears altogether. It has already been pointed out (p. 49) that the coastal plain is so covered with vegetation that it is impossible in traversing the country to gain an adequate idea of the character of its gravels. Even in the places where streams cut across the plain, the exposures seldom show satisfactory sections. There is therefore little data regarding the unconsolidated deposits obtainable except from the scattered pits of prospectors.

Stratigraphy.—The best series of sections have been obtained in the neighborhood of Spruce Creek, where four pits have been sunk to bed rock and a record kept of the various horizons that were passed through. The first section, located about 2 miles inland from the shore line just west of Spruce Creek, was as follows:

Section in coastal plain 2 miles from sea, near Spruce Creek (No. 1).

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay, with large amount of ice	15	15
Angular fragments of apparently slide rock, consisting mainly of chloritic schist	15	30
Clean river sands, becoming coarser toward the bottom	18	48
Yellow-red gravels	2	50
Dark fine sand	4	54
Black clay, with some angular fragments	4	58
Fine sand, light colored	4	62
Black peaty material, containing some fragments of wood	2	64
Fine sand and black mud	3	67
Black clay containing well-rounded pebbles an inch in diameter	3	70
Fine iron-stained beach sand, with schist and black quartz pebbles	3	73
Black schist (bed rock).		

One hundred yards south of this hole is another with the following section:

Section in coastal plain 2 miles from sea, near Spruce Creek (No. 2).

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay, with much ice	8	8
Reddish fairly rounded gravels like the material between 30 and 48 feet in hole No. 1	12	20
Alternating layers of black mud and beach sand; not very gritty	20	40
Light-colored yellowish sand	1½	41½
Decomposed peaty material, with some wood fragments	½	42
Black sand, mud, and quartz pebbles	8	50
Schist bed rock	1	51

One hundred yards south of the last hole is another with the following section:

Section in coastal plain 2 miles from sea, near Spruce Creek (No. 3).

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay, with much ice	8	8
Angular fragments, with some water-made pebbles	12	20
Black, dirty, fine-grained sand	6	26
Clay, with some reddish-yellow gravels	3	29
Light-colored beach sand	3	32
Black peaty material, with some quartz pebbles	3	35
Gravels of black angular schist, with some well-rounded quartz pebbles	8	43
Bed rock of black schist.		

Seventy-five yards southeast of the last hole is another with the following section:

Section in coastal plain 2 miles from sea, near Spruce Creek (No. 4).

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay, with much ice	8	8
Black, somewhat angular fragments, with some well-rounded pebbles	15½	23½
Yellowish sand, with very fine small pebbles; looks like sea sand	4	27½
Decomposed peaty material with strong offensive odor	3	30½
Black dirty wash, with occasional very well rounded beach pebbles 8 inches in longest dimension	8	38½
Bed rock, black schist, with some limy layers.		

Thickness.—The most significant features brought out by the above sections are the thickness of the gravels and the presence of certain comparable horizons. There is a well-marked thinning of the deposits seaward; thus in the first section the depth to bed rock is 73 feet, but in the last it is only 38½ feet. Unfortunately these elevations have not been referred to sea level, so that no exact statement can be made as to the slope of the bed-rock floor on which the sediments were deposited. It is probable, however, that the slope of the floor between these points is under 5 feet to 100. Not only does the deposit as a whole thin seaward, but the individual beds show this same tendency; for instance, the blue clay is 15 feet thick in the first section, but is only 8 feet thick in the most southern section. Certain members, it is true, show no constant direction of variation in thickness, but on the whole the thinning of the individual beds seems so well marked that one is led to the conclusion that the slope of the coastal plain is largely due to the thinning of the deposits seaward, rather than to subsequent erosion or tilting. This is, however, a point which should be considered by prospectors, for facts are still too meager to permit a final statement.

One of the most marked strata, which seems to be fairly constant throughout the area explored by the four shafts, is the layer of black peaty material. This bed occurs pretty constantly at an elevation of 10 feet above bed rock, and although it shows some variation in thickness it averages between 2 and 3 feet. This layer of vegetation may represent a submerged land surface or it may be the accumulation of mud and marsh vegetation in a salt-water lagoon. The presence of spruce fragments is not conclusive, for logs might have been washed into ancient lagoons just as they are at the present time, or, on the other hand, the spruce may have grown on the land near the point where the fragments are found. Although no definite conclusion has been reached, it is tentatively suggested that the tidal marsh origin seems to have most support from the known facts.

Although these sections are characteristic of part of the deposits, there are many places where different features predominate. Thus a shaft sunk near Uncle Sam Mountain, about 3 miles north of the mouth of Pine Creek, passed through more than 40 feet of angular black slate fragments without encountering any water-worn gravels. Still farther west a shaft showed in the upper portion a bed of muck about 4 feet thick, resting on 48 feet of angular black graphitic schist slide rock, which was underlain by 8 feet of very yellow iron-stained and well-rounded gravel. The gravel was about the size of peas or a little larger. West of Solomon River a hole has been drilled to a depth of 80 feet on the divide between Manila Creek and Jackson Creek, at an elevation of about 180 feet. Not much ice was encountered in the upper portion of the hole. An examination of the material thrown out on the dump seems to indicate that the drill passed through a deposit consisting mainly of well-rounded river wash. It is reported that at a point half a mile west of the survey bench mark, on the reef nearly opposite the mouth of Pine Creek, bed rock is exposed on the beach at exceptionally low stages of the tide. This report was not verified, but if it is correct it indicates the character of the floor on which the coastal-plain gravels were accumulated and throws light on the thickness of the deposits. The thickness differs greatly in different parts of the plain. This variation is both local and areal: Local thinning takes place where the bed rock was not deeply eroded before the laying down of the coastal-plain gravels; an example is the occurrence of bed rock at sea level near Pine Creek, cited above. Areal variations in thickness must be considered on a larger scale. When thus considered the deposits are found to thin both toward the sea and toward the hills. The coastal-plain sediments thus form a lens-shaped body, which thins out to a minimum against the former land and to another minimum seaward at such a distance from the former coast line that little land waste was brought out by the various transportational activities.

Size and character.—There is also a marked areal variation in the character of the gravels, according to their geographic position with respect to ancient cliffs and headlands. On the present beach the detritus markedly increases in size from Solomon toward Topkok Head. Ancient beaches responded in like manner to the presence of sea cliffs, and the variation in size of material is largely attributable to this factor. Then again the character of sediments on the sea floor near the mouths of rivers differs from more remote sediments. Sediments laid down in sheltered lagoons, like Taylor Lagoon, differ from those that are deposited in water affected by strong waves and currents. All of these different conditions recognized in the present sea floor and adjacent region must have been represented in the past, so that the alternation of different kinds of material in the coastal plain is to be expected and demonstrates the presence in the past of rivers, lagoons, shore lines, and other allied features.

STREAM GRAVELS.

Local origin.—The most important general fact about the creek gravels is that they are chiefly of local origin. As has been pointed out in the discussion of the geography (pp. 34, 45), the drainage area of the streams has suffered little decrease through the capture and diversion of creeks which previously flowed into the region. Consequently there is almost no material from foreign drainage basins. This is a condition very different from that in the Nome region, where some of the streams that flowed from the mountains southward across the plateau province into Norton Sound have been captured by the Kruzgamepa drainage, which flows into Port Clarence. The recognition of the local origin of the gravels is of some economic importance, for it will serve as a guide to anyone searching for a certain horizon.

Although carefully sought, no ledges of granite save the small dikes on Willow Creek have been found in the entire Solomon-Casadepaga region. Also no granite has been found in any of the streams save the Niukluk and in the lower courses of its tributaries, where they flow across the flood plain of this river. The Niukluk, outside of the area, heads in hills formed of the Kigluaik group and associated granites and obtains from these the granite fragments by which its gravels may be differentiated from those of all the other streams of the coastal plain. Many of its north-flowing tributaries, whose lower courses traverse its flood plain, have not yet been able to cut through its gravel filling and from this derive the granite pebbles occurring in them.

Character.—The physical characters of the stream gravels vary greatly, owing to differences in the material of which they are composed and in the sizes and gradients of the streams by which they were formed. The more schistose rocks yield fragments which are flat and of comparatively great length and breadth as compared with their thickness. The less sheared rocks, such as the greenstones, produce pebbles that are generally more rounded and as a rule are larger than the schist fragments. The quartzitic Hurrah slate usually breaks into angular fragments of medium size, which are seldom rounded when found in creek-bed deposits. The limestones, because of their softness, are usually not abundant in the gravels. The schistose limestones are usually more resistant than the less metamorphosed varieties. In many places where limestone forms the bed of the creek the gravels are but slightly rounded, because much of the drainage is carried underground and it is only in times of heavy rains that there is much surface water. As a consequence, in many places the fragments along the stream are mainly of angular limestone which have been weathered from the ledge and have been transported only a short distance by running water.

The creek gravels may be distinguished in general from the marine gravels by the less perfect water rounding of the larger fragments, by the greater variety of schist pebbles, by the dirtier character of the finer-grained material, by the presence of such structures as "shingling" in the direction of stream flow, by the areal distribution of the gravels, and by the fossils. While each of these criteria taken separately may not be conclusive, when several are recognized they allow an interpretation to be made with a good deal of assurance.

Complications, however, occur where gravels formed by one process are rehandled by some other. Thus many of the streams which cross the coastal plain have not cut to bed rock, but are flowing in places on marine gravels. In such cases the gravels originally formed by marine agencies are now being eroded and deposited by stream action, and their form and characters partake in a measure of each of these processes. In places some of the later stages may be deciphered, but in most instances the later process has so obliterated the earlier that no adequate interpretation is possible.

The gravels of the smaller streams are seldom more than 2 or 3 feet thick; and especially in the headwater portions consist of fragments that are angular and but poorly water rounded and are derived from few varieties of rock. In the larger streams, on the other hand, the gravels are frequently thick; for example, on Solomon River, near Rock Creek, there are many places where a body of gravels 30 feet deep has been found. As there are rock walls to many of the streams these gravels are probably the filling of a rather narrow earlier valley. The same general features are also noted on Casadepaga River.

Practically all the gravels are loose and unconsolidated, but in a few places they are slightly cemented. The areas of the cemented gravels so far disclosed are very small and unimportant from an economic standpoint. The cementing material is generally lime, but a small amount of gravel cemented by iron was also seen. Lime-cemented gravels were observed on Mystery Creek near Problem Gulch. The gravels cemented by calcite are generally near the heavy limestone areas. Iron-cemented material occurs near Adams Creek in a region where greenstone, limestone, black slate, and chloritic schist are intimately associated in complex relation. In the Iron Creek region to the west and north, the iron-cemented gravels bear a close relation to the areas in which the Hurrah slate occurs.

The creek gravels and low bench gravels show but little decomposition, chiefly because the gravel is still being transported by streams so that the products of decomposition are removed and fresh surfaces are constantly exposed. The absence of deep decomposition is in part due to the fact that rock decay goes on more slowly in a cold climate than in more temperate regions and that rock disintegration by frost and changes of temperature is more effective. This conclusion has been reached from a study of the component minerals of weathered rocks of the Nome group, which must have long remained undisturbed except for surface creep. When these rocks are examined under the miscroscope it is seen that even such minerals as feldspar, which changes rapidly under the conditions prevalent in temperate zones, have been but little affected by decomposition.

Age.—So far no organic remains which throw light on the age of the creek gravels have been found, but from their relation to the present streams they must be in the main of quite recent origin. In the case of the deeper gravels of Solomon and Casadepaga rivers there are no data at all as to when the filling began to take place. It is suggested to prospectors that the saving of any shells, plants, or other organic remains which may be found in the gravels is of importance not only for scientific purposes but also for practical economic reasons. For instance, it would be of value to know what were the time relations between the lower and upper gravels in Solomon River.

HIGH-LEVEL GRAVELS AND GRAVEL-PLAIN DEPOSITS.

Types.—Under high-level gravels and gravel-plain deposits are included all deposits, except those of the marine coastal plain, which consist of water-rounded fragments and which occur at a considerable elevation above the present-day streams. The marine gravels might also be considered under this head, but their mode of origin is so different that they have been discussed separately (pp. 101–104). If the term be thus restricted, the deposits are probably of fresh-water origin and may be broadly divided into two types—first, those which mark the flood plains of former streams and, second, those which were formed by other processes. As neither of these types has yielded any considerable placer-gold returns they have not been prospected to any extent, and consequently facts regarding their character and distribution are scanty.

Distribution.—The largest areas of high-level gravels of undetermined origin are those which occur along the northwestern border of the quadrangle near American Creek and Niukluk River, at a maximum elevation of about 800 feet above the sea. Their surface forms a plain gently sloping toward the north. Here and there it is cut by streams of small size, which, in general, flow on unconsolidated gravels. The larger streams, however, such as American Creek, have cut through and have in many places exposed ledges. The deposit would therefore appear to be thinner toward the hills and deeper toward the mouths of the streams.

Source.—The gravels are composed of a great variety of rocks; granite, schist, limestone, black slate, and greenstones being common. Their composition is so similar to the present-day stream gravels of the Niukluk that it is believed they must have been brought in large measure from the Kigluaik and Bendeleben mountains. The region is one, however, in which the problems involved can only be solved by a critical study of a larger area than that under consideration.

The plain in question forms the watershed between the Port Clarence and the Golofnin Sound drainage. It is from 4 to 8 miles wide, and as it is covered with water-rounded gravel of unknown thickness it can not represent a structural barrier which has separated east and west flowing streams, but must be a watershed which was previously no obstacle to streams but which has become so because of stream diversion or capture. Evidence that this is the case is afforded by the canyon character of the middle portion of American Creek, where the stream has cut a gorge 300 feet deep across a ridge about 800 feet high. The fact that the courses of many of the tributary streams trend in a direction opposite to that in which the main stream flows is further evidence in support of this view. (See pp. 46–47.)

From studies of the areas which might be continuations of this gravel-plain deposit widely different hypotheses of origin have been set forth. Collier [a] states that in some high-level gravels on Quartz Creek, in the Kougarok district, a spruce log 5 feet in diameter and 80 feet long was found and near it part of the jaws and teeth of a horse. As no spruce is found in the drainage basin of the Kruzgamepa and its tributaries at the present time and as there is no evidence of spruce having grown in the region in the past, it was believed that the log might have come from some distance. Collier, however, thinks that the presence of small twigs and spruce cones shows that the material has not traveled far—is of local origin.

[a] Collier, A. J., Reconnaissance of northwestern portion of Seward Peninsula: Prof. Paper, U. S. Geol. Survey No. 2, 1902, p. 27.

Brooks,[a] however, in considering the same general area, states:

Some fragmentary evidence from drill records goes to indicate that much of the basin is filled by clay deposits whose genesis can probably be best explained by lacustrine action. The determination of the outline of this old lake and of the cause of its formation must await further investigation. It is worthy of mention, however, that the surface deposits of gravel and sand in the Kuzitrin basin probably, as a rule, do not exceed 20 feet or 30 feet in depth.

In this same region there are some higher-level gravels which are at least 100 feet above the main streams. These are described by Brooks [b] as follows:

A similar feature is found along the northern margin of the Kuzitrin lowland and the lower part of the Turner Creek and some of the tributaries of the Noxapaga, reported by Collier to be incised in deep gravel deposits indicating an eastward extension of this same feature. When exposed, the alluvium of which these terraces are made up is nearly everywhere seen to be composed of the same character of material—that is, well-rounded and stratified brown sands and gravels. There can be no doubt that these benches are the remnants of an extensive gravel sheet.

A glacio-fluviatile origin for the gravel plain has also been suggested. Near the mouth of Iron Creek, in the Kruzgamepa Valley, it has been noted that evidences of water action are observable up to an elevation of about 500 feet above the main stream near that place. This place has been described and an explanation offered to account for the high-level gravels and certain bowlders from a foreign drainage, as follows:[c]

Although the question has not been carefully studied in the field, it is suggested that possibly these bowlders have been brought by glaciers from [the] Kigluaik Mountains and carried into their present position by ice blocks floating on a lake formed by glacial obstruction of the drainage. This suggestion is to be regarded only as a working hypothesis, but it fits in with the known facts, which may be summarized as follows: The angular unweathered form and foreign character of the granite and the presence of the shore lines at considerable elevations. Lakes of this type are common in regions that are at present glaciated.

In 1908 the region around Iron Creek was studied in more detail and the results have been published.[d] From these studies it was determined that 800 feet marked a fairly widespread level of deposition, which coincided closely with the observations made in the northern part of the Casadepaga quadrangle. At the mouth of Iron Creek some wood was found in the gravel-plain deposit. The surface of the plain at this place is about 300 feet in elevation, and the wood was found in a shaft at a depth of about 40 to 45 feet. F. H. Knowlton, in an unpublished letter concerning these fragments, says:

This material consists of two small pieces of fairly well preserved wood. Thin sections of these have been made by Doctor Thiesen, of this office, and as nearly as

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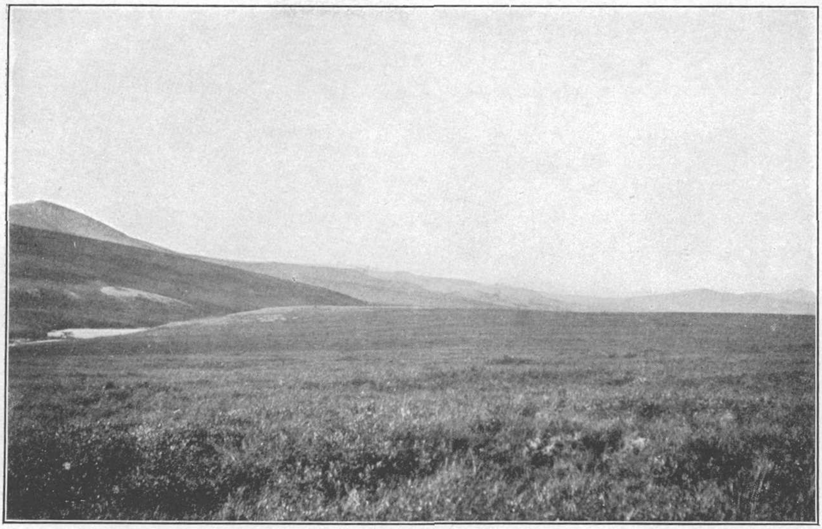
[a] Brooks, A. H., The Kougarok region: Bull. U. S. Geol. Survey No. 314, 1908, p. 168.

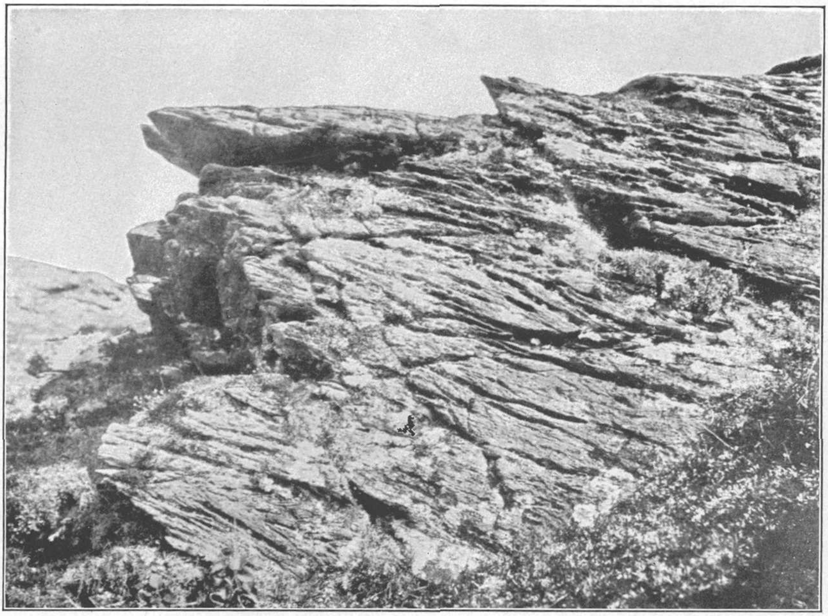
[b] Op. cit., p. 173.

[c] Smith, P. S., Geology and mineral resources of Iron Creek: Bull. U. S. Geol. Survey No. 314, 1907, pp. 159-160.

[d] Smith, P. S., The Iron Creek region: Bull. U. S. Geol. Survey No. 379, 1909, pp. 302-354.



A. BENCH OF CASADEPAGA RIVER BETWEEN THORP AND BIG FOUR CREEKS.



B. CLEAVAGE IN SCHISTS, VICTORIA CREEK.

can be made out their identity is as follows: *Picea* sp.? (spruce) and *Pseudotsuga*, possibly *P. douglasii* Carr., the well-known Douglas spruce. The *Picea* shows the poorest preservation, and the species can not be determined; but the other (*Pseudotsuga*) is almost certainly as indicated above.

From the fact that these are apparently both living species, I should incline to regard the deposit containing them as comparatively recent—that is, Pleistocene or interglacial.

Downstream from the Casadepaga quadrangle there are benches of gravel along the Niukluk, which are a hundred or so feet above the water. During the season of 1907 these gravels were prospected to some extent by a drill, and in two places gravels of mixed character were found, forming a deposit over 250 feet thick. The bottom of these gravels would be considerably below the present sea level. It is suggested that these gravels occupy a stream-cut canyon and are of fluviatile or lacustrine origin.

These various examples from near-by regions have been introduced to show that at the present time, within a rather small area, there are deposits which stand at nearly the same height above sea level but which exhibit different characters and possibly different origins. They emphasize the fact that extended study based on numerous test pits is necessary in order to determine the character of the deposits that form the surface of the lowland which stretches from Port Clarence to Golofnin Bay. In the small portion of this large area discussed in this paper practically no prospecting has been done, and the character of the deposits is undetermined. So far as known no deposits of economic importance have ever been found in this region, but whether this is due to lack of prospecting or lack of values is not known.

Besides the high gravels of undetermined origin and character which have just been described there are many deposits that are to be referred more or less directly to previous stages of existing streams. Deposits of this kind are to be seen along the Casadepaga and some of its tributaries. Plate XI, *A*, shows a portion of the Casadepaga near the mouth of Big Four Creek. The broad older valley in which the present stream is incised is shown in the central portion of the view, with the western slope of the valley to the left. Gravels showing good water rounding are found in this high-level bench. A section of the same old flood plain, somewhat south of the point from which the view was taken, near Goose Creek, showed a depth of sands and gravels of about 30 feet. There is a slight covering of moss and muck resting on 25 feet of gravels, probably river wash, below which is a horizon of sand. In the upper 25 feet the gravels are frozen, but near the bottom of the hole water seeps in and the ground is apparently unfrozen. Near this place an exposure, in a natural section, shows about a foot of fresh gravel and sand underlain by 6 inches of sand and silt, in turn underlain by a foot of rusty iron-stained gravel. Evidently this deposit thins and thickens rapidly.

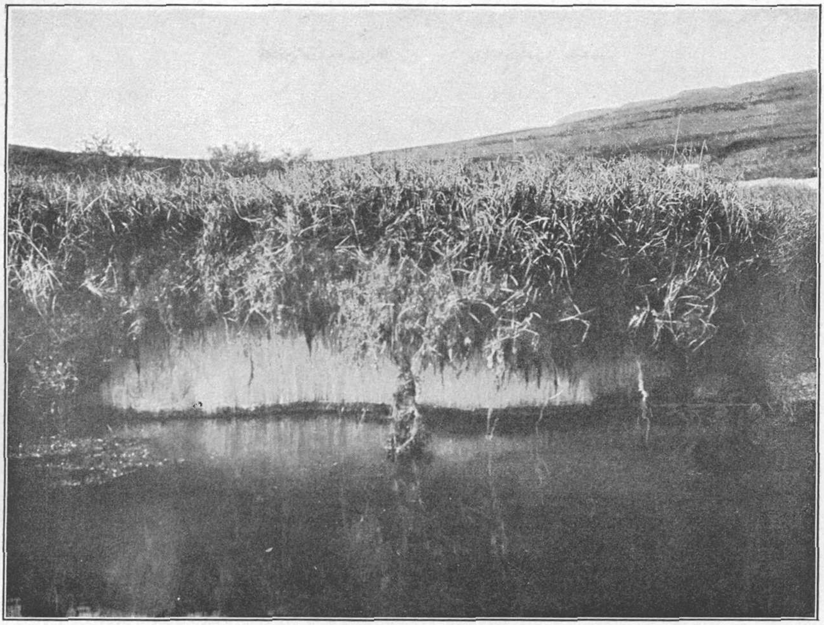
Examples of benches at higher levels than the present streams might be multiplied greatly, but are sufficiently indicated on the geologic maps, Plates VI and VII, which show all the larger recognized areas of water-worn gravel deposited at elevations above the present stream. This type of deposit is best recognized at low levels, for in such places the deposits are as a rule most recent and therefore least obliterated. In one case, however, the presence of washed gravels on a divide over 1,300 feet above the sea has been recognized. This deposit was found on the ridge between No Man and Castle creeks. The gravel consisted mainly of well-rounded quartz pebbles which were yellowish, owing to iron stains. No estimate of the depth or extent of the gravel could be formed, as the surface is heavily covered with vegetation, and the only exposure was afforded by the rupturing of the turf in the rear of a small earth run.

ICE.

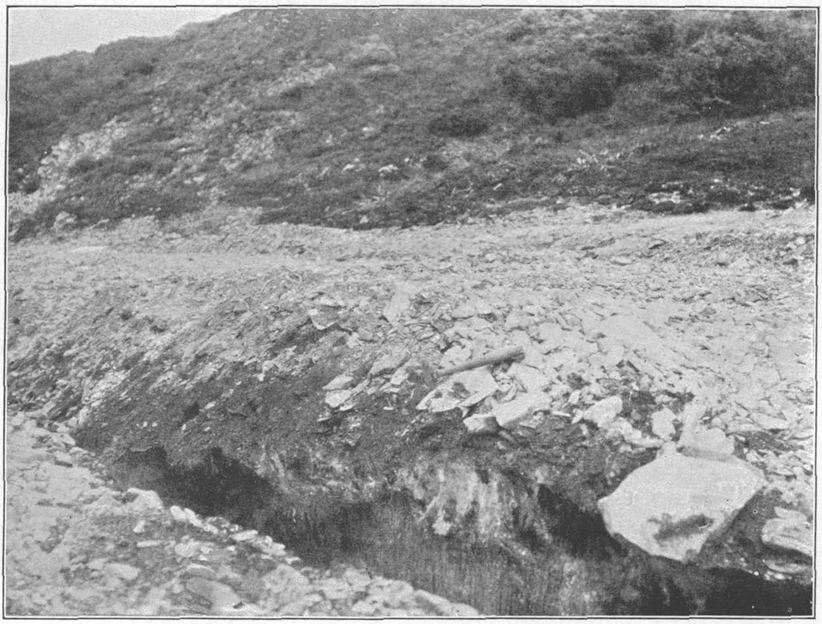
Although ice can not be considered an unconsolidated deposit, yet the relation of ice in Seward Peninsula to the other unconsolidated deposits permits its treatment under this head. Although practically all of the surficial deposits of the district are frozen, beds of ice are usually found only in the deposits occurring at a slight elevation above sea level. Plate XII, *A*, shows a layer of clear ice underlying the covering of vegetation. The turf has been ruptured so that the ice is exposed to the air, and melting takes place until, by the undermining action, a sufficient mantle of moss has accumulated to shelter the ice from the warm air.

How such beds originate is still in doubt, but it is probable that they are formed in different ways at different places. Two hypotheses have been suggested: First, that the ice is formed by the freezing of water which creeps along planes of porosity; and, second, that it is due to the burial of snow banks or surficial ice under waterlaid or slide deposits. But while each may be applicable to certain ice deposits, neither can be extended to cover all cases. Moffit [a] points out, for instance, that veins of ice such as are often found cutting the silts must have been formed after the silts were deposited, thus lending support to the first hypothesis. Such veinlets are very common in practically all the gravel deposits. Plate XII, *B*, however, shows clearly that in certain places the second explanation is the correct one. This view was taken on Lost Creek, a tributary of American Creek. It shows ice underlying creek wash, most of which was

[a] Moffitt, F. H., et al., Geology of the Nome and Grand Central quadrangles, Alaska: Bull. U. S. Geol. Survey. (In preparation.)



A. ICE UNDERLYING VEGETATION, SPRUCE CREEK.



B. ICE UNDER CREEK GRAVELS, LOST CREEK.

deposited during the spring floods of the year in which the photograph was m le. The ice here, as well as that at the place where the photograph reproduced in Plate XII, *A*, was taken, shows the vertical prismatic crystals so characteristic of river ice.

STRUCTURAL GEOLOGY.

GENERAL STATEMENT.

As already stated (see p. 69), all the rocks of the Solomon and Casadepaga quadrangles, up to and including the greenstones, show by their physical characters that they have undergone profound deformation and readjustment. From differences in amount of metamorphism it is believed that although all these rocks have been subjected to at least one period of folding and faulting, the older ones have in many places undergone two or more such periods. In the following pages are presented the various facts that have been learned from the field investigations regarding the character of these deformations. It will not be possible or desirable to go into many of the details, for the structures are so complex that only broad generalizations can be made. A careful study of the geologic maps, Plates VI and VII, will afford the most comprehensive idea of the general structures, but it must be remembered that these maps present only the larger facts and are not intended to show the features of selected small areas. In reading them it is necessary to follow the stratigraphic columns closely, or the structure may be so obscured as to be unintelligible.

DETAILS OF STRUCTURE.

DEFORMATION.

Before attempting to give a general interpretation of the geologic structure it is desirable to present some of the specific facts on which the general conclusions are based. For this purpose it is necessary to emphasize the great amount of deformation that has affected the region under consideration. This deformation is due to various dynamic processes which have folded the rocks. In places the folding has been so intense that the stresses have broken the rocks and produced thrust faults, by which one block has been pushed over another for distances often amounting to many thousand feet. Beside the thrust faults there are other faults, probably belonging to a different period of deformation, whereby the crust of the earth has been shattered and the blocks have rearranged themselves as though by gravity. Each of these three types is represented and may be found in different parts of the field.

FOLDS.

The most noticeable structure in all of the rocks of the sedimentary sequence from the lowest exposed part of the Solomon schist to the uppermost member of the Hurrah and Puckmummie formations is cleavage. The presence of this structure shows that the rocks in which it is formed have been subjected to stresses that have sheared the rock, developing new minerals under great pressures along certain planes. Plate XI, *B*, shows an exposure of the Solomon schist on Victoria Creek in the southern part of the Casadepaga quadrangle. Weathering has proceeded fastest along certain of the cleavage planes and emphasizes their presence. Cursorily viewed, the view seems to show that the general direction of the cleavage is flat lying, and this is the impression that one gets of the structure wherever the outcrops are studied hastily. If, however, the lower left-hand portion of the plate is examined, the complexly folded character of the cleavage becomes evident. So closely folded is this cleavage that save under favorable conditions the fact that the lamination is not parallel might escape detection. When, however, this structure is recognized, it may be shown that the actual structure is very different from the apparent one. In the view noted, instead of the prevailing slope or direction of the cleavage being toward the right it may actually be in the other direction. Figure 15 shows this condition in a diagrammatic manner. The heavy line represents a single cleavage plane. When any small portion of the plane, as, for instance, *CD*, is studied, it appears to be almost horizontal. If, however, the whole crumpled plane is considered, it becomes evident that the dotted line *AB* more nearly represents the true inclination of this structure. It should be noted that while figure 15 is only a diagram it is in no way exaggerated and is in essential respects a copy of Plate XI, *B*.

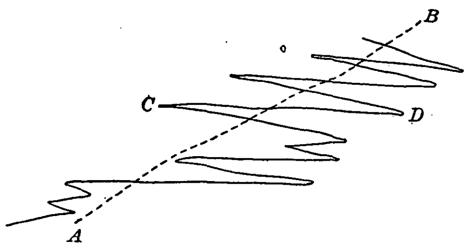
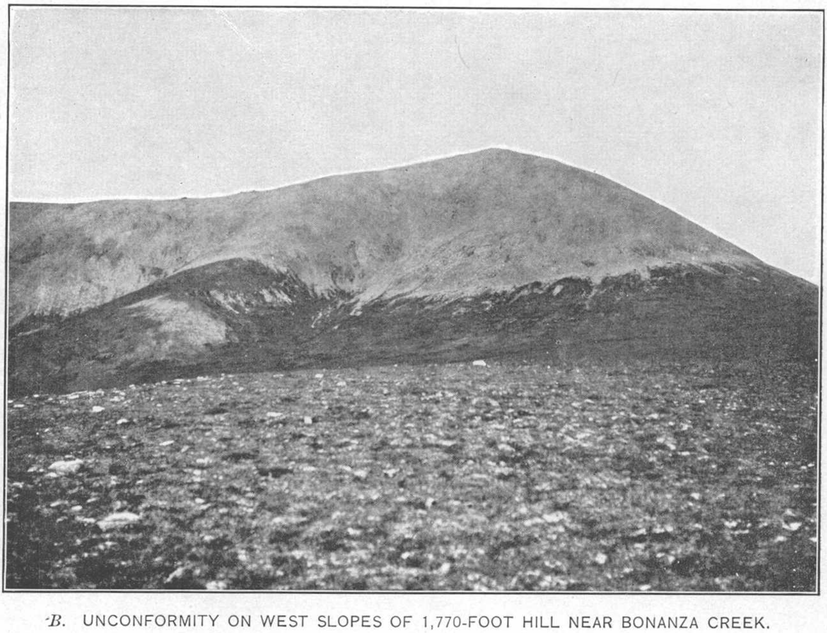


FIGURE 15.—Diagram showing folded cleavage.

Such a pronounced deformation of the cleavage is noted only in the Solomon schist, but in other members the folding of original structures, such as bedding, may be found to be nearly as intense. Undoubtedly the inability to recognize this feature in most outcrops where the exposures are not good has led to an overestimation of the thickness of the different beds. It is also in large measure owing to this intense folding that many of the relations between different horizons are so obscure and can not be stated with definiteness. Even the tracing back of the cleavage of the most recent structure

A. FOLD ON SHOVEL CREEK.



B. UNCONFORMITY ON WEST SLOPES OF 1,770-FOOT HILL NEAR BONANZA CREEK.

yields only a vague interpretation of the conditions of the previous stage, for in the Solomon schist the next earlier recognizable feature is another cleavage, which of course throws no light on the actual structure of the region and which has in large measure obliterated the preceding stages.

The intensely crinkled and contorted structure represented in figure 15 is more or less localized areally. Thus, intensely crumpled areas may be found separated from similar areas by uncrumpled schists, as diagrammatically represented in figure 16. This figure represents the cross section of a single cleavage plane. Such a structure as this necessarily can be made out only on exceptionally good and continuous exposures. It is believed that the sudden thickening of the beds in different parts of the field may be due in large measure to the reduplication of the beds by intense crumpling such as that shown in figure 16, and that the true thickness is shown in the intervening areas which correspond to the unfolded portions in the same figure.

Whether or not this is the correct interpretation can not be stated with definiteness, for the discordance between the dips is generally so slight that it can not be readily measured and save under exceptionally favorable circumstances can not be detected. Plate XIII, *A*, shows an intensely appressed fold on Shovel Creek near the mouth of West Creek. The harder layers are thin limestone bands in the midst of slates and schists which apparently belong to the upper part of the Solomon schist. From the geologic map it will be noted that the outcrop is in the area between the Sowik limestone near the mouth of Shovel Creek and the same formation near the mouth of Kasson Creek. It is small wonder that in a region of such complexly folded rocks the question of unconformity is not easy to settle. From the view (Pl. XIII, *A*) it will be seen that the limestone beds form a complete fold, the apex of which is clearly recognizable. If, however, one considers the schist layers to the left, it will be seen that the discordance between the dips is not sufficiently great to prove that they, too, bend around the end of the anticline. Therefore, anyone who was not fortunate enough to find some exceptionally good exposure, such as the one figured, and was therefore forced to rely on dips and strikes alone, would almost inevitably conclude that the beds all dipped toward the right. But this conclusion would mean that the beds were progressively younger from left to right, whereas it is clear from the illustration that the beds are progressively younger from the center of the fold toward both sides.

