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# THE FORTYMILE QUADRANGLE

## YUKON-TANANA REGION ALASKA

BY

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By ALFRED H. BROOKS.

In planning the surveys and investigations of Alaska the attempt was made to cover first those regions which were of the greatest economic importance. As a result many of the mapped areas are very irregular in outline, and it was found desirable to introduce greater uniformity into the published maps as rapidly as the data available for their preparation would permit. With this end in view there has been projected a system of maps covering quadrangular areas outlined by parallels of latitude and meridians of longitude, this being in conformity with the Geological Survey's practice in making surveys within the United States proper. But as the Alaska surveys are for the most part of a reconnaissance character and the region is very thinly populated, it has seemed best to adopt a map unit larger than that used in the States. This unit will include 4 degrees of longitude and 2 degrees of latitude, making a map about as large as can be conveniently handled. It is hoped that eventually all these published reconnaissance topographic maps can be accompanied by sheets showing the geology and the economic resources, but in view of the great demand for the topographic maps it has been deemed advisable to publish some of them immediately in connection with such accounts of the geology and mineral resources as may be available. Nor is it deemed desirable in all cases to delay the issuing of maps until the areas have been completely covered.

The following report, with its accompanying maps, is the third of this series to be issued, and, like the others, covers a part of the Yukon-Tanana region. Others will be published as fast as the accumulation of the field notes will permit. The topographic surveys on which the maps are based were made under the direction of E. C. Barnard in 1898. This is the first of this series of publications which is accompanied by a geologic reconnaissance map on the same scale as the topographic map, and it therefore marks a distinct advance over those previously issued. The geology, however, is treated in the same

general way as in the previous reports, the complete analysis of the many intricate problems being deferred until more facts regarding the phenomena have been collected.

The mapping was done by Mr. Prindle between the years 1903 and 1907. In 1903, 1904, and 1905 he traversed portions of the area, and in 1907 he spent several weeks in studying the rocks exposed along Fortymile River. The work of a number of other geologists has also been utilized in the preparation of the map and report.

# THE FORTYMILE QUADRANGLE, YUKON-TANANA REGION, ALASKA.

By L. M. PRINDLE.

## INTRODUCTORY STATEMENT.

The Fortymile quadrangle is delimited by meridians 141 (which is the international boundary) and 142 and parallels 64 and 65. The

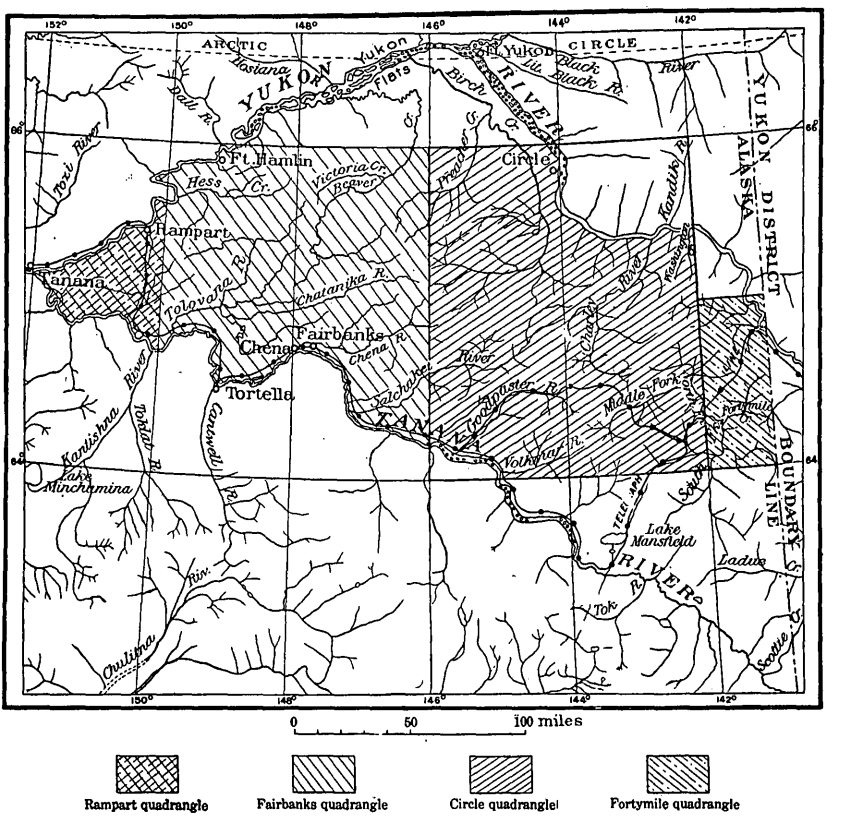



FIGURE 1.—Index map showing location of quadrangles in the Yukon-Tanana region.

area is about 70 miles long from north to south and 30 miles wide. The relation of this quadrangle to the other quadrangles of the Yukon-Tanana region is shown in the index map, figure 1.

Placer gold was discovered on Fortymile River in 1886, and within a few years gold was being produced from many creeks within the limits of the quadrangle. The subsequent discovery of other placer deposits withdrew men from the Fortymile region, but gold has been mined there continuously since the time of its discovery. New productive areas have been developed, and the old areas have been worked by new methods until the ground available for work by the methods hitherto employed is largely exhausted. With a gradual decreasing annual production that reached in 1907 about $150,000, the introduction of methods capable of handling cheaply large quantities of ground has been rendered imperative to meet the conditions that now prevail. Such methods have been in use for several years in the Dawson region, and the results attained there by dredging have been influential in the determination of methods to be employed in the Fortymile region, where the conditions are in many respects similar. The most important item of mining development in the Fortymile region in 1907 was the introduction of dredges and experimentation with this method.

The investigations of the Geological Survey have helped in the development of the district. On account of the growing importance of the Yukon-Tanana region a party consisting of Spurr, Goodrich, and Schrader investigated the placers of the Fortymile, Birch Creek, and Rampart districts in 1896.[a] The Fortymile quadrangle was mapped topographically by E. C. Barnard in 1898 on a scale of 1:250,000, or about 4 miles to the inch. The district was traversed by the Peters and Brooks party during the fall of 1899 on their trip from Pyramid Harbor to Eagle.[b] In connection with the systematic survey of the Yukon-Tanana region, begun in 1903, the areas adjoining the Fortymile district have been topographically mapped on the same scale as that of the accompanying map (Pl. IV, in pocket), and geologic reconnaissance trips have been made by the writer through the country lying between Yukon and Tanana rivers. All the producing creeks were visited in 1903; in 1904 and 1905 portions of the quadrangle were traversed, and in 1907 the areas adjacent to the Fortymile were visited.

As a result of these various trips, a body of material has been gathered bearing on the geology and mineral resources of the Fortymile quadrangle which has not yet been altogether correlated and studied in detail. Geologic surveys have not been carried on systematically throughout the quadrangle with the idea of mapping it areally as a unit, but have been largely incidental to the other work,

[a] Spurr, J. E., Geology of the Yukon gold districts, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 87–392.

[b] Brooks, Alfred H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including description of the copper deposits on the Copper and Tanana rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 331–391.

*A.* VIEW UP AMERICAN CREEK.

*B.* VIEW UP WADE CREEK.

and consequently there are many areas that have not been under observation. It is believed, however, that there are sufficient facts at hand upon which to base a preliminary outline of the geology and gold resources of this region—an outline justified by the demand on the part of the mining interests for information of this character. The material is being studied in more detail, and a comprehensive discussion of the problems involved is reserved for the report on the geology of the entire Yukon-Tanana region that is in preparation.

## GEOGRAPHIC SKETCH.

### RELIEF.

The topographic map expresses, by means of the contour lines, which represent lines of equal height above sea level, the form of the surface of the country. A study of the map (Pl. IV) shows that the region in general is not characterized by definite topographic trends, but rather by undulating, more or less flat-topped, ridges uniform in height and trending in various directions. The flat-topped character is shown in Plate II, *B*. There are a few isolated prominences, locally known as domes—Fortymile Dome and Steele Dome, for example—and in the northwestern part of the quadrangle the ridge of Glacier Mountain, with its rough outline, accentuates the resistant character of the rock composing it. But the predominant characteristic of the country is one of uniformity. This is further emphasized by the valleys. They have been cut to about the same level below the ridges, and those of streams of about the same size are similar. The highest points of the area are in Glacier Mountain, where an altitude of 6,000 feet is attained. The Yukon at Eagle is about 800 feet above sea level. The altitude of most of the ridges is about 3,000 feet. The valleys in general are about 1,500 feet below the ridges.