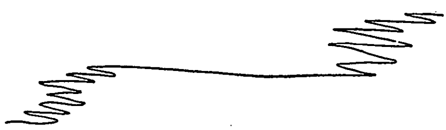


FIGURE 16.—Diagrammatic section of structure in schists.

In the description of the microscopic character of many of the schists it was noted (p. 51) that in some of the thin sections more than one structure could be found. Figure 17 shows in very formal and diagrammatic manner such a rock. The outlined areas are supposed to represent mica and chlorite flakes of two distinct generations. It will be seen that a part of the flakes are so distributed that their long axes mark a folded structure. The other grains are more nearly parallel and mark a structure having a slight slope to the left. This condition is frequently noted in the rocks from the area and is perhaps more typical of the older than of the younger members of the sedimentary sequence. The presence of these two structures clearly points to two periods of dynamic metamorphism, for the mica-like minerals have been developed by mountain-building processes such as folding and shearing. It should be pointed out that while two or more cleavage structures may frequently be noted in the thin sections of the different rocks, in the field they are not easily recognizable and in most places can not be made out at all.

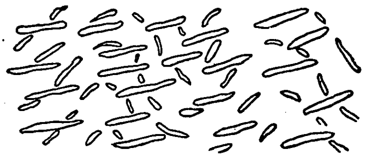


FIGURE 17.—Diagram of rocks showing two structures.

NORMAL FAULTS.

The structure of the region is further complicated by faults. Dislocations caused by faulting may be classified as of two types, thrust faults and normal faults. The normal faults are of widespread distribution and are not limited to any particular part of the field. In the areas where the Solomon, Casadepaga, and Puckmummie schists form the country rock, the breaks in the series are not easily recognizable, for the lithology over considerable surfaces is so uniform that notably discordant beds are not brought into contact. It is therefore frequently impossible to decide even where an actual fault plane is observed, whether the dislocation indicates a displacement of only a few inches or many hundred feet. Furthermore, the schistose character of the rocks tends to mask the usual signs of movement, so that its identification becomes extremely difficult. Plate V, showing a typical exposure of the Hurrah slate on a tributary of Big Four Creek (previously referred to on p. 77), shows an area of complex faulting. This plate may be more thoroughly understood by

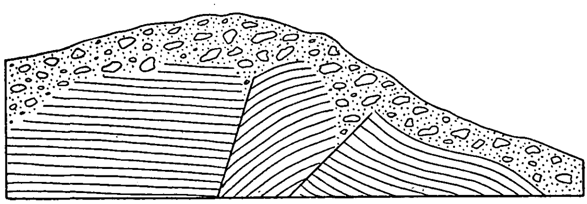


FIGURE 18.—Diagrammatic sections of faulted slates shown in Plate V.

an examination of figure 18, which shows in diagrammatic manner the various dislocations. There are two fault planes which may be considered as having broken the crust at that point into three blocks. The bedding of the left-hand block is practically flat and is indicated by the horizontal lines. The bedding in the next block to the right, however, is strongly inclined toward the left, as though the block had moved upward relative to the block to the left. The bedding of the right-hand block dips to the right at an angle which is high near the fault plane and decreases slightly as the distance from this plane increases. Such a condition is to be explained by considering the block on the right as having moved downward with reference to the block in the middle. Considered as a whole, the central block has moved upward with respect to those on either side. If this is the fact, it would follow that the pressures which produced the fracturing were compressive in character and had squeezed the central block upward, allowing a shortening of the crust and relieving the stress.

THRUST FAULTS.

The dislocations shown in figure 18 are probably of slight amount and could not be represented on a scale such as that of the geologic maps, Plates VI and VII, but in other parts of the area this is not the case, and displacements of many thousand feet are indicated by the way in which different rocks abut along the strike.

Large thrust faults in the Mount Dixon region are indicated on the geologic map (Pl. VII). One, for instance, is shown in the headward portion of Bonanza Creek, especially near the 1,770-foot hill. A view of this fault taken from the rocky knob to the northwest of this hill, about a mile from Gander Creek, where American Creek swings against the bluff, is shown in Plate XIII, *B*. The bare white hill is of Sowik limestone, and the lower slopes, which are grass covered, are as a rule of Solomon schist; the contact between the two, which may be more or less distinctly traced in the view, is nearly flat, sloping gently toward the left to the first small gulch, then appearing to rise on the ridge between the gulch and the next small draw to the left. In the ridge between these two gulches another limestone, marked in the illustration by the white, more steeply inclined beds, is cut across by the overlying Sowik limestone. Such a feature may be explained in either of two ways—first, as an unconformity caused by erosion of the lower beds and later deposition of the overlying rocks; second, by unconformity through faulting. When the smaller details are studied, however, it seems probable that the latter explanation is to be accepted. One of the chief lines of evidence that supports this interpretation is the fact that the contact is extremely brecciated, as though it had been a plane of considerable movement.

Another view of the limestone area of Mount Dixon furnishes one more illustration of the immense overthrusting that has taken place. This view, Plate XV, *A*, was taken from near the mouth of Thorp Creek on Casadepaga River. The highest hill is Mount Dixon. The limestones are the white bare exposures, whereas the Solomon schist is generally covered with vegetation or is dark colored. If this view is compared with the geologic map, Plate VII, it will be seen that the western or left-hand part of the limestone is truncated by a sharp line which by its regularity does not suggest a normal sedimentary contact. Farther up the slopes, at a height about halfway between the level of the lowlands and the top of the hill, a band of dark vegetation marks the position of schists which apparently underlie the limestone that forms the summit of the ridge but overlie the limestones at its base. When this schist is traced beyond the limits of this view its areal distribution is seen to be similar to that represented on the geologic map. Such a distribution is strongly suggestive of displacement along a fault plane, and it is believed that

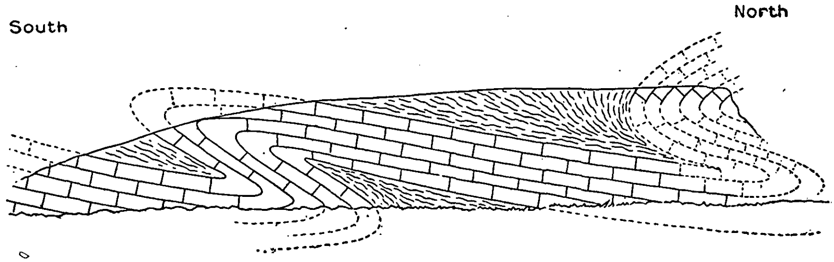


FIGURE 19.—Diagrammatic section of fold and fault on Goodenough Creek.

this schist and overlying limestone have been thrust on top of the lower-lying limestone. If this is the case, the two limestones are identical in age, and the complex relations are due to faulting. At this place, as well as at the one described on the western slopes of the 1,770-foot hill, the fault plane is evidently rather flat.

It is not possible as yet to explain the reason for the overthrust faulting, but from scattered bits of evidence it is believed that the direct cause was the intense folding to which the region was subjected. It is not possible at this place to inquire into the character or origin of the forces that produced the folding, but that it was intense can not be doubted. A striking example of deformation of this sort is afforded by the exposures on Goodenough Creek, a tributary of East Fork from the south. Reference to the diagrammatic section (fig. 19) will make the essential features evident. From this section it will be seen that the structure in the left-hand or southern part of the exposure is closely folded and overturned toward the south. So intense has been the deformation that the limbs of the folds are nearly parallel. This is more clearly shown in Plate XIV,

FOLD ON GOODENOUGH CREEK.

which is a reproduction of a photograph taken from a point close to the apex of the fold. In the northern or right-hand portion of the illustrations a discordant dip is shown, in which the rocks are inclined toward the south. This is to be explained, as indicated in figure 19, by a fault nearly parallel with the dip of the underlying beds along which the upper block has been moved. It seems to show that the folding of the bed to the north resulted in such great appression that the beds finally broke and one part was pushed over the other, in this way relieving some of the stresses by shortening the crust of the earth at that point by the amount that one block has been thrust over the other. It should be pointed out in this connection that an overthrust fault occurs on a tributary of East Fork, not much more than a mile away, and while it probably is not the same fault it belongs to the same series and was produced by similar forces acting at essentially the same time. It will be realized that with so great deformation minor discordances are to be expected and greatly increase the difficulty of interpreting the structure. The Goodenough Creek fold and fault, however, are unusually free from minor complexities when the size of the exposure is considered, for it is nearly a quarter of a mile between the limits of the outcrop.

FIELD INTERPRETATION.

From the foregoing it will be seen that the detailed facts which have been studied all point to a very complex structural history. With so many kinds of structure indicated, no particular habit for those areas where exposures are inadequate for a complete determination of the facts can be assumed. Even with fairly good outcrops a great variety of interpretations is possible. Figure 20 represents a section such as is found in many places in the field in which schist and limestone occur. This drawing is intended to indicate a limestone interbedded with the schists and essentially contemporaneous with them. The beds to the left are successively younger than those to the right, and all are conformable. It is of course a question whether the cleavage in the schists is parallel to the origin of bedding, and it is perfectly reasonable to interpret this structure as having been produced in beds unconformable with the limestone. In order to illustrate the subject in hand, however, it may be assumed that a depositional unconformity is not considered. Although this possibility is excluded here, it must be remembered that it is a possibility which must be carefully considered in the field and often can not be definitely determined.

FIGURE 20.—Typical section showing relation of limestone and schist.

In figure 21 the same distribution of beds is shown as in the preceding figure, but instead of indicating a normal sedimentary sequence a fault is represented as occurring between the limestone and the schist. It should be noted that in this case the fault might be drawn with any angle of inclination to fit individual exposures. As the planes of schistosity and bedding that are here represented as identical would afford planes of weakness, it would not be at all unlikely that the fault plane was parallel to these structures. In such cases the direct recognition of the fault in the field might be impossible. Furthermore, as the fault plane, where it is exposed at the surface, is usually a plane of weakness on which weathering and disintegration go on faster than on the rocks on either side, the actual fault in the field can seldom be directly seen. For this reason, a talus-covered gap in the section usually intervenes between the rocks on the two sides of the fault and a slight discordance in the dips of the rocks on opposite sides might easily escape detection. If a fault occurs as shown, it follows that the beds to the right of the fault are progressively younger from left to right, whereas to the left of the fault they have also the same sequence but may or may not be the equivalent of those to the right. As the fault may trend obliquely across the strike of the beds certain members may be entirely cut out or in the other direction may appear to increase, because not so much has disappeared through faulting. It is for this reason that in some places within the area of the quadrangles beds apparently increase in thickness more rapidly than could otherwise be accounted for.

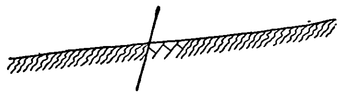


FIGURE 21.—Section showing relation of limestone and schist separated by a fault.

Instead, however, of explaining the condition represented in figure 20 by faulting, it may be a folded structure similar to that shown in figure 22. In this diagram the same section as in the previous figures is indicated by the solid lines, and a compressed fold which might explain the sequence is shown by the dotted lines. In the light of the closely appressed fold shown in Plate XIII, *A*, it is evident that this interpretation must be invoked to explain many of the facts of areal distribution that have been noted. It is believed that the great thickness of Sowik limestone represented in the western part of the area mapped is to be explained in part by the reduplication of the beds through folding, as is indicated in this figure. Where this is the case, it is evident that dips and strikes afford but meager information as to the actual sequence. For instance, the beds shown

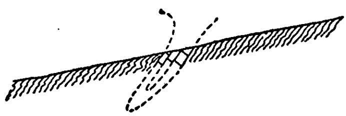


FIGURE 22.—Section showing relation of limestone and schist, folded structure.

in figure 22 are progressively younger from both ends of the diagram toward the center, although the bedding would seem to indicate that the beds were successively younger from right to left.

IGNEOUS CONTACTS.

Another detail of structure is the contact between the igneous and sedimentary rocks. It is seldom possible to get any extensive vertical section of the contact, but by piecing together information from several localities, it is possible to gain a more or less accurate idea of the conditions. Figure 23 shows a cross section of the east margin of the Casadepaga quadrangle. The highest point shown in this figure is the 1,185-foot hill east of Big Four Creek, and the section runs almost due east and west. In this area the greenstones and feldspathic schists of the Casadepaga formation occur in the western part and truncate the Sowik limestone abruptly. The contact between it and the Hurrah slate is not evident, for there is sufficient dip to this formation to carry it over the top of the exposures of the igneous rocks, and it has therefore been removed by erosion. The structures due to folding have been prolonged into the Casadepaga schist so that they are much sheared and have many new minerals developed. It seems evident, however, that the contact is distinctly igneous in its character and at this place is highly inclined. Apophyses have penetrated along the bedding and cleavage planes so that there seems to be no reason for regarding the contact at this place as due to faulting. When, however, the metamorphism has been more intense it is difficult if not impossible to unravel the character of the contacts, and it is necessary to generalize to such an extent that the actual line of contact may be far different from the one indicated.

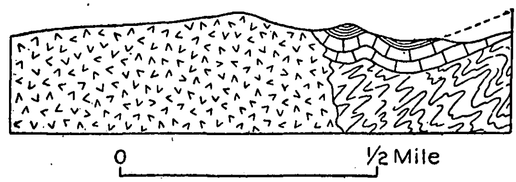


FIGURE 23.—Cross section east of 1,185-foot hill east of Big Four Creek.

In the description of the older basic intrusive rocks (pp. 73–75) reference has been made to many of the details of structure which have led to the conclusion that the rocks forming that division were not of sedimentary origin. It will therefore be unnecessary here to take up the question at greater length. It should be noted, however, that the fact that these rocks are of igneous origin gives rise to a very irregular distribution and relation to the other rocks of the region. As a result the character of the structures they present is perhaps more in doubt than is that of any of the other members.

GENERAL STRUCTURE.

From the description of the detailed structures observed at different places it is clear that the structure of the region as a whole is so complex that it can be described only in either a very detailed or a very general way. A few of the details have already been enumerated, and it is now intended to present the broadest structural facts and interpretations. No attempt will be made to draw any general structural sections, for such could hold good only for the small belt of the region which they were designed to fit. It should be remembered, however, that such sections can be constructed for any particular place from the information afforded by the geologic maps, Plates VI and VII, if the stratigraphic sequence already outlined (see p. 50) is constantly borne in mind. For instance, where the Hurrah slate abuts directly against, or appears to directly overlie the Solomon schist, a break in the sequence must be indicated. Either the Sowik limestone, which should occur between these two members, has been cut out by faulting or it has been removed by erosion.

From facts gathered in many parts of the field it is believed that most breaks in sequence are due to thrust faults with nearly flat planes of movement and not to erosional unconformities. Owing to lack of exposures, however, the direction and inclination of most of the planes can not be at all closely approximated. Here and there the straight course of the contact between two unlike members suggests a steeply inclined fault; for example, the junction between the Hurrah slate east of Solomon River and the Solomon schist and Sowik limestone to the west may be cited. But though vertical faults occur in many places, it seems certain that the larger faults, which have determined the major features of distribution of the different groups and formations, are flat-lying thrust faults.

Although this feature has not been proved to have any direct economic bearing, it is of importance geologically, for in a region which shows that it has undergone much movement by compressive stresses, the areal relation between different rocks is extremely intricate, and many older horizons lie on top of newer ones. This is in itself an unusual condition, and one to be explained only by considerable horizontal or slightly inclined movements. Undoubtedly, however, the great deformations that have been referred to have had an indirect economic effect in shattering and shearing the rocks so that more or less open spaces were developed in which circulation of mineral-bearing solutions of contemporaneous or later date took place. It is probable that the widespread mineralization and the absence of distinctly concentrated mineralization is due to this cause.

An important consideration geologically is the fact that the beds do not show the same amount of metamorphism in all parts of the geologic sequence or in all parts of the field. It is believed that this is due to the fact that part of the metamorphism is formational and regional and part is local. By regional formational metamorphism is meant metamorphism that affected all beds up to a certain horizon, and did not affect any above it. Such a condition is to be explained by assuming that beds above that horizon had not been formed at the time of the folding and accompanying metamorphism but were laid down subsequently. Local metamorphism on the other hand is of less widespread extent than regional metamorphism (which affects large portions of the earth's crust), being due to some restricted process, such as igneous intrusion or to movement along local planes, whereby new minerals and structures have been produced.

Formational regional metamorphism is a criterion of age, for all rocks which do not show the structures produced by it are younger than those that do. In determining the history of the region it is therefore of prime importance to determine whether there is more than one period of metamorphism, and, if there is, to ascertain what rocks have been affected by it and what have not. In the area of the Solomon and Casadepaga quadrangles it seems certain that there have been two periods at least, and that certain rocks may be distinguished from the others by the greater amount of metamorphism they have undergone. The Solomon schist, considered as a formation or group, has been intensely metamorphosed, but the overlying beds have not been affected to the same degree. It seems evident, therefore, that after the deposition of the Solomon there was a period of mountain building succeeded by a period of erosion and denudation before the laying down of the Sowik limestone. Although the other evidence on this unconformity is not such as might be desired, the difference in amount of metamorphism in the two members is convincing.

In addition to the strong period of metamorphism marked by the earlier deformation of the Solomon schist, there was another epoch of mountain building which was intense and had a great effect in determining the later major structures. It is to this period of deformation and shearing and folding that the rocks up to and including the Hurrah slate at least were subjected. To this period are to be assigned many of the observed thrust faults and close overfolds, such as those shown in Plates XIII, *A*, and XIV. It will be noted that this later dynamic metamorphism must have affected all the rocks older than the Hurrah slate. Therefore the Solomon schist, which already had one structure produced by similar causes, had a new secondary structure superposed on the earlier one. It is this double metamorphism which has made the Solomon formation so complex and has given it such irregular structure and areal distribution. The effect of the more recent deformation was to partly efface the earlier structures and make the dominant features conform to the later deformation.

Therefore it is only in exceptionally favorable places that the two structures can be made out and in many of the favorable places it is impossible to determine the direction of the oldest structure.

The second period of deformation which has been described seems in general to have been the result of compressive strains which acted in an east-west direction. These forces, therefore, produced folds and overthrusts normal to that direction. In other words, the axes of the folds were in the main north and south and the traces of the fault planes on the surface were also in that direction. It is not intended to make the assertion that the forces acted precisely in an east-west direction, but merely to point out that the trend was more nearly that way than north and south. An examination of the geologic maps, Plates VI and VII, brings out the fact that most of the outcrop areas of the formations have their longest axes north and south, thus suggesting that the forces which folded and overthrust them must have been practically normal to this direction. As regards the direction of overthrusting or the direction toward which the folds are overturned, there seems to be evidence to show that in general the rocks to the west were thrust over those to the east. It should be noted, however, that in such complex structures it is not possible to prove the point as conclusively as could be desired.

The presence of this north-south structural trend has already been noted by Moffit[a] in the northeastern part of Seward Peninsula, and seems to be more marked to the east than to the west. The fact of its being more pronounced in the eastern part of the peninsula might suggest that the thrusting or overturning was toward the west rather than toward the east, as has been suggested for the Solomon and Casadepaga quadrangles. It is impossible to consider here the question in its broad application to the whole of Seward Peninsula, but it is believed that a more thorough examination of parts of the area outside the field covered by this detailed report should be undertaken before any generalization or extension of the facts learned in the Solomon-Casadepaga region is attempted. The fact, however, stated by Moffit,[b] that the folds are seldom overturned in the Fairhaven region might be taken as indicating that the structures seen there are not comparable with those noted in the field under discussion.

In the later sedimentary rocks which have so far been described as having only one structure, there are places where more than one has been observed or suggested. This seems to indicate a period of deformation not so intense as that of the two already described but still marked by folding and some faulting. The folding was of a

[a] Moffit, F. H., The Fairhaven gold placers: Bull. U. S. Geol. Survey No. 247, 1905, p. 23.
[b] Loc. cit.

much more open type, and no close or appressed folds or thrust faults were produced. At the time this deformation took place the rocks seem to have been much nearer the surface than they were when subjected to the other two periods of folding, so that fracturing was much more common than before. As a result, no new shear or flowage structures were produced, and the rocks and their older structures were but little changed.

Data regarding the forces that produced this latest folding are not sufficient to definitely settle their direction. It appears, however, that while the axes of the older folds were north and south, the later ones were more nearly east and west. As there are no known rocks within the region that have been affected by this period of deformation alone, it is nearly impossible to work out its areal extent or the precise effect it had upon the older structures. It, however, needs to be assumed in order to explain the areal distribution of the different formations but more particularly to account for the dislocations and distortions that certain of the structures, formed in the preceding period of mountain building, have undergone. There is as yet no direct evidence to definitely associate the features produced by the east-west folding with any of the larger features of Seward Peninsula. It is, however, not unlikely, as suggested by Brooks in the 1900 report, that later research will show that this third period of folding is coincident with the doming that produced the Kigluaik Mountains farther west. If this is the case, it would be expected that, as areas more and more remote from this uplift were studied, this deformation would decrease. Judging from the reports of Mendenhall[a] on the Norton Bay region, the east-west axes of folding disappear and are not recognized in that area. The Solomon and Casadepaga region, lying nearer the mountains, would probably show the effects more, and such seems to be the case.

Mountain-building movements do not appear to have affected the region since the deposition of the various gravels that cover so great an area of the two quadrangles. There is, however, a long interval between the oldest unconsolidated deposits and the youngest hard rocks, allowing abundant time for other periods of diastrophism. The fact that the Mesozoic-Tertiary coal-bearing rocks in other parts of the peninsula have been folded and are now standing at high angles indicates that relatively recent deformations have taken place. It is by no means improbable that the latest folding which has been observed in the Solomon-Casadepaga region may have been produced contemporaneously with the deformation of these coal-bearing rocks. Proof of this fact must, however, await further investigation.

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

In addition to the formational metamorphism already described, there are local changes in the rocks that must be explained in other ways. Of these local phases igneous intrusion is responsible for the greater number. In the older rocks the effects are not marked structurally, but instead new minerals are produced. In the case of the more recent rocks, however, the contact region is sometimes marked, not only by a change in the mineralogical composition of the wall rock, but by indistinct structures, probably directly referable to the intrusion. This is particularly the case with the later intrusives of the granite and basalt type. In the areas, however, where the Casadepaga schist occurs, structures caused by the contact metamorphism of these supposedly igneous rocks were not noticed. It is believed that the absence was due to the amount of deformation and recrystallization that the rocks underwent as a result of the intense formational metamorphism that took place later than the deposition of the Hurrah slate. It has already (p. 66) been pointed out, however, that Brooks, who studied the contacts of similar rocks near Bluff, states: "Further evidence of the intrusive character of some of these schists is found in the fact that at various localities the limestone walls near the contact with the schist are more or less metamorphosed." Further search in more favorable exposures within the quadrangles might afford instances similar to that at Bluff.

The metamorphism and the production of new minerals close to the greenstones is by no means uncommon. Garnets, amphiboles, etc., are developed at many of the places where the greenstones cut or are close to the Solomon schist and are seldom or never found in that group at any considerable distance from the contact. In those places where greenstones occur in close relationship with the Sowik limestone, the limestone becomes more granular and "sugary." This condition was not noted, however, in those places where the limestone was cut by the Casadepaga schist.

Other localized areas of metamorphism seem to be arranged parallel to the major overthrust faults as though the movement along the plane had resulted in more pronounced shearing of the contiguous rocks than in those more remote. If this observation is accepted, it would indicate shearing along a great number of planes parallel to the major plane rather than definite fracture and dislocation along only one fault. Such an interpretation can not yet be asserted definitely, for the metamorphosed character of the rocks prevents the recognition of individual beds or other features that might be identified for any considerable distance, and it is therefore impossible to determine the details of the general movement indicated at any particular place.

HISTORICAL GEOLOGY.

General statement.—In attempting to present the various events that have occurred in the Solomon and Casadepaga quadrangles in the order in which they took place, many difficulties are encountered because of the inadequacy of the evidence. It is of use, however, to assemble in this way the facts that have already been noted in other parts of the report, so that an idea of the successive steps by which this part of the earth's crust has come to take on its present features may be obtained. It should be realized that the events recorded are not of equal importance and do not in any way represent equal lengths of time. This is unavoidable because the further into the past the history is traced the more fragmentary is the evidence, only the larger events leaving any trace of their occurrence, whereas recent movements of only a few feet may be read with full assurance. Evidence as to the more remote events gradually becomes more and more scanty, until finally a stage is reached beyond which it is idle to speculate.

Solomon schist.—The laying down of the Solomon schist is the oldest recorded event in the region. These rocks are deformed and contorted, and no remnants of organic life that may have been deposited in them when they were formed on the sea floor have been discovered. Consequently there is no direct evidence of their geologic age. Previous writers, however, most notably Collier,[a] on the northwestern part of Seward Peninsula, have assigned the schistose members of the Nome group (corresponding to the Solomon schist) to a pre-Ordovician age, because they underlie limestone containing Cambro-Ordovician or Silurian fossils. Such a determination serves for little more than to fix the upper age limit, and it would in no way preclude the possibility of the schists being very much older. If the interpretation on page 56, viz, that the next overlying member rests unconformably upon the Solomon, is correct, it necessarily follows that a long period elapsed between the Solomon and the Sowik, and this would make the schist much older than Ordovician-Silurian. In the absence of fossil evidence, however, and because of the lack of assurance whether the Solomon schist is really the equivalent of that described by Collier as underlying the Ordovician-Silurian limestone, precise age determination is impossible.

First period of deformation.—After the Solomon schist had been deposited and thoroughly consolidated, probably some of the older quartz veins were formed. At that time a good many feet of other deposits had been accumulated over the lower members of the Solomon. Oscillations of the floor on which the sediments were laid down are marked by several changes of these sediments from arenaceous to

[a] Collier, A. J., and others, Gold placers of parts of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, 1908, p. 73.

calcareous and back again. These movements were slight and did not materially affect the larger features of the region.

At the close of a long period of relative quiescence, mountain-building forces became operative and the rocks were folded, and secondary structures such as cleavage and schistosity were produced. The former sea bottom became land, and probably mountains were formed. During this period of deformation, more of the older quartz veins may have been produced, taking advantage of the dislocations and shear zones produced by the folding. It is a question of some theoretical interest, but of little practical importance, whether the folding resulted in actual mountains or whether erosion may not have removed the crests of the folds as rapidly as elevation thrust them upward. After the period of deformation and vein formation or else concomitantly with these processes, erosion began to wear down the mountain-built structure.

There is no conclusive evidence as to how far the reduction of these ancient highlands proceeded, but from the fact that the next overlying formation was probably of widespread continuous distribution, not only throughout Seward Peninsula but also throughout the central-plateau province of Alaska from the international boundary to Bering Strait, it seems probable that the surface was reduced to a very low relief; it is not possible, however, to reconstruct this surface, for so many periods of deformation have since taken place that the necessary evidence is destroyed.

If the assumed correlation of the Solomon schist with the schists in the Port Clarence region is correct, a long time must have elapsed between the laying down of the Solomon sediments and the deposition of the next higher horizon. In other words, all the deposition, all the mountain building, and all the erosion that reduced the central plateau province to a nearly flat plain must have taken place before the Ordovician. That this postulated unconformity was a widespread feature and not a mere local dislocation receives some support from the fact that a well-marked unconformity below the Ordovician has been reported by Brooks and Kindle in the upper part of the Yukon basin.[a] The determination of the pre-Ordovician age of the unconformity was based on fossils found in the overlying horizon. The Ordovician has not been sufficiently well differentiated in other parts of Alaska to permit a statement of its relation to the older rocks.

Sowik limestone.—After the folded and mountain-built Solomon schist had been more or less reduced by erosion, submergence took place, whereby marine conditions again prevailed. The shore line of this sea must have been far inland from the Solomon and Casadepaga region, for there is no evidence that shore deposits were formed, but

[a] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, p. 363.

instead limestones and associated rocks were laid down. Representing this interval is the Sowik limestone.

It is not possible from direct fossil evidence to determine the age of the Sowik limestone. As has been previously stated the work of Collier and others has shown that there is a limestone in the Port Clarence region that is Cambro-Ordovician in age, but as that area is over 75 miles from the region under discussion and as displacements of great extent are known to occur in the interval between the two places, it seems unwarranted to make more than the statement that the Sowik and the Port Clarence may both be of Orodvician age.

The typical Sowik limestone is that occurring in the western part of the quadrangle from below the mouth of Kasson Creek to Sowik at the junction of Kruzgamepa River and Iron Creek. The known area of this typical Sowik limestone has been extended on the evidence of the structural features, so as to include the limestone north of Canyon Creek, the limestone of Banner-Quartz Creek, and the limestone of the Mount Dixon region. According to the earlier writers, there are known fossiliferous Ordovician and Carboniferous limestones in Seward Peninsula, and according to Moffit there is a massive limestone 1,000 feet or so thick near the base of the Kigluaik group, which is supposed to comprise practically the lowest rocks exposed in Seward Peninsula. If this limestone really belongs to the Kigluaik, it is impossible that it should correspond to the Sowik, for in these quadrangles it seems certain that the Sowik must be Ordovician or Carboniferous.

Only a few indistinct fossils were found in any of the areas occupied by the Sowik, so that definite evidence is wanting. It should be noted that although E. M. Kindle, as stated on page 55, hazarded a guess that these fossils might be Carboniferous, he specifically declared that it was "without weight if there was any evidence against it." Though there is no direct evidence against this interpretation, and, though the writer wishes to point out specifically that the question is by no means settled, it is suggested that in the light of the fact that the earlier reference to the areas now mapped as Sowik correlated them with the Ordovician fossiliferous rocks such an interpretation should be continued until definitely disproved or the facts more adequately explained by another correlation.

As Ordovician deposits were laid down in the eastern part of Alaska near the international boundary and in the York Mountains on the west, it seems probable that they were also deposited in the intervening areas. It is assumed that the unconformity at the top of the Solomon schist marks the same unconformity as that described by Kindle and Brooks on the upper Yukon, and therefore the first limestone occurring above that break in the two places is identical. It is realized that this is slight grounds, but from the fact of known Ordovician occurring in Seward Peninsula it seems unreasonable to assume that the unconformity at its base extended up to the Carboniferous in the Solomon and Casadepaga and only to the Ordovician 75 miles farther west. The possibility of the Ordovician having been removed by subsequent erosion in the areas under discussion so that although originally present the Carboniferous was laid down on the pre-Ordovician schists has also been considered, but it does not seem to be supported by any known evidence. It is therefore assumed for the time being, until more field evidence from outside areas is collected, that the Sowik is of Ordovician age.

In discussing the limestone beds in the Solomon schist it was noted that on the upper part of Bonanza Creek a dolomitic area was found a short distance west of the heavy Sowik limestone. The exposures at this place are poor, and the great amount of thrust faulting makes it impossible to decide whether the dolomite is a part of the Sowik limestone or is a distinct member. Although it can be traced for only a mile, it has a thickness of nearly 250 feet, and may represent an important horizon. From the studies of Kindle in the White Mountain area, at the head of Golofnin Sound, it has been determined that the heavy limestone exposed at that place belongs in the Silurian. This limestone is dolomitic and will not effervesce with acid. In the upper Yukon region, on Porcupine River, a dolomitic limestone, also of Silurian age, has been noted by Kindle.[a] So far as known, the only dolomitic limestone in the central part of Alaska is of Silurian age. It therefore would seem probable that either this dolomite is Silurian or is the locally dolomitized equivalent of the Sowik limestone to the west. If the interpretation that it is Silurian be accepted, it follows that the faulting previously noted has resulted in thrusting the Ordovician limestone on top or insetting the block of Silurian limestone into its present abnormal relations. As there is so little dolomite in the quadrangles, it seems probable that the dolomite is only a dolomitized portion of some of the other limestones, and it is treated as such in this report. The same is also the case regarding the dolomite noted at the head of Crater Creek, only there it seems to be much more definitely interbedded with the Solomon schists. It should be realized, however, that the structures are so complex that other interpretations are possible.

Hurrah slate.—Apparently conformably overlying the Sowik limestone, although the evidence is not entirely conclusive, the Hurrah slate was laid down. Between the deposition of these two horizons, however, there must have been a decided shallowing of the water, as the Hurrah sediments were coarse grained and siliceous

[a] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 324-325.

and vegetal matter was abundant. The physical condition under which the Hurrah slate was deposited is not clear, but the basin must have been some distance from the shore line, as no coarse fragments were brought into it to form conglomerates. The abundance of carbonaceous matter, however, strongly suggests some sort of sheltered lagoon conditions. Alumina and soluble constituents are nearly lacking, and this would point to the conclusion that the land from which the sediments were derived was nearly devoid of rocks other than sandstones or rocks from which the soluble constituents had been in large measure leached. No fossils have been found in this formation.

Lithologically the formation resembles more or less closely two other groups of rocks in other parts of Seward Peninsula. One of these areas is that of the slates at York, in the extreme western part of the peninsula, and the other is the Kuzitrin formation of Brooks, which has since been included by Collier[a] in the undifferentiated part of the Nome group. The stratigraphic position of these two divisions has not, however, been definitely determined. According to Knopf[b] the slates near York "are faulted against a series of crystalline limestones on the west [the Carboniferous] and underlie the Port Clarence limestone conformably on the east." If this be the case, it seems impossible to correlate the Hurrah slate with that formation. Collier,[c] however, says that the slates at York may be of the same series as the Carboniferous limestone farther west, or they may conformably underlie that formation, or they may be the equivalent of the undifferentiated schists of the Nome group. He further points out that if the second supposition is correct the similarity between them and the rocks which conformably underlie the lower Mississippian at Cape Lisburne would suggest a Devonian age. This might further be substantiated by reference to the Yukon section in the upper Yukon River, as determined by Brooks and Kindle,[d] in which the Upper Devonian is represented by black and gray shales and slates, with a few invertebrate fossils. E. M. Kindle, in an unpublished paper, regards the Devonian age of the slates near York as highly probable. It seems, however, that the doubt that exists as to the true stratigraphic sequence is so great that it precludes the possibility of arriving at any definite conclusion regarding the position of the slates even in the type locality. As this is so, it seems inadvisable to attempt to correlate them with outside areas. It should be pointed out, however, in this connection that if subse-

[a] Collier, A. J., and others, Gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, Pls. X and XI.

[b] Knopf, A., Tin deposits of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 358, 1908, p. 12.

[c] Collier, A. J., op. cit., p. 80.

[d] Brooks, A. H., and Kindle, E. M., Paleozoic rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, p. 202.

quent work should prove that the Hurrah slate is Devonian, a considerable erosion interval would have to be interpolated after the deposition of the Sowik to allow time for the Silurian dolomite to be laid down and removed or else f Silurian in practically every part of the field to be cut out by faults. The latter hypothesis seems to call for such special conditions that it is regarded as nearly impossible. As regards the other alternative, that of introducing an erosion interval the data concerning the conformity of the Sowik and Hurrah are not sufficiently conclusive to prevent the hypothesis from being considered a possibility.

If the lithologic similarity between the Kuzitrin formation and the Hurrah slate is suggested as grounds for correlation, there are many difficulties that would require such specialized conditions that they would be nearly impossible to fulfill. According to Collier,[a] who has summarized the work on this formation, although he does not represent it on the geologic map accompanying his report, the Kuzitrin forms the upper part of the Kigluaik group and the lower part of the Nome group. It is recognized in the Kigluaik Mountains and along the south flank of the Bendeleben Mountains. In the earliest work in western Seward Peninsula it was extended to include the slates at York. If the position assigned to the Kuzitrin is correct, there seems to be but slight ground for correlating the Hurrah with it. As conditions practically identical with those in the York–Cape Prince of Wales region prevail from the crest of the Kigluaik Mountains southward one may be permitted to reserve judgment or to question the interpretation advanced.

Puckmummie schist.—South of the Niukluk, as noted on page 62, the series of arenaceous and quartzitic schists and slates known as the Puckmummie schist is faulted against the Solomon schist and Sowik limestone in such a manner that although the dip of the structure indicates that it underlies these rocks the probability is that it overlies them. The Puckmummie schist seems to correspond most closely with the Hurrah slate in general lithologic character and probable field relation. If, however, the above interpretation is correct, the conclusion seems almost unavoidable that the black hill 2 miles north of the northern margin of the Casadepaga quadrangle is a continuation of the same formation. This hill was studied by the reconnaissance parties in 1900 and was assigned to the Kuzitrin formation. It is evident, therefore, that a more detailed study of some of the near-by outside areas might throw important light on some of the correlations. But as this has not been done it is undesirable to do more at this place than suggest the possible equivalency of the Hurrah and a part of the Kuzitrin. This correlation, however, would not affect the

[a] Collier, op. cit., pp. 69-70.

interpretation of the actual age of the beds, for underlying the Kuzitrin is a heavy limestone, in places 1,000 feet thick, which might be the equivalent of the Sowik limestone.

Older basic intrusives.—Reasons have already been advanced for considering the feldspathic schists of the Casadepaga region as of igneous origin and probably as the sheared equivalents of the greenstones. On this assumption the Casadepaga schist is more recent than the Hurrah slate. Some doubt is felt as to this conclusion because of the much more sheared and schistose character of the Casadepaga. In only one place does the greenstone definitely cut the Hurrah slate, so there is the possibility of the particular exposure in question being due to later intrusion or deformation. From the field relations, however, it seems certain that the Casadepaga schist does overlie the other rocks. If this be true, the close of the Hurrah was marked by notable volcanic activity. Whether these intrusions reached the surface and poured out upon it is not known because of the metamorphosed condition of the rocks at the present time. Associated with these intrusions was vein formation partaking of the nature of pegmatitic action in more acidic rocks.

Renewal of deposition.—There must have been a considerable period of deposition subsequent to the period of igneous intrusion just noted before the next event took place. No definite proof of this deposition is afforded by distinct beds attributable to this process, but its occurrence is postulated to account for the apparent deep burial of the Casadepaga schist. That these schists were deeply buried is shown by the metamorphic changes that took place in them when subjected to mountain building.

Second period of deformation.—Bringing to a close the period of deposition came one of intense deformation, during which the rocks were crumpled and sheared and overthrust on each other. It is believed that to this deformation was due the larger outline of Seward Peninsula and in large measure the present areal distribution of the rocks. It did not perhaps produce as great metamorphism as the post-Solomon deformation, but it must have been a period of very widespread diastrophism. Searching for evidence of its age in other parts of Alaska where more definite stratigraphic sections have been determined does not afford any conclusive information. In fact the evidence so far disclosed has been to emphasize the fact that no statement of the geologic time when this deformation took place can be made. Brooks and Kindle, in the report on the upper Yukon already referred to, note unconformities in the Paleozoic and Mesozoic above the Ordovician (1) at the base of the Lower Devonian; (2) between the upper and lower Carboniferous; (3) at the base of the Lower Cretaceous or Upper Jurassic; and (4) between the Upper and Lower Cretaceous. It is therefore possible that any of these might be the equivalent of the deformation in Seward Peninsula, but probably it is one of the oldest. Speculation on this point is unwarranted from the scanty data now at hand.

Later vein formation.—As a result of the mountain building, it is probable that open spaces were formed at different places, some of which were subsequently filled by veins. This seems to have been pretty clearly the case with the calcite veins which, as already described, were formed by the transfer of material from the limestones to adjacent open spaces under the influence of great pressure. Quartz veins were probably formed at the close of this orogenic movement, and such were undoubtedly the oldest of the so-called "younger" veins. There is no direct evidence which requires the veins to have been formed at precisely this time, but vein formation usually follows more or less closely on periods of deformation, and it is known that the veins were not affected by this period of metamorphism, whereas they were affected by the next later one and must, therefore, have an intermediate age.

Acidic intrusives and third period of deformation.—Some time after the general north and south folding and deformation, and probably after an erosion interval of greater or less length another period of igneous intrusion took place. It is believed from the reports of others and from some unpublished studies by the writer that this was closely associated with the east-west deformation suggested by Brooks by which the Kigluaik-Bendeleben Range was blocked out. The intrusive was of acidic composition, and is the equivalent of the granite so widely distributed in other areas, but occurring so sparingly within the Solomon and Casadepaga quadrangles. It is not intended to assert that the mountain building of this stage was due to doming through igneous intrusion, though that interpretation of the facts is possibly correct. It seems rather that the granite intrusions must have extended over a considerable time, for some are more sheared than others. This condition would seem to be best explained by assuming that a part were injected in the early stages of deformation, and that having consolidated they were later sheared by a renewal of deformation, but that others were intruded near the close of the period of diastrophism and were therefore but little affected. The petrographic description of the granite found on Lower Willow Creek shows that the granite found there is unsheared and must therefore have been formed subsequent to the deformation. There is, however, so little material representing this part of the history of the region that all determinations are more or less tentative. The presence of tourmaline in many of the schists in small microscopic crystals seems to point strongly to the conclusion that a considerable amount of granite which has not reached the surface may underlie many areas where its presence can not be determined by surface indications.

According to such an interpretation, the narrow dikes at the mouth of Rocky Creek are the apophyses of a deep-seated body of granite. It is probable that if a batholith of granite does occur it is far below the surface in the area here discussed. Contemporaneous with the granite intrusions was the formation of certain of the younger set of quartz veins and pegmatites. It has not been possible to prove that these veins differ in any material respect from the other veins except for the lesser amount of deformation they have undergone.

Conglomerates.—Certain conglomerates have been found in the Solomon and Casadepaga region that are entirely unsheared and do not appear to have been affected by any considerable deformation. It is impossible to assign them to their proper stratigraphic position with respect to other regions. The beds to which these conglomerates most closely correspond are the coal-bearing sediments of late Mesozoic or Tertiary age.

Not enough is known about the conglomeratic beds in the Solomon and Casadepaga region to permit a final statement concerning their inclination, but their unsheared character may be affirmed with definiteness. The fact that they are thoroughly consolidated puts their formation well back into the Tertiary or late Mesozoic, for deposits of known late Tertiary age in adjacent areas are entirely unconsolidated. Unfortunately the pebbles forming the conglomerates afford but little information concerning the rocks of the region from which they were derived. Schist, limestone, quartzite, and slate are the only rocks recognized among them. No granite has been found, and, as a consequence, the time of the granite intrusion with respect to these sediments can be determined only by inference. The negative evidence afforded by the few specimens of conglomerates seen is so weak as to be negligible if opposed by any other more definite facts. The unsheared character of the conglomerates seems to show either that they were formed on the surface at the time when the last stage of the granite intrusion was taking place within the crust, or that the sedimentation took place after the volcanism but before streams had cut deeply enough to expose the granite. It is interesting to note that Collier, in studying the coal-bearing rocks on Sinuk River, reported [a] "A diligent search of this conglomerate failed to reveal any pebbles of granite, although granite pebbles are common in the surficial deposits * * *. The absence of granite pebbles suggests that the sediments may be older than the granite intrusives, though it may be due to lack of drainage from that direction."

Late basic intrusive rocks.—Within the area studied in detail there are no facts which permit the determination of the relative time when the later basic intrusive rocks were formed. It seems probable, how-

[a] Collier, A. J., and others, Gold placers of parts of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, 1908, pp. 83-84.

ever, that their intrusion took place at a relatively recent date. Not only are the rocks entirely unsheared and apparently undeformed, but their mineralogical composition shows but little alteration due to weathering. It is not believed that the dikes were the feeders of the most recent basic effusive rocks, which form such large areas in the Kuzitrin-Noxapaga-Koyuk basins. Instead, it seems more likely that these correspond more or less closely with the basic intrusive rocks north of Teller, such as at Mukacharni Mountain. The outcrops on Monument Creek show by the amygdaloidal character of the rock that they must have been near the surface at the time of the intrusion. If this is the fact, the larger outlines of the topography had been blocked out prior to their formation. A later age for the basic intrusive rocks is assumed (1) because basic dikes of similar composition are known to cut the granites in the Kigluaik Mountains, and (2) because of the relation of the basaltic rocks to the structures and topography. It is not known positively whether the lava brought up through these fissures overflowed and formed extensive masses, but it is probable, owing to the absence of any float, that such effusions could only have been of very small extent in this area.

Tertiary erosion and deposition.—After the intrusion of the basic rocks there was a period of considerable erosion. In the Solomon and Casadepaga region there are no criteria by which the amount can be directly measured. Farther west, however, it seems clear that valleys were entrenched several hundred feet. As this erosion progressed the related action of depositing the waste products at other places went on. To this stage are to be referred some of the high-level gravels and the beginning of coastal-plain sedimentation. Only a few exposures of the coastal-plain gravels have been made within the detailed mapped area, so that facts are wanting for precise determination of the age of this period. From the region around Nome it has been shown by fossil remains that the oldest part of the coastal plain may be as old as the lower part of the Pliocene. No attempt has been made to correlate the Nome region directly with the Solomon area, and therefore it is impossible to state that the lowest beds at the two places are equivalent. In fact, such equivalence seems extremely unlikely, if the areas at present inland from the shore line are alone considered. While doubt may be cast upon the exact equivalence of the different beds from the surface to bed rock in the two regions there seems slight room to question that the beginning of coastal-plain formation in both was late in the Tertiary. According to this determination a long time elapsed between the last definitely determined date—that of the deposition of the Port Clarence limestone of Ordovician age—and that of the laying down of the Tertiary sediments of the coastal plain. In this long interval must be appropriately distributed the various events which have already been enumerated.

During the deposition of the high-bench gravels and the unconsolidated deposits of the coastal plains, most of the present stream valleys were developed and the contour of the region began to have more or less its present form. Some of the rearrangements of the drainage took place whereby water was diverted from one basin to another. On the whole, however, few streams from areas within the quadrangles were diverted, and few changes on a large scale were effected. The area was not, however, stable, but was subjected to oscillations of small extent, whereby the shore line advanced or retreated at irregular intervals, so that parts of the present coastal plain were in turn above or below water.

Pleistocene history.—With the close of the Tertiary new climatic conditions began to take the place of the former milder temperatures, and in the Pleistocene a period of glaciation was instituted. It is doubtful whether the glaciation, which was effective mainly in the Kigluaik and Bendeleben Mountains, directly influenced the topography of the region forming the subject of this report. By "directly" is meant by the actual incursion of tongues of ice or glaciers. Indirectly, however, the effect of the glaciation was well marked in the northern part of the Casadepaga quadrangle. There the obstruction of drainage produced lakes of greater or less extent, and on these lakes blocks of ice carrying detritus from the mountains to the north floated, and on melting, left their burden of waste irregularly distributed. Some notable changes of drainage were effected at this time, as, for instance, the one in the course of American Creek. (See pp. 46–47.) The material which marks the event is the gravel with abundant granite pebbles, differentiated on the geologic map, Plate VII, as the gravel-plain deposit. It has been noted, however, that this gravel-plain deposit contains material of many different types, and that many different activities took part in its formation. There were creek gravels, lake-shore deposits, glacial débris, and possibly some marine conditions at work at different stages, so that the history is complex. It is clear, however, that the maximum glaciation occurred before the deposition of the greater part of the present gravel-plain deposits and that the high-level lake gravels mark almost the close of glaciation. Unfortunately, no fossils have been found in these deposits, so there is no faunal evidence to confirm the geologic age of the unconsolidated materials.

The influence of glacial conditions is also marked in the coastal-plain province, though its traces are not so pronounced as in the vicinity of Nome. The evidence consists in rather large, angular, slightly waterworn fragments of rocks, many of which are from a foreign drainage basin. Granite is the most easily recognized foreign material in the upper part of the coastal-plain deposits. At Cape Nome and at Cape Darby granite masses are known, so that this material may have been derived from either of these places and transported by along-shore currents. The unwaterworn character of the bowlders, however, points to the conclusion that they could not have been directly water transported. Instead, it seems probable that coincident with the maximum glaciation in the mountains to the north the coastal-plain province was in the main under water; and that, while thus submerged, blocks of ice carrying fragments of rocks from more or less remote points floated on marine or lacustrine waters into the region and on melting or capsizing deposited the detritus they had been carrying. In this way the blocks of granite might have been carried long distances without showing any pronounced erosion and would have in addition an irregular distribution. This condition seems to be even more clearly determined near Nome, where the coarse, angular granitic blocks are found only in the upper few feet of the coastal-plain deposits.

With the close of the maximum glaciation there seems to have been a gradual emergence of the coastal-plain province with but few halts or interruptions in the uplift. During this elevation the streams entrenched themselves below the level of the coastal plain and in places small diversions of drainage occurred. In the plateau province there seems to have been an uplift as well, and many of the streams cut narrow gorges into the preexisting valleys. This uplift was not uniform, so that the amount that the different streams have incised their valleys below the old valley floor ranges widely in different parts of the field. It seldom amounts, however, to more than a hundred feet on the larger streams, and on the headward portion of the small tributaries it diminishes until its effect becomes unrecognizable.

After the uplift just described, there was a slight depression whereby some of the streams were forced to build up their floors by laying down gravels. To this movement is to be referred the filling noted in the lower part of Casadepaga and Solomon rivers. Plate XV, *A*, shows a typical portion of the Casadepaga flood plain below the mouth of Thorp Creek, looking northward to Mount Dixon. The bed-rock floor at this place lies from 20 to 30 feet below the general level of the present bed. In this view the bench formed by the preceding stage of down cutting is clearly shown in the middle distance. The filling of deeper channels is also noted in the lower part of Solomon River, where at certain places 30 feet of gravel has been encountered. Because the larger streams were most quickly affected by changes in the relation of the crust to sea level, they are the ones that afford the best evidence of some of the smaller movements, such as those just described. It should be noted that all of these later movements are insignificant as compared with the great deformation that followed the close of the deposition of the Hurrah and Puckmummie formations or the lesser period of mountain building nearly coincident with the intrusion of the granite.

Recent events.—The remaining part of the history deals with practically present-day conditions. All of the streams had been formed by the close of the latest period of depression, except perhaps some of the smallest of the headwater tributaries. No diversions of moment occurred, and the general features of the topography had been established. The deposits of this last stage were produced under existing conditions, as is clearly indicated by their closeness to the activities by which they were formed. Stream gravels, marine sediments, and non water-sorted waste are all in actual process of formation. Movements of a small amount are undoubtedly taking place now, just as they have taken place in the past, but the relative slowness of the changes renders the effect on the existing forms so slight as to be neglected.

ECONOMIC GEOLOGY.

INTRODUCTION.

Gold mining, the only developed industry of Seward Peninsula, is adding materially to the wealth of the world each year, the total value of the product up to the close of 1908 reaching more than $47,000,000. To this output the area under discussion has contributed a considerable amount, but the figures are not available.

The gold has been mostly taken from placers, there being only one producing lode mine in the district. Other auriferous lodes occur and a little copper ore has been found, but none of them are of proved commercial importance. The present high cost of transportation, labor, and other expenses of mining and reducing ores has retarded the prospecting of deposits, which, if located in regions of less adverse conditions, would be worthy of investigation. It is probably safe to say that to be of commercial importance, ore bodies in this field must carry values at least twice as great as if located under similar conditions as to railway and water transportation in the States. Gold placers are more favorable for economic exploitation, but even with these the cost of mining is very much larger than it is in the States.

In view of the smallness of the population and the high cost of labor and supplies, it is evident that other mineral deposits, such as building stones, structural materials, etc., some of which may be present, can have no present value and need not here be considered. On the other hand, the surface waters are of first importance to the placer-mining industry. In fact, many placers only have value because they are so located that they can be mined by the use of water under head.

The water supply will, therefore, be briefly discussed (pp. 217–227). Unfortunately, exact data on stream flows is exceedingly scant, being mostly that resulting from the investigations of F. F. Henshaw and A. T. Barrows during 1908.

Though much has been accomplished in the way of improving transportation facilities in this field during the past decade, the cost is still excessive. The landing of freight by lighters at Solomon is expensive—in 1908 the cost of freight from Seattle varied from $15 to $20 a ton. A railway running from Dickson up the Solomon Valley and across the divide and down the Casadepaga to Penelope Creek bisects the field and makes the more important part of the district readily accessible. The northwestern part of the field lies but 6 to 8 miles from the Seward Peninsula Railway at Iron Creek.

Though the district can boast but few wagon roads, yet the topographic conditions are such that teams not too heavily loaded can traverse much of it. Nor is the construction of wagon roads difficult or, considering the cost of labor, expensive. Wages during 1907–8 for ordinary manual labor were about $5 a day with board, the value of the latter being usually counted at $1 to $2.50 a day. In winter wages are usually somewhat lower than in summer. Experienced mechanics, dredge men, etc., are usually employed by the month at one and a half to twice as high wages as they would receive in the States. Many of these spend only the open season on the peninsula.

In considering the cost of operating, it should be remembered that this region furnishes nothing in the way of food, supplies, fuel, or timber, all of which are at present imported from Puget Sound ports. Some spruce occurs in Norton Sound region to the east but probably could not be utilized to advantage in this field. Lignitic coal is also known to occur in the same district, but of the extent of the deposits nothing is known and it appears unlikely that their utilization would have any commercial advantage over the imported coals. If a deposit were found sufficiently near at hand and in sufficient bulk to warrant the establishment of an electric plant at the coal mine, it is possible that cheaper power might be obtained. More encouraging are the prospects of utilizing some of the water powers in this and adjacent regions for hydro-electric plants. This is a phase of the power problem which deserves serious consideration on the part of those who contemplate any extensive mining development.

The following statement of the mineral resources is based on a detailed study of the geology, both as expressed in the natural exposures and in mining excavations. It is not intended as a final analysis of the many intricate problems connected with the bed-rock occurrence of the metalliferous deposits. The intricacy of the geology, lack of bed-rock exposures, and the almost entire absence of underground workings make it impossible to determine the genesis of the metalliferous deposits and to present any very definite conclusions as to their distribution in bed rock. Certain facts have been brought out in regard to the bed-rock association of the auriferous deposits, and these are presented in the hope that they may be of use to the prospector and miner and may make the geologic map more useful as a guide in the search for ore bodies.

A brief history of the mining development will first be presented, followed by an account of the bed-rock occurrence of metals, and this in turn by a description of the gold placers. Finally, the data on water supply will be briefly summarized.

HISTORY OF MINING.[a]

Gold was discovered in this area in 1898 on the Casadepaga, and mining was begun the next year on both the Casadepaga and the Solomon. There was considerable creek mining in a small way in 1901 and 1902, and by 1903 some small dredges had been installed on Solomon River. In that same year the work of constructing the Council City and Solomon Railway was begun, but this road did not reach Penelope Creek, its present terminal, until 1906.

Interest in lode prospecting was first stimulated by the discovery of gold-bearing veins on the Solomon in 1900. The development of the Hurrah quartz mine reached a productive point in 1900. The years 1903 to 1905 witnessed much activity in ditch building in this field, but many of these enterprises were ill considered.

Meanwhile the mining of the rich placers of Hurrah and Shovel creeks stimulated further prospecting. The installation of the Three Friends dredge, completed in 1905, marked the beginning of larger enterprises. In 1908 the Nome, Montana, and New Mexico dredge was launched and there was considerable activity in various parts of the field, mostly with small plants.

LODE DEPOSITS.

MINERALIZATION.

VEINS.

The occurrence of veins has already been noted and their division into three main classes has been made. (See p. 90.) 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

[a] For a detailed account of the development on the different creeks, see pp. 137-214.

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 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 evidences 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.

DISSEMINATED MINERALIZATION.

Origin.—The mineralization of the area is not entirely dependent on the veins, for sulphide mineralization is widespread in the schists themselves. Sulphides have been recognized in practically every rock in the region at places where direct connection with veins was out of the question. It is not intended to imply by this statement that the sulphides may not have been introduced by the same processes that formed the veins, for this is a question which can only be satisfactorily answered by a careful study of numerous good and extensive exposures and the sampling and assaying of the wall rocks from the vein to the unveined country rock. While it would be desirable to do this, it has not been done as yet, and therefore the point can not be settled.

Mineralization in basalts.—As already noted (p. 93), some of the recent basalts, particularly one found on West Creek, show disseminated sulphides. From the distribution of the minerals, it would seem that the sulphides were original.

Mineralization of greenstones.—In the older igneous rocks sulphides are also common. East of Solomon River minerals were found disseminated through the greenstones on the divide north of Rock Creek (tributary to Topkok River), at the head of Big Hurrah Creek, near the mouth of Victoria Creek, and at the head of Coal Creek. West of Solomon River and in that portion of the region around Johnson Creek disseminated sulphides were found in the greenstone at the head of Squirrel Creek and also on the divide west of Johnson Creek. East of Casadepaga River the same thing was seen on a branch of Big Four Creek above Surprise Creek. At this latter place the sulphides were found not only in crystals scattered throughout greenstone, but also as thin coatings on the joint planes, thus showing that at this place at least all the sulphides were not original constituents of the greenstone. Here both copper and iron pyrite were recognized.

Near the mouth of East Fork, on the west side of Solomon River, there is a typical feldspathic schist, which shows an abundance of well-formed crystals of pyrite scattered throughout the rock without any definite arrangement with respect to fractures and cleavage. The sulphide is a good deal weathered on the outside, but the central part is fresh and shows undecomposed material with characteristic brassy color. The feldspathic schists do not have as much disseminated mineralization as do the other schists.

Mineralization in limestones.—Many of the limestones show small amounts of well-crystallized sulphides scattered through them without any definite relation to veins. Such a limestone was seen on Coal Creek, midway between Rock and Fox creeks. Here the sulphides are very abundant and badly decomposed, so that the limestone is a rusty-brown color and is spongy from the amount of soluble metallic minerals that have been removed. At this place there has been considerable faulting and it is probable that much of the mineralization has been introduced along the fault planes. Limestones on Emerald Creek, a tributary of Kassan Creek, also show numerous well-formed scattered crystals of sulphides. A similar limestone occurs farther up Shovel Creek on Adams Creek.

In the Casadepaga drainage, sulphide mineralization in the limestone has been noted near Curtis Creek. Here float was found which showed both iron and lead sulphides scattered through a white crystalline limestone. The ore minerals were arranged in bands roughly parallel to the color banding of the limestone. This structure also seemed identical with the original bedding. Near the same place on the divide between Ridgeway and Moonlight creeks a heavy limestone was found with a small amount of sulphides with sharp perfect crystalline forms. Although their amount was small, their presence clearly indicated that mineralizing processes had been effective.

Mineralization at schist-limestone contacts.—The most peculiar type of disseminated mineralization is that so often found in a replaced zone near the contact of the limestones and the underlying schists. Two and sometimes more feet of the contact portion is often formed from a rock consisting of recrystallized quartz. From the field occurrence the rock would appear to be a silicified limestone, but when it is studied under the microscope limestone or calcite can seldom be seen, although many of the samples effervesce slightly with acid. No matter what theory is accepted for the origin of the rock, the quartz of which it is formed is of later origin than the limestone above or the schists beneath. What is more important, however, is the fact that sulphides have often been formed coincidently with the crystallization of the quartz. The places where this condition was observed had the sulphides too sparsely disseminated to be of economic importance, but local enrichment or segregation might afford a workable ore body. As a rule, copper sulphides, which in places have altered into the carbonates of copper, are more abundant than any other sulphides. No clear evidence as to the age of these quartz bands with respect to the quartz veins has been found, except in one exposure near Spruce Creek. At that place a vein of quartz belonging to the later series, as was shown by the comb of perfectly terminated quartz crystals extending from the walls of the fissure, cut the replaced quartzose band in no uncertain manner.

Places where this kind of deposit has been found are indicated on the geologic maps, Plates VI and VII, but a few cases may be noted to show their widespread distribution. Near the head of Penny Creek a quartzite lying at the base of a heavy limestone contains sulphides. This is probably the locality noted by Brooks in 1900 as showing mineralization. At the head of Daisy Creek, near the contact of the limestone and greenstone shown in Plate VIII, *B*, there is a 1-foot band of this material with scattered sulphides. On the 1,625-foot hill east of the lower part of Big Four Creek, in the saddle, at the contact of the limestone and the schist, there is a quartzite which looks like a replaced limestone; it contains numerous cavities filled with perfectly terminated quartz crystals but with apparently no sulphides. In many places around Mount Dixon there is also a similar quartzitic rock; as a rule, however, on this hill the sulphides have been altered into carbonates and oxides, so that seldom are any of the original sulphides recognizable. In one instance the copper carbonates occur in a drusy cavity.

Mineralization in conglomerates.—On Birch Creek, near the mouth of Shea Creek, as already noted (see p. 66), a conglomerate was found which was filled with small crystals of disseminated iron sulphides. This mineral occurs most abundantly in the matrix between the pebbles, but it is also present in the pebbles themselves. Where it occurs in this part of the conglomerate it is especially abundant in the limestone pebbles and is almost wanting in those pebbles formed entirely of schist. The sharp crystalline outline and the absence of all metamorphic effects would place the time of this mineralization later than the metamorphism and folding of the region.

Miscellaneous mineralization.—The other kinds of rocks, namely, the schists and slates, are found to exhibit this same disseminated mineralization. It is not feasible to go into details as to all the places where sulphides have been found, for the list is a long one. The following widely separated examples from different lithologic facies may serve to indicate how widespread the process has been. On Oro Fino Gulch, a tributary of Adams Creek, there are numerous small strings of sulphides parallel to the cleavage of the limy schists. Near this place, on Doverspike Creek, the same mineralization is seen in black, somewhat graphitic schist. Near the head of Butte Creek, at the contact of a chloritic and feldspathic schist, the schist is impregnated with sulphides, which have been more or less completely changed to limonite. On the lower part of the mapped portion of O'Brien Creek in a micaceous limestone there are abundant sulphides. On Casadepaga River, near the mouth of Squirrel Creek, there is a limy schist with a small amount of sulphides, apparently without crystal form. The schist and sulphides are cut by a few small quartz strings showing a little mineralization.

Another type of mineralized deposit, indicated only by float, occurs in the limestone hills at the head of Shovel Creek. Particularly on the slopes of the 1,375-foot hill at the head of Virginia Creek was this kind of material noticeable. The float showed fragments of limonite often 3 or 4 inches in length, which, from their position, must have been formed in the limestones. The ore showed frequent cavities containing calcite, and the general impression gained at the time the float was found was that it represented the replacement of the limestone by an iron-bearing solution. The limestone occurred in stalactitic growths and as round botryoidal forms. A porous structure is characteristic of the limonite. No sulphides from which the iron mineral might have been derived were found.

Summary.—Although considerable space has been devoted to a description of rocks containing disseminated mineralization, it is believed that few, if any, lode deposits of economic importance will be developed in them. It is only where peculiar conditions cause a localization of the ore-bearing solutions that valuable deposits are likely to be found. The fact, however, that mineralization is widespread is important as showing the magnitude of the field open to the intelligent prospector. Scores of instances of veins showing sufficient mineralization to warrant prospecting might be noted, but as there are many veins of similar appearance which after having been opened up were abandoned, investors should be warned to examine each particular claim on its individual merits and not to accept or decline any property without careful investigation.

LODE DEVELOPMENTS.

BIG HURRAH MINE.

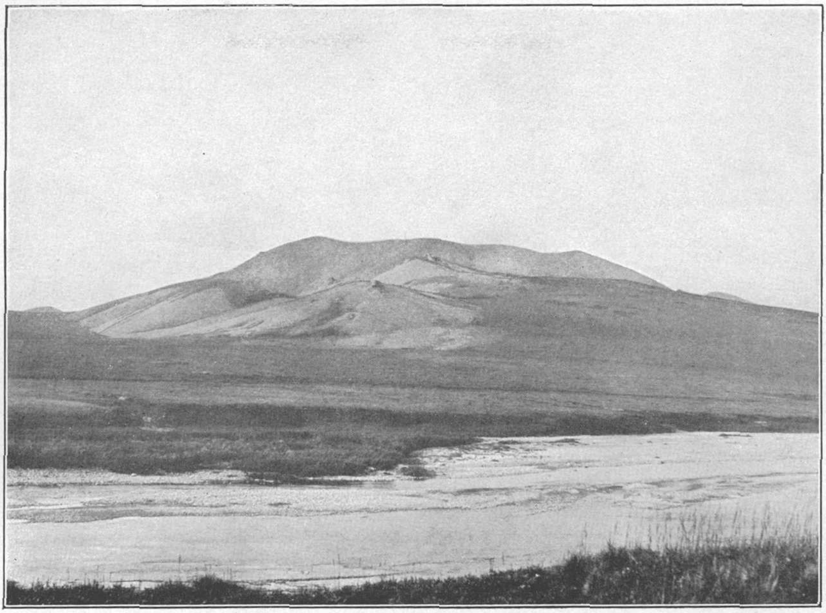
General statement.—Up to the present time in the entire region there has been only one mine which has been placed upon a paying basis. This is the Big Hurrah mine, which is located at the junction of Big Hurrah and Little Hurrah creeks. The lode was discovered in 1900, but no considerable amount of work was done on it until 1903. From 1903 to 1907 the mine was in nearly continuous operation, but in July of the latter year it was closed because of difficulties with the administration of the property and was not run at all during 1908. Owing to the fact that the mine was stopped and the pumps drawn soon after the Survey party reached the region in 1907, it was possible to spend only half a day underground and consequently not as thorough an examination could be made as was desired. In this hasty study few facts in addition to those published by Collier [a] were learned.

A general view of the Big Hurrah mine is shown in Plate XV, *B*. At the extreme left of the view is the main shaft house with the tall smokestacks. At the extreme right is the stamp mill, which is connected with the shaft house by a covered way, so that the passage between the two may be used winter and summer. The other buildings are the bunk houses and shops customarily found around a mine.

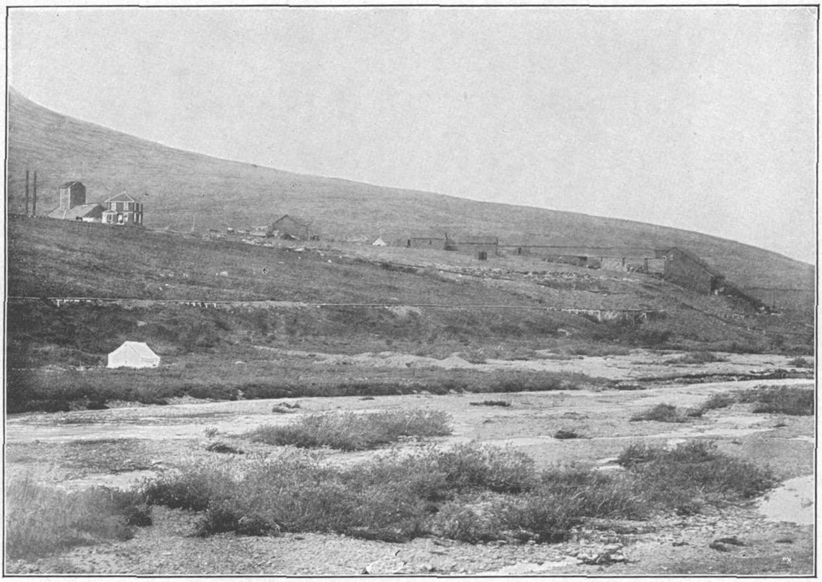
Veins.—There are several veins at this place, but the middle one has been most extensively worked. At the present time the shaft is down more than 250 feet and several hundred feet of drift are turned off. The veins occur in a black, hard, somewhat graphitic, quartzitic rock which breaks into more or less rectangular fragments. This rock occurs in a rather narrow belt, a mile or so wide, extending from Uncle Sam Mountain to the head of Solomon River. The country rock is much fractured and is thoroughly intersected by quartz veins or stringers from a fraction of an inch up to several feet in width. The veins have all been more or less crushed and crumpled, but they have not been so greatly deformed as to lose their continuity. The amount of deformation which they have suffered suggests that they belong to the later series of quartz veins, which were formed either coincidently with or later than the second period of metamorphism that the region has undergone.

A striking feature of the quartz in the Big Hurrah mine is the absence in it of much sulphide mineralization. To one familiar with many of the gold lodes in the States, the almost entire lack of iron stains on the quartz and the absence of any undecomposed sulphides in the rock is very noticeable. It seems, therefore, that the gold must occur in the quartz mainly in a native state rather than mechanically mixed with pyrite or other metallic compounds. If this is true, it has an important bearing on the successful search for gold lodes in the district, for the prospector, instead of being able to approximate the value of a ledge by sight alone, must have recourse to competent assays to determine the gold content. It is known that much of the quartz which is said to run $10 to $14 a ton in gold looks like a hard, dense, unmineralized rock which would generally be

[a] Collier, A. J., and others, Gold placers of parts of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, 1908, pp. 228-231.



A. LOWER CASADEPAGA VALLEY, MOUNT DIXON IN BACKGROUND.



B. BIG HURRAH MINE.

passed by as "bull quartz." The lode prospector should be advised to sample carefully all strong quartz leads and have the samples accurately assayed, rather than simply to neglect the lead because it looks lean and unlike the auriferous quartz found in many known productive camps. By no means would he always be repaid for his trouble, for undoubtedly many of the leads are barren, but he might discover lodes that would be overlooked in the more crude prospecting. In a quartz lode of low tenor, where the gold is in finely disseminated particles, it would be practically impossible to gain reliable information from roughly crushing the ore and panning.

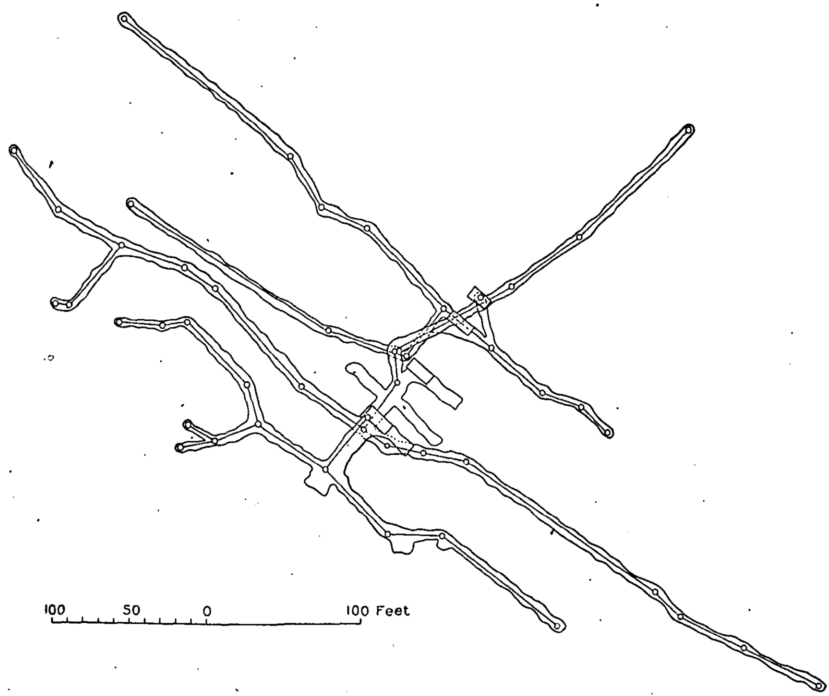


FIGURE 24.—Plan of underground workings of Big Hurrah mine.

Developments.—The main developments at the Big Hurrah mine have been by means of an incline shaft which has a general though not constant slope of about 60°. The strike of the veins is northwesterly and the dip is to the southwest. The upper portion of the vein has also been worked in part by adits run in from the outcropping of the vein on Little Hurrah Creek. A general plan of the underground workings is shown in figure 24. North of the main lead there is another vein about 50 feet below in the foot wall. This vein, unlike the two farther south, has a northwesterly dip, although the strike is essentially the same as the others. It is the belief of the mine operators that this northern vein is a continuation of one of the others, the structure being therefore anticlinal. From the evidence of the structure as shown in the rocks of the neighborhood, as well as from the amount and character of deformation of the veins, it is suggested that such an interpretation is not the correct one, but further developments alone can definitely determine the truth.

Ores.—The ore as a rule is in bunches of quartz, some of which show a considerable segregation of gold, but the best grade is in what is called locally "ribbon rock." The ribbon character is due to bands of quartz separated from each other by small partings or horses of dark, graphitic schist, of varying width, but all relatively narrow. The ore breaks down rather readily, as both the hanging and foot walls are generally determined by fault planes which show slickensiding. The faults, however, do not continue uninterruptedly throughout the mine. The movement was along a number of fault planes which were essentially parallel. The time of mineralization seems to have been later than the main folding and deformation of the region, but earlier than the slight faulting which is marked by the dislocations already noted. It may therefore be associated with the later stage of mountain building which gave rise to the east-west structural trend now visible in the Kigluaik and Bendeleben mountains.