### DRAINAGE.

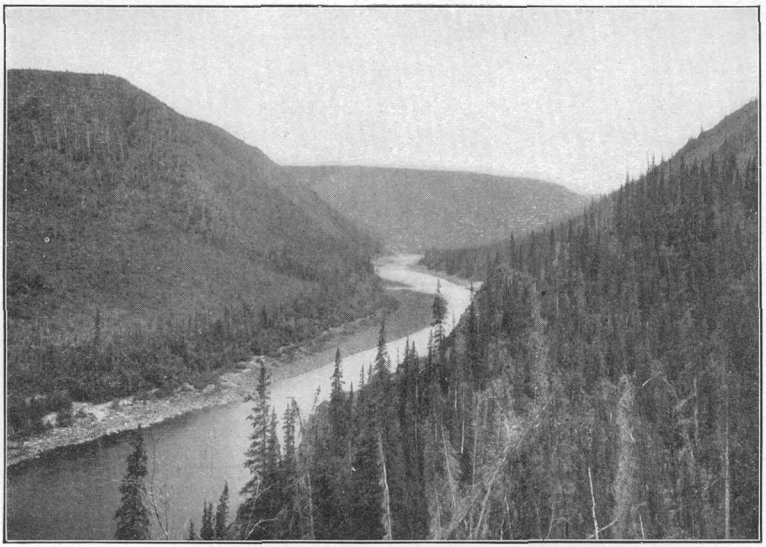
The map shows the extensive ramification of the drainage units and the complexity of their intergrowths. The valleys have been formed by the streams that flow in them. The drainage of the northern third of the quadrangle is to Yukon River, and, acting on an area of relatively high relief adjacent to a major stream, has formed deep, narrow, high-grade valleys. Fortymile River, formed by the union of North and South forks, receives all the drainage from the southern two-thirds of the quadrangle. The narrow, deeply cut character of the Fortymile Valley is present also in the lower valleys of its tributaries.

The valleys in general maintain their depth nearly to the head, where there is an abrupt descent from the level of the ridges. The upper portions of the valleys are narrowly V-shaped (Pl. I, *A*),

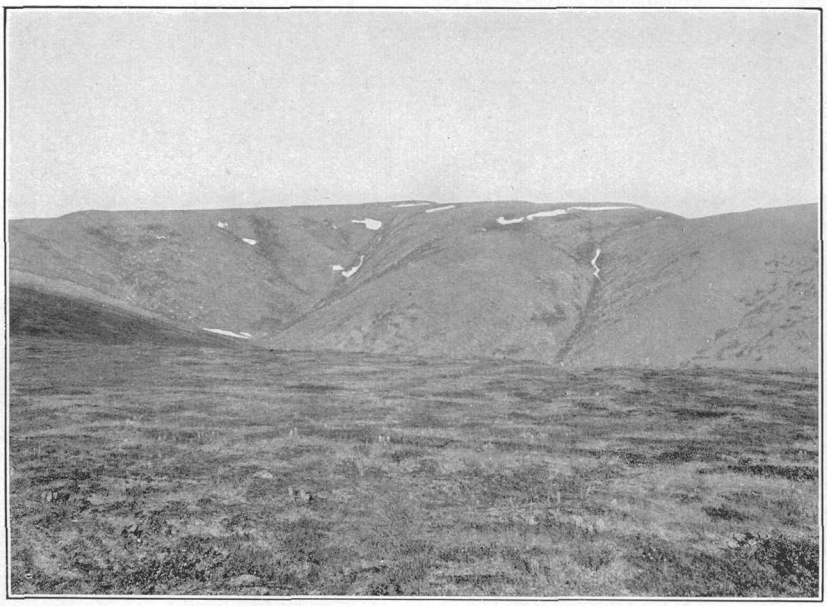
and in a few this characteristic persists nearly to their mouths. Ordinarily, however, the streams have developed a stream flat a few hundred feet in width, rather sharply differentiated from the lateral slopes (Pl. I, *B*). It is frequently the case that the slope forming one side of a valley rises abruptly from the valley floor, while the other slope merges gradually with the level of the ridges. This habit produces an unsymmetrical cross section of valley, which is very common throughout the Yukon-Tanana region. The grade of portions of the smaller valleys where mining is in progress ranges from less than 80 to more than 100 feet to the mile. The grade of the Fortymile within the limits of the quadrangle is probably about 6 feet to the mile, and that of the Yukon somewhat in excess of 1 foot to the mile.

The streams are shallow and rather swift, and most of them are cutting bed rock through a large part of their valleys. The Fortymile, draining as it does large areas outside of the quadrangle and receiving several large tributaries within the quadrangle, is the largest stream and carries the largest quantity of water. Notwithstanding the abundance of water, the swiftness and shallowness of the stream render it difficult of navigation even for poling boats. The Seventymile is comparable in size to Dennison or Mosquito Fork, and carries at ordinary stages sufficient water to enable small boats lightly loaded to reach nearly the western limit of the quadrangle. All the streams except the Fortymile are easily fordable on foot at ordinary stages of the water. The quantity of water in all the streams is subject to great variation from the fact that there is a direct relation between the amount of water carried by them and the rainfall. The ground being for the most part permanently frozen, the greatest part of the rainfall finds its way rapidly to the streams, which soon remove it. A few days of dry weather consequently influence very appreciably the water level in the streams and quickly reduce below the required amount the quantity available for mining purposes in the smaller streams.

The drainage of the quadrangle might be called homogeneous from the fact that most of the streams head at about the same level and that equal streams are cut to about the same depth and have approximately the same grade. This homogeneous character of the drainage has an economic bearing when the necessity of increasing by artificial means the water supply at any given point arises. The absence of commanding ridges with abundant water supply at higher levels renders it necessary, in advancing any undertaking that involves an artificial increase of the water supply, to draw upon similar units of drainage, and the differences in elevation are so slight that, in order to obtain the efficiency available in such narrow vertical



*A*. CANYON OF FORTYMILE, 500 FEET BELOW THE LEVEL OF THE OLD VALLEY.



*B*. FLAT-TOPPED RIDGE OF QUARTZITE SCHIST.

Between Davis and Poker creeks. Altitude approximately 3,800 feet.

limits, careful preliminary measurements of water supply and grades are required.

A characteristic of many valleys in the Fortymile quadrangle is the presence of benches at various heights, from a few feet to more than 500 feet, above the present level of the streams. These are a part of the great system of benches present throughout the greater part of the valley of the Yukon and those of its tributaries, and mark different stages of stream development. The significance of these benches lies in the fact that streams have a tendency to register a long-continued maintenance at a certain level by the development, through lateral cutting, of an approximately level bed-rock floor of considerable width upon which stream deposits are in the course of time deposited. With renewed opportunity for downcutting, a canyon may be cut below the level of this floor, like that of the Fortymile below the floor of the old valley of the Fortymile that is so prominently developed as a high bench throughout the portion of the Fortymile Valley included in the quadrangle. Pauses in the process of downcutting are duly indicated by benches of intermediate height. The high bench and present canyon of the Fortymile are shown in Plate II, *A*. The benches are particularly well developed in the valley of the Fortymile and the adjacent portions of the valleys of its tributaries and along parts of the valley of the Seventymile. Attention has long been directed to the benches from the fact that the stream deposits left upon some of them have proved to be richly auriferous.

## CLIMATE AND VEGETATION.

The latitude of the area entails strongly contrasted seasons and a wide range of temperature. The summers have the variability characteristic of those in many parts of the States. Some of them are very warm and predominantly dry; in others, rain is frequent and abundant. Their shortness is compensated by the great number of hours the sun is above the horizon. The temperature has an annual range of about 133° F. The maximum attained is about 90° F. and the minimum about —75° F. The following table shows temperatures observed at Eagle:[a]

*Maximum and minimum temperatures observed at Eagle.*

| | Maximum. | Minimum. | | Maximum. | Minimum. |
|---|---|---|---|---|---|
| | °F. | °F. | | °F. | °F. |
| January | 23 | —75 | July | 82 | 31 |
| February | 38 | —74 | August | 80 | 24 |
| March | 56 | —56 | September | 78 | 8 |
| April | 59 | —12 | October | 68 | —28 |
| May | 82 | 10 | November | 39 | —52 |
| June | 87 | 26 | December | 39 | —68 |

[a] Brooks, Alfred H., and Abbe, Cleveland, jr., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 158–161.

The dates upon which the observations were made were as follows: October, 1882, to May 9, 1883; August 22, 1884, to May 12, 1885; August 16, 1885, to May 19, 1886; August 15, 1899, to December, 1900; November and December, 1901; February to December, 1902.

Frosts are uncommon between May 15 and the end of August, and the conditions are favorable for an abundant growth of vegetation. The precipitation is low, an average of 11.35 inches having been reported from Eagle.

The climatic conditions have an important economic bearing. The Yukon becomes lower and clearer as the time for the freeze up approaches, and closes to navigation at dates ranging from about October 10 to November 20. A thickness of approximately 6 feet of ice is formed, which does not break up till about May 10 to May 20. Much of the ground is permanently frozen, but notwithstanding the extreme cold there is much water in the ground throughout the winter. The water in the streams frequently breaks through and overflows ice already formed, and although quickly frozen is a source of troublesome and expensive delays where streams are used as routes of winter travel. Constant repetition of this process in the smaller valleys results in the accumulation of such a thickness of ice that it lasts till late in summer and interferes with the work of mining. Dams, mining equipment, and roads may be buried beneath such accumulations of ice and rendered valueless. This process of glaciering is so characteristic of the region that it must be provided against in construction work.

The spruce is the predominant tree, but aspen and birch are common, and there is a thick growth of alders and willows along many of the streams. Spruce is abundant and of considerable size in the valleys of the larger streams, and throughout the area it covers the slopes as high as the climatic conditions permit, and the lower ridges in the vicinity of the main drainage lines are covered with it, together with a small proportion of birch (fig. 2). Dwarf birch and scattered bunches of alders are common on the higher ridges. The spruce is of sufficient size to furnish a limited quantity of logs 12 to 15 feet or more in length and a foot in diameter. It has been used generally for sluice boxes and to some extent for dredge building.

Food for stock is rather plentiful and sufficient for forage purposes in many of the valleys. Timber for fuel has proved abundantly sufficient up to the present time.

The well-nigh universal covering of moss retains the frost in the ground, but by stripping away the moss where there is sufficient soil and by repeated cultivation ordinary vegetables can be grown in abundance. At the present time a large part of the supplies of the road houses in the Fortymile quadrangle are furnished by the gardens, and nearly every miner has a small patch of ground under cultivation.

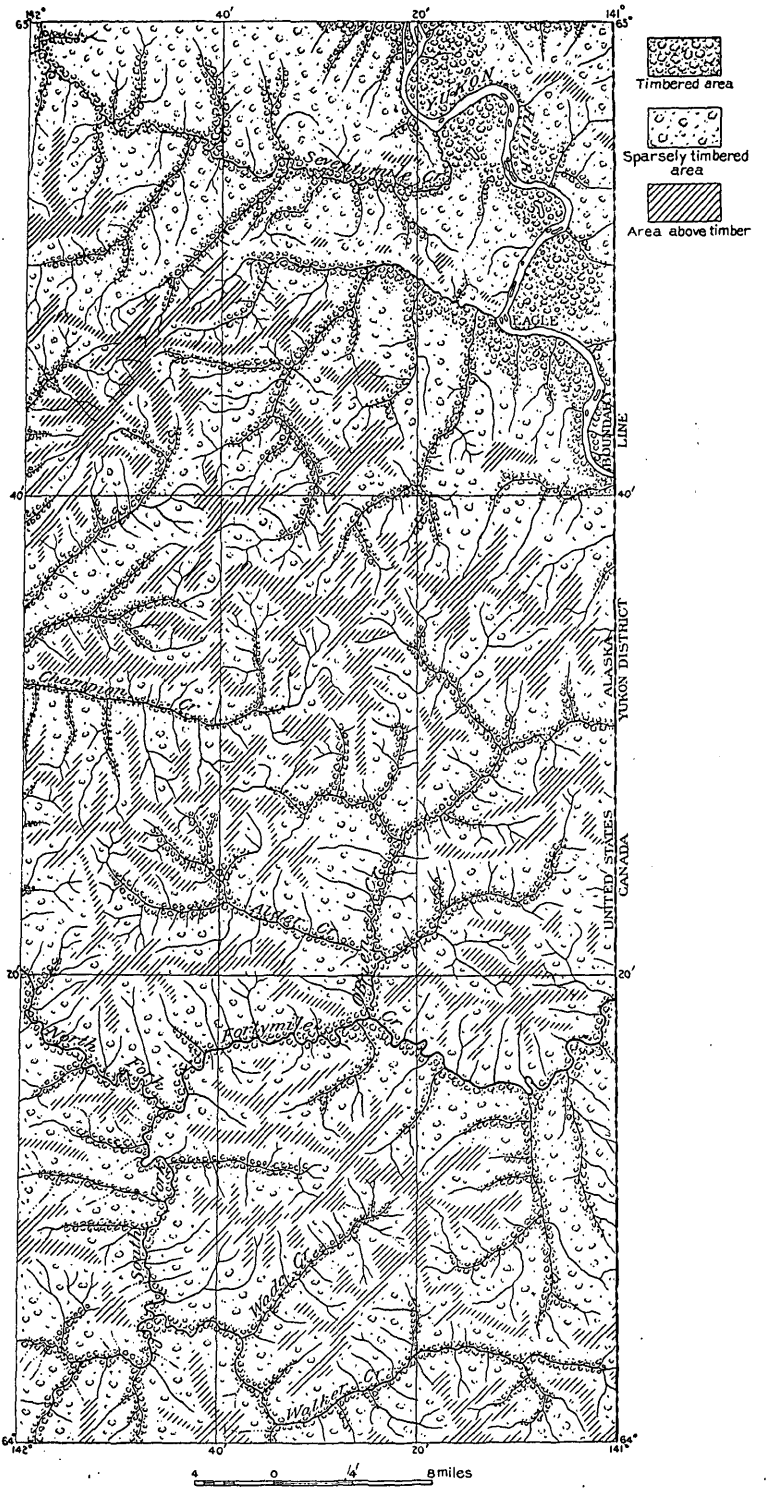



FIGURE 2.—Map showing distribution of timber in the Fortymile quadrangle.

## TRANSPORTATION.

Transportation of supplies to the localities where mining is in progress has always been a time-consuming and expensive process. Eagle is the main supply point on the Alaskan side of the boundary, but many of the localities are so situated that it has hitherto been more feasible to procure supplies from Dawson on the Canadian side. Most of the supplies for the Fortymile area are purchased in Dawson and freighted up the Fortymile on the ice by horse sleighs during the winter months. The Fortymile affords access to the remote tributaries where work is being done, but is a roundabout road, and the overflows to which it is subject are often an additional source of delay. Several hundred tons of dredge material were shipped by this route during the winter of 1906–7, when the freight rate to the vicinity of Franklin Creek was about $70 per ton. Summer freighting on the Fortymile is done by poling boats, but it is a difficult stream to navigate even by this method. Long reaches of quiet water are separated by bed-rock riffles where the water is swift and shallow. Supplies are frequently lost or long delayed by low water, and the rates from Fortymile Post on the Yukon to Chicken Creek—the farthest locality to which supplies are carried by this method—is 25 cents per pound (1907). The Canadian wagon road from Dawson to Glacier—a distance of about 60 miles in Canadian territory—is utilized during the summer to a certain extent for the transportation of supplies to creeks on the Alaskan side in the vicinity of the boundary.

The road commission has surveyed a government wagon road from Eagle to the Fortymile country and has already completed about 9 miles of it, from Eagle to American Creek. It is hoped by the construction of such a road to bring Eagle into closer relations with the Fortymile country. Work is also being done by the commission on a road that will make the Seventymile area more accessible from Eagle. In the fall of 1907 a road was in process of construction from the head of Canyon Creek to Walker Fork, in order to avoid the long haul up the Fortymile.

The mail route from Eagle to Valdez passes through the Fortymile country and affords a mail service to the miners of that country. The mail is carried by pack train during the summer season, and in consequence of the large mail-order business the facilities are generally overtaxed.

There are stations of the Government telegraph line at Eagle, at North Fork, and at Kechumstuk, both the latter localities being outside the limits of the quadrangle. The installation of a telephone line has been under discussion by the miners, and a system connecting all the creeks with the supply points would be of great service.

### INTERNATIONAL BOUNDARY.

Work was commenced in 1907 on the location of the international boundary southward from the Yukon. A topographic map of the country for 2 miles on each side of the boundary is being made by representatives of both Governments and will afford definite information to the miners as to the position of the line.

## GEOLOGIC SKETCH.

### STRATIGRAPHY.

#### INTRODUCTION.

The Fortymile quadrangle is composed of a group of highly metamorphosed rocks, predominantly schists and limestone, assigned provisionally to the pre-Ordovician;[a] of Paleozoic rocks, including phyllites, limestones, and greenstones belonging to the Devonian and shales, slates, limestone, sandstone, and conglomerate belonging to the Carboniferous; of clays, lignite, sandstones, and conglomerates belonging to the Tertiary; of Pleistocene and Recent bench gravels and stream gravels; and of intrusive igneous rocks, some of which have been metamorphosed.

The vertical distribution of the rocks is shown in the table on page 16; their areal distribution is shown on the geologic map, Plate V.