Equipment.—The Big Hurrah mine is well equipped for carrying on all the necessary mining and concentration processes. The ore is broken down mainly by hand, although two machine drills are used. After the ore has been broken it is loaded in cars and trammed to the shaft, hoisted to the surface, trammed on tracks through the covered way to the ore bins in the stamp mill. From the bins the ore is drawn as required to feed the stamps. These are of the usual California pattern with automatic feed. The mill is equipped with four batteries of five stamps each. A sufficient fall is obtained from the storage bins so that no rehandling of the ore is necessary. After passing through the batteries the pulp flows over plates treated with mercury. Part of the values are caught on the plates, but the tailings are collected in a launder and distributed to oscillating tables. There are four tables, two of the ordinary Frue type and two of a form which has been developed at the mine. On the tables some of the heavy fragments, which consist of small particles of gold mixed with quartz and also sulphides, are caught. The tailings from the tables are carried to a settling pond formed by diking a flat on Little Hurrah Creek. No attempt has been made as yet to rework the tailings in the settling pond, but presumably when the accumulation is sufficient to warrant the trial they will be rehandled. No estimate of the amount of gold lost in the milling process was attempted, but the fact that a settling pond had been built suggests that the need of an extra process was felt and that at times the loss of gold in the tailings may have been high. It often seems to be the case that the presence of graphite prevents gold from amalgamating readily. If this is so, probably considerable losses are to be attributed to this cause.

The recovery of the gold from the batteries and tables is similar to that in general use. A battery is stopped, the box is thoroughly cleaned, and the plates scraped and reamalgamed. The amalgam from the plates and the material from the boxes are put into a barrel amalgamator and the barrel rotated for half a day with an excess of mercury. After rotating for this length of time the barrel is stopped and the amalgam removed. The excess mercury is squeezed out and the amalgam either retorted or sent to the bank. The concentrates from the tables are sacked and shipped outside for treatment.

The main hoisting plant and the mill have been run by steam, but as it costs $8 a ton to deliver coal from Solomon to the mouth of Big Hurrah Creek, and as there is then a 2 or 3 mile haul by team, the expense is so great that it is purposed to use oil or gasoline when the mine is again opened. A gasoline engine was in use during the last part of the time the mill was in operation and was extremely satisfactory. This form of power would be especially economical in the hoisting plant, because the work there does not require such a constant power as coal and the engine would require oil or gasoline only while actually working.

MISCELLANEOUS LODE DEVELOPMENTS.

In the belt of black graphitic quartzitic schist already noted as occurring in the Solomon and Casadepaga regions there is widespread evidence of mineralization, though save in the immediate neighborhood of the Big Hurrah mine no considerable prospecting has been done. At the small dry gulch leading from Uncle Sam Mountain there is a prospect pit which has been abandoned for some time. It is sunk on the black quartzitic schist, which is very much sheared and folded; in fact, many of the small quartz veins form a complete S. The quartz of the veins has a peculiar appearance, owing to the presence of a halo of milky crushed quartz around a central, more glassy portion. Some of the quartz is heavily iron stained, but as a rule no sulphide minerals are evident. Even on top of Uncle Sam Mountain prospectors have been looking for veins, for there are two abandoned pits slightly to the west of the highest point. In these holes a somewhat mineralized black, slaty schist intersected by numerous quartz veins is exposed.

In the lower portion of Linda Vista Creek, a tributary of Big Hurrah Creek, there is a vertical quartz vein which strikes toward the northwest. It is 7 or 8 feet wide and has been faulted twice. Much of the rock near it is considerably crushed. The main evidences of metallic mineralization consist in the large number of limonite stains which cover the quartz. Somewhat north of this vein there is another hole in which an 18-inch quartz vein is exposed. This vein strikes in the same direction as the other but dips only about 60° SW.

About a mile north of the mouth of Little Hurrah Creek a good deal of prospecting has been done in the past, although work has now been entirely abandoned and the pits are filled with water. This property also occurs in the area of black quartzitic schists, which here strike northwest and dip at a low angle to the northeast. Two inclines with a slope of about 30° have been driven, but the character of the veins could not be determined, owing to the water. Near the inclines there has been about 300 feet of open cutting, but in the exposed area only narrow quartz veins which pinch out within a short distance are visible. The quartz, like so much of the quartz in the black quartzitic slate area, shows but sparing amounts of metallic minerals. Evidences of faulting are common.

On the first tributary to Solomon River from the west below East Fork an adit has been driven on a vein occurring in the black graphitic slates. This vein is located along a fault which has an indeterminate throw, and is distinctly later than the fault. The amount of mineralization is not very great, although in places the rocks are considerably iron stained. The adit is only 20 feet long, and the mineralization becomes progressively less toward the breast, and the amount of drag indicated by the wall rocks also diminishes. No work has been done at this place for some time.

A series of veins occurring in the chloritic-schist areas away from any contacts with other rocks has been opened on West Creek 2 miles above the mouth. Some work is done here every year, and there are 600 or 700 feet of underground workings, but the mine has not yet shipped any ore. The development is on a north-south vein, which was opened by an adit that drifted along the vein for over 350 feet. In this drift both walls were decomposed chloritic schist, which in places showed marked slickensiding. Another adit about 300 feet long has been driven on a vein farther west, which shows the same general character as the first. A crosscut following a small cross stringer has been run from the eastern drift. The quartz from all the veins is practically the same in character. It is white and somewhat shattered, but is apparently not sheared nor folded, and presumably belongs to the later set of veins. In addition to the quartz the veins carry abundant chlorite and a small amount of pyrite and marcasite. The later metallic minerals occur in small stringers and vugs. The wall rocks are also said to be gold bearing and the foot-wall schist is reported to carry from $8 to $10 a ton in gold, but no assays of the rock have been made by the Survey.

SUMMARY OF MINERALIZATION AND LODE DEVELOPMENTS.

From the foregoing description of the places where mineralization has been observed, certain conclusions seem to be justified, and as these may be of service to the prospector they are set forth here. It should be understood, however, that with subsequent underground developments whereby more extensive exposures are afforded, certain of the interpretations may require modification.

The most highly mineralized rock of the region is the Hurrah slate. Everywhere this is intersected by quartz veins ranging in width from a fraction of an inch up to several feet. Gold is known to occur in many of these veins, and it seems probable that one of the best places for a prospector to search for lode deposits is in this formation. Owing to the less deformed character of the veins in the Hurrah slate these are likely to show greater continuity than those in most of the other formations. It is possible that the carbonaceous material in the slates may have acted as a precipitant for the ore-bearing solutions, but it is believed that the great abundance of veins in these rocks is due to the physical character of the members, which has permitted much jointing and fracturing.

The next most mineralized area is along the contact of the Sowik limestone and the underlying schists. Mineralization at this place is widespread and very diffuse, so that lodes of workable character are hardly to be expected. This widespread mineralization, however, has had an important effect on the production of placer deposits, as will be shown in a later section. The location of mineralization along these contacts seems to be due to the permeability of the limestone and possibly also to the precipitating effect of the carbonate. Under favorable conditions where the mineralizing solutions were prevented from diffusing over a large area veins of economic importance may perhaps be found, though the crumpled and contorted character of the contact would probably make the actual tracing and mining of these deposits expensive.

In the Solomon schist there is but slight chance of finding valuable lode deposits in the older series of quartz veins. The newer quartz veins, however, undoubtedly cut the Solomon, and among these economically important veins may be discovered. Although it is not regarded as feasible to mine the older veins they are of immense importance as having furnished a considerable portion of the gold now found in the placers. Pockets of rich ore may be found in the older veins, but the discontinuity of the leads will prevent any large mining operations being developed on them.

Among the rocks of igneous origin and basic composition there seems to be slight reason for prospecting for minable veins. Not only were few veins of any extent noted in these rocks in the field, but also (see pp. 214–215) where these rocks occur placer deposits are practically wanting. This seems to point quite conclusively to the determination that gold-bearing veins are relatively infrequent in these areas. No adequate data are at hand to show the relation of the acidic igneous intrusive rocks to mineralization.

PLACER DEPOSITS.

CONDITIONS OF FORMATION.

For the production of placers at least three conditions are essential. First is the presence of mineralized zones from which valuable minerals may be derived. If the region shows no such mineralization, the chances of finding rich placers is so remote as to be almost negligible. It has already been stated that mineralization is widespread throughout the region, but that in areas occupied by certain kinds of rocks the mineralization is not as great as in areas where other kinds of rocks form the surface. Therefore, in these less mineralized areas the placer deposits are fewer and of less value than those in more mineralized regions.

Besides the presence of mineralization there must have been a period of preparation whereby the hard vein matter in which the gold occurred was so broken up that a separation of the heavy from the light particles could be effected when subjected to sorting action. This stage of preparation is generally the result of a longer or shorter period of weathering, whereby disintegration and decomposition take place. This process is not of as much importance as the first, for a placer could be made from unweathered ledge matter. The gold, however, resulting from the simple wearing away of the fragments of vein material by rolling and sliding would be very fine, and as the pebbles would travel far before all the valuable mineral had been released from the worthless gangue the placer thus formed would be of considerable length but of low tenor. This process can, however, be better comprehended by considering it in connection with the next step in the formation of placers.

The third stage may be called the sorting stage. Although sorting may be effected in any way which causes movement of the already prepared vein matter, the two most common ways are by water sorting and by gravitative sorting without the presence of water. In the remarks on the formation of unconsolidated deposits of non-water-sorted waste, it has been noted that on any slope a slow downhill creep of material takes place. Although no deposits of economic importance, due to this kind of sorting, have been recognized in the Solomon-Casadepaga region, there are deposits in near-by areas where the placers are due to such action. Such a deposit has been described by Moffit [a] near Nome, and another has been noted on one

[a] Moffit, F. H., and others, Geology of the Nome and Grand Central quadrangles, Alaska (in preparation).

of the tributaries of Ophir Creek in the Council district. It is evident that as the material is moved the heavy particles will tend to work downward, perpendicularly, while the lighter particles will move more nearly parallel with the slope. A concentration will thus be effected. While such a concentration will generally be slight, still, if the original vein was rich, it may make a profitable placer. The most effective sorting, however, is done by running water. It is this agent which, acting in the same manner as water in a sluice box, washes the lighter material downstream, while the heavier particles drop to the bottom and are thus concentrated. The way that the broken up and somewhat comminuted fragments which have been produced by weathering from the parent ledge are fed into the streams, is by the downhill creep of material under the influence of rainfall and gravity. By this process the waste gradually comes within the reach of streams and is then sorted. For the production of a rich placer, however, a large amount of waste must be sorted. This requires as a rule steep gradients for the streams and steep slopes to the valley walls. Steep valley walls are important, for otherwise the creep of material is so slow that long periods may be consumed in transferring even a small amount of material from the hill slopes to the streams. Steep gradients to the streams are necessary; for otherwise, if a large amount of waste is fed into them, they are liable to choke, and the streams will build up their beds in order to gain a sufficient slope to flow on, and sorting will be reduced to a minimum.

As the streams flow onward the lighter material is rolled along the bottom, or if it is sufficiently fine it may be carried in suspension or in solution. Gold is slightly soluble, but little of that found in placers has been transported in solution. The fine particles may also be carried in mechanical suspension, but the weight of gold is so great that only a small amount is transported in this way. The bulk of the gold in streams is probably moved by rolling and sliding along the floor of the bed. In this way the original particles of gold become constantly smaller. It is true that an enlargement of some of the particles may be shown to have resulted from the welding of two or more smaller particles, but on the whole the effect of the movement of the particles is to wear them away and thus decrease their size. It was for this reason that emphasis was placed upon the preparation of the material by weathering before it was handled by running water. With the greater comminution, the gold becomes harder to save and consequently the value of the placer is less than where the gold is coarser and may practically all be recovered.

There are several other minor considerations which should be noted, but they are not of as prime importance as those already stated. Among these the character of the bed rock, or of the impermeable horizon which serves as bed rock, is perhaps the most important.

Everyone who has studied the distribution of gold in placers realizes that the bed rock serves the same purpose as the riffles in a sluice box. If the stream has a very smooth bed, it is evident that slight place for lodgment would be found. Therefore a stream bed which offers many little irregularities behind which the heavy particles can escape the full force of the current will be most effective in causing concentration. Conversely, in those streams where such natural riffles are more or less wanting the gold will not be concentrated into rich pockets. Fortunately, however, the beds of ordinary streams are sufficiently rough to effect some concentration even on the smoothest stretches. One of the most promising places to look for little accumulations of gold is behind bowlders or pebbles of the more resistant rocks in the stream beds. For instance, in the Casadepaga region, where there are numerous greenstone bowlders which are very hard and wear away but slowly, accumulations of gold are often found. In fact, it is said by an old prospector that, when searching for gold, it is best to select a stream where there are numerous greenstone bowlders, not because the gold came from them but because they formed good riffles for intercepting it.

The schists form a good bed rock for holding the gold, especially when they have a steeper dip than the stream, so that the water flows across the beveled edges. This forms a rough frayed surface into which the gold can penetrate and lodge. In some places the gold works down so far along the division planes of the schist that several feet of this must be removed in order to recover the values. Limestone also forms a good bed rock for catching gold, especially where it is interlaminated with schist. Limestone areas, however, are the regions where underground drainage may occur and where, with the disappearance of the water, the sorting of the gravels is slight except at times of heavy rains.

To summarize the foregoing statements as to the conditions which are necessary for the production of placers of economic importance: It is necessary, first, that there should be a mineralized area from which valuable heavy metals may be derived; second, that the mineral-bearing material should be so disintegrated and decomposed that the constituents may be separated according to their relative weights; third, that the waste thus prepared should be sorted so that a separation by gravity may be effected. It has been further pointed out that the larger the amount of material sorted, other things being equal, the more valuable will be the concentration resulting. Further, a larger amount of waste is transported and sorted in a region with steep slopes and stream gradients than in one in which the slopes are gentle and the streams sluggish. Finally, the amount and distribution of the concentrates depend largely on the character of the stream bed, so that a stream with good natural riffles, other conditions being equal, will have better placer deposits than one with a smoother bed. However, as the beds of all streams are more or less rough, this factor is not so important as the others.

GENERAL METHODS OF MINING PLACERS.

The general principle underlying all the processes for the extraction of gold from gravels is that, for a given-sized particle, gold is so much heavier than any other common mineral that it will not be carried so far by a transportational agent. All that is theoretically necessary, therefore, is to feed gold-bearing gravel into running water, and a separation will be effected. Practically, however, many mechanical and physical difficulties must be overcome. In the first place it is necessary to have the concentrates collected in such a manner that they may be removed. This necessitates carrying on the operation in a confined space, such as a sluice box, in which riffles must be placed to supply a rough surface to catch the gold. The gravel must be gotten into the boxes and the tailings must be removed. The first process is commonly effected in small plants by "shoveling in," and in the larger and more expensive plants by some other means, such as dredges, steam shovels, scrapers operated by steam, horse, or water power, and hydraulic elevators or giants. The tailings, or gravel from which the gold has been separated, may be disposed of by men with shovels, by scrapers, or by other means, unless the natural fall of the stream is sufficient to keep the material from choking the outlet. In this region, however, mechanical means of removing tailings must be employed. Water must be had at sufficient elevation to flow through sluice boxes; and this necessitates the construction of ditches, many of them of considerable length, or the use of pumps.

CLASSIFICATION OF PLACERS.

Brooks has classified placers according to their origin and form as follows:[a]

I. Residual placers.
II. Sorted placers:
  - Hillside.
  - Creek and gulch.
  - River bar.
  - Gravel plain.
  - Bench.
  - High bench.

III. Re-sorted placers:
  - Creek and gulch.
  - Beach.
  - Elevated beach.

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[a] Bull. U. S. Geol. Survey No. 328, 1908, p. 115.

This classification is very complete, but as he has pointed out there are many placers which might be considered as intermediate between these definite divisions. In the Solomon and Casadepaga region it has not been considered expedient to adhere to so minute a subdivision, and the placers will all be treated under one of two heads—as stream and bench placers or as coastal-plain placers. All the profitable placers probably belong in Brooks's Class III—"re-sorted placers,"—but the distinction between sorted and re-sorted deposits is generally difficult or impossible to make.

STREAM AND BENCH PLACERS.

INTRODUCTION.

A stream placer is a concentration of valuable heavy minerals either in the bed of a stream or on the floor of the valley periodically overflowed by the stream. The distribution of the values depends on the physical conditions in force when the deposit was being formed. Thus the values in a stream that is building up its bed will be found in different positions with respect to the gravels than those in a stream that is on the whole wearing down its bed. The character of the gold also varies according to the physical conditions, for in a stream where all the gravel is in more or less constant motion downstream the gold will be bright. If, however, the gravels in which the placer gold is found move but slightly, perhaps because the stream is filling in its bed rather than eroding, the gold is often covered with a film of iron stain or some other coating so that it is rusty. In the portion of this report dealing with placers, gold is the only valuable mineral found, and so the word "gold" is used instead of the more general term of "heavy valuable mineral" which should be used when expressing the general broad characters of placers. In some places both rusty and bright gold is found in the same gravel deposit, showing that some of the material has been recently abraded and part has not been transported for a longer time. The outline of the gold particles shows great differences under varying conditions. Thus, when the gold has not traveled far since it was freed by disintegration and decomposition from the parent vein, it is generally in delicate filaments or angular pieces, sometimes showing crystal forms. When, on the other hand, the material has been carried farther away from the vein from which it was derived it is more rounded, has all its corners smoothed off, and is worn down into rather flat scales of small size and generally of a bright gold color. The shape, however, is largely determined by the original form of the grain of gold. If the gold in the vein was in thin sheets, the gold in the streams will generally be in flakes or plates; but if the gold in the original vein matter was in pieces of more or less equal dimensions, the gold in the placer will occur in rounded grains. The farther the gold is from its source, as a rule, the freer it is from adhering vein matter. For instance, near the vein, placer gold frequently shows fragments of quartz or other gangue mineral attached to it, or the gold is seen to occur in strings through the quartz. Farther downstream, however, because it has been subjected to more erosion and weathering, it is rare to find any quartz attached to the gold. The more the deposit has been re-sorted the more abraded become the fragments, so that in those regions where two or more processes have been at work the gold may become very fine. It has also been more or less conclusively shown that the farther the gold has traveled from its source the purer does it become.

HISTORY OF PLACER MINING DEVELOPMENTS.

Mining of creek placers was the first development of the mineral resources of the district. As far as records go, the discovery claim on Solomon River was staked early in the summer of 1899. This claim was located near the mouth of Big Hurrah Creek, and as is noted on the map, Plate VI, is in a region near the contact of the schists and heavy limestone. Since that time the work of mining placer gold from the streams has been steadily in progress, and practically all the placer gold comes from this source.

Although it is impossible to follow all the successive stages of the development of the region, there are certain steps which give as it were an epitome of its history. In the first place, the earliest prospectors employed methods of very primitive pattern: Pick and shovel, whipsawed lumber for sluice boxes, and green willows for fuel. For a while the rich diggings near Nome kept men from seeking other fields. Then followed a period in which all parts were believed to be phenomenally rich, and the whole region was staked and restaked and plans for active work were formed. By 1903 a couple of small dredges had been built and were in successful operation, but in the main the methods employed were simple pick and shovel ones. In 1905 a large dredge, described in more detail on page 159, was completed, and it has been eminently satisfactory. In 1907 attention was first seriously diverted from the creek and low-bench gravels to the coastal-plain deposits, but throughout this entire period the stream gravels have been the main source of the placer-gold production.

DISTRIBUTION OF THE PLACERS.

In the detailed description of the various stream placers that have been examined the general order of treatment will be geographic, but it will be the purpose of the paper to emphasize the geologic facts about these placers. As a rule, the mechanical processes used in handling the gravels will not be described except where they present new adaptations of old processes or the solving of old problems by new devices.

In the area covered by the Solomon and Casadepaga sheets placer mining has been most extensively carried on in the Solomon River basin. In this basin the portion where the most productive placers have been found extends along the main river from Rock Creek to Big Hurrah Creek. Of the tributaries of Solomon River, Big Hurrah Creek and the tributaries of Shovel Creek have been the most productive. Practically no gold has been produced from the creek gravels of Casadepaga River, but the benches on each side not only of the main stream but also of its tributaries have been exploited with profit. The side streams have had the most valuable placers. Of the tributary streams, Ruby, Banner, Goose, and Willow have yielded the best returns. On the side streams both benches and creek gravels yield placer gold, the creek placers being richest where auriferous deposits from the benches have been reconcentrated. Mining on the creeks that lie outside of the Solomon and Casadepaga basins has been done at only a few places, and in general the production has not been satisfactory. The general distribution of the gold placers is shown by appropriate symbols on the geological maps, Plates VI and VII.

PLACERS OF THE SOLOMON RIVER DRAINAGE.

PRODUCTION.

The creek placers of the Solomon River basin have been far more productive than those of any other part of the area under consideration and will therefore be described first. The larger part of the production has come from Solomon River itself, from its large western branch, Shovel Creek, and from its smaller eastern tributary, Big Hurrah Creek. Numerous smaller streams have, however, yielded placer returns, but the work has generally been carried on by camps of only a few men each, so that although the production per man may have been considerably more than wages, yet the total production has been small as compared with that of the Nome region. There is hardly a stream in the basin that has not been prospected and reported to yield colors, but during 1907 in the entire Solomon River basin probably less than 125 men were employed in placer mining. Brooks [a] estimated that in 1900 about $10,000 was taken from Solomon River and its tributaries. In 1904, however, the production had increased so materially that Brooks [b] estimated it to be about $200,000. In 1905, according to Moffit,[c] there was no considerable

[a] Brooks, A. H., and others, Reconnaissance of Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 69.

[b] Brooks, A. H., Placer mining in Alaska in 1904: Bull. U. S. Geol. Survey No. 259, 1905, p. 20.

[c] Moffit, F. H., Gold mining on Seward Peninsula: Bull. U. S. Geol. Survey No. 284, 1906, p. 136.

increase in the production. In 1906, however, a large dredge completed in the previous year increased the yield of the region, although the amount produced by the small operators probably fell off. In 1907 the production increased slightly, but most of the increase was made by the dredge and the production of the smaller operators was probably less than that of the preceding year. In 1908 an exceptionally dry season notably hampered mining work, so that from thirty to sixty days of the usual one-hundred-day season were lost. A new dredge was built and operated for part of the season, so a part of the decrease in other lines of work was made up for in this way.

SOLOMON RIVER TO SHOVEL CREEK.

Mouth of Manila Creek.—There was no mining on Solomon River below Big Hurrah Creek in 1900, but by 1903 there had been some developments a little above the mouth of Manila Creek. The placer here was described by Collier,[a] as follows:

> A river-bar deposit about 3 miles from the coast has been worked for two seasons by a dipper dredge. The pay streak here has an average width of about 200 feet and a thickness of 9½ feet, most of the gold being concentrated in the lower part. It rests upon a soft mica schist bed rock, which is mined by the shovel to the depth of about 1 foot. Overlying the bed rock is a layer of clay several inches thick that carried good values. The pay streak is said to be spotted, but has been estimated to contain from 12 to 30 cents to the cubic yard.

Purington,[b] who found this work still going on in 1904, reported that the average thickness of the gravels was about 5 feet, the deepest section exposing 12 feet of gravel, and that most of the material was unfrozen. Although the pay was spotted, the ground probably ran somewhat over a dollar a yard. As a rule, the gravels were not very coarse, the largest bowlders found being only about a foot in greatest dimension. The dredge was equipped with buckets of a capacity of 1 cubic foot and the gravels were sorted in a long sluice box. Purington estimated that 75 per cent of the entire gold content of the gravels was caught by the mercury plates in the upper 6 feet of the sluice box and that the remaining 25 per cent was saved in the next 8 feet. There was no mining at this locality between 1906 and 1909.

A reference to the map, Plate VI, will show that although the bed rock at the dredge is schist, the bluffs near Manila Creek and extending upstream for nearly three-fourths of a mile are formed by a heavy limestone. It would seem, therefore, that the placer occurs not far away from the contact of a massive limestone and the underlying schist—a place which, as already pointed out, is frequently marked by mineralization.

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[a] Collier, A. J., and others, Gold placers of parts of Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, 1908, p. 224.

[b] Purington, C. W., Methods and costs of placer mining in Alaska: Bull. U. S. Geol. Survey No. 263, 1905, p. 165.

Collier[a] further notes that in 1903 mining was being done near this place in the flood plain of the river, which at that point was about 400 feet wide. This deposit, like that just described, rests upon a bed-rock floor about 3 feet higher than that of the river. The values are found in a clay, overlying bed rock. Two ditches, one 3 miles and the other 9 miles long, supplied about 1,000 miner's inches of water. Mining was done by shoveling into sluice boxes, but it was intended to hydraulic the gravels in the future. This deposit has not been worked recently. In fact, in 1907 and 1908 no work was in progress on Solomon River below Rock Creek, and although there were some abandoned camps, work had been given up such a long time before that the marks of it had been almost obliterated.

Three Friends property.—Between Rock Creek and Johnson Gulch the ground is held by the Three Friends Mining Company, which is mining the gravels of the river by means of a large dredge of the Bucyrus type. The width of the valley floor at this place ranges from 400 to 600 feet. The depth of the gravel varies much, but is on the average between 15 and 20 feet. This enterprise may be regarded in many ways as a model of the careful application of business principles to mining. The thorough and systematic prospecting of the ground by trenches and drill holes should serve as an example to all those contemplating mining by dredges.

The Three Friends Company's dredge was built in 1905 and began its first work in September of that year. (See Pl. XVI.) It is similar in all essential respects to the dredges in use at Oroville, Cal. Each of the buckets is made of high-grade steel, weighs over 1,100 pounds, and has a capacity of 5 cubic feet. The gravels, after having been elevated by the buckets, are dumped on shaking screens, and the material which passes through is distributed to tables where the values are retained. The coarse tailings are fed to an endless rubber belt conveyor and are stacked in ridges at the rear of the dredge.

The freezing of the tailings and the conveyor belt in the late fall or early spring was prevented by covering the stacker with old canvas and running a small exhaust-steam pipe a short distance along the conveyor. By this means it has been possible to operate the dredge after the other creek operators have been forced to close down. The high cost of the coal used as fuel has led to the consideration of plans for a hydro-electric installation. In fact, the dredge was so constructed that the steam plant could be easily supplanted by electricity. Such a change would not only reduce the cost of power, but it would also permit increased production by reducing the time necessary for cleaning up.

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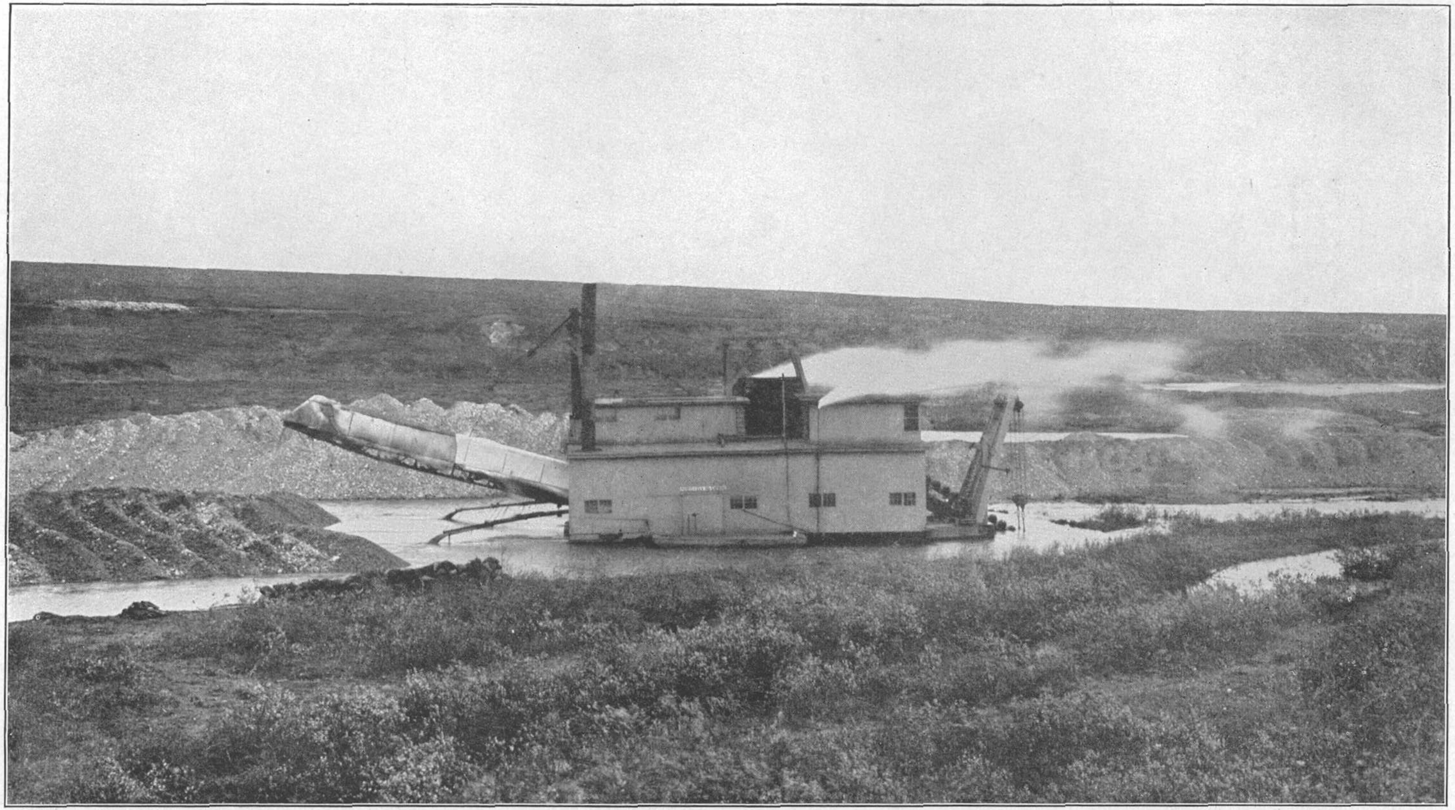
[a] Bull. U. S. Geol. Survey No. 328, 1908, p. 224.



DREDGE NEAR MOUTH OF JOHNSON GULCH, SOLOMON RIVER.

A technical description of this dredge recently published by Rickard[a] gives some figures regarding the enterprise not heretofore available for publication. According to the article, the dredge cost $118,000, was modeled after Exploration No. 2 dredge at Oroville, Cal. Its capacity is 3,700 cubic yards a day, and its cost of operation is estimated at about 10½ cents a cubic yard. If, however, the total cost is made to include not only the actual operating expense, but also items to cover depreciation, maintenance, and amortization of the capital, the cost is brought up to 18 cents a cubic yard.

While these statements of the cost of handling the gravel are of great interest, it seems wise to interject a word of caution against applying these figures to all dredging enterprises in Seward Peninsula. It should be remembered that such low operating expenses are possible only under particularly favorable physical conditions All the ground to be dredged was carefully tested in advance of actual mining, and the area and extent of permanently frozen ground outlined so that it could be avoided. Most of all, however, sufficient acreage was obtained to last out the life of the dredge. By attention to this last detail the amortization charges per year were greatly reduced, for it is evident that such charges are much lower where the installation will have a life of ten years than where it will have one of only five years. In the case of the dredge in question the company, according to Rickard, controls 4,000 acres, of which less than 100 have been dredged out in the three years that the company has been operating.

Still another fact that has contributed to the success of the work at this point has been that the bed rock over the larger part of the area is schist, which is much more easily excavated than the hard limestone which can be handled only by very powerful dredges.

The geology of this part of Solomon River is complex. Near Rock Creek the bed rock is schist, but its direction of dip and strike is variable. On the east side of the river the rock is a light-colored chloritic schist with small dark specks. In places it shows small pits which seem to have been formed by the weathering out of crystals of iron pyrite. But on the opposite side of the river the schist is light silvery in color, has abundant mica, and shows many parallel quartz stringers and calcite veins. The dip at these two places is in almost precisely opposite directions. Farther upstream, nearly opposite the mouth of Jerome Creek, the bed rock is a calcareous schist which in places is practically a pure limestone. Still farther upstream, in bluffs opposite Moran Creek and extending as far as Johnson Creek, are ledges of a heavy, massive bluish-white limestone. It is believed that the contact between the limestone runs very nearly through the ground that is being mined by the dredge. Whether the contact at this place is a normal depositional contact is not definitely known. It is believed,

[a] Rickard, T. A., Dredging on the Seward Peninsula: Min. and Sci. Press, vol. 97, 1908, pp. 734–740.

however, that the contact is marked in part by a fault. This is suggested by the lack of relation between the strike direction and the contact. On the other hand, the progressively more calcareous character of the schists as one approaches the contact suggests conformable relations between the two, such as has been pointed out in other parts of the field. The significance of the limestone-schist contact as a probable locus of mineralization has already been suggested (pp. 141-142).

All the observations recorded above concerning the character and distribution of bed rock in this portion of Solomon River have been based upon ledges which appear in the bluffs of the stream. The depth of the gravels, as previously stated (p. 105), seldom exceeds 30 feet. It would appear, therefore, that a narrow rock-walled canyon was cut and subsequently filled, and that the values occur with deeper gravels near bed rock. The bed rock at the Three Friends Company's dredge is a series of calcareous schists, sufficiently decomposed to permit the dredge to pick up 12 to 18 inches from the top.

The gravels are all apparently of local origin. Owing, however, to the larger area tributary to this part of the river, the rock fragments belong to widely different kinds of rock. No granite was seen in any of the gravel, although searched for. The only doubtfully foreign material which was found was some magnetic iron or magnetite, which, owing to its great weight, collects in the sluice boxes. It seems probable, however, that this mineral, as well as the other material found in the creek placers, is of local origin, although the ledges from which it was derived have not been actually observed.

The gold appears to be found mainly in the lower layers of the gravel, although colors may be found practically from the surface down. Most of the gold which was seen was in rather thin platy scales of a bright color. Few nuggets of any size have been found. In a letter one of the owners of the Three Friends property, W. L. Leland, makes the following statements:

There are four different runs of gold. One is the ordinary smooth wash gold that you generally find in the streams of the Seward Peninsula, and, judging from its color, I believe that it is of unusual fineness. There is not very much of this kind of gold. Perhaps 1 per cent of the gold is of coarse nature that has apparently been carried some distance in the original rock in which it was formed. In many instances the quartz has partly disappeared and the space where the quartz probably was is filled with a sort of oxide—iron rust. There are spots on the gold that will amalgamate; however, it will not sink in quicksilver, owing to the adhering quartz and the iron rust. The majority of the gold where we are dredging is fine (not flour gold). What I mean by this is, you can readily see and count every color with the naked eye, and by using a powerful glass it is seldom that you can find any additional colors of flour gold. It is the ordinary flake-wash fine river gold. Then there is a considerable quantity of square thin colors of gold. * * * Another peculiar thing about this class of gold is that all of the grains are about the same size. As an estimate, would say that they are each about one-fiftieth of an inch square and as thick as ordinary writing paper. I have never noticed this peculiar shape of gold elsewhere. When we take pains to remove all the shot and bullets from the amalgam before melting, our gold runs $19.02½ per ounce. * * *

I would judge that 95 per cent of the gold we get by the dredging process is in smaller pieces than 3 grains in weight. Out of a cleanup of, say, $10,000 I would estimate that there would be $40 or $50 in nuggets weighing from $1 to $12 each. The nature of the nuggets is rough and scraggly. * * *

Mouth of Jerome Creek.—A short distance above the mouth of Jerome Creek, on Solomon River, a small amount of mining low-bench gravels was done in 1908. The bed rock at this place is a few feet above the level of the river, and is of a yellowish, somewhat calcareous character. It is overlain by about 12 feet of well-rounded waterworn gravels, the largest pebbles of which are from 6 to 8 inches in diameter. All of the gravels are frozen except where exposed by surface strippings. Throughout the greater thickness of these beds valuable heavy minerals are almost entirely wanting. Near the base, however, there seems to have been a slight concentration, and some pay gravel is found. Together with the gold in the concentrates is a large amount of magnetite and ilmenite and a small amount of garnet. Water for the development of this ground is delivered from the ditch on the east side of Solomon River intaking on Big Hurrah Creek (see p. 219) and is carried by hydraulic pipe to the point where it is used. This place is interesting, as it gives an insight into the character of the gravels that form notable deposits along Solomon River as far north as Quartz Creek.