The quadrangle is not one of a few well-defined formations maintaining constant characters over areas of considerable extent, but one in which there is wide variation of material within narrow limits. The different formations possess a heterogeneity of lithologic character which their representation on the map does not express, and their frequent occurrence in small areas necessitates detailed field treatment of the quadrangle that has not yet been given to it. Furthermore, the complexity of the rocks of sedimentary origin has been increased by their metamorphism and intrusion by igneous material, and the igneous rocks also occur largely in areas so small as to be easily overlooked in reconnaissance work. The stratigraphic succession and the distribution of the rocks indicated on the geologic map are therefore generalized to a certain extent, but it is believed that they express with a fair degree of accuracy the geologic relations of the material occurring in this quadrangle.

An inspection of the geologic map shows that the metamorphic rocks form nearly the whole of the southern half of the quadrangle and that the northern half is composed predominantly of Paleozoic

[a] The rocks designated pre-Ordovician include those to which the names Birch Creek and Fortymile have been given by Spurr and Nasina by Brooks. It is not desirable in this report to enter into a detailed discussion of the nomenclature and correlation of the schists. This is one of the most important problems of Yukon-Tanana geology and is to be treated fully in a later report on the geology of the region.

rocks and more recent sediments. Paleozoic and more recent sediments occur also in the southern part of the quadrangle, and local areas of these rocks have perhaps been included within areas assigned on the map to the metamorphic rocks. The data regarding the rocks below Eagle are taken from the work of Brooks and Kindle.[a]

*Provisional tabular statement of stratigraphy of Fortymile quadrangle.*

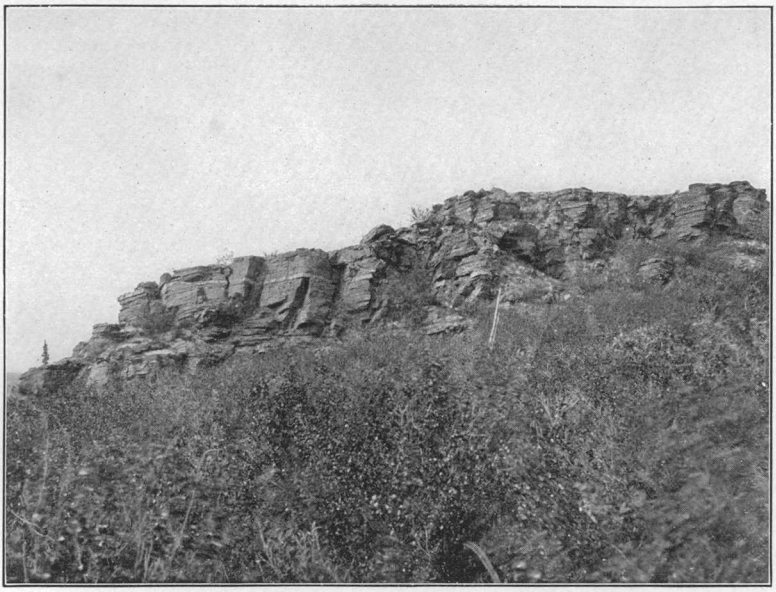
| System. | Series. | Formation. | Lithologic character. |
|---|---|---|---|
| Quaternary | Recent | | Stream gravels and silts. |
| | Pleistocene | | Bench gravels. |
| Tertiary | Eocene | Kenai | Clays, sandstone, lignite, shales, and conglomerates. |
| Carboniferous | | Nation River | Gray shales with heavy conglomerate beds and some sandstone. |
| | | Calico Bluff | Black and gray shales and slates with some limestone beds. |
| Devonian | | | Slates, phyllites, quartzites, cherts, limestones, greenstones, and tuffs. |
| Pre-Ordovician | | | Quartzite schist, quartz-mica schist, carbonaceous schist, hornblende schist, gneisses, and crystalline limestone. |

## PRE-ORDOVICIAN.

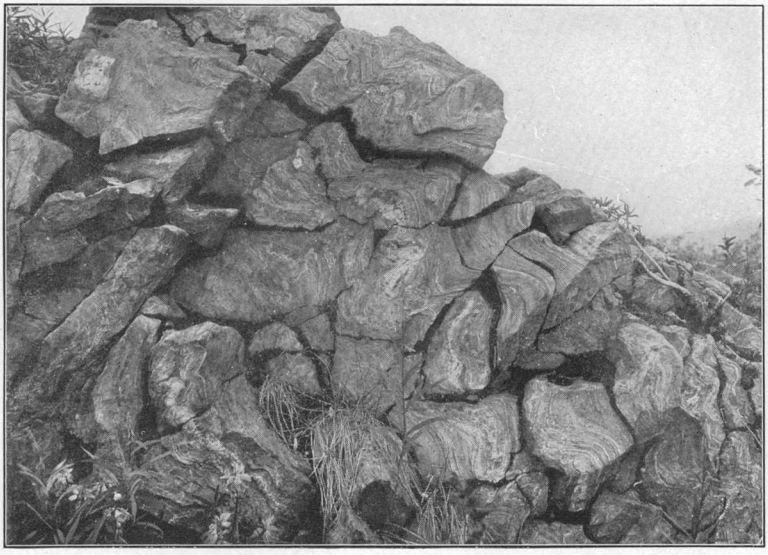
Under the provisional designation pre-Ordovician is included here a complex of crystalline rocks, some of which are very definitely of sedimentary origin and some of which are as definitely of igneous origin. Through metamorphism, however, the original constituents and structures have been largely replaced by new constituents and new structures and in some of the rocks the distinctive character of their mode of origin are practically obliterated. The complex at the present time, therefore, is a unit in the sense that all the heterogeneous materials of which it is composed, having undergone the processes of metamorphism, exhibit certain general characters due to these processes and have thus attained a partial homogeneity that affords a basis in the area under discussion for the separation of this group from others. The rocks composing it are regarded as the oldest in the quadrangle. Where the original composition has been similar to that of the overlying rocks and where metamorphism has not expressed itself forcibly it is very difficult to delimit this complex precisely from the later formations.

The area covered by these rocks in the Fortymile quadrangle is only a small part of that occupied by them in the Yukon-Tanana region. The types represented include quartzite, quartzite schist, calcareous quartzite schist, quartz-biotite schist, garnetiferous mica schist, hornblende schist, carbonaceous schist, crystalline limestone, biotite gneiss, hornblende-biotite-plagioclase gneiss, and biotite augen

[a] Brooks, Alfred H., and Kindle, E. M., The Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 255–338.



*A*. SCHISTS WITH THIN GRANITIC SILL ON TRAIL FROM WADE CREEK TO WALKER FORK.



*B*. CONTORTED SCHIST ON RIDGE NORTH OF MOSQUITO FORK.

gneiss. In most of the schists garnets are common, and epidote is very abundant in both schists and gneisses. All of these rocks occur in frequent alternation over large areas. Along the Fortymile from Franklin Creek to the boundary there is exhibited a constant succession of these recurrent types. The crystalline limestones occur interbedded with the schists in beds from a few inches to a hundred feet or more in thickness, being in close contact on either side with quartzite or quartz-biotite schist or with hornblende feldspathic schists or gneisses. At some localities very pure quartzites occur associated with the limestones, and at other localities there are quartzites that contain a considerable admixture of calcareous material.

The structure is very complex. The rocks have been very closely folded (Pl. III, *A*). In places they are apparently nearly horizontal, but here and there such horizontality is the result of the overturning of the folds to a nearly horizontal position. In general the attitude is highly inclined and the dips and strikes vary greatly within small intervals, closely appressed folds being common and pitching in many places at high angles, the pitch of minor folds becoming in places, so far as observable, practically vertical. Shearing has been extensive, and through the shearing of highly pitching folds of thin-bedded quartzite and alternating beds of mica schist rods of quartzite a foot or more in length with elliptical cross sections an inch or more in longer diameter have been developed. In a weathered cross section of such beds the eyes of the quartzite in a micaceous matrix present the appearance of pebbles in a metamorphosed conglomerate. The complicated folding which these rocks have undergone precludes any estimate of thickness.

The structure and composition of these rocks have been further complicated by the intrusion of a large amount of igneous material, some of which has been so closely incorporated with the schists as to be not easily recognizable as of different origin. Innumerable small dikes and sills (Pl. III, *A*), which have permeated these rocks and have in part been folded with them, are reduced to lenticular masses ranging in size from the minute remnants of a crumpled sill a quarter of an inch or less in thickness to the more massive fragments of a sill a foot or more in thickness. Crosscutting dikes have given off minute sheets of thin material along the structural planes of the schists or gneisses until a considerable proportion of the rock has become granitic in composition. There is also much material of intermediate composition, and basic dikes are common. In a word, it would seem that the intimate intrusion of this complex of schists is indicative of their proximity to large masses of igneous material, to which, perhaps, a large part of their metamorphism and a part of their complex structure are due.

The distribution of these rocks is approximately shown on the map. The boundaries indicated have not been traced out on the ground to their entire extent, and must be regarded only as provisional. It is probable that small areas of younger rocks have not been differentiated. Besides the large area of these rocks that form predominantly the southern half of the quadrangle, there is a small area appearing in the upper part of the Seventymile Valley, from the falls to the boundary of the quadrangle. A narrow ridge of undetermined extent, probably to be correlated with these rocks, is located at the base of the ridge limiting Mission Creek on the north. A narrow belt of them is apparently exposed round the north side of the intrusive mass of Glacier Mountain. The approximate northern boundary of the main area extends southeast of Glacier Mountain and crosses the boundary at a point which is probably not far north of Fortymile Dome.

An attempt to separate the complex into distinct formations is not justified by the facts at present available. The uppermost part is apparently carbonaceous schist with interbedded quartzite, also in part carbonaceous, and crystalline limestone. From these beds there is apparently a gradual metamorphic transition, with repeated alternation of beds originally different in composition, to more and more crystalline rocks and to rocks that have undergone an increasing amount of intrusion, and the base of the formation is probably most thoroughly magmatized.

### DEVONIAN.

Green and black phyllites and cherty slates, cherts, greenstones, serpentine, quartzites, and limestones, all regarded for the most part of Devonian age, characterize a large part of the northern half of the quadrangle. It is possible that Silurian or Carboniferous rocks are included in this grouping, but at present there is no evidence for their separation. They form the bluff just below Eagle, the bluffs above Eagle on the north side of the river, and are abundant below Eagle along the Yukon, where they are in close relation with Carboniferous rocks. In the southwestern part of the quadrangle they occur on the Fortymile from the mouth of Dennison Fork to a point about 2 miles above Franklin Creek. The drainage area of Chicken Creek is formed partly of these rocks. A belt of them is present also in the area about the headwaters of King Solomon and Champion creeks. This belt apparently terminates to the southeast, and to the northwest probably connects with a considerable body of these rocks that lies outside of the quadrangle. There is also a small area of them on Canyon Creek.

The lithologic character varies greatly. The greenstones and next to them the limestones are the prominent members of this group. This formation offers a strong contrast to the preceding rocks by an

absence of the intense metamorphism generally characteristic of the latter. In the sedimentary part of the formation the characteristics of sedimentary rocks still prevail and the limestones in places still retain fossil evidences of animal life. At two localities, one at Thirteenmile camp southeast of Eagle, and one on the Fortymile just below the mouth of Napoleon Creek, the writer found fragments of crinoid stems in the limestones, but these are of little value for stratigraphic purposes. The limestones are in places thin bedded, bluish, and occur interbedded with shaly phyllites; at other localities there are massive beds up to 150 feet or more in thickness.

The contemporary igneous material so characteristic of this formation is predominantly of a diabasic or basaltic character and much of it is tuffaceous. The relation of these rocks to the limestones is well shown in the ridge that extends east and west along the north side of Mission and Excelsior creeks. Here a gray limestone about 150 feet thick is capped by a very fine-grained green vesicular basaltic rock. Black shaly slates are associated with the limestone in this same ridge at a locality near Eagle, and the green rock forms the capping, as at the other locality. Besides the igneous material interbedded with the sediments there are dikes of diabasic character. The Devonian rocks have been closely folded, but otherwise have suffered little alteration.

The succession of rocks assigned to the Devonian is not completely exposed at any locality observed in the Fortymile quadrangle. A partial section is shown in the ridge extending northeast from Glacier Mountain, between the headwaters of Excelsior Creek and Seward Creek. The intrusive mass of Glacier Mountain is bordered by quartzite schist assigned to the pre-Ordovician. The succeeding rocks are fairly well exposed for about a mile. The attitude over a part of this distance is nearly vertical. The base of the Paleozoic rocks is taken to be a band of carbonaceous phyllites outcropping over a width of about 500 feet. These are followed in order by an outcrop of massive limestone about 600 feet wide, a massive quartzite 50 feet thick, black and gray slaty phyllites outcropping at intervals over about half a mile, and then meager outcrops of more limestone. A mile farther along the ridge are greenish slates, and 2 miles from them, beyond an area about three-quarters of a mile wide of loosely consolidated conglomerate and sandstone assigned to the Tertiary, are outcrops of greenstone. Shales and slates, which carry a few Devonian fossils, occur at several localities below Eagle on the Yukon. These beds, which aggregate about 1,000 feet in thickness, represent the uppermost member of the Devonian, and are succeeded conformably by the lowest member of the Carboniferous. As this formation was not definitely recognized in other parts of the quadrangle, the rocks are here grouped with the other Devonian terranes, though they probably represent a horizon higher in the geologic column.

## CARBONIFEROUS.

The Carboniferous is represented within the limits of the quadrangle by two formations, the Calico Bluff and the Nation River. These formations are present below Eagle on the Yukon and have been studied by Brooks and Kindle,[a] from whose description the following paragraphs are quoted:

> The lower of the two well-defined formations, for which the name "Calico Bluff" is proposed, embraces about 900 feet of black and gray shales, with some slate, and numerous interpolated thin beds of limestone. The whole formation carries an abundant fauna, assigned to the Mississippian by Dr. George H. Girty. Its typical exposure is at Calico Bluff on the Yukon, about 15 miles below Eagle. The Calico Bluff formation is separated by an unconformity from the succeeding formation, here called the "Nation River." There can be little doubt of this unconformable relation, though no complete section was found showing both. The relations are inferred from the apparently abrupt change in character of sediments to fine limestone from coarse fragmental material. It is not improbable, however, that detailed mapping may reveal a considerable thickness of strata lying between the Calico Bluff and Nation River, as here described. Whether such strata, if found, should be included in one or the other of these formations, or be mapped as a distinct stratigraphic unit, must be left to the future to determine.
>
> * * * The physical changes involved in the transition from Devonian to Carboniferous sedimentation embraced a continuation of the deposition of shale-producing sediments, interrupted at intervals by periods of limestone deposition. The Carboniferous fauna seems to have made its first appearance in the region with the advent of limestone-forming conditions during the temporary cessation of the deposition of black-shale sediments. The regular and frequent alternations of closely folded light-colored limestone and dark shale which characterize the Carboniferous portion of the nearly vertical face of Calico Bluff give it an unusual and striking appearance, as seen from the river.
>
> The Carboniferous fossils obtained here were submitted to Dr. George H. Girty, who reports the following species from bed 9j, * * * the lowest bed holding Carboniferous fossils:

*Fossils from bed 9j, Calico Bluff.*

| | |
|---|---|
| Fenestella sp. | Productus sp. |
| Polypora sp. | Spirifer aff. bisulcatus Sowerby. |
| Cystodictya sp. | Spirifer aff. keokuk Hall. |
| Stenopora? sp. | Spirifer sp. |
| Rhombopora sp. | Reticularia aff. setigera Hall. |
| Derbya? sp. | Martinia? sp. |
| Chonetes aff. choctawensis Girty. | Leiorhynchus sp. |
| Productus aff. cherokeensis Drake. | Aviculipecten sp. |
| Productus aff. inflatus McChesney. | Myalina sp. |
| Productus aff.? hirsutiformis Walcott. | Macrodon aff. carbonarius Cox. |
| Productus aff. punctatus Martin. | Bellerophon sp. |
| Productus aff. setigera Hall. | Phillipsia sp. |
| Productus aff. biseriatus Hall. | |

[a] Brooks, Alfred H., and Kindle, E. M., The Paleozoic and associated rocks of the Upper Yukon: Bull. Geol. Soc. America, vol. 19, 1908, pp. 255–314.

From the black shale above this fauna * * * a small fauna was secured containing three species, reported by Girty as follows:

Liorhynchus aff. mesicostale Hall.
Goniatites undet.
Orthoceras sp.

The *Liorhynchus* of this fauna is a recurrence of the species * * * which is referred to the Devonian. It is characteristic of some of the species of this genus in the New York Devonian to be associated with black shales at various horizons in a section, while they are entirely absent from the intervening sediments.