Moran Gulch.—On Moran Gulch, a few hundred yards from Solomon River, an outfit of two men in 1908 hydraulicked bench gravels which seemed to be more closely allied to Solomon River than to Moran Gulch. In thickness the gravels show considerable local differences, but the average is about 9 feet. In section the unconsolidated material consists in the upper part of muck and vegetation; this is underlain by layers of more or less clear ice mixed with muck; and this is underlain in turn by 3 or 4 feet of well-rounded gravels resting on a decomposed-schist bed rock. Exploitation at this place has failed to reveal any rich ground, but it is a question whether the mining methods practiced may not be responsible for the slight returns. No drain has been carried up to the workings, and it is the practice to pipe the gravels into the sluice boxes through a large pool of standing water. Furthermore, bed rock is cleaned only with the hydraulic nozzle. Owing to these two methods of work, it seems highly probable that a share of the values is not recovered. Water is delivered to this ground from the ditch on the eastern side of the Solomon River valley, intaking on Big Hurrah Creek. Work was in progress at this place only during the latter part of 1908.

Above Johnson Gulch.—Just above Johnson Gulch, upstream from the Three Friends Company's property, another dredge operated by a different company was installed during 1908 in the short space of seven weeks. It was not a new dredge, having been originally in use near Hope, Alaska, but it had seen so little service as to be practically as good as new. Almost the entire first part of the summer was lost from actual productive work in assembling the dredge, and it was after September before mining began. Work was carried on until the close of the open season, about the end of the third week of October, and a large amount of gravel was moved. The chance of comparing this dredge, which is of the Risdon type, with the modification of the Bucyrus farther downstream, is exceptionally good, and should afford considerable data for a rigid examination of the efficiency of each type.

In operation the 5-foot buckets raise their load of gravel to the level of the upper deck of the dredge and dump it onto an inclined plate which directs the material into a revolving trommel. The oversize from this is discharged into flat pans which form a bucket conveyor, and the tailings are stacked at the rear of the dredge. The finer material, after passing through the screen, is fed to tables covered with cocoa matting on which are laid expanded metal riffles. No quicksilver is used on the tables. The greater part of the gold is caught in the upper part of the tables, but the lighter material after it has left the tables is carried in a sluice with riffles, and a small additional saving may thus be effected.

According to Rickard,[a] the actual operating expense at this dredge, without allowing for depreciation, interest, or amortization, is a little over 14½ cents per cubic yard. The ground has not been carefully prospected in advance of mining, so that no statement of the average tenor of the gravels is possible. It would seem, however, from the fact that the values lie mainly in the lower layers and on bed rock, that the financial success of the enterprise depends in large measure on the efficiency of the dredge in cleaning the bed rock, which over a portion of the area to be worked is a hard limestone.

Mouth of Shovel Creek.—The next locality upstream where placers have been worked is near the mouth of Shovel Creek. In 1903 Collier reported that a steam shovel was being used to develop the ground both in the Solomon River bed and on the flats east of the river. The gravels at this place are about 9 feet deep and consist of pebbles of great variety, all of which seem to be of local origin. Most of the bed rock is a very dark schist. There are, however, limestone areas in which it was found that the shovel was not so serviceable as where schist occurred. On top of the bed rock is a layer of clay, on which the greater part of the values were found. This clay proved troublesome for the economic treatment of the ground, for it clogged the trommels and thus prevented the distribution of the gravels. Pur-

[a] Rickard, T. A., Dredging on the Seward Peninsula: Min. and Sci. Press, vol. 97, 1908, pp. 734–740.

ington stated that in 1904 work was still in progress at this place. According to his report, the cost of operations was about 50 cents a cubic yard. In the season of 1904 the dredge worked about fifty days of twenty hours each. The shovel proved effective, but the ground handled was rather easy to mine, for it was not permanently frozen. The seasonal frost, however, lasted until the middle of July, so that about a month and a half was lost at the beginning of the season and mining work ceased early in the fall. The gold was very irregularly distributed and occurred in a pay streak which in places was 200 feet wide. No estimate of the average tenor of the ground was obtained, as it was reported that the values ran from 30 cents to $12 a cubic yard.

In 1905 this property was not being operated and the shovel had been removed to a near-by bench claim. (See p. 172.) When the region was hastily traversed in 1906 no mining was being done near this place, and the shovel had been removed again, this time to one of the near-by creeks. In 1907 and 1908 no work was in progress on the main river near the mouth of Shovel Creek, and much of the old work had been obliterated.

SOLOMON RIVER, SHOVEL TO QUARTZ CREEKS.

Between the mouth of Shovel Creek and Quartz Creek the gravels have been exploited, but so far the claims on the benches seem to have yielded better returns than the present river gravels, where only a small amount of gold has been won.

Mouth of Penny Creek.—In 1903 Collier noted that near the mouth of Penny Creek six men were employed mining the gravels of Solomon River. Pans reported to run 30 cents each had been found, and about 100 feet of the valley floor had been prospected. In 1906 this portion of the river was visited after the freeze up, when all work had been abandoned. In 1907 there was some mining of the creek gravels near this place. Work, however, did not begin until rather late in the season. The river was kept out of the cuts by the construction of a wing dam of sacks filled with gravel. About six men were employed, but no estimate of the production was furnished. The gravels are here from 5 to 8 feet in depth, and the values are found near bed rock. The bed rock is mainly limestone, though in places there are bands of silvery chloritic schist. The false clay bed rock which had been noted in places downstream was practically wanting. The gold was, as usual, rather flat and flaky and of the bright river-placer type. Somewhat farther upstream a section of the gravels in the flood plain showed 2 feet of muck and 5 feet of river-washed gravels resting on blocky graphite schist bed rock. A large amount of work has been done all along this portion of Solomon River, for piles of tailings, abandoned sluice boxes, etc., are seen on all sides.

Between Shovel Creek and the mouth of Quartz Creek on the main river four camps were working during 1908. One outfit of only two men was mining low-bench gravels about a quarter of a mile above the mouth of Shovel Creek. Water for sluicing was delivered by a gasoline pump. The values in this ground are reported to be low and the returns therefore were probably small.

Farther upstream and only a short distance above the mouth of Penny Creek an outfit has been mining bench gravels west of the river. The gravels are about 10 feet deep. All of the upper gravel is well worn and the cobblestones are smooth and rounded. Bed rock, so far as exposed, is limestone which is much fissured as well as dissolved. In one place a pothole at least 8 feet deeper than the average level of the bed-rock surface has been dissolved in the limestone. At time of visit attempts to prospect this pothole had not succeeded in reaching the bottom, but so far as they had gone had failed to reveal any workable auriferous gravel. For the first one hundred or so feet from Solomon River the gravels were completely thawed, and it was only after getting in about 150 feet that frozen ground was struck. So far as could be determined, the upper gravels contained so small an amount of gold that for mining purposes they may be considered barren. Near the bottom, however, a pay streak of 1 foot of sand and gravel was encountered. The values are not limited to this thin layer, for gold has been found penetrating the cracks and crevices of bed rock to a depth of at least 4 feet. It is the practice at this place to sluice off the upper gravels and then to wash the pay-streak gravels and take up by hand from 1 to 4 feet of the bed rock. The pay streak is not only thin but also narrow, for it seldom has a width of over 30 feet, and 15 to 20 feet would probably be about the average. Water for sluicing is furnished by the ditch already noted on the east side of Solomon River.

Mouth of Quartz Creek.—Half a mile below the mouth of Quartz Creek a party of five men took advantage of the exceptionally dry season of 1908 and have been mining in the bed of Solomon River. The river has been turned aside and small areas of the old bed have been surrounded with sod dams covered with canvas to keep the water out. Bed rock in the eastern part of the claim is limestone, but toward the western side of the valley floor it is schist. The gravels are thin, nowhere exceeding 3 feet in thickness, and are probably more or less thoroughly set in motion each year by the stream. In consequence the values occur almost entirely on or within bed rock, so that it is necessary to take up by hand from 1 to 3 feet of the limestone to recover the gold. All of the gold from this ground is coarse and shows but slight evidence of having traveled far. In 1907 a $150 nugget was found, and in 1908 a $70 one was taken from near the bed-rock surface. The latter was not very bright gold and had a great deal of quartz and schist attached. From the character of the material associated with the gold, it was evident that the nugget had been derived from one of the older much-contorted quartz veins occurring in the chloritic schist that forms a part of the Solomon formation. The smaller pieces of gold are almost invariably bright and show no tarnish or rust. This character is in part due to the kind of bed rock on which they occur, for it is a notable fact that seldom in a region where limestone forms the country rock is the gold discolored.

An old dredge that for two years had been lying abandoned near the mouth of Big Hurrah Creek was resurrected in 1908 and placed in commission a short distance below the mouth of Quartz Creek. It is a small affair with four pan buckets. Power is furnished by a gasoline engine, the water being pumped by a 10-inch and a 3-inch pump. The larger pump delivers the water for the main line of sluice boxes, while the smaller is used on the so-called "slough-over" from the bucket line. Hungarian or pole riffles are used in the boxes, and most of the gold is caught in the upper half of the string. Unfortunately, the machine is not strong enough for the work it is called upon to do, and more than half the season was lost in making repairs. Bed rock in the eastern part of the claim is limestone, but in the western part schist predominates. Most of the mining is being done on the western part, for the dredge is not capable of cleaning the hard limestone. It is estimated that the dredge can handle 400 yards of gravel a day, but this maximum is seldom attained.

Just east of the last-mentioned dredge near the mouth of Quartz Creek bench ground at slight elevation above the river has been developed on a small scale. Bed rock is limestone, in places much brecciated. The gravel here and there is 10 feet thick, and this has allowed some winter work by drifting. No well-worn gold is found on this claim, all the pieces being chunky and often of considerable value. The largest piece was worth $250. This heavy gold seems to occur near the contact of the Sowik limestone and the Solomon schist. At this place the bench gravels are often cemented. Both iron and lime form the cementing material, and in a few instances placer gold has been found in the midst of the cement. Owing to the cemented character of a part of the gravel some gold is undoubtedly lost in sluicing, for no attempt is made to break up the agglomerate, and so the pieces roll through the sluice boxes. Whereas the greater part of the gold on this claim is bright, that occurring in the places where iron-bearing solutions are present is rusty and will not amalgamate.

Almost directly above this bench ground, but at a somewhat greater distance from the river, are other well-made gravels which extend at least 50 feet above Solomon River. The highest gravels are well exposed in an artificial cut for a ditch on the nose between Quartz Creek and Solomon River. The gravels are well rounded, and some of the pebbles are 6 or 8 inches in diameter. Fragments of all kinds of local rocks were noted. Greenstone, black schist, and limestone are most abundant. Nearly 100 feet in elevation above the cut there is a prospect pit, but the fragments thrown out from it are mostly angular, and show practically no water rounding. No values have been obtained from the place. A little lower than the highest exposure of water-worn gravels a prospect pit has been sunk on a terrace of Quartz Creek. All the débris on the dump is schist, mostly of the dark variety, which is heavily iron-stained. The material is rather irregular, but looks like river wash. From the configuration of the rock floor on which these gravels rest, it would seem that they occupy a stream-cut channel, for ledges of limestone rise above the level of the gravels both to north and south.

SOLOMON RIVER, QUARTZ CREEK TO BIG HURRAH CREEK.

The earliest work on Solomon River was on the Discovery claim, near the mouth of Big Hurrah Creek. Richardson,[a] who visited the region in 1900, states that in 1899 about $150 was taken out by three men, who worked less than two weeks in prospecting the river gravels at that point. At this claim the Solomon River flood plain is 600 to 800 feet wide, and although bed rock in the river rises to within 1 to 3 feet of the water, the flood-plain deposits here and there on either side show 6 to 8 feet of gravel. No productive work was done on this portion of the river in 1900. In 1903 a dredge had been built and had been in operation more or less successfully for some time. The buckets had a content of about 1 cubic foot each, and the dredge was estimated to have a capacity of 400 or 500 yards a day. The gravels that were mined were creek gravels from 2 to 6 feet thick. Pans taken from areas which were known to be especially rich yielded Collier 3 or 4 cents to the pan. This, however, is believed to have been above the average which could be obtained in actual practice. The gold is reported to have been rather coarse when compared with the general run of Solomon River gold. There is, however, considerable fine gold mixed with it, and it is suggested that the coarser gold may have come from the neighboring benches, where nuggets valued at over $100 have been found. The finer gold may have come from longer distances within the Solomon River basin. The gold is of high grade or fineness, mint assays reported by Brooks giving a fineness of 0.905. Some difficulty was experienced in dredging because in places permanently frozen ground was encountered. The distribution of the frost was not

[a] Reconnaissance of Cape Nome and Norton Bay regions in 1900; a special publication of the U. S. Geol. Survey, 1901, p. 100.

regular, and it was rather unusual to find frozen gravels so near the river. In 1904 this dredge had moved somewhat down the stream from its position reported in 1903. In 1906 and 1907 it had entirely ceased operation on the main river, but in 1908 it was being used at the mouth of Quartz Creek.

In 1903 there was some work being done about a mile below the mouth of Big Hurrah Creek, on a low bench. The gravels at this point showed a section of 4 or 5 feet of muck and sand resting on about 4 feet of pay gravels, which in turn were on a much-shattered limestone bed rock. The pay penetrates bed rock to such a distance that it is often necessary to take up and clean 3 or 4 feet. The gold is described by Collier as consisting of coarse nuggets mixed with fine gold, all of which was worn smooth and contained little or no quartz. The width of the pay streak was about 200 feet. The bed rock is 7 or 8 feet above the normal river level.

In 1907 there was some work being done on the benches a little more than a mile below Big Hurrah Creek. The gold was mostly coarse. Nuggets worth from a few dollars to $200 and over have been found. The gravels and covering from the surface down to bed rock are about 8 feet thick, but only the lower foot or so carried good values. The bed rock is a limestone, which is much cracked and fissured, so that the gold has penetrated deep into it and a considerable thickness must be taken up and cleaned. Although the bed rock under the particular gravels that were being worked was limestone, less than a fifth of a mile upstream it is schist. The contact therefore must be near at hand, and suggests an explanation for the occurrence of the large nuggets that have been reported.

Still farther upstream are two or three camps established during 1907, all of which have been developing benches at essentially the same elevation. The gravels occur at an elevation seldom as high as 25 feet above the normal surface of Solomon River and usually rest on a bed rock of white, somewhat crystalline limestone. The depth of overburden is from 2 to 8 feet, and consists of muck and tundra vegetation. This is underlain by distinctly water-washed gravels which seem to be of river-made origin. No fragments of rocks derived from foreign drainage basins were recognized. The elevation of the gravels above the present stream is so slight that probably no considerable drainage modifications have taken place since their formation. Although considerable enterprise has been shown in the development of these bench deposits, and although some coarse gold has been found, the production has not affected materially the output of the district.

In 1908 only one of the bench deposits between Quartz Creek and Big Hurrah Creek was mined. This mine was on the east side of Solomon River about two-thirds of a mile below Big Hurrah Creek.

Three men were engaged at this place, and the method of mining was by drifting from a vertical shaft. Water for sluicing is furnished by a small gasoline pump which takes water from Solomon River. The pay gravels are hoisted by a gasoline engine, and the bucket dumped by the man attending to the sluice boxes. Bed rock is a heavy, white, much-fissured limestone, in which the gold has penetrated to a considerable depth. No values are found in the upper part of the overlying gravels, and as the ground is solidly frozen, the drifting method is applicable. No statement could be obtained as to the tenor of the ground, but from the fact that the work has been continued for several years, it would appear that the results were satisfactory.

SOLOMON RIVER ABOVE BIG HURRAH CREEK.

Between Big Hurrah Creek and East Fork no mining of stream gravels was in progress in 1907 or 1908. On all sides, however, numerous evidences of previous work were found, but the methods employed had apparently been those of the prospector rather than of the producing miner. The ground, however, would seem to be promising, for black carbonaceous quartzitic slate similar to that occurring at the Big Hurrah mine forms the bed rock for a considerable portion of the distance. This schist is frequently intersected by quartz veins which belong to the same series that have been found at other places to be auriferous. There are many exposures of the black slate in the steep walls which mark the limits of the slightly filled valley. The flood plain in places is 500 feet or more in width, and the depth of gravels varies much, but is seldom over 6 or 8 feet. In other places, however, the flood plain is contracted to only a few score feet. The river is frequently split into two or three channels, with islands of gravel between the different branches. Limestone is practically absent in this part of the river, though it caps the hills to the west.

Near the mouth of East Fork a broad flat in which the gravels are 5 to 8 feet thick was worked in 1903. Collier states that the gravels rest upon a schist and limestone bed rock. The gold is fine, flat, and smooth, and is said to be uniformly distributed. The gravels are reported to carry upward of $1 a yard, but this estimate has not been verified. Just above East Fork an outfit of five or six men were mining creek gravels in 1907. Work began here late in the season and stopped early in September, so that the gravels were probably of low tenor. Nearly opposite Jones Creek a camp was established and some prospecting had been done. The amount of work accomplished was, however, small. Still farther upstream, near the mouth of Winnebago Creek, three men were handling the gravels with a two-horse scraper in 1907. The gravels were on the western bank of the river and were slightly above the level of the stream. In this part of the course the stream follows the eastern side of the rather narrow flood plain, leaving a flat 200 to 300 feet wide. This flat is probably overflowed annually during the spring, and even later in the season during heavy rains it is in larger part covered. The gravels are so little decomposed that it is probable they are frequently transported by the water. The gold is reported to be on the whole fine, and few nuggets of any size have been found.

Between Winnebago Creek and Coal Creek no mining was in progress during the two years in which the area was studied by the Geological Survey, and there are few indications that much work has been done here in the past. The bed rock consists of a series of thin dark schist bands interlaminated with limestones, some of which are fairly thick. The flood plain of the river gradually widens toward the north, expanding from 200 or 300 feet near the mouth of Winnebago Creek to 700 or 800 feet near Coal Creek. A large amount of work has been done in the past on the gravels of Solomon River, near the mouth of Coal Creek. The pits have, however, long since been abandoned, and Collier, who visited the region in 1903, makes no mention of any work being in progress at that time. The gravels were rather thin and the tenor was low. A hydraulic elevator has been installed, but not much of the mining was accomplished by its use. The power for the elevator was derived from a ditch which tapped Coal Creek above Boise Creek and brought the water to the nose between Coal Creek and Solomon River, from which point the water was carried in a pipe to the elevator. A head of nearly 200 feet was thus obtained.

North of Coal Creek no mining was done on the gravels of Solomon River during 1907 and 1908. Three or four deserted camps were seen and a few where prospectors were living. These gravels seem to have been pretty thoroughly prospected in the early days. Richardson states that in 1900 considerable work was done in this part of Solomon River. According to his report the gravels in the river bed were about 4 feet thick and rested upon a calcareous schist bed rock. The gold was fairly coarse, $3 and $4 nuggets having been found. The gravels were not, however, sufficiently rich to be profitable with the high charges that prevailed during the earlier days. The gradient of the stream is very flat, the gravels are thin, and the water supply slight, so that the placers are difficult to handle economically. Collier, who visited this region in 1903, makes no mention of any work being carried on in this part of the river, so it is presumable that the time of its productivity was limited to the earliest years of gold discovery in Seward Peninsula.

Above Big Hurrah Creek the Solomon River benches seem to have been neglected, and little or no prospecting has been done on them. The relation, however, of some of the side-stream placers to the benches of the main stream suggest that much more prospecting is warranted. In places the side streams show gold values only where they cross the Solomon River benches. This fact would suggest that some of the present-day creek placers are reconcentrations of the older bench gravels. From the reports of the few prospectors who have worked on some of the benches above East Fork the gravels were promising.

TRIBUTARIES OF SOLOMON RIVER.

General statement.—Solomon River itself is not the only part of the basin where placers have been mined. Not only the larger tributaries, but also the smallest hillside gullies have been panned by the prospectors in their search for gold. While it is probable that not all the gold-bearing ground has been discovered, it is believed that the streams have been sufficiently prospected to point out whether there is likelihood of finding placer deposits or not. In describing the work which has been done upon the streams the various creeks will be taken up successively, starting with the mouth and proceeding toward the head of Solomon River. For the present those side streams which are flowing on gravel deposits of the coastal plain that have not cut down their courses to bed rock will be omitted, to be taken up later under the portion dealing with the coastal-plain placers (pp. 207–214).

Tributaries south of Shovel Creek.—Manila Creek is the most southern tributary of Solomon River which has cut its floor down to bed rock. The country rock along the lower course of this stream is limestone, but near the forks, three-fourths of a mile upstream, the material exposed in prospect pits is schist, so the contact between the rock is almost precisely marked by the branching of the creek. In the lower part of the stream, where limestone is the bed rock, the gravels are poorly rounded, and consist almost exclusively of limestone fragments with a small amount of greenstone float. There are many small springs along this part of the valley. Practically no ground of value has been found in this part of the stream. Above the forks along the southern branch there has been considerable prospecting, but no deposits of value have been discovered. At a short distance above the forks, however, the stream has not cut down to bed rock, and is probably flowing on coastal-plain gravels.

Two small streams, Eureka and Rock creeks, join Solomon River from the west about 4 miles from the coast. The former stream is less than three-fourths of a mile in length, and no placer deposits of value have been found along its course. On Rock Creek, however, some remunerative work has been done. Collier notes that in 1903 three outfits were mining on Rock Creek. As the entire stream is only about a mile in length, it is evident that almost all of the ground was occupied. The gold is reported to have been of two different kinds; one was fairly coarse and formed a small part of the entire content; the other, the larger, was in fine, smooth particles. When this creek was visited in 1907 and 1908 no work was in progress and many of the houses that had been built during the period that the gravels were being worked had fallen into decay. Bed rock consisted of a silvery-gray schist. From the difference in elevation of bed rock near the mouth and in the upper part of this stream it is suggested that its present course has been attained in comparatively recent times. A large amount of sheared greenstone float, heavily iron-stained, occurs on the surface. Black graphitic slate fragments and quartz pebbles are abundant in the gravels. The absence of the black graphitic rock in the immediate neighborhood suggests that it may have been derived from the coastal-plain gravels, which probably form the material over which the upper part of the stream is flowing. The difference in the character of the gold is also suggestive that part may have been derived from the coastal-plain gravels, while a part may have come from veins at no considerable distance from the placers. Practically no limestone was found in the gravels.

At the mouth of Rock Creek a device was practiced that has not been tried elsewhere in the district. This consisted in running the water of the creek through boxes equipped with amalgamated riffles. When this equipment was seen the amalgam was so bright that probably but low values had been caught. No information, however, was obtained as to how long the riffles had been amalgamated, and as it might have been done only a short time before, there are not adequate grounds for discussing the efficiency of the method. The small amount of water flowing in Rock Creek and consequently the slight transportation effected would seem to defeat the plan. Such an equipment costs almost nothing, and can be left almost indefinitely without attention, so even a small extraction of gold would be profitable.

On Jerome Creek some mining has been done in the past, but it is practically deserted at the present time. Some work was still in progress in 1907 near the mouth, but farther upstream the shacks were deserted and the pits had been abandoned for several years. The bed rock in the greater part of the lower portion of the creek is limestone with a few rather narrow bands of schist. In the upper part of the creek the stream is flowing on the gravels of the coastal plain and has not cut down the bed rock, but chloritic schist is probably the country rock. The pay is irregularly distributed, and there is both coarse and fine gold.

Shovel Creek and its tributaries.—Shovel Creek, the next stream to the north, and its tributaries have probably contributed as much gold as any of the branches of Solomon River. The main stream is about 7 miles long and flows more or less parallel to Solomon River. The geology of this region is very complex, and in the different parts many kinds of rock are encountered. The general features are shown on the map, Plate VI, but there are many smaller beds which can not be shown owing to the scale of the map. Thus, below West Creek for nearly a mile there is an alternation of thin limestones, black slates, and chloritic schists in rapid succession, and each shows a variety of dips and strikes. The complex structure has already been described and illustrated. (See Pl. XIII, *A*.)

A short distance above the mouth of Shovel Creek, on the north side, a flood-plain deposit at a slight elevation above the surface of the stream was mined during 1907 by a small outfit. The section showed 2 or 3 feet of muck overlying 1 foot to 2 feet of gravels, which were reported to run $6 a cubic yard. It is not known, however, whether this was the average tenor of the ground or was obtained from an especially rich portion. The thinness of the gravels in comparison with the thickness of the overburden makes mining more expensive than in deeper gravels. On the other hand, the width of the pay streak, which is reported to be over 400 feet, makes the ground promising. Water is obtained from a ditch which has its intake on Shovel Creek above Mystery Creek. In many places the gravels are frozen and therefore the cost of mining is increased. Thawing is done by sluicing off the overburden and allowing the sun and air to melt the ground. On account of the small body of gravels melting can proceed rapidly.

Further upstream the steam shovel that was formerly on Solomon River is in operation. This machine was moved in 1906 to the portion of the creek between Boston and Cadillac creeks, and has been doing more or less effective work ever since. The bed rock in the creek north of Boston Creek is limestone much fissured and creviced. Downstream, schist forms the bed rock, with thin limestone layers here and there. The gravels are thin, averaging probably not over 3 feet. The gold has worked down into bed rock for a considerable distance, and in practice it is necessary to take up from 2 to 3 feet of bed rock in order to extract the gold. The pay streak is about 200 feet wide, and seems to follow the main valley of Shovel Creek very closely. It is reported that below Cadillac Creek gravels running $13 to $16 a cubic yard were obtained, but these were exceptionally rich.

Considerable difficulty has been found in handling the gravels in this part of the creek because of the small amount of water available, the coarseness of the blocks of bed rock, and the low gradient of the stream. Shovel Creek, from Mystery Creek to its junction with Solomon River, has a fall of less than 25 feet to the mile. To overcome the mechanical difficulties incident to mining, the operator of this property has devised a scheme which presents many novel features. The shovel, its dipper having a capacity of about a yard, dumps the gravels upon a griddle formed of railroad iron. The griddle is agitated by a cam giving a short horizontal motion. The oscillation of the griddle causes the finer material to shake through the openings and the coarser to move down the slope, so that very little water is necessary. The oversize from the shaking griddle finally drops into the revolving trommels of different sizes set up with a strong pitch. Directly underneath this sorting apparatus is a string of sluice boxes into which the fines pass and are sluiced, finally being dropped at the lower end of the string of boxes. The trommels also discharge the oversize at the lower end. The whole sluicing and sorting plant is built on a movable car, so that when the pile of tailings has accumulated to such an extent as to nearly choke the apparatus the machine is pulled into a new position. In this way no rehandling of the tailings is required. Power is furnished by coal.

No mining was done on gravels of Shovel Creek above the steam shovel just described in 1907 and 1908. All along the valley, however, are excavations, which show that prospecting has been carried on, but apparently the returns did not justify further work. The tributaries of Shovel Creek have been and still continue to be producers, and most of the gold that has come from the Shovel Creek basin has been derived from the creek placers or the benches of the side streams.

Boston Creek, the most southern tributary, is a very small stream, not more than half a mile long, with practically no flowing water in it, as the bed rock is limestone and most of the water is carried by subterranean drainage. No deposits of value have been found in its basin. A short distance north of the mouth of Boston Creek, on the eastern side of the Shovel Creek valley, is Cadillac Creek, a small stream only a mile in length. This stream has been quite thoroughly prospected, but no pay gravels have been discovered, and the creek has been abandoned. The valley is formed almost entirely of limestone, and there is little or no surface water.

Mystery Creek and its branches, Problem and Puzzle gulches, has an annual production of about $30,000. While some of this is still derived from the present-day creek gravels, most of the gold is won from benches. In 1900 practically no mining was done, but in 1903 Collier reported that three or four outfits of about six men each were sluicing along its course. In 1907 and 1908 the most active work on present stream gravels was between Puzzle and Problem gulches. Most of the ground, however, is held by a company which has been engaged in bringing water from the Bonanza Creek drainage over into Mystery Creek, and it is probable that with the completion of this ditch work will be pressed in the region. If water under head can be obtained cheaply, there can be no doubt but that much of the present-day creek gravel, which has been previously mined by primitive methods, would pay for rehandling on a large scale. In 1907 there were only three outfits at work on creek gravels in Mystery Creek, and none of these consisted of more than three men each.

The bench gravels of Mystery Creek are very important, not only on account of their gold tenor but also because of the employment they afford during the winter, when practically no mining is in progress in any other part of the Solomon-Casadepaga region. This is a serious drawback, for many of the better men drift away and do not return, or if they return get in late in the summer, when the early period of abundant water is past.

Above Mystery Creek a fairly well pronounced bench is observable, and it is here that a good deal of the gold-bearing gravel has been encountered. In 1900 Brooks reported that some prospecting had been done on this bench but that the pay was not as good as in the present stream gravels. From 1900 to 1907 this creek was not visited by members of the Survey. It was found in 1907 that much mining had been done and that the results of the work had been to uncover a very complicated relation of channels and fillings. For instance, a shaft starting on a bench at that point 35 feet above the creek, passed through 43 feet of unconsolidated material before encountering bed rock, although in the near-by creek it was necessary to sink only 2 or 3 feet to reach bed rock. This would indicate that an earlier deeper channel had been eroded and later filled; then that the stream, flowing on a course somewhat southwest of the axis of the older one, had cut its channel down to bed rock. This deep shaft shows the following section: At the bottom a bed rock of soft, decomposed, dark-colored schist; gravels, 6 to 8 feet; a capping of cemented limestone wash from 2 to 18 inches thick, made of rather angular fragments cemented by lime; and above, to the top, an accumulation of slide and muck. The bench is most pronounced on the northern side of the creek, although recognizable also on the southern side. Values are said to be found for a distance of three-quarters of a mile in the bench. No measurements were made by members of the Survey, but the width of pay streak is reported to be from 100 to 150 feet. The depth of bed rock varies considerably in different portions, but the relation of the bonanzas to the form of the bed-rock surface has not been thoroughly determined. All the gold from the bench is fairly coarse, and most of it is dark and somewhat rusty. Banks pay $17.50 an ounce for the gold, but it is reported to assay $18.75. In form the gold is often wiry, and in many specimens quartz is attached to the nuggets.

On Puzzle Gulch only one man was at work during the summer of 1907. The gold from this creek is very coarse and many of the pieces have quartz attached. In shape some of the gold is wiry. It is reported that an old channel has recently been discovered in Puzzle Gulch at a lower level than the present stream channel. Prospecting has, however, not gone far enough to show whether this old channel carries values or not. The general character of Puzzle Gulch gold is such that there can not be much doubt as to its local origin. The gravels consist of limestone, black slate, chloritic schist, and greenstone, all of which form the bed rock in different parts of the region.

In 1900 Richardson visited Problem Gulch and reported that the bed rock for almost the entire length of the creek was schist. There are, however, no outcrops along the creek, and the only definite information concerning it is afforded by prospect pits. Richardson states that the gravels are as a rule from 2 to 3 feet thick, and rest upon a much-decomposed bed rock. In mining, about 2 feet of this disintegrated bed rock is washed, together with the gravels. The gold is reported to be rather coarse and of a bright yellow color. The gravels are reported to pay $10 a day to the shovel. When this creek was visited in 1907 very little work was going on, as many of the operators were unable to get water. A hole, however, which had been sunk on the southern side of the stream at an elevation of about 450 feet showed a condition which was entirely unexpected, and is not understood. This shaft was 45 feet deep and passed through 40 feet of stratified sand. The dip of the sand appeared to be easterly; that is, the layers sloped downstream. The sand was very fine grained and subangular, with fine mica dust. Wash gravel somewhat rounded is found on top of the same. This gravel is not as a whole well rounded. It is not known whether any pay was found in the sand.

Above Mystery Creek as far as West Creek some of the small side streams have been prospected, but no satisfactory returns have been received and work upon them has been abandoned. On West Creek, however, a good deal of work has been done and is being continued each year with satisfactory results. The geology of this creek shows a succession of different kinds of rock, all dipping westward at varying inclinations. Near the mouth there are ledges of schist. This is succeeded by a heavy bluish-white limestone, which in turn is followed by more schist, followed by limestone which is rather thin. West of this limestone is more chloritic schist, which extends for nearly three-fourths of a mile and is succeeded by a black, very quartzose slate, much metamorphosed. Richardson states that the average thickness of the gravels in West Creek is between 3 and 4 feet. In the lower part of the creek the gold is rather fine, but increases in coarseness toward the head of the creek. One nugget worth $3.60 was reported to have been found associated with quartz embedded in schist. From this occurrence Richardson points out that there can be no doubt but that the gold in the upper part of West Creek was derived immediately from small veins and lenses of quartz in the adjacent schist. Garnet, magnetite, some pyrite, chalcopyrite, and arsenopyrite are associated with the gold. Collier reports that in 1903 nine claims were being worked, but that the size of the different camps was small, only three or four men being employed on each claim. In 1907 only six claims were in operation, but this probably did not affect the amount of gold obtained, as mining, especially in the lower part of the creek, was conducted more energetically and on a larger scale.

A short distance above the mouth of West Creek a small bucket dredge operating on a track has been in use and has handled the ground efficiently and at a low cost. It is estimated that the dredge will handle 200 yards in ten hours, and as it only requires three men on each shift, and as gasoline is used for fuel, the expenses per yard of dirt mined are low. The ground is fairly well adapted for a light dredge of this sort, because the gravels contain few large bowlders and are not permanently frozen. Furthermore, pay in the lower part of the area mined is on a clay false bed rock, so that the dredge is not called upon to remove the undecomposed schist and limestone which forms the true bed rock beneath the clay. The gravels average 3 to 5 feet in thickness, and the amount of overburden is not great. The pay streak is very wide in the lower part of the stream but narrows somewhat toward the west. In the pay streak the gold is on the average fine and bright. There is also some gold in the upper gravels, but the richest portion is at the bottom. It is roughly estimated that the entire material will run at least $1 to the cubic yard.

The ladder with the buckets makes a cut about 20 feet in length along the exposed face of gravels. The sluice boxes are on the dredge and are so arranged that the tailings are distributed at the rear, on ground which has already been mined and consequently give no difficulty. Water for sluicing the gravels is brought in a small ditch and carried to the dredge in a canvas hydraulic pipe. Few difficulties have been experienced in thus sluicing the gravels, although the method adopted was in large measure an untried one.

On the next claim above the dredge on West Creek the gravels are thin and most of the values are found in the cracks and crevices of limestone bed rock, which is pried up with a crowbar and carefully washed by hand. This is a slow process and the production of gold, though probably more than wages, is small. Still farther upstream an outfit is mining 2 to 3 feet of creek gravels of low tenor. The overburden is ground sluiced off and the gravels shoveled into boxes. The bed rock is chloritic schist, in places somewhat heavy.

Farther upstream, where the first tributary from the north joins West Creek, a creek placer is operated. This ground has already been worked over several times, but wages can still be gained. The washed gravels are shallow and will not average much more than 2 feet in thickness. Values are found not only on bed rock but also throughout the gravels. The gold on bed rock is usually coarse and of a rusty color and is more abundant than in the upper part of the gravels. Where the gold occurs in the upper part of the placer it is usually fine and bright and the tenor of the ground is low. The bed rock at this place is a coarsely crystalline schist, much iron-stained. On the first small tributary to West Creek from the south a little work has been done during the last season, but the production was small.