The following species have been recognized from the several beds from j to n of the Calico Bluff section, by Doctor Girty, which were not included in the fauna of division j:

*Fossils from beds 9j to 9n, Calico Bluff.*

Zaphrentis sp.
Archæocidaris sp.
Fenestella sp.
Pinnatopora sp.
Polypora sp.
Rhombopora sp.
Cystodictya sp.
Stenopora sp.
Stenopora? sp.
Schizophoria sp.
Chonetes sp.
Chonetes aff. choctawensis Girty.
Productus aff. biseriatus Hall.
Productus aff. semireticulatus Martin.
Productus aff. hirsuitiformis Walcott.
Productus aff. parvus Meek and Worthen.
Productus aff. cherokeensis Drake.
Productus aff. cora D'Orbigny.
Productus, 2 sp.
Spirifer aff. bisulcatus Sowerby.
Spirifer aff. keokuk Hall.
Reticularia aff. setigera Hall.
Ambocœlia? sp.
Camarotœchia? sp.
Camarophoria sp.
Aviculipecten sp.
Macrodon n. sp.
Pleorophorus aff. subcostatus Meek and Worthen.
Pleorophorus sp.
Chiton sp.
Trachydomia? sp.
Pleurotomaria, 3 sp.

Doctor Girty makes the following statements regarding the horizon represented by the Carboniferous of Calico Bluff and other sections representing a similar horizon:

"I have been unable to trace the affinity of this fauna with a member of the Russian section, but presumably it is somewhere near the age of the *Productus giganteus* zone, in which case a gap of considerable extent separates this from the Upper Carboniferous fauna described below. The fauna of the Calico Bluff section appears to be related to that of the upper part of the Mississippian section as developed to the south and west of the typical area. I refer to the "Spring Creek" limestone and Marshall [should read Moorefield—G. H. G.] shale of Arkansas and the Caney shale of Indian Territory (and probably the Eureka [should read White Pine—G. H. G.] shale of Nevada), which from available data appear to represent the upper portion of the typical Mississippian section. This relationship of the Alaskan fauna I believe to be a real and not a fancied one, and while belonging distinctly with the faunas just mentioned, rather than with the typical Osage and Kinderhook, it would at present be unsafe to say that these localities represent the upper Mississippian alone."

Since the preceding observations of Doctor Girty indicate that the nearest faunal equivalents of the Calico Bluff fauna in the United States are repre-

sentatives of the upper portion of the Mississippian section, it should be pointed out that all of the available stratigraphic evidence indicates that it is the earliest Carboniferous fauna present in the Yukon section. The stratigraphic evidence appears to place it somewhat lower than the faunal evidence and to indicate that it represents both the upper and lower portions of the Mississippian section.

A section about 2 miles above the mouth of Seventymile River, on the opposite bank of the Yukon, exposes the Carboniferous series seen at Calico Bluff and some higher beds which show the Lower Carboniferous shales terminated by a coarse conglomerate which, with some interbedded shales, is about 200 feet thick. This conglomerate may represent the base of the Nation River series. The limestones and shales here show about the same association of species as in the Calico Bluff section.

The Nation River series includes about 3,700 feet of gray clay shales with some clay slates interpolated with heavy beds of conglomerate and some sandstone. It is typically exposed along Nation River, where it includes some small seams of bituminous coal. The limits of this formation are well defined. The base is believed to be marked by an unconformity which separates it from the shales and limestone of the Calico Bluff formation. At the top it is limited by the heavy limestone which previously formed the topmost member of the Carboniferous and will be described below.

Two conglomerate beds are particularly striking in this formation. One occurs at the base and is very massive, and the second, which is not quite as heavy, occurs about 1,000 feet above the base. The succeeding thousand feet is largely made up of shales, with some fine conglomerates and sandstone, while the upper 500 feet of the formation is chiefly gray shales. Some bituminous coal beds occur in the lower part of the section.

The Nation River formation has yielded no fossils except a few plant fragments, upon which Mr. David White has reported as follows:

"This collection consists of three fragments of rock with one counterpart containing small fragments of carbonized wood, decorticated stems, etc. The plant remains bear evidence of transportation, maceration, and trituration, the result being that none of them are definitely determinable, even generically. One fragment, about 1 cm. in length and 6 mm. in width, evidently represents a branch of some lepidophyte or gymnosperm. Although it is partially decorticated as the result of maceration, so that the epidermal characters are lost, the subepidermal features of this branch so closely resemble those of certain Carboniferous strobiliar axes and earlier types of phyllotaxy that I am inclined to regard it as probably belonging to one of these Paleozoic forms. In fact, though constrained to emphasize the poor condition and limited characters presented by the specimen and the consequent hazard of any attempt at identification, I am nevertheless disposed to regard this fragment as belonging to one of the Carboniferous lepidophytes. Among the latter it bears the closest resemblance to some of the early forms in the basal Carboniferous, or the late Devonian."

The stratigraphy and the invertebrate faunas of the associated formations strongly support the opinion that the Nation River coal is of Carboniferous age. The coal seam occurs near the axis of an anticline, the beds dipping away in opposite directions at angles of 30° to 60° on the north and south sides of the Nation River Valley. South of the river they pass under a massive white limestone, carrying an Upper Carboniferous fauna, and in which a series of open folds is developed along the north side of the Yukon. Considerable interest attaches to the beds at the Nation River coal mine because it is the only locality in the Yukon Basin where beds of Carboniferous age have afforded coal.

### TERTIARY.

The rocks regarded as Tertiary include sandstone, clay, lignite, shale, and conglomerate. The state of consolidation varies greatly at different localities, but the plant remains, which are in many places very abundant in these deposits, have been referred, so far as they were determinable, to the Kenai formation, of Eocene age. The most extensive body of these deposits is in the valley of the Seventymile, where a well-defined belt of them extends northwestward toward the Birch Creek region. To the southeast a portion of this belt forms the lower hills south from Eagle and extends still farther southeastward to Yukon River.

Northward from the areas of Paleozoic rocks that form the hills around the headwaters of American and Wolf creeks there are found, in the valleys of these streams and in the ridge between them, brownish sandstone, clay, lignite, ferruginous nodules with plant remains, and loosely consolidated conglomerate. These rocks were observed about 4 miles above the mouth of Wolf Creek in the valley of a small tributary from the west. Farther north, on Wolf Creek, about 1½ miles above the mouth, a bluff of conglomerate 125 feet high forms the west side of the valley. The conglomerate is composed essentially of black and red chert pebbles and vein quartz, with a few pieces of granite and diorite. The conglomerate in places grades into a brownish sandstone. On the west side of Mission Creek, about 2 miles above Excelsior Creek, there is a bluff 150 feet high of similar conglomerate. Brownish sandstone is associated with it and there are ferruginous nodules with plant remains. The rocks at this locality dip northwest about 50°.

Still farther to the north, in the lower part of the valley of Bryant Creek, there is an almost continuous section of these rocks nearly a mile wide. About 4 miles above the mouth of Bryant Creek are thin-bedded gray and black shales, grits, and conglomerate. In the shales are numerous heavy, yellow, ferruginous nodules containing plant remains, which are also abundant in the thin-bedded grits. The strike is about N. 70° E. and the dip 15° N. About 700 feet downstream are precipitous slopes of conglomerate with an east-west strike and a nearly vertical dip. These beds, with possibly some shales, occur over a width of about 3,000 feet, and are succeeded by 60 feet of dark and gray paper shales and grit with the same strike and dip and in close contact with conglomerate on both sides. The shales contain many plant remains, and the sandy beds of the conglomerate next to them exhibit irregular impressions a foot or more long and up to 4 inches wide. These show generally well-defined linear markings, and there seems little doubt that they represent some form of vegetable life. The shales are succeeded by 350 feet of con-

glomerate, and this by more fine sediments, 50 feet thick, composed of gray, micaceous, somewhat loosely consolidated, leaf-bearing shales and grits and fine-grained compact shales, in which leaves have been very perfectly preserved. These shale beds, like the others, are in contact on both sides with conglomerate. That on the downstream side outcrops, with possibly some interbedded shales, for nearly a quarter of a mile, to a point where a wooded slope descends gradually toward the Seventymile. Precipitous slopes were seen nearly 2 miles to the north, across Seventymile. These were not visited, but the continuation of these slopes a few miles to the west is composed also of conglomerate. The maximum size of pebbles observed in the conglomerate was 5 inches; the average was from 1 to 3 inches. The material is mostly black, gray, and green chert, quartzite, and vein quartz. The rock grades into a sandstone with a cement resembling mortar. All the way to Barney Creek the ridge on the north side of the river is made up of this formation, either nearly vertical or dipping steeply toward the valley. The cement contains much ferruginous matter, and the rock breaks down easily into its constituent materials, which form loose heaps of gravel and sand. The spurs on the south of Seventymile are also of this material as far as the falls. The steepness of the dip is well shown in the nearly vertical position of the leaves so abundant in the shale.

In the Chicken Creek area patches of sandstone with associated shale, clay, and lignitic coal occur. There are ferruginous nodules containing fragments of dicotyledonous leaves, and there are also badly preserved plant remains in the shales and sandstones. So far as these are determinable they indicate the relationship of these beds with the Kenai, to which they are provisionally referred.

On Napoleon Creek and on the Fortymile at the mouth of Walker Fork there are breccias, conglomerates, sandstones, and coal-bearing beds similar to those of Chicken Creek. The unconformable contact of this formation with underlying Paleozoic rocks is well exhibited on the east side of the Fortymile about 900 feet above the mouth of Walker Fork. The older formation is composed of gray, green, and black phyllites with some cherty beds. The overlying formation commences with a breccia about 15 feet thick, composed of fragments up to 4 inches or more in diameter of the underlying greenish phyllites, cemented with a ferruginous sandy matrix. This is overlain by about 4 feet of fine-grained bluish argillaceous beds, the material of which breaks with a conchoidal fracture. Overlying this fine material is about 20 feet more of breccia, followed by alternating beds of shale and massive conglomerate. The shales carry abundant poorly preserved plant remains, but unfortunately none were found sufficiently well preserved to admit of determination. These rocks are tilted and

exhibit dips up to 40°. In the absence of evidence to the contrary they are correlated with the other occurrences and regarded as Kenai.

A deposit on the west side of Mission Creek about a quarter of a mile above the mouth of Excelsior Creek is unlike those above described. The bluff, about 90 feet high, is composed mostly of very slightly consolidated angular material consisting largely of granite. There are fragments of coarsely porphyritic light-colored granite 2 feet or more in diameter, also much fine material of the same kind and a few waterworn pebbles, but apparently no chert pebbles, which are so characteristic of the other deposits. There are some thin beds of gray sandstone and clay with carbonaceous matter. This deposit is about 1½ miles below the locality on Mission Creek where conglomerate associated with rocks containing characteristic Kenai fossils occurs. It is regarded provisionally as Kenai.

A conglomerate of doubtful age occurs on Moose Creek just at the eastern edge of the quadrangle. It is strikingly coarse, containing bowlders up to 6 feet or more in length. The rocks composing it are principally schist, but there is also a small proportion of limestone. One bowlder of limestone was observed, the exposed portion of which measured 6 by 15 inches. Vein quartz pebbles are fairly abundant. The cement is composed for the most part of coarse sand, but in some places fine sand occurs in limited quantities between the bowlders. In the vicinity of the limestone that forms the hill east of the Fortymile and north of Moose Creek the deposit is finer and the constituents are more angular.

No evidence of the stratigraphic position of this conglomerate was observed. Its state of consolidation is similar to that of the other deposits, and it probably does not differ greatly in age from them. Provisionally it is included with them.

Lithologically there is much difference between the elements included above in the Kenai, and there is also much difference in the degree of consolidation, even within narrow limits in the same outcrop. All the paleontologic evidence at present available precludes a separation into distinct formations. It may be stated that in general the lower portion of these deposits seems to be characterized by the presence of finer material and that the uppermost portions are conglomeratic. The clays, sandstones, and lignites are, wherever observed, close to the underlying older rocks. The thickness of these deposits in the Fortymile quadrangle is probably greatest in the valley of the Seventymile, where it reaches perhaps 3,000 feet or more. The beds have been closely folded in the Seventymile Valley and reduplication is possible. The formation has probably originated from lacustrine conditions giving place later to fluviatile conditions.

Following is a report by F. H. Knowlton on the material collected by the writer during 1903 from the rocks assigned to the Kenai:

3AP 224. Irene Gulch, Chicken Creek: Fragments of stems, indeterminable.
3AP 224½. McDowell claim, Chicken Creek: *Equisetum* sp.
3AP 237. Mouth of creek, 1 mile west of Chicken: Black carbonaceous shale with minute plant fragments, indeterminable.
3AP 251. Chicken Creek: Fragments of dicotyledons, possibly *Corylus MacQuarrii*, but uncertain.
3AP 330. Wolf Creek: *Taxodium dubium?* Heer; *Populus* sp.
3AP 336. Branch of Wolf Creek: *Populus*, cf. *P. Richardsoni* Heer; dicotyledonous fragments.
3AP 337. Branch of Wolf Creek: Only fragments of stems and bark.
3AP 348. Bryant Creek: *Sequoia Langsdorfii* (Brgt.) Heer; *Taxodium dubium?* Heer; *Populus arctica?* Heer; *Populus Richardsoni?* Heer; *Corylus MacQuarrii* (Forbes) Heer; *Quercus platania* Heer; *Betula prisca?* Ett.
3AP 349. Bryant Creek: *Sequoia Langsdorfii* (Brgt.) Heer; *Corylus MacQuarrii* (Forbes) Heer; *Populus arctica* Heer; *Populus Richardsoni?* Heer; *Juglans nigella?* Heer.
3AP 350. Bryant Creek: *Sequoia Langsdorfii* (Brgt.) Heer; *Equisetum* sp.; *Populus latior* Heer; *Populus Hookeri* Heer; *Fagus Deucalionis* Unger; *Quercus furcinervis* (Ross M.) Unger; *Juglans* sp.?
3AP 355. Mogul Creek: *Sequoia brevifolia?* Heer; *Corylus MacQuarrii* (Forbes) Heer; *Populus* sp.?
3AP 432. Mission Creek, 2 miles above junction with Excelsior: *Corylus MacQuarrii* (Forbes) Heer; *Betula prisca* Ett.; *Fagus Deucalionis* Unger.

Listing the species from all the localities, we have the following:

Sequoia Langsdorfii.
Sequoia brevifolia.
Taxodium dubium.
Populus arctica.
Populus latior.
Populus Richardsoni.
Populus Hookeri.
Corylus MacQuarrii.
Quercus furcinervis.
Quercus platania.
Fagus Deucalionis.
Betula prisca.
Juglans nigella.

Taking well into account the fact that not all of the above species are determined with absolute certainty, it is nevertheless perfectly clear that all are of the same age, and I do not hesitate to say that this is Arctic Miocene.[a] Not a trace of the Cretaceous element appears.

## ALLUVIAL DEPOSITS.

The alluvial deposits include the bench gravels that are common on so many of the benches throughout the area and the deposits of the present streams. The deposits of the higher benches are sharply differentiated from those of the present streams; those of some of the lower benches merge into the present stream deposits. There is no definite evidence in the area as to the age of the higher bench

[a] This flora was first described as the Arctic Miocene. Subsequent investigations have shown that it is of Eocene age, but the old name is still retained.—L. M. P.

gravels, but they are correlated with the high gravels in other parts of the Yukon-Tanana region and referred to the Pleistocene.

The high bench of the Fortymile is very marked and is sufficiently distinctive to lend itself to topographic expression, even on the scale of the map of the Fortymile quadrangle. It is especially well developed between Steele Creek and the mouth of Canyon Creek on the north side of the river, and at a level of about 300 feet above the stream, on this bench, gravels are found that are reported to be auriferous. Nugget Gulch cuts this bench. Most of the pay gravel found in Nugget Gulch is reported to have been in that portion of the valley that cuts the high bench, and is due perhaps to reconcentration from the latter. Gravels about 200 feet above the Fortymile were observed near Bonanza Bar. The high gravels of Lost Chicken Creek, described elsewhere in this report, proved to be richly auriferous. There are extensive deposits of gravels in the Mosquito Fork Valley at a height of about 300 feet above the stream. On Mission Creek 20 feet of stream gravels were observed forming the capping of a bluff 70 feet high. There is another bench in the Mission Creek valley at a height of 15 to 20 feet above the stream, and a bench of similar height has extensive development in the valley of the Seventymile, where it is distinctly differentiated from the gravels of the present stream. No detailed studies of the material or distribution of these various bench deposits have been made, but so far as observed they are composed of material of fluviatile origin and are all definitely related to the valleys in which they occur.

The stream gravels have been derived from the bed rock within the valleys of the streams along which they occur, or from the older gravels present on the benches, or from conglomerates composed of fluviatile material, and betray no evidence of other than a fluviatile origin. They are described in relation to the gold occurrences.

Silts have been abundantly deposited in the valley of the Yukon at different levels down to that of the present flood plains. These were probably laid down under lacustrine conditions and under the interaction of lacustrine and fluviatile conditions, and date probably from the Pleistocene to the present time.

It has been impossible to differentiate these deposits upon the map. The areas covered by the deposits of the present streams are roughly delimited, and it may be accepted as a general fact that in nearly every valley there are deposits, more or less extensive, of bench gravels.

## STRUCTURE.

An examination of the map (Pl. IV, in pocket) will show that the major structures of the pre-Carboniferous rocks trend in a northwesterly direction. Thus they are parallel with the dominant tectonic features of this part of Alaska. As has been stated, the pre-

Ordovician rocks are very intricately folded, with great complexity of dips.