None of the other tributaries of Shovel Creek up to Kasson Creek are being exploited at the present time, and there is slight evidence that more than desultory prospecting has ever been done on them. Kasson Creek, however, especially in its lower part, was one of the earliest producers in the region. The lower portion of the creek is on a much faulted and smashed limestone, but the upper part, above Lost Creek, is in a schist region. Some greenstone masses form part of the divide between Kasson and Butte creeks, and float of this rock is common in the gravels. The abundance of limestone in the lower part of the valley causes much of the water to be carried by subterranean drainage, and for nearly a mile there is no water at all in the bed. In 1900 Richardson reports that two parties were at work near the mouth of the stream. At that time the gravels were worked with rockers and water was carried from Shovel Creek. In 1903, however, when this creek was visited by Collier, about 40 men were employed, and gravels were being mined on 7 claims in the creek bed. The gold-bearing sediments are described as occurring on a much-fractured limestone bed rock and as penetrating the crevices of the limestone to a great depth. The pay streak, which was confined practically to the creek bed, had a width of 16 to 100 feet. The ground was worked by quarrying out irregular blocks of the bed rock and washing them in sluice boxes. Water for the sluicing was furnished by a ditch about 2 miles long which had its intake on Shovel Creek. During the mining operations excavations penetrated the bed rock in some places to a depth of 20 to 30 feet.

In 1907 Kasson Creek had relapsed into a state of relative inactivity, only a little mining in the lower portion being in progress. At this place there is practically no gravel. In places above the bed rock there is about 3 feet of fine sand, much of which is auriferous, but the main values are found in the crevices of the limestone. Pay at this place is reported to be rather fine and well rounded, but the gold that was seen seemed fairly coarse, with numerous nuggets. The values are not regularly distributed, but are found in pockets and rich spots. The unevenness of distribution suggests that the gold has been derived from a rather local source. There was no mining on Lost, Topnotch, or any of the other tributaries of Kasson Creek in 1907. Deserted cabins and abandoned ditches show that in the past much of this ground was being actively mined. All of the larger tributaries follow more or less closely the contact between the heavy limestones and the schists. It seems to be the general impression of miners in the district that there is still much gold in these creeks, but the lack of an adequate water supply is a serious handicap in working them.

In 1908 work was continued on the southern side of Kasson Creek by a small party that tunneled into the slide of loose rock searching for a channel. Gravels were found, but as the excavation was not timbered caving took place, a man was killed, and mining was then abandoned. No work was accomplished on any of the tributaries of this stream.

A little more than a mile north of Kasson Creek, Shovel Creek branches, the eastern fork retaining the name while the western is called Adams Creek. The latter flows across the belt of heavy limestone and heads in a series of schist and greenstone hills near the northwestern margin of the Solomon quadrangle. No mining was done on this creek in 1907, but the many pits and the piles of tailings along it show that it was for a long time a producer. Richardson reports that in 1900 the stream gravels were mined, but he was the only member of the Survey who has visited the creek up to the time of the present party. In the report of the work done in 1900 he says:[a] "The gravel in the stream bed varies from 4 to 6 feet in thickness. Magnetite and garnet are associated with the gold, which is both coarse and fine. The largest nugget found on Adams Creek was worth $4.20. Several $2 nuggets have been found. The assay value of the gold is $19.40 an ounce. From 50 to 60 ounces are said to have been taken out during twenty days' sluicing on one claim." None of the tributaries of Adams Creek are yielding gold.

On the western branch, the one retaining the name Shovel Creek, no mining was done during either 1907 or 1908. The main stream flows on a limestone bed rock, which is exposed at practically all points and is not covered with gravel. Some greenstone intrusives cut the limestone, but the igneous rock, where seen, was not mineralized. Some mining on a small scale has been done in the past on the gravels of some of the tributaries from the east. Though the broken and shattered character of the rock and the number of different kinds

[a] Brooks, A. H., and others, Reconnaissance of the Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 101.

of rock exposed in a small area would suggest this as a promising place for prospecting, the returns have apparently not been encouraging.

Tributaries between Shovel and Big Hurrah creeks.—The next tributary of Solomon River, upstream from Shovel Creek, is Penny Creek. This is a small stream that with its main branch is only 4 miles in length. The bed rock differs greatly in different parts of the basin, but, on the whole, is a limestone in the lower and upper portions, with schist occupying the intermediate region. Some work was done on the lower part of the creek in 1900. In 1903, when visited by Collier, work was in progress not only near the mouth but also for some distance upstream. Concerning Penny Creek, Collier says: [a]

> The gravel in some places rests directly upon broken limestone bed rock that has been penetrated by the alluvial gold, but more commonly a bed of clay intervenes between the limestone and the pay streak. In a placer 2 miles above the mouth of the creek 2 feet of gravel was observed resting upon a mixture of broken limestone and clay that had been excavated to a depth of 4 feet. Although the creek has produced considerable gold since 1900, the scarcity of water makes it difficult to work. Nearly all the gold has been obtained by the use of rockers, and sluicing can only be done for a few weeks each year after periods of heavy rain.

In 1907 there was no mining of stream gravels on Penny Creek except at the mouth. The gold from the lower part of the stream is coarse. Richardson, in 1900, saw an $18 nugget from this portion of the river, and $4 and $5 nuggets were fairly common. On Minnesota Creek, the main tributary to Penny Creek, no mining was done in 1907. A few prospectors and some claim holders doing their annual assessment work were seen, but no gold was produced. The side streams of Minnesota Creek, especially those from the west, such as Sapphire, Meddler, and Bear gulches, have been exploited in the past and a large portion of the creek gravels turned over.

On Penny Creek and its tributary, Minnesota Creek, no bench mining was done in 1907 except in the very headwaters portion of Meddler Creek, a small tributary of Minnesota Creek. Work at this place was hampered by the extreme elevation and the consequent difficulty of getting water to wash the gravels. When the property was visited much of the work was so badly caved that no section could be obtained. It appeared, however, that most of the material was so angular that it could have been but slightly waterworn. From the character it was suggested that the deposit was due to weathering and the downhill creep of material through the action of gravity. The possible occurrence, however, of gravels at such an elevation and with such a relation to the surrounding topography is of so much importance in gaining a complete history of the region that the suggested slide interpretation should not be accepted without a more complete study of the deposit in place. This ground was worked for

[a] Bull. U. S. Geol. Survey No. 328, 1908, p. 227.

only a portion of the summer, so that it is doubtful whether a profitable placer has been located. It is currently reported, however, that much of the gold which has been found is very coarse and that most of it is bright.

No mining was done on Quartz Creek in 1907 and 1908 except at the mouth, and this work was conducted on the bench gravels of Solomon River rather than on those of Quartz Creek. These deposits have already been described. (See pp. 164–166.)

Big Hurrah Creek.—North of Quartz Creek is Big Hurrah Creek, the first of the large tributaries of Solomon River from the east. This stream is of particular interest, for on it is located the only productive gold mine in Seward Peninsula. It was of interest therefore to note that the gold tenor of the stream was higher than that of any of the other streams. It suggests an intimate connection between the mineralized black slate and the production of valuable placers. The geology of the creek is shown on the map, Plate VI, but on such a generalized map that it is impossible to indicate all the small variations that occur. Suffice it to say that at the mouth there is a limestone which is succeeded upstream by black quartzose slates which extend as far as Little Hurrah Creek. Above this creek there is a series of schists and some limestones. Much of the divide, especially between Tributary Creek and the streams draining into the Klokerblok, is formed of igneous rocks. Big Hurrah Creek therefore flows over a great diversity of different kinds of rocks, whose relations show deformation and intrusion to have interrupted their orderly succession.

Work on Big Hurrah Creek has been carried on ever since 1900, but showed a decided decrease in 1907. Near the mouth, later in the season, the most vigorous work was conducted by hydraulicking. Two elevators were on the ground, but only one was in use at a time. The gravels, which were on the average 3 to 4 feet thick, were piped to the elevators and sorted. The gold was, as a rule, bright and fairly coarse. Several nuggets of considerable size, with quartz attached, were seen. None of the nuggets, however, showed any of the country rock, such as schist or slate, adhering, although it is reported that a nugget with black slate has been found. This ground had previously been mined, but the present operations show that values may still be obtained in this portion of the creek.

In 1908 hydraulic work was continued on this group of claims about half a mile above the place where mining was conducted in 1907. The unusually dry season, however, hampered mining, and not so much was accomplished as was expected. On this ground there are three elevators, but only one is in use at a time. Bed rock consists of black, somewhat graphitic, very siliceous slate, breaking into more or less rectangular blocks, and is typical of the Hurrah formation. A few narrow black limestone beds occur, but they are of slight extent. Bed rock is cleaned only with the hydraulic nozzle, and is not hand picked. While this undoubtedly saves expense, there must necessarily be a considerable loss of gold. It is reported that the gold from this part of Big Hurrah Creek is bright and medium coarse. It is usually flaky, but some small nuggets are found. Most of the values occur along the southern side of the present creek floor. The northern part of the valley bottom is said to show only a small amount of gravel, the material for the most part being slide that carries but low values.

Near the mouth of Linda Vista Creek a good deal of mining has been done. The gravels here are from 4 to 5 feet deep and, as a rule, rest on a clay false bed rock. This clay often consists of much decomposed mica schist, which in turn is underlain by more gravel. Collier described the gravel as consisting of more or less angular schist, some pieces 3 inches in diameter, mixed with well-rounded greenstone, filled in with finer material consisting of mica schist and some quartz pebbles. Except in the small islands in the stream itself, the gravels are overlain by fine sand and muck. Much of the fine sand occurring on the surface has been brought downstream from the Big Hurrah stamp mill. The values in this part of the creek are fairly evenly distributed from the surface down, and there is no decided enrichment on the false bed rock. The ground is worked by ordinary shoveling-in methods. Still farther upstream a small outfit has been at work on creek gravels, which in places are 8 to 9 feet thick. The gravels lie on a blue clay which is directly above bed rock. The values show concentration on the clay layer. The ground was reported by Collier to run nearly 10 cents to the pan. A short distance above Little Hurrah Creek one man was mining in the early part of the summer. The gravels were about 4 feet thick and rested on a schist bed rock. They consisted of pebbles of a great variety of different kinds of rocks. Pay, however, seemed to have been of low grade, for the work was abandoned in July and no further work attempted in the vicinity. The production therefore was small. Above Huff Creek two men were engaged in mining creek gravels, but information concerning the developments is wanting. The production was slight, however, as work did not commence until late and closed early. No work upstream from the junction of Tributary Creek and Big Hurrah Creek was done in 1907.

Bench mining on Big Hurrah Creek was practically suspended during the summer of 1907, and only a very little gold, mostly by prospectors, has been taken from the high-level gravels of the creek. In the past, however, much more attention has been paid to the gravels which form the benches of the stream. Such benches are particularly noticeable in the middle portion of the creek. Collier reported that in 1903 considerable mining was being done on a bench claim at the mouth of Lion Creek. At this place the bed rock was overlain by 2 to 3 feet of well-washed gravel consisting mainly of black schist fragments. An attempt to hydraulic the deposit was made, but was apparently unsuccessful, as work closed down early in the season and was not renewed. The same bench extends along the south side of Big Hurrah Creek and shows similar characters throughout. Thus a little below Lion Creek a deposit was worked in the past which consisted of several feet of gravels made up largely of black, chiefly graphitic schist fragments. The bed rock is a much decomposed schist. It was noted that where the black graphitic layer was wanting values were also wanting. Above the layer of black graphitic schist slide was 3 feet of gravel, consisting of coarse 3 to 6 inch fragments mixed with clay and sand.

Few of the tributaries of Big Hurrah Creek have produced placer gold in the past, and at the present time none are being developed. The only place where the work has amounted to much is on Lion Creek, a small stream less than 2 miles long, which joins Big Hurrah Creek near its head. This creek was mined in 1903, when the region was visited by Collier. He reports that at the mouth the gravels were about 4 feet thick and carried gold more or less irregularly distributed from the surface down. The bed rock is salmon-colored schist, with weathered pyrite cubes, and directly underlies a 50-foot bed of limestone that crosses the creek at its mouth. The schist is much decomposed. Collier states that although the values are higher on bed rock than in the overlying gravel, the gold does not seem to have penetrated the cracks and crevices to any noticeable degree. Upstream from the mouth, near a small gulch coming in from the south, considerable work has been done, and mining can have ceased only a short time ago. The fragments are large and fairly smoothed, but, being schist, they are shingly rather than round. The gravels are reported to have yielded about $2 a cubic yard in gold. Water power for sluicing was developed by damming the creek where it passes through a narrow gorge in bed rock. In this manner a considerable pond was formed which gave a nearly continuous supply of water during the season.

On Lion Creek itself, about 2 miles upstream from the mouth, considerable prospecting has been done. An adit 200 feet long was driven on the bed-rock floor under a bench deposit. But according to Collier up to 1905 no pay streak yielding as much as a cent a pan had been located, and the deposit was therefore abandoned and has not been reopened. The surface of the bed rock is almost horizontal and stands about 20 feet above the water level of the creek.

Other tributaries of Solomon River.—None of the small gulches which join Solomon River between Big Hurrah Creek and East Fork have produced any placer gold from creek gravels. East Fork, a stream 7 miles in length, has produced practically no gold. This is strange, for it runs over rocks similar to those that appear in the basins of productive creeks. From the mouth to Goodenough Creek bed rock is a greenish-gray chloritic schist with much wrinkled cleavage. Above Goodenough Creek, as far as Orphan Creek, limestones of a dark, nearly black color, light bluish-gray limestones, and slates of the black quartzitic variety form the country rocks. There are in places broad flats in the valley floor, as, for instance, near Matson Creek, where indications are favorable for the formation of placers, but although the creek has been fairly thoroughly prospected there have been no adequate returns.

Above East Fork, the next tributary of Solomon, on which creek placers have been mined, is Butte Creek. All along the lower part of this stream there is evidence of past mining, but in 1908, the only work in progress was on South Fork, a short distance above the junction. In the lower portion the bed rock of this stream is mostly schist; in the middle part it is a heavy limestone occupying a syncline; and upstream schist continues all the way to the divide. When the stream was visited in the fall of 1907 work had been suspended for the season, but it was evident that the bulk of the summer's operations had been on the benches on the northwestern side of the stream. The creek gravels have, however, been thoroughly turned over in the lower portion of the stream, and it seems to be the general impression that most of the gold which can be recovered by hand methods has been won. The main valley of Butte Creek is heavily filled with willows, and only desultory prospecting and development of water rights have been done.

The benches on the south fork of Butte Creek are pronounced, and the present stream has intrenched itself in them, but the amount of gold which has been won is slight. Most of the work during the summer of 1907 was on the western side of the valley where the benches are best preserved. The gravels rest on a schist bed rock and are about 8 feet thick. The surface of the bench does not stand more than 20 to 25 feet above the level of the South Fork. The deposit is frozen, and as it is so thin that it must be worked by open-cut methods, it is rather difficult to handle. When the creek was visited work for the season had closed, but it was evident from the hydraulic pipe, etc., lying around that hydraulicking was anticipated. From the character of the excavation it seems that this method had been recently adopted. Not much ground had been turned over, and it is probable that the amount of gold won was not much more than wages for the small number of men that were employed. The limestone-schist contact, which is not far away from the deposits, suggests the possibility of finding good ground near this place.

No mining was done on Johns Creek in 1907. Richardson notes that in 1900 about twenty men are reported to have visited this creek and spent a longer or shorter time. Water, however, was scarce, and as no well-defined pay streak was found, few of the prospectors remained long in the neighborhood. Richardson estimated that not more than $25 was taken from this creek, and it is doubtful whether much more has been found since. The bed rock, except in the upper portions of the valley and in a small area near the mouth, is schist.

Coal Creek, another of the large eastern branches of the Solomon River, is practically of no economic importance. No mining was done on the main stream in 1907, and from all the indications no considerable work has ever been done. In 1908 the only work in the entire basin was on some creek gravels in the upper part of Fox Creek, the first small tributary to Coal Creek from the south above the mouth. The ground being worked lies near the contact between a series of limestones and schists, which form the divide to the east and north of the creeks. The miners are hampered by lack of water, and only a small production from the claim is anticipated.

None of the other tributaries of Solomon River were mined during 1907, but along many of them there is evidence of previous work. None of this earlier work was, however, on more than a two-man scale, so that the production from this part of the river is small. Gold examined from Nugget Gulch, a small tributary from the east above Montana Creek, was fairly coarse and bright and showed some quartz attached. The difficulty of obtaining sufficient water without expensive ditch construction has prevented active development.

STREAM AND BENCH PLACERS OF THE CASADEPAGA RIVER BASIN.

CASADEPAGA RIVER.

General statement.—The stream placers of Casadepaga River are similar in most respects to those of Solomon River, but, owing in part to the greater distance from supplies and in part to the absence of thorough prospecting, the production is less than from the Solomon River basin. The gold values of the gravels of Casadepaga River were recognized even before those of the more southern river, and we have the statement on the authority of Brooks that the Casadepaga was prospected to some extent in 1898 and that claims as far up as Goose Creek were located in that year. In 1899 prospecting extended farther and farther up the side streams, and a few thousand dollars were won in the course of the development. In 1900 the season was very dry, and this had a deterrent effect, so that Richardson characterizes the year as having been devoted mainly to a continuation of the prospecting which had been done in earlier years; he estimates the production as having been about $15,000, most of which was taken from the side streams. In 1902 and 1903 the Casadepaga drainage basin was not visited by any members of the Geological Survey, and reports as to developments are lacking. In 1904 the region showed renewed activity, but only the primitive pick and shovel methods were in use and the production was small and came mainly from the side streams and from benches. In 1905 Moffit reported that only a small amount of work was being done in the Casadepaga basin and that most of this was on the side streams. When the region was visited in the fall of 1906 by the writer the general impression gained was that the work was carried on more by individual prospectors than by settled companies, and that as a result of this method the production from the river and its tributaries was small.

When this region was studied with more detail during the season of 1907 the impression gained in the earlier more rapid survey was confirmed. It was found that the entire number of operators amounted to only about 50 and that few of these were making wages. In the lower portion of the river, from its junction with the Niukluk to Fool Creek, no mining work had been done, although the country is completely staked and held by groups of claims. The prospecting which was being carried on in this part of the river in the fall of 1906, by drilling, seems to have been unsuccessful, for the drill has been removed. There is no data, however, to show whether the drill records failed to reveal remunerative ground or whether the price set on different claims was considered prohibitive.

In the Casadepaga basin benches have been somewhat more extensively prospected than in the Solomon River region, but few men are employed and the production is consequently small. The evidence from past work, however, seems to point clearly to the conclusion that the benches in many places contain gold in paying quantities and that successful mining ventures only await sufficient funds and energy to be profitable. All along the main river benches are well developed and form a prominent feature in the landscape. The gravels which compose them have been but slightly prospected, yet from the meager testing done and from the relation of creek placers to the benches it is certain that some of them carry values.

A good section of the bench gravels of Casadepaga River is afforded by a natural cut about an eighth of a mile above the mouth of Bonanza Creek. The gravels at this point are about 10 feet thick, with the base not exposed. The pebbles are almost entirely formed of limestone and white quartz, but there are also a few schist fragments. The gravels are well rounded and are very clean. Farther upstream, near the mouth of Fool Creek, the gravels show fewer pebbles of limestone and the upper portion of the deposit is generally covered by a layer of rather fine sand.

Fool Creek to Penelope Creek.—At Fool Creek, on the main river, one man has been prospecting the gravels and sluicing enough for a grubstake. The gravels rest on bed rock, exposed in the banks of the river a few feet above the water surface. The gold is often in fairly coarse pieces, nuggets having been found up to $11 in gold, but its distribution is very spotted, so that the returns per yard are low. Although no commercial sampling of the ground was made, it is currently reported that the gravels do not run more than 60 to 70 cents a yard. Associated with the gold is considerable iron pyrite, which is but little oxidized and suggests that this may not be far from a sulphide-bearing vein. This ground should perhaps be classed as a bench claim, but the very slight elevation of the bed-rock floor above the stream seems warrant for placing it in the creek placers. The elevation is so slight that the pits are flooded whenever there is high water in the river. The ground is sluiced with water caught in a small pond artificially dammed and is carried to the boxes in hydraulic pipe, the tailings being discharged into the river. The gravels are frozen and are thawed by exposure to the sun and air by stripping, without recourse to steam or fuel thawing. Near this place another outfit has been at work on similar gravels and on some gravels lying in small bars at the side of the stream. The production from this part of the river is so small as to be almost negligible, except for its importance in showing that there is gold in the lower part of the Casadepaga.

Brooks, in 1900, reported that the bench of Casadepaga River carries values where it is traversed by Dawson Creek, and that fine gold was found on a mica schist bed rock when the deposit was explored with test pits. Still farther upstream, near the mouth of Dixon Creek, this same bench has been prospected and is reported to carry about $3 a cubic yard in the lower portion. The pay streak is rather thin and consists mainly of irregularly shaped fragments of dark rotten schist which rest upon a more undecomposed schist bed rock. The line of contact between the bed rock and the pay streak is not well defined.

Between Dawson and Dixon creeks, in 1907, two camps of only a few men each were mining the gravels of a deserted channel of the Casadepaga, but the values were reported to be low. The depth to bed rock varies considerably in different parts of this channel, but the gravels were all of the typical river-wash character. The bed rock in this portion of the river shows considerable variation in short distances, ledges of heavy limestone being interrupted by much folded and contorted mica and chloritic schist, which appears to be very thick. Some coarse gold has been found, but there does not seem to be any defined pay streak, and the spotted distribution of the pay makes the cost of mining too high to be profitable.

Near Dry Gulch the bench of Casadepaga River is somewhat masked by the dissected alluvial fan of Dry Creek, which has in part covered the older gravels. Richardson, in 1900, says that he obtained no measure of the thickness of the bench gravels, but suggests that they may be as much as 50 feet deep. Shallow prospect pits 8 or 10 feet deep have been sunk, in which colors are reported to have been found from the grass roots down to the bottom. The gold is usually fine. Nuggets, however, worth $2 have been found, and the ground in places is reported to run $4 to $5 to the cubic yard. The character of the bench gravels through this part of the river's course is somewhat different from that obtaining in the other portions of the basin, for the gravels are not so clean and are more mixed with mud—a condition that would seem to be due to the alluvial-fan origin already noted. Besides mud the gravels contain considerable black sand and garnet. Concentration of values has often taken place on layers of clay occurring through the deposit.

In 1907 a prospector's tent was noted at the mouth of Dry Creek, but it was apparently abandoned and no work had been done at that point in recent years. Upstream from this place as far as the western boundary of the Casadepaga quadrangle (above Johnson Creek) no mining was being done on the present stream gravels. Not only was no work in progress in 1907, but evidence of past work was slight, and it is believed that the values so far found have not been sufficient to induce extensive prospecting. There can, however, be no doubt but that pay may be found in the present-day stream gravels where old benches have been undermined and reconcentration effected. Such places should be carefully examined by prospectors.

Although no recent mining of stream gravels was noted above Dry Creek, some mining of bench gravels was done in previous years about half a mile above the mouth of Dry Creek on the bench already described. During the past season, however, mining has been inactive, the ditch has been allowed to fall into disrepair, and little or no gold has been won. A section near this point, where the bed rock rises close to the surface, shows at the top about a foot of rather coarse gravel and sand with a very fresh undecomposed appearance. Below is a foot of fine sand and silt, which in turn is underlain by a foot of very rusty, somewhat decomposed gravel.

Penelope Creek to Moonlight Creek.—Much difficulty has been found in prospecting the gravels of Casadepaga River, because in many places they are deep and the ordinary prospector is unable to sink to bed rock. All the gravels, however, are not deep, and the variation in thickness suggests that the holes strike different portions of the buried stream course. At the mouth of Penelope Creek one of the deepest gravel deposits has been found. The depth to bed rock was 57 feet, in which distance the hole penetrated several different kinds of unconsolidated deposits. The upper member was a fine sand consisting almost entirely of quartz. This was underlain by fine gravel which rested upon 20 feet of blue clay. Beneath the clay was a bed of sand and gravel more than 20 feet thick, which rested on another clay bed. The clay rested on a much-decomposed bed rock of micaceous schist. A little way upstream from Penelope Creek the depth to bed rock was 20 feet, and near the mouth of Spruce Creek it was only 8 feet. Still farther downstream the depth again increased to 20 feet, but it soon decreased again, so that a short distance below Dixon Creek it was only 7 or 8 feet. Half a mile above the mouth of Big Four Creek the thickness of the gravels was 17 feet. In all cases these measurements were to bed rock and not to false or so-called clay bed rock.

Midway between Goose and Canyon creeks a continuation of the broad bench trenched by the Casadepaga is reported to show good values, but so far has been only slightly prospected. At this place the bench is about 30 feet above the normal water surface of the Casadepaga. Some development work was done at this place in 1906 and still more in 1907, but so far no production has been made. During the summer of 1908 a hole 30 feet deep was sunk in the flat, but the only materials found were gravel and sand. At a depth of 25 feet from the surface, or about 5 feet above the river level, quicksand was encountered which was reported to be similar to that found on Banner Creek. This material was not seen in place, but on the dumps it appeared to be a bluish muck mixed with fine sand. The 30 feet of sand and gravels that have been penetrated so far have been frozen, and it has been necessary to thaw them with steam points in order to sink, but water is beginning to seep into the bottom of the shaft, so that the ground below is probably not heavily frozen.

Near the mouth of Monument Creek bench gravels which appear to belong to the same general level as those marked by the broader benches downstream are found. These have been prospected in slight measure on the southern side of the stream, but values seem to have been wanting, as work has been abandoned. Late in the season in this same general region, but on the northern side of the stream and at an elevation of a few hundred feet above the water, three men were engaged in exploring some high-level gravels. Prospecting progressed hardly farther than the preliminary stage of setting up the apparatus when the region was visited by snow, so that none of the ground could be examined. The origin and character of the material has therefore not been definitely determined. If, however, it proves to consist of ancient stream gravel, it will throw much additional light upon the past history of the region. The developments will therefore be watched with considerable interest.

Mouth of Moonlight Creek.—Exploration of the old channels which were reported by the writer in 1906 in the vicinity of Moonlight Creek has been abandoned, and no work was done in 1907. An investigation of the old workings was not satisfactory, as many of the pits had caved so badly that interpretation of the character of the material was impossible. In the lower cuts, however, it seemed clear that the material was river wash. It would probably correlate with the deposits on the lower bench of the Casadepaga, which it is believed can be traced uninterruptedly from the mouth of the stream to the extreme western portion mapped on the two quadrangles. The excavations on the higher levels, however, were so badly caved and exposures were so poor that it is impossible to decide whether the material is waterworn or is merely slide. There seems to be no topographic expression of any kind at this elevation, and the presence of old channels at the level, while perfectly possible, seems not to have been demonstrated. One is therefore compelled to reserve judgment until the question is more definitely proved by more extensive exploration or better exposures. The fact, however, that the gold values are reported to be low will probably preclude any considerable work on these particular deposits in the near future.

Mouth of Blind Creek.—Near the mouth of Blind Creek, which enters the Casadepaga about a mile above Moonlight Creek and about a mile from the western margin of the quadrangle, a strongly marked bench of the Casadepaga may be recognized. A number of prospect holes have been driven in this deposit, but the values obtained were probably not satisfactory, as the pits have been abandoned. The character of the material thrown out of these pits seems to be less well rounded than that which is found in the bench farther downstream. The shape of the fragments might, however, be due to the shorter distance that they have traveled and the smaller volume of water which has been effective in their transportation. It is suggested also that the angularity may be due to their deposition by the former side stream rather than by the old main Casadepaga.

TRIBUTARIES OF CASADEPAGA RIVER.

General statement.—The larger part of the gold that has been won from the Casadepaga Basin has come from the benches and stream gravels of the tributary creeks. Although practically all the larger side streams of Casadepaga River have marked benches along their courses, Goose, Canyon, and Willow creeks are the only ones where bench mining has proceeded to any extent. In part these benches are those of the main river, while in part they are the extension of the gradient established by the main river up the side streams. Thus, in the lower part of Goose, Dry, and Dixon creeks the streams traverse the Casadepaga bench, but farther upstream there are distinct benches formed by the streams which preceded the present streams. All the gravels, whether belonging to the benches of the main or the side streams, carry some gold. The gold is generally in fine scales and the largest pieces rarely exceed a value of 45 cents. The gold is of a high degree of fineness, the banks paying $18 an ounce, although it is reported that it assays $19.50. The concentration of the values in these benches seems to have taken place mainly on thin partings of clay which occur irregularly distributed throughout the gravels. There is also some concentration on bed rock, but the clay seams are reported to run on the average higher than the bed rock. Associated with the gold, magnetite and garnet are frequently found in fair amounts. Although the gold is fine and bright, it is the general impression of prospectors that it has not traveled far. This determination is in part based upon the fact that the larger pieces, although small, often show fragments of quartz attached.

Tributaries from the mouth to Goose Creek.—No productive mining has been done on the lower tributaries of Casadepaga River. Puckmummie Creek, which joins the Casadepaga a short distance above the junction with the Niukluk, is small, only about 3 miles in length. It has been prospected in its upper part and about a mile above the mouth. No pay gravels have been discovered, although colors of gold can be raised in every pan. The gravels are thin, seldom more than 2 or 3 feet in thickness. The pebbles all seem to be of local origin except in the lower part of the creek, where some gravels of the Niukluk River are evidently being reworked by the present-day stream.

Bonanza Creek, or Klondike, as it is locally called, is a long stream which heads in a region where the bed rock is schist, but in its lower course flows across a series of limestones. The stream gravels for some distance above the mouth are mainly fragments of limestone. The next most abundant pebbles are of quartzose schist, and the least abundant are of black quartzitic slate. Practically no gold has been won from this stream, and there is evidence of only slight exploration in the eastern 4 to 5 miles of its course, where the bed rock consists more or less extensively of limestone. In this part of the valley water is often entirely wanting, and long stretches of the bed are simply gravel-floored paths. Farther upstream, where the schist forms the bed rock, there has been more prospecting, but there is no sign that the work was ever remunerative. Ben Gulch, a small side stream from the north entering Bonanza Creek about 2 miles above its mouth, has been staked, and a little work done on the gravels, which are mostly rather angular limestone fragments mixed with considerable schist float. In the lower part, Ben Gulch carries no water. The present bed of the stream occurs in the bottom of a narrow V, cut in a broader, older form.

Although prospecting has been done on many of the small streams, such as Nipple Gulch and Little Dixie Creek, no mining has been done on any of the side streams until one comes to No Man Creek. At the mouth of this creek one miner was at work in 1907 for a short time. The production was small, and although the placer was of the creek type the values were probably due to the reconcentration of gravels of Casadepaga River, through which the lower part of the stream flows. The gold values are probably low and, with the primitive methods used, barely produce wages.

Big Four Creek, which was partly explored in 1898, was named for the four prospectors, Mordaunt, Blake, Libby, and Nelson, who first staked claims along its course. This creek has a length of over 12 miles. The bed rock in most of the upper portion is feldspathic schist and greenstone, but there are large areas where it consists of black slate, massive limestone, and chloritic schist. The larger geologic features are represented by the geologic map, Plate VII, but there are many details which can not be represented on this scale. The rocks of the basin as a whole show evidences of the same deformations as in productive placer areas, and in places the kind and character of the rocks is also the same. There seems, therefore, no reason why placers should not be found in parts of this valley, but, from the absence of mines, it appears that no rich ground has been located. The distance from any source of supplies, the slowness of ice and snow in disappearing in the spring, and the high cost of putting in the necessary ditches, etc., have probably had a retarding influence on the development of the region.

In 1907 only one man was mining in the Big Four basin. At this place, about a half mile or so above the mouth, creek gravels were being exploited. The gravels, however, are so deep that, with the ordinary apparatus at the command of the small operator, the seepage water can not be kept out and it is nearly impossible to get to bed rock. The gravels were rather fine and contained interlaminated layers of clay. Frequently the clay beds have served for the local concentration of gold, and it is possible to get good prospects from some of these less permeable layers almost on the surface. The gold from the upper part of the gravels is bright and fairly coarse for stream gold. No nuggets of any size are found in the upper layers. Bed rock has not been reached near the creek in the lower part of the stream, so it is not known whether there is any concentration upon it. The general unfrozen character of the gravels and their frequent agitation by the overflowing of the stream would suggest the probability of finding a greater concentration on bed rock. It is reported, however, that the gold values are generally better near the surface than a few feet below. Such a condition suggests that the presence of gold in the top layers is due to the concentration of the particles by the washing away of the lighter fragments, or sand grains.

Dawson Creek joins the Casadepaga opposite the mouth of Big Four Creek. Bed rock occurs along the Casadepaga a short distance upstream from the mouth of Dawson Creek at an elevation of several feet above the river. Dawson Creek has cut through this rim and the high-level bench gravels that occur above. The mining at the mouth of Dawson Creek is being done on both the creek and bench gravels, but, because the two are handled more or less together, they will be considered together. The production from this ground can not amount to very much, as it is being developed on a very small scale. The upper part of Dawson Creek flows almost entirely on limestone, but at the mouth bed rock is a micaceous schist, with small interlaminated bands of limestone. The bed rock of the ground that is being worked is, for the most part, schist. The creek gravels are apparently derived from the local basin of Dawson Creek and also from the bench gravels which have come from the larger drainage area of Casadepaga River. The creek seems to have contained values only in that part where the old bench deposits have been reconcentrated by the present-day stream in the recent gravels. The bench gravels, which are being undermined and reworked by the stream, are in places 8 to 10 feet in thickness.

Dixon Creek follows more or less closely the contact between the Mount Dixon area of limestone and the chloritic schists which lie to the southwest. Brooks notes that a claim near the mouth of this stream is reported to have yielded a few thousand dollars in 1899. At the time of Richardson's visit, in July, 1900, no mining was in progress, and no systematic work is being done at the present time. This is due in part to the absence of water, except for the short period just succeeding a heavy rain. Claims are, however, located on the creek, and a little gold, some of which is quite coarse, is found. It is estimated that about $15,000 has been taken from this creek since its discovery.

Thorp Creek, a small stream entering the Casadepaga nearly opposite Dixon Creek, was the scene of some mining in the past, but at the present time no work is done on it. Brooks states that in 1900 four men had dug a ditch about 40 feet long by 4 feet deep in the bed of the gulch, which is a channel across the ancient flood plain of the Casadepaga, but had not reached bed rock. The gold was reported to be rather fine and was associated with quartz and magnetite. The values, however, were not heavy, and it is probable that the ground was paying only low wages. It was learned, however, in 1908, that some coarse gold had once been found on Thorp Creek. The gold was not so coarse as that from some of the near-by streams somewhat to the west and upstream from this creek.

Dry Creek is a small stream hardly a mile in length. In the lower part of its course it flows across bench gravels which were undoubtedly laid down by the Casadepaga in an earlier period of its development. The values in Dry Creek are presumably derived from the reconcentration of these bench gravels. One man is reported to have mined creek gravels on Dry Creek during the summer of 1907, but the ground was not actively developed and the production was probably not much more than sufficient for a grub stake.

Regarding Spruce Creek, which enters the Casadepaga a short distance below Dry Creek, in the 1900 report Brooks states that it produced 40 or 50 ounces of gold in 1899. No mining was done on the creek in 1907, but the evidences of work in the past have not been effaced. This earlier work seems to have been carried on most extensively in the lower portion of the creek about three-fourths of a mile above the mouth. At the mouth the stream is flowing practically on bed rock, having cut its bed below the ancient flood-plain deposits of the Casadepaga, thus presenting a very different condition from that shown on Dry and Thorp creeks. The place already noted where mining has been active is near a much broken and dislocated limestone which forms a bed at least 50 feet thick; its entire width is not exposed and it may have many times this thickness. The gold that has been won from this claim is reportep to have been coarse, many good-sized nuggets having been found. It was as a rule bright, and some pieces showed quartz attached. It is estimated that the total value of the production of gold from the creek is between $8,000 and $10,000.

On Lightning Creek no mining was done in 1907, but in the middle part of its course there had been a good deal of prospecting, and a few furrows, evidently the preliminary line for a ditch, had been turned. A slight terrace stands between 5 and 10 feet above the water in this part of the stream, and it seems probable that the values which the prospectors obtained in the creek gravels may have been reconcentrated from the older bench gravels through which the stream is now flowing.

Penelope Creek is a stream 5 miles in length, but the lower part only is productive. The stream has been rather thoroughly prospected, but many peculiar conditions have been encountered, for the satisfactory solution of which much more extensive prospecting is required. One of the most unexpected of the conditions is the presence of a deep channel. About a mile above the junction of Penelope Creek and the Casadepaga a hole passed through fine gravel for 57 feet and failed to reach bed rock. The top of the gravel consisted of well-rounded pebbles and river wash, with colors scattered throughout. Below, the material became a mixture of the river gravels and slide. The material was frozen all the way. This hole was then abandoned and another hole started about 150 feet from the creek. The depth of this hole, before it reached bed rock, was over 90 feet. The first 40 feet was through well-rounded creek wash, which here and there showed colors of gold. This was underlain by 24 feet of yellowish clay, which in turn was underlain by 29 feet of a mixture of washed gravels and slide. The upper 7 feet of this lowest member was almost entirely formed of well-washed gravel. At the bottom of this last member bed rock was struck. Another hole near this same place started about 13 feet lower than the 93-foot hole, and went down more than 86 feet without reaching bed rock. It passed through 40 feet of washed gravels and some slide, and then encountered clay, which was described as "greasy" or "soapy" in feeling. So much time was spent in exploration that the production was small. All the gravels encountered seem to be more or less auriferous, but it is a question whether they can be worked at a profit unless a definite pay streak is discovered. Bed rock appears in the walls of the stream about 1¼ miles from the mouth, so the gravels must occupy a peculiar local basin.

Richardson found that in 1900 some work had been done on the lower part of Penelope Creek, although bed rock was not reached. He was informed that pans from this creek averaged 5 cents each, but did not verify the statement. The great depth of the gravels, together with the narrow canyon-filled character of the valley at this point, is not conducive to cheap mining. It has been estimated, though the figures can be regarded as probably little better than a guess, that the gravels of Penelope Creek will average about $2 a yard. Water for sluicing is at present brought in a low ditch which taps Penelope Creek a couple of miles from the mouth. The method of work at the present time is horse scraping.

Tributaries from Goose Creek to Lower Willow Creek.—Goose Creek, which joins the Casadepaga nearly opposite the mouth of Penelope Creek, divides about a mile above its mouth into two branches of about the same size, the northern being called Quartz Creek and the southern retaining the name Goose. The bed rock throughout the major part of the western or main stream is schist, but here and there it is limestone, often in rather heavy bands. Mining is not very active at present on either of the streams. Near the mouth ground is held and annual assessment work is kept up, but the production from this part of the stream is practically negligible. Bed rock is not exposed, the gold concentration occurring on a so-called false bed rock of clay.

In 1907 some work was done on Goose Creek about half a mile above its mouth. The gold was fine and flat, generally occurring in scales; practically no nuggets have ever been found. All the gold is bright, as though it had been rather recently subjected to movement or had not traveled far from the ledge from which it was derived. The gravels are thin, seldom more than 2 or 3 feet in thickness. The gold is found on a layer of clay which immediately overlies a schist bed rock; associated with it in well-rounded, small kernels is a good deal of a reddish iron mineral which seems to be iron pyrite weathered to hematite or limonite. In one instance a stalactitic growth of the iron mineral was observed. It is reported that the best values are found in the little areas of quiet water behind protecting bowlders. These more resistant bowlders are generally greenstone and are often a foot or more in length. It is, however, expressly stated by the miners of this claim that no gold has been observed in the greenstone, and that the accumulation of gold in pockets near them is due entirely to the mechanical effect of the riffles which the bowlders produce.

At this place an interesting experiment in handling gravels by water-power scrapers is being tried. The tenor of the gravels is so low that shoveling in by hand is not profitable, and some method was therefore sought which should increase the amount of gravel mined daily. Owing to the inventiveness of the owners, an adaptation of a water wheel gave the needed increase in power. As this method has never before been tried, so far as known, a statement concerning the general arrangement may be given.[a] In this particular plant the owners acknowledge that they have not sufficient water for the best working of the scheme, but this seems a detail which does not vitiate the principle involved.

By this plan a ditch taps the creek about a third of a mile upstream from the water wheel. Water is delivered to the wheel in a flume (fig. 25) at the rate of 1 to 1½ cubic feet per second. The wheel (*B*) is 12 feet in diameter and, after having served as a motive power, the water passes into a launder beneath, from which it is carried to the sluice boxes. The wheel has its axle extended a foot or more on both sides of the bearings, and two loose pulleys (*C*) are attached on each side. Wire ropes are attached to the pulleys and to ordinary scrapers. As the wheel is revolved and one pulley thrown in gear the rope is wound up, thus pulling the scraper. Each scraper has a rope attached to its front and rear end, so that it may be pulled forward or back as one or the other pulley is thrown in gear. It was originally planned to operate two scrapers, one to shovel into the boxes and one to haul away the tailings. Owing, however, to the lack of sufficient water, it has been found that not more than one scraper can be satisfactorily operated at a time, but this could be remedied by a larger ditch, greater fall, or steeper pitch, so that the defect is not vital. It is esti-

[a] For a more complete description see Smith, P. S., A new utilization of water power for placer mining: Mining Science, vol. 57, 1908, pp. 50-52.

mated that with this outfit three men, one acting as engineer on the wheel, one handling the scraper, and one tending to the sluice boxes to keep them from choking, can handle 50 yards of creek gravels a day and remove the same amount of tailings from the foot of the string of boxes. If this is the case, it is evident that with very little expense the efficiency of a man is increased many times. Therefore it would seem as though much ground that at present is slightly below the line of profit for shoveling in might be handled by water-power scrapers. It should perhaps be pointed out that the entire equipment of this plant was manufactured on the ground 40 miles from town with no machine shops available, so that, with ingenuity, a water-power scraper might be installed at low cost, even in some of the most inaccessible regions. This feature alone should be of considerable importance to miners in slightly developed regions.

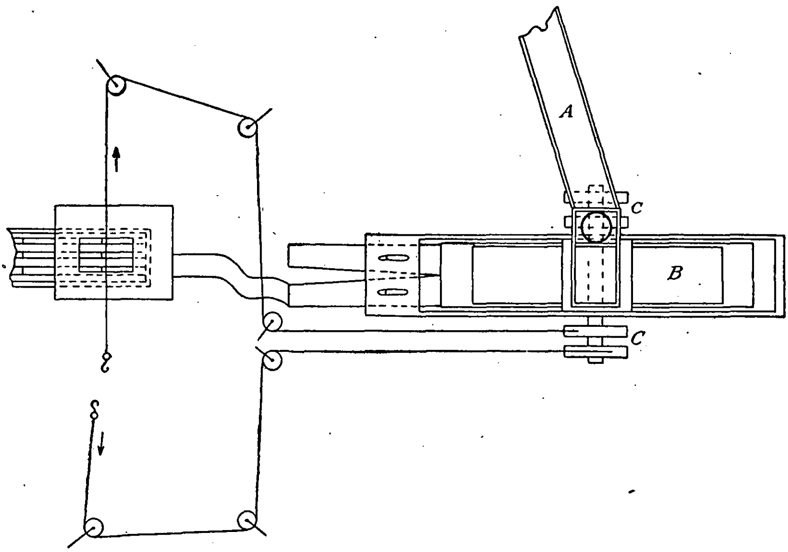


FIGURE 25.—Diagram of water-power scraper on Goose Creek.

The only other place where mining is in progress on Goose Creek is on creek gravels about 3 miles above the mouth, where a small side stream enters from the west. Higher values very frequently occur in the main stream near the mouth of a tributary gulch, probably owing to the fact that the amount of waste is greater at the junction than in any other part of the stream. Work on the placers noted, however, has not been pushed vigorously, and the production for 1907–8 was small. Work was conducted at this camp by only two men, and commenced late and closed early.

A mining camp which has been in operation for several years is established on Quartz Creek, a short distance above its junction with Goose Creek. Near the mouth the bed rock is schist, which continues upstream for nearly half a mile. The gravels that are being worked are those exposed in the present creek and in the banks of the valley where it is incised in the gravel deposits of an older valley. The depth to bed rock changes rapidly; in some places the bed rock rises within 3 feet of the surface and there are no gravels present. There does not, however, seem to be any difference in the gold tenor between the high and the low points of the bed rock. The gold has worked its way far into the schists, so that it is necessary often to take up 2 feet of bed rock in order to recover the values. The gold is all very coarse, and is dissimilar from that found on the claims lower down on Goose Creek. The largest nugget from this ground was worth about $8; it had considerable quartz attached. Farther upstream the bed rock changes to a limestone. The contact between the schists and limestone seems to follow closely Gold Moon Gulch, in which several nuggets of good size have been found. Mining here is very difficult, so that the production has been slight. The bed rock is a much fractured limestone, in which underground caverns have been dissolved. Practically no water is flowing in the creek, and as soon as water brought by ditches is turned in for sluicing it disappears. A nugget valued at $15 has been taken from a claim on this creek. There can be little doubt that the coarse gold found on Gold Moon and Quartz creeks has come from veins occurring in the country rock in the near neighborhood. The bright angular character of the gold and the abundance of attached pieces of quartz all point to the local origin of the gold.

The gold on both Goose and Quartz creeks is found associated with considerable garnet and some magnetite. From assays quoted by Brooks in the 1900 report the value of Quartz Creek gold as shown by mint receipts is $18.60 per ounce. The production of the basin, however, is small, because so few men are employed. In 1907 there were probably less than eight men employed at any time throughout the season.

The lower portion of Canyon Creek has never been productive. The present bed of the stream is rather heavily covered with large slabs of almost unrounded rock. This present channel is in a recent cut 10 feet or so below a higher level valley. Bed rock is exposed in many places along the walls and is covered by a veneer of gravels seldom more than 2 or 3 feet thick. In 1906 no work was done on the creek, but in 1907 some of its side streams were mined and extensive plans made for its future development. On Sunshine Creek the ground is reported to show good values, but the creek had not been thoroughly prospected. The main activity during 1907 was the construction of a ditch from Texas Creek. This was a very necessary piece of work, as practically no water can be obtained from Sunshine Creek itself.

The most active preparations for future development, however, were conducted on Boulder Creek near its junction with Canyon Creek. The creek gravels at this place have been rather thoroughly prospected by pick and shovel methods in the past. The old creek gravels are said to have been rich, but at present the mining is mainly on the gravels, which are found on the old rims. The rim is practically at the same elevation as the bench that runs along the northern side of Canyon Creek. In character the gold is bright and not greatly worn. The larger nuggets are worth about $12, but most of the gold now taken out is in flat pieces ranging from the fraction of a cent in value to nuggets worth slightly less than 50 cents. The gold assays $18 an ounce according to mint receipts reported by the owners of the property. The claims were mined by means of hydraulic giants and elevators, but the elevator has not been successful. In 1907 the first part of the season was consumed in the preliminary work of ditch building, etc., so that only a short time was left for productive mining. The output was therefore small, but it was hoped that with a full season the returns may be large. Boulder has long been known as a rich creek, for Brooks reports that 50 ounces of gold were said to have been taken from the gravels in 1899 as the result of only a few days' work. The gravels are shallow, but are reported to have carried values almost from the surface to bed rock.

On Canyon Creek it is a notable fact that almost all the productive area is bench ground or places where the benches have been cut by streams and a reconcentration effected. It is also considered of some economic importance that the best ground is found only on the north side of the creek. Whether this distribution is effected by the greater melting, etc., on the south side of the divide (the north side of the stream) and the consequent tendency to crowd the stream toward the south has not been determined.

The bench gravels between Sunshine and Boulder creeks are rusty and are directly overlain by tundra muck and vegetation. They are much better rounded and cleaner washed than the gravels of the present Canyon Creek bed. The gravels will average about 12 feet deep and carry values throughout, although the best values are found on bed rock and in the crevices. In width the gravels vary much, but west of Boulder Creek they are known to be over 200 feet. The bed rock throughout this entire portion of the stream is schist, with a few narrow limestone bands which appear as reefs in the midst of the schist series. The gold seems to be localized in the benches extending from Sunshine Creek to a short distance above the mouth of Boulder Creek. No satisfactory statement as to the average tenor of the ground was obtained.

During 1907 the operators have been mainly busy installing the plant, building ditches, and doing other things necessary for handling large bodies of gravel with profit. The plant was in operation less than a month and the output was therefore small. With the dead work largely cleared away it was expected that another season will see an increased production. In 1908, owing to the dry season, but little mining was done on either these benches or on the creek gravels.

Not only the benches on the main Canyon Creek but also those on the side streams are gold bearing. It has already been pointed out that much of the present-day stream placer of Sunshine Creek has been derived from the reconcentration of the bench gravel along that stream. Little actual mining has been done on Sunshine itself and the returns are practically negligible, but the preliminary examinations have shown sufficient values to warrant further work for a distance of at least half a mile above the junction with the main stream.

None of the other small streams tributary to the Casadepaga south of Canyon Creek as far as Banner Creek carry producing placers. On Banner Creek mining has almost ceased, for the only values seem to be those that have been lost on account of primitive methods by which the creek was previously worked. It has, however, been a rich creek, and much gold has been won from it. Brooks[a] gives the following description of Banner Creek:

> Banner Creek had some water in it in July, but not enough for sluicing. One claim, in 1899, is reported to have yielded $400 to four men who sluiced two days and a half. When Mr. Richardson visited this creek two men were at work near the mouth, where the gravel is 8 to 10 feet thick. The gold is rather coarse, though flattened, and assays $19.20 an ounce. Farther up the creek more or less work had been done and the prospects were reported good.

By 1906 Banner Creek was nearly mined out, and in 1907 was worked by only two men. The gravels were about a mile above the mouth. They were of the ordinary stream type, but showed fragments of many different kinds of rocks, this being due to the great differences in the bed rock of the basin. The gravels worked at the present time occur very close to the contact of the heavy limestone which occupies the lower part of the Banner Creek basin and the schists which form the upper part. The gold values occur throughout the gravels, but they are better on bed rock. Production from this ground probably does not much exceed wages. Mining is done by ordinary pick and shovel methods.

Ruby Creek, the next stream above Banner Creek entering the Casadepaga from the south, has been without question the most

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[a] Brooks, A. H., Reconnaissance in the Cape Nome and Norton Bay regions, Alaska, in 1900, a special publication of the U. S. Geol. Survey, 1901, p. 109.

productive creek in the Casadepaga drainage. The operations on this creek in 1900 were described as follows: [a]

Ruby Creek, so named for the numerous small garnets found in it, is about 3 miles long, and flows in a comparatively broad valley. Bed rock is a mica schist dipping S. 65° W. at an angle of 45°, and jointed east-west. Numerous small quartz veins parallel both to the schistosity and to the joints occur in the schists. Pebbles of garnetiferous greenstone are common in the creek, but the rock was not seen in place. At the head of the creek gray limestone and graphite quartz schist are exposed. In July there were about twenty men on the creek. Almost every claim had at least one representative on it, though prospecting and preliminary work rather than actual mining was being done. Several ditches have been dug in the creek bottom and crosscuts have been made into the adjacent bench. In the lower part of the creek there is a depth of 2 or 3 feet of gravel through which the gold is pretty well distributed. Many garnets and a little black sand are associated with the gold. The gold is coarse, rather dark colored, and is said to assay $19.55 an ounce. The largest nugget found was worth $5.50.

From 1900 to 1906 the creek was the scene of almost constant operation. In the latter year, when visited, no one was at work, although it was reported that two outfits had been mining earlier in the season. It is currently reported that the mining on Ruby Creek was carried on with much care, so that the tailings will probably be of very low tenor. Whether the gravels of this creek can be profitably reworked by some economical method of handling large bodies of low-grade ground is a question which can not be determined without considerable testing. The shallowness of the gravels, will, however, make it difficult to find such a method. As one traverses the creek the large amount of old work is impressive. Hardly a foot of the creek gravels from the mouth of Ruby Creek to a mile above Iowa Creek has escaped handling. Not only the main creek, but even the small side streams have been prospected and staked. Iowa Creek, a small branch which carries practically no water during any season, shows numerous pits and stakes even beyond the point where the stream bed is cut through the vegetation. In 1907 there was no mining on Ruby Creek, except at the mouth on some gravels which occur on a low bench at a slight elevation above the river. At the mouth the gold was brighter than it is farther upstream. This condition would seem to be explained by the fact that the region has been recently uplifted so that erosion is proceeding headward. As a result the lower part of Ruby Creek flows in a narrow incised trench in the older, broader valley into which the newer valley merges a short distance upstream. As a result of this condition the gold in the lower part has been recently moved and a part at least has had its rusty coating worn away; whereas upstream no considerable movement has occurred and the rusty coating still remains.

In 1908 Ruby Creek was visited by the Survey party early in July. There was practically no water in the creek, and all mining operations

[a] Brooks, A. H., and others, op. cit., pp. 109-110.

were at a standstill. Plans had been made to have a force of 8 or 10 men at work on the claims near the mouth, but the exceptionally dry season caused this project to be abandoned. As a result, practically no productive work was accomplished.

Tributaries between Lower Willow and Johnson creeks.—Lower Willow Creek, or, as it was formerly called, Left Fork, joins the Casadepaga nearly opposite the mouth of Ruby Creek. It is a stream about 8 miles long, heading in the Iron Creek divide and flowing in general easterly across the dominant structure; therefore in different parts of its course it has different kinds of bed rock. In 1900 Brooks reported that there was no mining on the main stream, and only one of the small tributaries has been developed at all. This side stream is west of the margin of the Casadepaga quadrangle. Soon after that time, however, prospectors found good values in the creek gravels and in the adjacent benches, near the mouth of Green Gulch, in the extreme western part of the mapped area, and mining work was pressed with some energy. Lower Willow Creek was not visited by any of the Survey geologists from 1900 to 1906, so that details as to the development of the region for that period are practically lacking. In 1906, when the creek was visited, it was so near the freeze-up that most of the miners had closed for the season. It was evident, however, that only a few outfits had been busy, and these consisted of only two or three men each. Near the mouth of the creek a couple of men had been mining all summer, and another party had been at work a mile or so upstream, but further than this only prospecting had been done.

In 1907 mining on Lower Willow Creek was more or less inactive. At the mouth a small amount of work was done, but it commenced late and closed early. In this part of the creek the geology is very complex, and the bed rock is formed of black graphitic slates, thin limestones, and chloritic schists. A little upstream two or three miners have been prospecting, but details concerning their operations are lacking. Below Rocky Creek the creek gravels have yielded a good deal of coarse gold, with very little fine gold. The bed rock through this part of the creek is almost entirely schist. Little productive work has been done during the past year. The gold from Willow Creek is said to assay $19 an ounce. Farther upstream, near the mouth of Rocky Creek and for nearly a mile above, the gravels have hardly been prospected, but from a short distance below Cahill Creek to the western margin of the quadrangle the ground has been more or less thoroughly prospected and values found. The gold from this part of the creek shows two entirely distinct phases; in one the gold is fine in small bright flakes, but in the other nuggets of coarse gold are frequent. It is reported that the nuggets are worth from $1.50 to $2.50. Both kinds of gold are found in the same pay streak.

Good wages can be made from the gravels in this part of the creek. As yet no ditches with any considerable head have been constructed, and therefore no operations on a large scale have been attempted. Undoubtedly much of the ground can be worked with profit, even by the expensive pick-and-shovel methods in use. Though prospects have proved the presence of pay in many places along the creek, there was no adequate return in 1908.

Lower Willow Creek, like Canyon Creek, shows benches along its valley walls from a few feet above the level of the water to an elevation of 30 feet or so. There are frequent rock outcrops from the mouth nearly to the western margin of the quadrangle, so it is believed that the depth of the bench gravels is not great except in those places where former stream channels occur. There was no production in 1907 from the Willow Creek benches, but they have been more or less thoroughly prospected, so that their tenor is known with some accuracy. From this work it would appear that the richest portion of the benches is along the northern side of the stream from near Rocky Creek to the mouth of Cahill Creek. It is reported that in this stretch of the river there is good wash gravel, occupying an old channel. The northern bed-rock rim of this channel has been exposed in several places and shows some concentration of values. The gold is generally much coarser than that found in the gravels of the present creek beds. The difficulty of obtaining adequate water supply without the expenditure of considerable money has hampered the development of the benches even more than it has the mining of the present creek gravels.

There was no mining on any of the tributaries of Lower Willow Creek during 1908, although colors have been found on practically all of them. Ridgeway Creek is known to carry gold for a distance of at least a mile above its mouth, and small nuggets are occasionally found. The great trouble with mining on Ridgeway Creek is the small supply of water available, so that either expensive ditches must be constructed or recourse had to "booming." On Cahill Creek gold has been found only on the lower half mile. As this part of the valley is incised in bench gravel, formed by Willow Creek at an earlier stage, it is possible that the gold may have been reconcentrated from the bench gravels by the present stream.

About a mile and a half above the mouth of Ruby Creek a small stream known as Rover Creek joins the Casadepaga from the south. Some desultory work has been done on the lower part of this stream, but the production, judging from the amount of development work, must have been small. In the upper part of Rover Creek the gravels are heavily iron-stained and consist mainly of very large, rather angular, blocks of greenish schist, with some greenstone. No bed rock is exposed in this portion of the valley.

From Rover Creek to the western margin of the quadrangle none of the tributaries of Casadepaga River have been profitably mined. All the streams have been prospected to a slight extent, but apparently the values found were not sufficient to warrant further exploration. The reason for the absence of pay in these streams is not known, for they are flowing over the same kinds of rocks as the streams where placer deposits of value are found and the physical history of the region seems to have been the same. It would seem advisable therefore to thoroughly prospect the ground before abandoning search for placers in this part of the Casadepaga River basin.

MISCELLANEOUS STREAM AND BENCH PLACERS.

Beside the two main rivers, which, with their tributaries, drain the greater part of the Solomon and Casadepaga quadrangles, a few other streams occur in the area, though none of them have any importance as producers of gold from creek placers. These streams may be roughly classified as belonging to the Niukluk, the Kruzgamepa, the Klokerblok, and the Topkok river systems, and the Norton Sound drainage. Prospecting has been done on these streams, but in the main only the upper headwaters branches come within the area of the quadrangles, and most of the gravels are coarse angular fragments which have been but slightly sorted by water. As a result, although many of the streams in their lower portions, outside the quadrangles, have produced placer gold, few of them have yielded workable deposits within the area mapped. It should be noted that benches occur on many of these streams, so that they offer ample ground for prospecting for this kind of deposit. The fact that no benches are being mined is no reason for abandoning the streams as unprofitable, for the physical conditions which have produced the benches in regions where the deposits are being worked seem to have been also effective in many regions where no mining is done at present. The character of bed rock in the vicinity of the productive and of the nonprospected benches seems to be the same. It is believed therefore that there is good ground for recommending more thorough testing of the benches of many of the streams flowing in other basins than those of Solomon and Casadepaga rivers. Though such search might not be immediately successful, and though rich bonanzas may never be discovered, it is confidently believed that in places economically important deposits of this type will be located and developed.

TRIBUTARIES TO NORTON SOUND.

Of the creeks entering Norton Sound between Topkok Head and Solomon River there is evidence of work having been done only on Spruce Creek. Collier reported that in 1903 some mining was being done on this creek, although it was not visited by him. When the creek was examined in 1907, there was no one on the stream, and it appeared as though operations had ceased some time ago. The largest amount of work had been done a short distance below the junction of Spruce and Beaton creeks. The gravels appeared to be of local origin, and no foreign material was noted. They were, as a rule, coarse, and showed but a small amount of water rounding. Many of the fragments were a foot in length. The larger pieces were usually flat and shingly. From the physical characters the gravels appear to be similar to ordinary river wash that has not been transported far. Although the gravels are of local origin—that is, are derived from the basin drained by the present creek—they are formed of pebbles from a great variety of rocks. The most common rock is schist, but greenstone bowlders are numerous. Black graphitic slate fragments and limestones are practically wanting. The gold is reported to have been found on a clay layer resting on bed rock. The character, form, and distribution of the gold won from this ground was not determined, but its amount is believed to have been rather small.

AMERICAN CREEK AND TRIBUTARIES.

Heading between Iron Creek on the west and the tributaries of the Casadepaga on the south and east, American Creek flows north and then makes an abrupt bend to the east, and finally joins Niukluk River a short distance upstream from the mouth of the Casadepaga. That this has not always been the course of the stream has been explained on pages 46–47. The placers of this stream all occur above the point of this diversion. All the headward portion is in the hilly country where outcrops abound, but the influence of the conditions that helped to produce the gravel plain are to be noted, even in this part of the basin, in the presence of waterworn gravels and angular fragments derived from foreign drainage basins up to an elevation of 800 feet, or well above the junction of Auburn and Jack Wade creeks.

This basin was visited by the Geological Survey party during the season of 1908; and at that time the only mining was in Auburn Ravine, near the extreme western margin of the Casadepaga quadrangle. Abandoned camps on many of the other tributaries showed that the ground had been more or less thoroughly prospected, and numerous claim stakes indicated that almost all the available ground was still held. Owing to the absence of miners, practically no data were secured concerning past work. The headward portion of American Creek lies in a region of limestones and schists, which in places are much dislocated. None of the black quartzitic slate is found except near the mouth of Lost Creek. Greenstones are rather uncommon.

Auburn Ravine is one of the largest valleys tributary to American Creek. It enters the main valley a short distance above the big bend and heads in the low saddle that leads to a tributary of Canyon Creek. Bed rock of the eastern side of the valley and of a large part of the creek is Sowik limestone, whereas the western divide is formed for the most part of Solomon and Casadepaga schists. Owing to the presence of limestone as the bed rock, most of the water escapes by underground channels and the creek bed is perfectly dry except for a short time immediately after a heavy rain. When the creek was visited in 1908 there was not even enough water in the bed of the stream to furnish a supply for cooking, and it was necessary to carry water from those places where the small side streams flowing on schist still afforded a little run-off. Under such conditions it is evident that the difficulties in the way of economically handling placer gravels are almost too great to be overcome. At one of the claims a short distance below Jack Wade Creek, which was visited about September 1, enough water could be collected in an hour by draining the side streams to allow from five to ten minutes' sluicing. While the owners were waiting for enough water to collect the larger bowlders were picked out and everything done to utilize every second that the water was flowing in the boxes. Under such discouraging conditions is mining conducted in Auburn Ravine.

Fortunately, however, the gravels of Auburn Ravine all the way from the mouth of August Gulch, the small headwater stream coming in from the west, carry values. Two outfits were mining on the creek during 1908, one located a short distance above Jack Wade Creek and the other about the same distance below. Work on the upper claim has been carried on for three years. The gold is all coarse, no fine or flour gold being found. Whether this condition is due to the absence of fine gold or whether the fine particles are lost in sluicing is not known, but it is certain that the percentage of small nuggets found is very large. A nugget worth $11 was the largest piece found on this ground. It was of a dark color, but most of the gold from here is bright and of a high quality. Assays made by one of the banks at Nome showed the gold to be worth $19.53 an ounce.

No true bed rock is found on this claim, but instead the auriferous gravels rest upon thin clay layers that serve as local horizons on which concentration has been effected. As a rule, the clay layers have a dip toward the east, and it is believed by the miners that there may be an older, deeper channel to the east. The indications, however, are not sufficiently conclusive to warrant such a determination. The gravels of the creek bed consist of large angular blocks of limestone that have evidently been derived from the steep hills to the east. All these fragments are much corroded, and the presence of solution lines shows that a large part of the angularity is due to chemical erosion. In one place there is a bed of clean, well-washed sand that does not look like ordinary river sand, but its origin is in doubt. Where this sand was encountered it was at least 10 feet thick, but as it seems to be missing in several of the near-by holes its areal extent can not be very great.

Samples of the concentrates from this claim proved to be interesting and in a measure unique. Garnet is, as usual, one of the most common minerals. With it are magnetite and ilmenite in about equal amounts. Ilmenite is found in particles up to half an inch in length. These two iron minerals have undoubtedly been derived from the greenstones and feldspathic schists that form the high hill between the heads of American and Auburn creeks. Most interesting, however, was the verification of the report of the miners that cinnabar, the sulphide of mercury, was occasionally found in the gravels. Of this statement there can be no doubt, for samples carefully studied in the laboratory have determined its presence.

On the claim below Jack Wade Creek practically the same conditions are found as those already described. Work at this place, however, has not been carried on for so long a time, and consequently less ground has been explored. At the lower claim the horizon of sand and gravel already mentioned is seen to lie definitely below the present stream gravels. The material is almost clear sand, with here and there narrow layers of small pebbles. At the base of the section angular, partly dissolved fragments of limestone are common. The section at this point is about 12 feet deep. Attempts to sink the prospect pit deeper were prevented by the caving of the walls, so that bed rock was not reached. From the character of the lower part of the gravels, it seems probable that true bed rock should be encountered within a short distance. The owners, however, are talking of testing the gravels with a drill, as they believe the depth to bed rock will be great. A thorough determination of the depth and character of the gravels would be desirable in any case.

On Mariposa Gulch, which enters American Creek from the south and west of Game Creek, a now deserted cabin is located at an elevation of between 625 and 650 feet. Only a small amount of prospecting has been done at this place, and there are no facts available as to the results. Below the cabin the valley is a tangled thicket of willows, and the stream has not cut its bed through the sod. Owing to the fact that float of a nearly black trap rock was found in the valley of this gulch at a vertical elevation of about 100 feet above the camp, it is believed that the gravels which will be encountered are of the gravel-plain type and are not of stream origin.

COASTAL-PLAIN PLACERS.

GENERAL STATEMENT.

Up to the close of 1908 no placers of economic importance have been located in the coastal-plain province within the Solomon quadrangle. The indications are, however, strong that with more thorough and systematic search auriferous gravels will be discovered, and so far as known there is no reason why deposits of economic importance should not be found in this region. In this connection it should be noted that Brooks,[a] in 1900, basing his judgment on the reconcentrated placers found in some of the streams that flow over the coastal-plain sediments, stated that the presence of gold in the coastal plain is clearly indicated and that probably the tundra belt near Solomon contains placers similar to those of the Nome region.

The search for ancient beaches has been considerably hampered by the widespread belief that such would be found at about the same elevation as those already known around Nome. Such, however, can hardly be the case, for in the present shore line of Seward Peninsula certain portions, as for instance near York and Nome, have recently emerged, while intervening areas, as near Port Clarence, have been depressed. If, then, in the very recent past there is evidence of irregular uplift and warping, how much more is deformation to be expected in more ancient earth features. Furthermore, the mechanical difficulties of uniformly raising such a structure as the coastal plain, consisting of diverse units of different size, weights, and balance, would be practically insurmountable. Instead, therefore, of supposing that every part of any of the old beaches must now be at precisely the same elevation above sea level, it is far more reasonable to imagine that only a few points would be at any given elevation, and that the majority would be either higher or lower.

Prospectors, however, should be cautioned that the mere finding of beach material in no way promises rich gold-bearing gravel. For the production of a valuable placer it is necessary that there should be mineralized bed rock within the area and that the waste derived from this mineralized area should have been sorted and concentrated. Therefore the question of finding gold-bearing gravels is not one of salt water or fresh, but of work accomplished. So no matter what the character of the water, if no concentration of the gravel occurred, no rich placers could be formed.

Although no deposits have as yet been found in the coastal plain province of this region, it seems desirable to point out the places where work has been done. Such statement will at least serve to give a general idea of the conditions occurring in any particular locality and in some places will give a clue as to the depth of bed

[a] Brooks, A. H., and others, op. cit., p. 81.

rock from the surface. Some of the more important excavations in the coastal plain have, however, been treated (see pp. 101–104), and will not be reviewed.

Before passing to the description of the various prospect pits it should be stated that practically every part of the coastal-plain province has been staked, so that it is presumed colors of gold have been found. Figure 26 shows the various places where prospect pits have been sunk.

DETAILED DESCRIPTIONS.

The most eastern prospecting has been done at the base of a low cliff half a mile from the coast at an elevation of about 75 feet, nearly north of the point where the road leaves the beach to cross Topkok Head. The pits, however, are shallow, and no beach gravel was exposed. The slight cliff at this place, however, suggests erosion by a body of water other than a stream. Half a mile nearly due west, but at an elevation of only 25 to 50 feet, an abrupt scarp about 12 feet high suggests the same origin as that of the cliff just described. Some prospecting was done at this place but was soon abandoned, judging from the small amount of work accomplished. One cut has been made into the gravel face presented by the cliff, and all the material exposed was somewhat rounded, shingly, rather dirty gravel. Another hole has been dug about 20 feet from the base of the cliff, and the material on the dump seems to be of essentially the same character as that exposed in the bank. There were numerous fragments of quartz, some of which were well rounded, but as a whole the gravels were mostly schist in small shingly pieces. The material does not look like beach sand and gravel, as it is too full of mud and is too poorly rounded, but the gravel could not be seen in place as the pits were full of water, so that careful examination was not possible.

Half a mile west of the last locality, at an elevation of about 50 feet, there is a large pit filled with water. The débris on the dump is angular, and a large part of it is apparently unwaterworn. There are, however, some iron-stained quartz pebbles which are well rounded and which look distinctly like beach pebbles. The material was not seen in place. Near Spruce Creek, on the western slope of the valley, at an elevation of slightly over 100 feet, a small exploration pit has been sunk. The material on the dump was mostly peaty stuff, with fragments of quartzitic schist of a greenish silvery color. These fragments were very angular and showed practically no water rounding. It would seem, however, that there is evidence of water erosion for over 100 feet vertical elevation above this place, although, owing to the lack of development work, this assumption is not definitely proved. The exploration of the coastal-plain gravels on the small stream just west of Spruce Creek has already been described. (See pp. 101–103.)

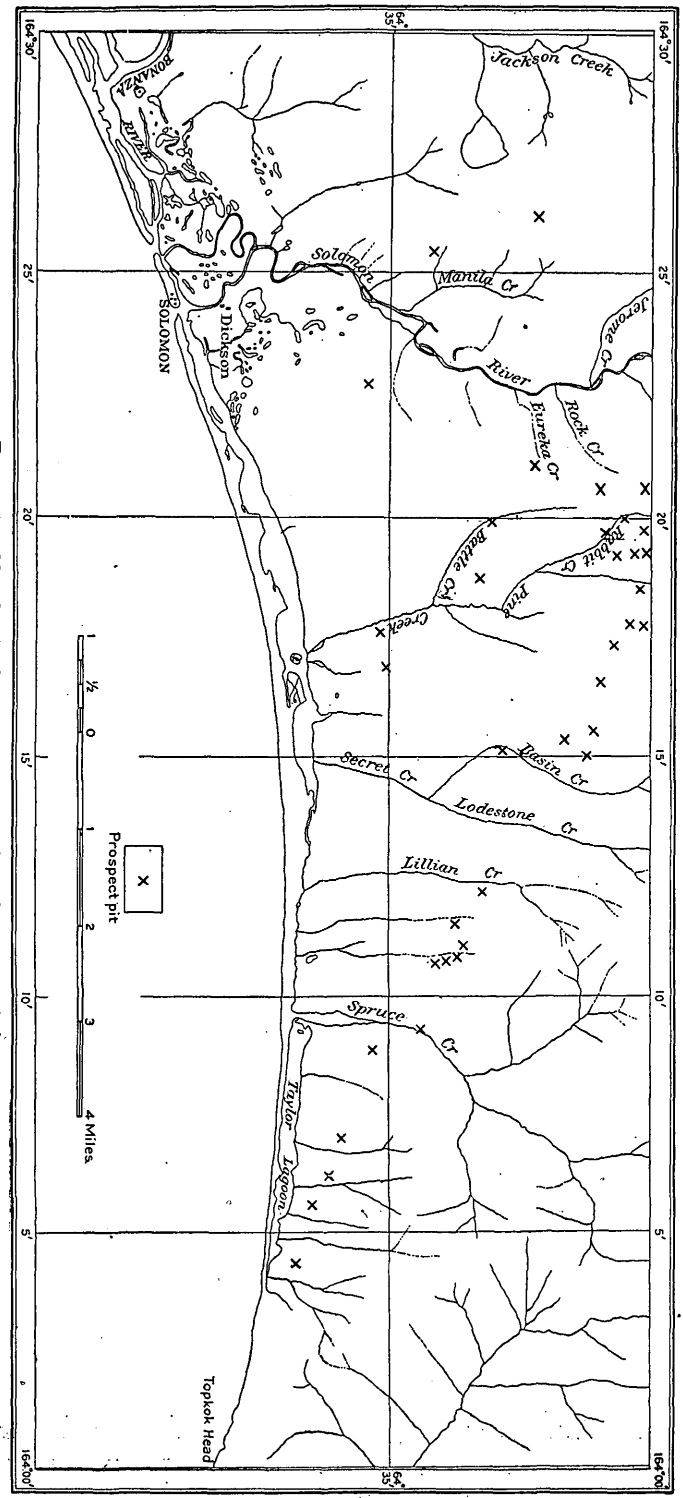

FIGURE 26.—Map showing location of prospect pits, Solomon coastal plain.

Near the head of the first small stream east of Lillian (Magnet) Creek a shaft has been sunk which does not reach bed rock. The material, namely, blue muck, mica-bearing gritty clay, and brownish sandy muck, which is exposed on the dump, seems to be similar to that exposed in the upper part of practically all the pits east of this point. A short distance east of Magnet Creek, at an elevation of slightly over 200 feet, a shaft has been sunk. Bluish muck is the main material forming the dump. Practically no gravel or wash has been encountered. From the size of the dump it is believed that the excavations reached no great depth.

West of Magnet Creek prospecting has been carried on along two main lines. One of these is not more than a mile north of the shore line and the other is much farther inland, near the termination of the coast plain. Much more work has been done on the latter line than on the former. At an elevation of about 300 feet, directly south of Uncle Sam Mountain, a shaft, which is now abandoned, has been sunk. The material on the dump at this place was black, dirty, graphitic, quartzose schist, and muck. The schist fragments were rather angular, and looked more like slide than river wash. This origin is also suggested by the surface form in the neighborhood. It is not known, however, whether bed rock was encountered, so no statement can be made as to whether the angular slide material overlies gravels or not. North of this shaft a few hundred yards is a more recent hole not filled with water. It is only 10 feet deep and shows no other material than heavy, black quartzitic schist slide.

When the region was visited in 1907 two men were operating on a lay, half a mile west of this pit, at an elevation of about 325 feet. A shaft 37 feet deep had been sunk, in which distance only angular slide rock of black quartzitic schist had been encountered. Bed rock had not been reached. Still farther west, at an elevation of approximately 300 feet, two men were sinking a shaft which passed through a thin layer of muck and continued in angular slide rock of black graphitic schist. A hundred and fifty paces south of this hole, however, beach gravel was found in an old shaft. Values were apparently wanting, for the outfit had abandoned this work and moved to the new hole north.

A short distance west of this last shaft and less than half a mile from Uncle Sam Creek, at an elevation of about 300 feet, a shaft 60 feet deep had been sunk. The upper 50 feet was through black, angular graphitic schist slide, but the lower 8 feet was in very yellowish iron-stained and well-washed gravel about the size of peas or slightly larger. Some of the upper portion of the upper 50 feet seemed to be made of slightly water-rounded creek wash, but as a whole this portion was characteristically slide. One hundred paces north of this shaft another had been started by the same two miners, and when visited was 40 feet deep. In this distance no material other than black graphitic schist in angular pieces strongly suggestive of slide rock had been encountered. The abandonment of the hole in which well-made gravel had been found strongly implies that no values were encountered in the gravel at that elevation.

West of these shafts, on the east bank of Uncle Sam Creek, at an elevation of about 225 feet, or less than 50 feet above the water surface of the creek, there has been some prospecting in the past and several good-sized dumps were seen. The material on the dumps consisted mainly of yellowish river wash made up almost entirely of schist fragments. There was also some black, angular slide rock and a few well-rounded pebbles of quartz, which appeared to be vein quartz. Fragments of this latter material were, however, rather infrequent. Southwest of this point on the other side of the creek, at an elevation of slightly more than 200 feet, two prospect pits disclosed some well-made gravel, which had a yellowish iron-stained color and looked like beach material. The pits, however, were badly caved, so that the gravel could not be examined in place.

Less than half a mile north of these pits three shafts have been sunk but apparently have not reached bed rock. The most southern of these shafts shows from its dump that it passes through considerable well-rounded gravel. The pebbles are formed mainly of vein quartz and well-rounded black slate. A hundred yards north of this point another shaft shows in its upper part a heavy layer of bluish frozen muck. This is underlain by clean, well-washed quartz gravel. The gravels are rather coarse, fragments up to the size of a walnut being common. The most northern of these three shafts shows material on the dump essentially similar to that from the others. At this place the gravels consist of well-rounded vein quartz as well as shingly black slate and chloritic schist. Practically no limestone is found in any of these gravels, although ledges of limestone are known to occur less than a half mile to the north. No work was in progress at any of these shafts during last season.

On the low divide between Uncle Sam Creek and Rabbit Creek, at an elevation of about 275 feet, a prospect pit has been sunk. The material thrown out from it shows much coarse, well-rounded gravel, which looks like beach shingle. Fragments of black schist, chloritic schist, and well-rounded vein quartz predominate in the gravel, but limestone fragments are apparently lacking. To the west of Rabbit Creek, at about the same elevation, 275 feet, another shaft has been sunk. It passes through an upper layer of muck and tundra vegetation and then into well-rounded and clean gravel which appears to be of marine origin. The section, however, was not seen in place, and no definite statement as to its origin can be made.

Some prospecting for ancient beaches was done during the winter of 1907–8 in the vicinity of Rabbit Creek, one of the many tributaries of Pine Creek. One shaft was sunk at an elevation of about 200 feet on Rabbit Creek, a short distance above the point where the flume that leads water from the upper part of Uncle Sam Creek to Rock Creek crosses the stream. Bed rock at this place is reported to be schist which was encountered about 30 feet below the surface or at an elevation above the sea of over 150 feet. The material in the upper part of the shaft was more or less shingly creek gravel, but lower down well-rounded quartz pebbles and sand indicated that marine agencies were responsible for its formation. The gold that was found in this lower gravel is bright, and although all of the pieces that were recovered by panning were very small, none of them seemed to be much worn, and many of them had the spongy appearance of crystalline gold. No quartz or country rock was found attached to any of the pieces, but the form strongly suggested that the gold had not traveled far from the veins from which it had been derived. As the ground had only been prospected by this one pit, no adequate idea of the tenor could be formed. It was reported, however, that one four-pan bucket had yielded 36 cents in gold. The gold, however, was irregularly distributed, and the values found were not sufficient to permit profitable development.

Farther up Rabbit Creek was a shallower hole in which the gravels were not as well rounded as in the lower pit, and they seemed more like creek wash than like beach or marine deposits. These gravels rested on a mica-schist bed rock that was slightly calcareous and had a salmon color, owing to the stains due to the decomposition of the iron minerals. Some of the gold was rusty, as though it had not been subjected to recent movement. The rusty color undoubtedly is due in part to the character of the bed rock on which the gold had accumulated, for evidence of a considerable circulation of iron-bearing waters could be found at many places in the gravels. In shape the gold was in thin plates, with the edges bent over. Only small fragments were recovered in pan tests, the largest being worth about a cent. On the whole, the gold did not appear to have traveled far from its place of derivation, and in shape was different from the characteristic beach gold found at Nome and at other points of the peninsula.

West of this last-described hole, on the valley slope, at a slight elevation above the creek and approximately 250 feet above the sea, a hole 45 feet deep has been sunk without reaching bed rock. Thawed ground was encountered and the miners were driven out by the water. Northeast of this hole and on the eastern bank of Rabbit Creek near its head, two holes 20 and 30 feet deep, respectively, were sunk to bed rock. In both, near the bottom, well-rounded beach wash was found. A section of this shaft showed in the upper part more or less angular slide and river wash. Below was sand and rather poorly formed gravel and then well-rounded gravel. In one of the holes the pebbles consisted almost entirely of black, graphitic slate similar to that forming the country rock of Uncle Sam Mountain, but in the other the pebbles were almost all of white-vein quartz. The pebbles, as a rule, measured about an inch by half an inch. Under the gravels was a rather thin sand layer that rested on a much decomposed schist bed rock.

The values at this place occur in the sand underlying the well-rounded gravel and penetrate into the upper part of the decomposed bed rock. A selected pan from this material yielded forty to fifty colors which together were worth about a cent. Some of the gold was iron stained, but most of it was bright. It would appear that the gold derived some of the iron with which it is stained from the decomposition of the iron minerals contained in the black quartzitic slate pebbles. Not enough iron was present at this place to form a cement, but a short distance downstream another hole 36 feet deep passed through several layers of cemented gravel. Too small an amount of gold was seen from the upper hole to permit a final opinion of the character of the sand layer as a whole, but it would seem that the gold is much finer and in the main is much more worn than that from any of the other holes already described. Although nearly all the ground is frozen, here and there thawed areas are encountered, so that the conditions of developing any productive deposits will be essentially the same as those surrounding similar types of deposits near Nome.

The other line of exploration already noted, a short distance back from the coast, has not been as extensively prospected as the more northern ones. The most eastern work on this line has been near the head of Dog Creek, the small stream entering the lagoon near Pine Creek. At this place, at an elevation of about 50 feet, considerable prospecting had been done during the early part of 1907 (although abandoned at the time of visit), for only the bottom of the hole was filled with water. A section shows 5 feet of moss and vegetation forming the upper part. Next below is 3 feet of blue muck, while below this is coarse, angular chloritic schist wash. Many of the slabs show an entire absence of water rounding. Below the slide-rock layer and nearly under water, there is a large amount of ice and muck. The entire section measures about 15 feet.

Half a mile west of this pit on the eastern bank of Pine Creek there is a small pit filled with water and having only a small dump. Most of the material thrown out is black angular schist that looks like slabs of bed rock, and the small size of the dump would indicate that, if this material is really bed rock, it must rise to nearly 50 feet above the sea, and consequently that the covering of gravels is very slight. Work at this place, however, had been abandoned for such a long time that it was difficult to make much out of the caved pits and dissected dumps.

About 2½ miles west of the Pine Creek pits, on the little knob about half a mile east of the Council City and Solomon River Railroad, there is a small pit which was probably not over 15 feet deep, but is now filled with water. The dump shows small amounts of muck, quartzitic, graphitic, and feldspathic schist, and greenstone. One small fragment of pegmatite was found. The material is all very angular, and does not show strong water rounding. No values were found and work has therefore been abandoned.

West of Solomon River not much prospecting has been done on the coastal-plain deposits. The most important section, namely, that obtained by the drill on the divide west of Manila Creek, has already been described in the earlier portion of this report dealing with unconsolidated deposits. Northwest of this point, at the head of Jackson Creek, at an elevation of 250 feet, the slope of the surface steepens abruptly and suggests a former stand of a body of water. Prospect pits, however, fail to disclose gravels of waterworn appearance. Instead, the only material shown on the dumps is angular schist float and muck. It is probable, however, that these holes have not penetrated to bed rock, and therefore the possibility of finding gravels below has not been proved or disproved. Farther south, and especially in the banks of Solomon River, about a mile from the sea, prospecting has been carried on to a slight degree. The material exposed in this place is practically all of river-wash character, but whether it was deposited on a delta or beneath the sea is not proved. So far, values have not been found, and they probably will be discovered only by more extensive and concentrated effort.

SUGGESTIONS TO PROSPECTORS FOR PLACER DEPOSITS.

The facts set forth in the preceding pages regarding the economic geology of the placer deposits seem to warrant certain general conclusions. In presenting these it should be understood that, as with all generalizations, exceptions will be found which will require the modification of any set rules. The following statements are to be regarded, therefore, as suggestions where prospecting is most likely to be successful, without intimating that placers may not be found under other conditions and in many other localities.

STREAM AND BENCH PLACERS.

One of the most notable facts brought out by a study of the distribution of the placers is the fact that where the feldspathic schists and greenstones of the Casadepaga formation form the country rock known placer deposits are wanting. This is well shown by the absence of placers on the tributaries of Topkok River that head within the quadrangle, on the eastern part of Big Hurrah Creek, and on nearly the whole lengths of East Fork, Coal Creek, and Big Four Creek. For this reason the prospector is advised not to spend much time searching in a region occupied by the Casadepaga schist for economically important placers.

On the other hand, the areas where placers have been most extensively worked have been downstream from the outcrop of the massive Sowik limestone or along the contact of this formation with the Solomon schist. This fact is shown by the numerous gold-bearing placers on Solomon River from Manila Creek to Big Hurrah Creek; by the placers on Shovel Creek and its tributaries; and by placers on Lower Willow, Canyon, Goose, Dixon, Banner, and Ruby creeks, Auburn Ravine, etc. It therefore seems advisable for a prospector to investigate the streams that occupy these relations to the heavy limestone, for the probabilities are strong that valuable placers may be discovered. It has already been pointed out on page 149 that diffused mineralization is almost universally found along the contact of the Sowik limestone with the Solomon schist, and although veins which might be mined as lodes are wanting, the concentration of contact material by streams undoubtedly explains many of the placers. The intimate relation between many of the rich placer districts and the limestone-schist contact is being more and more strongly emphasized the more Seward Peninsula is studied. As instances in support of this conclusion from areas outside of the Solomon-Casadepaga region, may be cited the Anvil-Dexter-Glacier region near Nome; the Manila-Goldbottom-Dorothy region, 20 to 25 miles north of Nome; the Iron Creek region; the Kougarok region; the Ophir Creek region in the Council precinct; the Bluff and Topkok region; the Inmachuk region in the Fairhaven precinct; and portions of the Sinuk-Cripple-Penny basins.

It has previously been pointed out that the Hurrah slate is a much mineralized rock, everywhere intersected by quartz strings, some of which are known to be auriferous. In areas where this formation is the country rock placers are usually found. The best example of this condition is shown by the creek and bench placers along Big Hurrah Creek. There are, however, some places where this rock is found but where placers are wanting. It therefore remains to be proved whether the absence of placers is real or is only due to lack of prospecting. On the whole, however, the Hurrah slate does not seem to be as important a placer producer as the limestone-schist contact.

Mineralization of the Solomon schist by veins carrying gold older than the period of metamorphism is a well-authenticated fact, and some of the placers have been produced by the disintegration and erosion of these rocks. On the whole, however, the deposits from this source are irregularly distributed and can not be traced over wide areas. For this reason prospecting for placers in a region of Solomon schist is analogous to pocket hunting in lode prospecting. Where, however, the Solomon schist is cut by the younger sets of veins the placer deposits may show a general relation to the trend of the veins.

As yet no adequate explanation of the deposition of the gold in the rocks has been found. The fact that veins and diffused mineralization occur in certain types of rocks and in certain localities is believed to be due in large measure, if not entirely, to the physical character of the country rock. For instance, the permeable contact between the schists and limestones offered a relatively easy passage for ore-bearing solutions. Whether the lime carbonate acted as a precipitant has not been determined. So, also, in the case of the veins in the Hurrah slate, it is possible that the carbonaceous material caused a deposition from the mineral-bearing solutions which was greater in the areas where this rock occurred than elsewhere. If, however, the physical condition alone is responsible for the mineralization, it seems clear that where the particular physical conditions are duplicated, either through precise similarity of lithology or through deformation, mineralization is to be expected. As an illustration, if porosity is the physical feature of the limestone that has permitted widespread mineralization, it is evident that where rocks, whatever their character, have been fractured and brecciated so that abundant open spaces have been developed, similar permeability to ore-bearing solutions may be expected. Mineralization has been noticed at a few places along fault planes where the rocks are smashed and dislocated, so that it is probable placers may be found downstream from such places.

GRAVEL-PLAIN PLACERS.

In the gravel-plain deposits that form the broad flat between Kruzgamepa and Niukluk rivers, the evidence as to the existence of placers is not clear. Much of the material of which this plain is formed has been brought from the Kigluaik and Bendeleben mountains, which are regions in which no gold veins have yet been found. This would suggest that economically important placers will be wanting. On the other hand, some of the material has come from the south and in that region gold-bearing veins and workable placers are known. The material from the north and south is more or less intimately intermixed. From this the conclusion is reached that the placer gold will be so scattered through a large amount of barren material that it could be extracted only by large companies capable of handling an immense amount of gravel at a low cost. Within the area studied in detail no holes have been sunk to explore the gravel-plain deposits. Three or 4 miles west, however, on Sherrett Creek, a number of holes from 70 to 180 feet have been sunk and no concentration or bed rock noted. From this fact it is believed that the prospecting of the gravel-plain deposits will be accomplished only at considerable financial risk and should therefore not be attempted by the individual or by small companies.

BEACH PLACERS.

Prospecting for beach placers in the coastal-plain province is being watched with interest, but results are as yet too meager to permit more than generalized treatment. It should be realized, however, that many of the same conditions affect beach placers as stream placers. The most important of these factors that the two have in common is the presence of mineralized areas in the neighborhood. The most highly mineralized areas have already been stated to be the contacts of the limestones and the areas of black slate. The limestone-schist contact practically does not reach the former shore line anywhere within the quadrangles, so that beach placers derived from this source are to be looked for at only a few localities, and the chances are against the contact having furnished much material to the ancient beaches. The Hurrah slate, however, formed part of the earlier shore line at the base of Uncle Sam Mountain and for some distance east and west. According to the accounts of prospectors, however, holes in this portion of the former shore line have yielded but small quantities of gold. It seems reasonable, therefore, to call the attention of prospectors to the facts and to suggest that search for ancient beaches will be attended by great difficulties and should not be attempted by those not financially prepared to spend much time and money in the exploration.

WATER RESOURCES.[a]

GENERAL STATEMENT.

Mining in the Solomon-Casadepaga region has been on a much smaller scale than in that around Nome, and consequently the utilization of the water power has not required the construction of such extensive lines of ditches as those which lead water from the Kigluaik Mountains to the Nome tundra. In all there are probably less than 50 miles of ditches in the Solomon and Casadepaga region,

[a] The detailed measurements set forth in the section of this report dealing with the water resources have been in the main collected by the hydrographic engineers of the Geological Survey. To several members of this corps the writer is indebted for information, especially Messrs. Henshaw and Barrows. Mr. Henshaw has been engaged in water measurements in Seward Peninsula since 1906, and Mr. Barrows made many of the observations on the streams of the Solomon and Casadepaga region during 1908.

and of this amount not one-half was in use during the last two summers. Many of the operators are using coal or oil or gasoline for power and are neglecting the development of power from water. It is probable that if any considerable new valuable ground is discovered the question of water supply will need careful consideration.

The relatively slight elevation of most of the region has an important effect upon the rainfall, and the average annual precipitation is probably only 10 to 15 inches. No rain gages were installed in the Solomon-Casadepaga region until the fall of 1908, so that records of the precipitation were not available. However, Henshaw has published the records of the Weather Bureau station[a] at Nome, and there is probably but slight difference between the two regions.

Precipitation, in inches, at Nome from December 1, 1907, to November 30, 1908.

December	0.30	July	2.10
January	.43	August	2.92
February	.76	September	.52
March	1.19	October	1.13
April	.02	November	.26
May	.19		
June	.90		10.72

From this table it will be seen that nearly half the annual precipitation comes during July and August. That the figures given above are characteristic and not abnormal is shown by the following table, published by Henshaw,[b] of the precipitation for 1906, 1907, and 1908 during the four summer months:

Rainfall, in inches, at Nome, July to September, 1906, inclusive.

	June.	July.	August.	September.	Total, four months.
1906	Tr.	2.38	2.50	1.02	5.90
1907	1.31	2.08	2.68	1.41	7.48
1908	.90	2.10	2.92	.52	6.44

Although there is probably but slight difference between the Solomon and Nome regions, the latter has an advantage over the former in having a mountain province, which receives a greater precipitation than the lower plateau and coastal-plain provinces and which conserves the snowfall, thus sustaining the flow of many streams during the dry periods. It is therefore particularly necessary to use the limited supply that is available with economy, if any large enterprises are to be carried on.

[a] Henshaw, F. F., Water-supply investigations in Seward Peninsula, 1908: Bull U. S. Geol. Survey No. 379, 1909, pp. 398–401.

[b] Henshaw, F. F., op. cit., p. 398.

DEVELOPED WATER SUPPLY.

The greatest amount of development of the water supply of the area is in the Solomon River drainage, and although some ditch building has been done in the Casadepaga basin the ditches are small and are intended for very local use. In the Solomon River area there are over 30 miles of ditches, and in the Casadepaga there are less than 15 miles. A brief enumeration of the ditches which have been constructed, with a statement of their present condition, whether abandoned or used, will be given.

SOLOMON RIVER DRAINAGE.

Commencing with Solomon River and its tributaries and proceeding from south to north, upstream, the first ditch seen is the Midnight Sun ditch, which has its outlet near Rock Creek. This ditch has its intake near Little Hurrah Creek at an elevation of between 175 and 200 feet. It follows along the southern slope of the valley of Big Hurrah Creek and then along the eastern side of Solomon River, making a considerable bend into Quartz Creek. This ditch is about 7½ miles long. South of Quartz Creek no water was flowing when the ditch was seen in July, and no mining work which would require the water from the ditch was in progress below this point during the season of 1907. In 1908 the water from this ditch was used at two or three placers between the mouths of Jerome and Penny creeks. Measurements on September 18, 1908, of the ditch near the mouth of Big Hurrah Creek gave a discharge of 18.6 second-feet.[a]

Two other ditches were noted in the Big Hurrah basin. One of these had an intake about half a mile above Lion Creek and was used to bring water down to the Big Hurrah mine. It followed the southern slope of the Big Hurrah Valley and was a little over 2 miles long. This ditch had been allowed to fall into disrepair, so that for the larger part of its course it could not carry water. The other ditch took its water from a point near the head of Tributary Creek about three-fourths of a mile above Daisy Creek. This ditch was only about one-half mile long, and then the water was carried by a pipe line along the south side of Tributary Creek to the Big Hurrah mine, a distance of about 2½ miles. Early in the summer of 1907 the pipe line and ditch were abandoned and the pipes taken up and disposed of.

The East Fork ditch, having its intake on East Fork, brings water to placer ground near the mouth of Big Hurrah Creek. This ditch has its intake between Etta and Goodenough creeks at an elevation

[a] Henshaw, F. F., op. cit., p. 383.

of 307 feet. It follows along the southern slope of the East Fork Valley and the east side of Solomon River. The ditch is about 5 miles long and at its outlet has an available head of about 125 feet. Measurements by Henshaw[a] show the following discharges from this ditch at an elevation of 290 feet near the mouth of East Fork:

Discharge, in second-feet, of East Fork ditch near mouth of East Fork at 290 feet elevation.

1908.	
July 4	11.9
July 12	0
August 6	7.5
August 27	12.6
September 18	12.7

North of this point comes the Brogan ditch on the west side of Solomon River. This ditch has its intake at the mouth of Johns Creek at an elevation of about 250 feet. It is about 4½ miles long, and in that distance gains an available head above Solomon River of between 50 and 75 feet. This ditch was one of the earlier ones constructed in the district, but it is no longer used and has been breached and would cost much to put into repair.

On Shovel Creek and its tributaries there are three waterways, two of which are ditches and the other a combination of flume and ditch. The most southern ditch has an intake on Shovel Creek a short distance above Mystery Creek at an elevation of about 100 feet. It follows the eastern slope of the valley and discharges so that the water is available on the flat at the junction of Solomon River and Shovel Creek. The ditch is about 2 miles long and the head acquired is nearly 40 feet. The other ditch takes its water from Mystery Creek a short distance above Problem Gulch, and leads it along the northwest side of the valley to near the mouth of Puzzle Gulch. This is a short ditch, only about three-fourths of a mile in length, but in this distance a head of 50 feet is obtained. The water is used for sluicing the bench gravels near the mouth of Problem Gulch. The supply is, however, not adequate. The combination flume and ditch on Shovel Creek has its intake between Adams and Virginia creeks at an elevation of about 280 feet. It is a very expensive piece of construction, as all the lumber of which it is made had to be shipped in. The necessity for a flume arose from the shattered limestone bed rock along the line. Broken porous limestone regions give great trouble to ditch builders, and in this case it was

[a] Henshaw, F. F., op. cit., p. 383.

believed that it would be less expensive in the end to build a flume for the greater part of the distance. Unfortunately, the project was not a success, and only the lower portion of the line, which is of ordinary banked earth construction, is in use. The entire waterway was about 1½ miles in length.

The only other important ditch in the Solomon River basin is one along the north side of Coal Creek. This ditch receives its water at an elevation of about 480 feet, nearly a mile above Boise Creek. The construction seems to have been carefully done, but at the present time no water is being carried by it. The gradient is so low that although the ditch is about 7 miles long, there is an available head at the outlet, above Solomon River, of nearly 200 feet. The water delivered by this ditch was used in mining the gravels of the flat between Coal Creek and Solomon River.

CASADEPAGA RIVER DRAINAGE.

In the Casadepaga basin, as has already been noted, there are but few ditches of even as great length as those in the Solomon region. In fact, there is only one ditch more than 2 miles in length, so that the entire ditch building may be regarded as the work of small holders of placer ground in a region where the local supply is adequate. Of these ditches only 4 or 5 need specific mention.

A ditch in Moonlight Creek basin is now less than a mile in length, but will be extended as developments warrant for 7 or 8 miles. This ditch has its intake at an elevation of about 500 feet on Moonlight Creek, just below a series of large springs formed by the emergence of water at the contact of limestone and schist. The water is led along the north side of the Casadepaga Valley. It is probably the intention of the owners to extend it along the north and west side of the river as far as Goose Creek, but at present its end is about opposite the mouth of Curtis Creek. This ditch is not in use. In 1908 Henshaw [a] made the following measurements of Moonlight Creek at the ditch intake. The drainage area is about eight-tenths of a mile.

Discharge, in second-feet, of Moonlight Creek at ditch intake, elevation 485 feet, in 1908.

	Discharge.
July 3	8.0
July 12	7.6
August 5	17.0
August 26	10.2
September 17	6.5

[a] Henshaw, F. F., op. cit., p. 384.

On Ruby Creek a small ditch has been built from near the mouth of Mud (Iowa) Creek to the junction of Ruby Creek and Casadepaga River. It has an intake at an elevation of about 450 feet, and at its outlet affords a head of nearly 100 feet. The ditch is 2 miles long, and the water is used for hydraulicking the gravels between Ruby Creek and the Casadepaga.

On Canyon Creek there is a ditch a little over 7 miles in length. It takes its water from Canyon Creek at the mouth of Allgold Creek at an elevation of about 510 feet and conducts it along the northern slope of the valley, making a long bend into Boulder Creek and finally discharges at Sunshine Creek. It is reported that this ditch has a fall of about 5 feet to the mile and it is estimated that it will carry 3,500 to 4,000 miner's inches of water. It was not entirely finished in 1907, but the water in the completed portion was being utilized while the construction was being pushed ahead. A lower ditch on Canyon Creek takes water from the creek near the mouth of Texas Creek and follows the northern slope of the valley to Boulder Creek. This ditch was not in use at the time this region was studied by members of the Survey.

On Penelope Creek a ditch 2 miles long has been built along the west side of the stream. It has its intake at an elevation of 400 feet and has an available head at the outlet of about 60 feet above the benches and stream placers where the water is used.

In the Goose and Quartz Creek region there are two small ditches. One of these takes water from Goose Creek and leads it around the nose between Goose and Quartz creeks to the latter creek, where it is used for sluicing the gravels; it is a small ditch and the head acquired is slight so that the water is used only in the boxes. The other ditch also takes water from Goose Creek and carries it to the water-power scraping plant described on pages 194–196; it also is a short ditch carrying only about a sluice head of water, with an available head of only about 12 feet.

Lower down on the Casadepaga there is a small ditch, now abandoned, which has its intake on Dry Creek at an elevation of about 400 feet. This ditch extends along the northwest side of Casadepaga Valley to the small creek next west of Dry Creek. It is small and is now badly caved.

UNDEVELOPED WATER RESOURCES.

The question as to what water power that is not used at present can be developed in the future is so vague that it can only be answered in a broad general way, unless specific instances are considered. To one contemplating the subject much information is afforded by a study of the maps, Plates III and IV, where the elevation of the country is shown with sufficient accuracy to allow the laying out of preliminary line for ditch construction. Broadly speaking, there is an area in the Solomon and Casadepaga quadrangles of 87 square miles which lies between sea-level and 300 feet elevation; 106 square miles between 300 and 600 feet; 148 square miles between 600 and 1,000 feet, and 57 square miles above 1,000. The prospector knowing the elevation of his ground can therefore roughly approximate the total area lying above that elevation from which water could possibly be derived.

If new rich placer ground is discovered which requires a large additional water supply much can be obtained from the tributaries of the main stream in the basin in which such placer might occur. Data regarding the amount of water available are annually collected by the engineers of the Geological Survey, and the following tables from Henshaw's report [a] show the measurements that have been made.

The first table gives the daily discharge of Solomon River below the mouth of East Fork. The drainage basin above the point where the river was measured has an area of about 66 square miles.

Daily discharge, in second-feet, of Solomon River below East Fork, 1908.

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1	130	164	70	20	44	100	......
2	100	115	85	21	43	90	......
3	75	95	100	22	44	90	......
4	72	223	93	23	43	130	......
5	70	626	......	24	44	120	......
6	69	280	......	25	43	115	......
7	69	150	......	26	41	107	......
8	62	112	......	27	40	93	......
9	76	110	......	28	43	90	......
10	72	110	......	29	43	85	......
11	70	120	......	30	360	85	......
12	76	140	......	31	636	110	......
13	63	170	......				
14	65	140	......	Mean	89.3	140	83.8
15	61	120	......	Mean of East Fork ditch	6.7	10	12.2
16	58	110	......				
17	58	110	......	Mean total	96.0	150	96
18	50	110	......	Mean per square mile	1.45	2.27	1.45
19	47	105	......				

Other measurements, made in 1908, of Solomon River near the mouth of Johns Creek, at an elevation of 245 feet, are as follows. The drainage area is about 40 square miles.

[a] Henshaw, F. F., op. cit., p. 383.

Discharge, in second-feet, of Solomon River near mouth of Johns Creek.[a]

Date.	Discharge.	Discharge per square mile.
July 4	60	1.5
July 12	37	.92
August 6	190	4.75
August 27	61	1.52
September 18	57	1.42

[a] Henshaw, F. F., loc. cit.

In the Casadepaga River basin also measurements have been made. The following table[a] shows the daily discharge measurements of Casadepaga River below Moonlight Creek in 1908 at an elevation of 400 feet. The drainage area above this point is about 47 square miles.

Daily discharge, in second-feet, of Casadepaga River below Moonlight Creek, 1908.

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1	110	76	60	19	30	56	......
2	70	56	55	20	36	56	......
3	66	56	52	21	36	42	......
4	100	100	50	22	30	42	......
5	100	246	50	23	25	75	......
6	66	300	50	24	25	70	......
7	56	76	50	25	20	70	......
8	56	56	50	26	20	66	......
9	56	56	49	27	20	60	......
10	49	56	48	28	20	55	......
11	49	76	45	29	20	52	......
12	49	76	42	30	1,080	50	......
13	49	127	40	31	420	70	......
14	42	76	38				
15	42	76	42	Mean	92.1	78.7	51.9
16	36	56	50	Mean per square mile	1.96	1.67	1.10
17	42	56	88	Run-off, depth in inches	2.26	1.93	.74
18	36	56	76				

No stations have been established upon the lower part of the Casadepaga, where a much greater volume of water at a lower elevation might be obtained. A few measurements, however, have been made on some of the tributaries that enter the river from the west. The following table[b] shows the records from a station on Lower Willow Creek a short distance above Ridgeway Creek. The elevation is 400 feet and the drainage area 15.4 square miles.

Discharge, in second-feet, of Lower Willow Creek near Ridgeway Creek, 1908.

Date.	Discharge.	Discharge per square mile.
August 4	6.0	0.39
August 26	10.4	.68
September 17	17.0	1.10

[a] Henshaw, F. F., op. cit., p. 384.

[b] Henshaw, F. F., loc. cit.

Another station was established on Canyon Creek a short distance below its side stream, Boulder Creek. Measurements here in 1908 were as follows.[a] The elevation is 355 feet and the drainage area 22 square miles.

Discharge, in second-feet, of Canyon Creek near Boulder Creek, 1908.

Date.	Discharge.	Discharge per square mile.
July 11	15.4	0.70
August 3	11.0	.50
August 25	21.9	1.00
September 17	27.0	1.23

No measurements have been made on any of the streams within the Solomon and Casadepaga quadrangles not included in the drainage basins of Solomon and Casadepaga rivers, except American Creek. One gage was set up on this stream just below the junction of Auburn Creek, and another below Game Creek. The upper gage is a short distance west of the margin of the map. As Auburn Ravine carries practically no water, the readings show the amount of water that is brought from outside areas to the northern part of the quadrangle. The increase in discharge noted between the upper and the lower station records the amount of water derived directly from the region included in the mapped area. This table, as well as the other water measurements, has been taken from Henshaw.[b]

Discharge measurements of American Creek, 1908.

Date.	Place.	Elevation.	Discharge.	Drainage area.	Discharge per square mile.
		Feet.	*Sec.-ft.*	*Sq. miles.*	*Sec.-ft.*
July 9	Below Auburn Ravine	600	2.0	13	0.15
July 18	....do	600	1.2	13	.092
August 3	....do	600	2.0	13	.15
September 17	....do	600	7.2	13	.55
July 9	Below Game Creek	480	5.7	24	.24
July 18	....do	480	2.6	24	.11
August 25	....do	480	5.9	24	.25

It is possible, however, that the volume of the streams in the basin in which the water is to be used is not sufficient, and it may be necessary to divert water from one large drainage area into another. There are three large areas which may be considered in this connection;

[a] Henshaw, F. F., loc. cit.

[b] Henshaw, F. F., op. cit., p. 385.

first, the coastal-plain province; second, the Solomon River basin; and third, the Casadepaga basin. The first of these areas would undoubtedly require more water than is locally received by it at the present time if mining should ever be done on the same scale that it is in the coastal-plain province near Nome. Water might be gained by tapping the larger tributaries of Solomon River, such as East Fork, Big Hurrah, Shovel, or Coal creeks, or even Solomon River itself. The ditches would have to be long, but not so long as those built in the Kougarok, Bluff, and Nome regions. West of Solomon River water might be carried to the coastal plain by tapping either the Solomon River drainage or the Bonanza River drainage to the west.

If the Solomon River basin did not afford enough water a slight addition could be gained by diverting some of the Casadepaga drainage. The lowest point on the divide between the Solomon and Casadepaga basins is slightly over 600 feet. This point is in the low pass by which the railroad crosses the divide. While water could thus be obtained, the length of the ditches necessary to give adequate supply would be so long as to be almost prohibitive in cost. The transfer of water from the Casadepaga and Solomon basins could of course be effected in either direction, but probably for a given length of ditch more water could be delivered from the Casadepaga to the Solomon basin than from the latter to the former. Very little additional water could be obtained for the Casadepaga region, except at an almost prohibitive cost.

The only one of these possible diversions of water from one drainage basin into another which has been attempted up to the present is the carrying of Bonanza and California Creek water over the divide into Mystery Creek. This project has not been completed. At the close of 1907 the end of the ditch was about 2 miles from the Mystery Creek divide. After crossing the divide it is intended to carry the water in heavy hydraulic pipes to the ground where the water is to be used. The pipe is already on the ground, so that it should not take a long time to complete the work of construction. The elevation of the divide where the ditch crosses is slightly in excess of 500 feet, and this will give a good head at the company's ground on Problem Gulch and Mystery Creek.

It is possible that with the further growth of Seward Peninsula mining the transformation of water power into electricity will also develop. Unquestionably there are many places where electricity may be generated cheaply by water. One such project is already under way on Solomon River but has been obstructed by adverse claims for the ownership of the water right. For this project it was proposed to tap Solomon River near East Fork and to lead the water by a ditch 2 or 3 miles in length, so as to acquire sufficient head to generate electricity to operate two large dredges. While this power will be sufficient for two dredges, it is probable that not all of it will be used for several years. If this venture is successful, many others will avail themselves of the opportunity and transmit the power thus obtained to regions where direct water power is not feasible or where power from the combustion of coal is precluded by the high cost of fuel and transportation.

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