The Devonian beds are somewhat less deformed, but their structure, too, owing to scarcity of outcrops in some areas and to lack of detailed mapping, can not be expressed in general terms. For this reason it has not seemed worth while to record graphically by means of a cross section an interpretation of the structure, which could be regarded as little more than a bold guess. From the evidence in hand it is perhaps fair to assume that the Devonian areas, as indicated on the map, mark synclinoria caught up in a highly deformed complex of metamorphic sediments and igneous rocks.

The strike of the Carboniferous rocks is at variance with that of the older terranes, being northeasterly. They occur as a series of broad, open folds, the best example of which in this quadrangle is the anticline shown in cross section along the river between Eagle and the mouth of Seventymile. Here the two Carboniferous formations are exposed in the limbs of the anticline, while the Devonian occurs along the axis of the fold. One nose of the anticline is exposed at Calico Bluff.

The Tertiary beds are but slightly deformed, though in places they exhibit vertical dips. The axis of deformation of the Tertiary terranes parallels that of the pre-Carboniferous terranes. This is probably connected with the form of their deposition in basins or valleys which were carved out of the older terranes.

## IGNEOUS ROCKS.

There is a large variety of intrusive igneous rocks in the Yukon-Tanana region, and these were fully described by Spurr.[a] Those that have been derived from the granito-dioritic magma are especially common. While extrusives of similar composition occur at short distances outside of the quadrangle, the extrusives within the quadrangle, so far as observed, are chiefly diabasic and basaltic and are confined to occurrences contemporaneous with the Paleozoic rocks, in which they are so abundantly interbedded as to have impressed their characteristics upon a large part of the entire group.

The intrusive rocks range in composition from persilicic rocks, composed almost entirely of quartz and feldspar, to rocks composed predominantly of hornblende or of augite. They occur as large intrusive masses, like Glacier Mountain and the large area that extends into the Fortymile quadrangle from the southwest and also as innumerable dikes and sills. Besides the variation in composition and in mode of occurrence there has been a variation in time of intrusion. Most of the intrusive masses are comparatively fresh, but some of them were

[a] Spurr, J. E., Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rep. U. S. Geol. Survey, pt. 3, 1898, pp. 224–249.

intruded early enough to undergo metamorphism along with the schists, and these present themselves now as gneisses of varying composition.

The persilicic rocks, termed alaskite by Spurr, occur as dikes or sills from many feet to a fraction of an inch in thickness. They are light in color, in some cases white, so that at a distance they simulate outcrops of limestone. They are composed essentially of quartz and feldspar with a little mica. The feldspar is orthoclase, albite, oligoclase, and in some cases mainly andesine with some microcline. The constituents are xenomorphic and range up to 3 millimeters or more in diameter. Cataclastic phenomena are general and exhibit themselves macroscopically as crumpling or as separation of the dike or sill into lenticular fragments, and under the microscope as bent twinning lamellæ in the feldspars, as comminuted marginal areas of the grains, or as fracturing of the grains, feldspar grains being frequently crushed into several fragments which have been cemented by a deposit of quartz. Sericite is sometimes present to a limited amount between the grains of quartz and feldspar, and many of the feldspar grains are sprinkled with it. Where good exposures of the schists intruded by these acidic dikes are shown it is possible to observe the transition of these rocks to quartz veins through disappearance of the feldspar.

Biotite granite has a darker color, due to the presence of the biotite. There are areas of considerable extent outside the quadrangle, but within the quadrangle it occurs commonly as rather small dikes and sills in the schists. The rock is generally even grained, but in some localities has a porphyritic development with individuals of alkali feldspar an inch or more in diameter. Most of the augen gneisses in the Yukon-Tanana region are referable to old intrusions of this kind of rock that have been metamorphosed along with the schists into which they were intruded.

A hornblende granite composed of quartz, alkali feldspar, abundant soda-lime feldspar, hornblende, some biotite, and titanite is rather commonly distributed. The alkali feldspars frequently show porphyritic development. Cataclastic phenomena are common.

The large intrusive mass forming Glacier Mountain and adjacent areas, so far as can be judged from material collected at several peripheral points, and from alluvial material derived from the mountain, is composed predominantly of a rock referable for the most part to quartz diorite. In most of the material examined the proportion of soda-lime feldspar is very abundant, the automorphic individuals of this mineral are in immediate contact with quartz grains, and the proportion of interstitial alkali feldspar is small. There are porphyritic dikes of this rock cutting the more evenly granular variety, and the prominent point at the head of Bear Creek is composed of this rock. In the schists surrounding the main body are numerous dikes, and

some of these are more basic, containing a large proportion of hornblende and approaching diorite in composition.

The large area of intrusives in the southwestern part of the quadrangle, forming the bed rock along Dennison Fork and a large part of the bed rock in the Chicken Creek area, is composed of the same kind of rock. This rock is porphyritic in places and is also cut by finer-grained porphyritic dikes of the same general composition. This rock also, like the granites, has its gneissoid representatives, older bodies of approximately the same composition having intruded the schists. Hornblende-plagioclase gneisses along the Fortymile are referable to this origin. Some of these are thoroughly recrystallized; others, presumably those intruded nearer the surface, exhibit different stages of reduction to gneisses by cataclastic action combined with some recrystallization. The occurrence of gold on Mosquito Fork is in a brecciated mineralized zone of this rock. Along Dennison Fork it is cut occasionally by felsitic dikes and dikes of basalt.

Dioritic marginal facies of the rocks above described and dioritic dikes occur to some extent. Dikes are found composed almost entirely of hornblende and biotite with a little plagioclase and quartz. But in general dioritic rocks are not so common as those of a more intermediate type.

A massive dike of pyroxenite occurs about 1½ miles below the mouth of Canyon Creek. The rock is composed predominantly of xenomorphic augite with some biotite and hornblende, titanite, and iron mineral. Some of it is coarse, with glistening biotite plates an inch or more in diameter that attract attention to the blackish outcrop of this rock. The rock in contact with it is quartzite schist. The dike is cut by some persilicic dikes. Another dike of similar composition was observed on the Fortymile just below the mouth of Discovery Fork.

The schists and the intrusives above described are cut by a few fresh basaltic dikes. Dikes of this rock have been observed on Wade Creek, Walker Fork, and Dennison Fork. The dike on Walker Fork is composed of pinkish augite, basic soda-lime feldspar, and olivine. A noteworthy constituent is a quartz inclusion, corroded, fractured, surrounded by a zone of augite, and entirely surrounding augite, which has crystallized from the magma in a corroded cavity of the quartz.

There is a considerable area of this olivine basalt in the Chicken Creek area. Part of it at least is probably intrusive, like the dike of the same material in the quartz diorite of Dennison Fork. Part of it, however, may be in the form of a flow. The rock on Myers Fork is composed of basic soda-lime feldspar, occasional large augites, abundant blades of iron mineral, and brownish-black undifferentiated material; amygdaloidal cavities are numerous.

The diabasic and basaltic material contemporaneous with the Paleozoic rocks comprises both intrusives and extrusives. The extrusives have been accompanied by more or less tuffaceous matter. These rocks have all been more or less altered and are composed at the present time largely of chloritic, uralitic, and serpentinous material.

The intrusion at different periods of so large a quantity of igneous material and the thorough manner in which much of this has become mingled with the rocks of sedimentary origin indicate conditions favorable for mutual influence. That the unaltered intrusions of quartz diorite have brought about contact metamorphism in the intruded rocks is shown by the andalusite contact zone about the intrusive mass that is situated just off the southwestern border of the quadrangle, at the head of Buckskin Creek.

The age of the latest intrusions of granular rocks has not been determined, but the Paleozoic rocks are penetrated by them. The intrusions like that of Glacier Mountain and that of Dennison Fork and Chicken Creek are similar in composition and occurrence to rocks of the Rampart region that have intruded Upper Cretaceous sediments. The end of the Mesozoic was a time of extensive intrusion, and it is probable that some of the rocks of intermediate composition in the Fortymile quadrangle were intruded at that time. The age of the fresh basaltic rocks is also indefinite. There are areas of fresh volcanics outside the limits of the quadrangle; some of these are probably at least post-Kenai in age, and the degree of freshness of some of them would indicate a comparatively recent origin.

## ORIGIN OF THE GOLD.

There are a few localities in the Fortymile region where gold has been found in the bed rock, and these are described in detail in the following section of this report. One of these localities is on Mosquito Fork, about 2½ miles west of Chicken Creek. The gold at this locality occurs in a brecciated zone of quartz diorite that has undergone silicification and mineralization. Another locality is near the head of Chicken Creek, where gold is found in thin calcite seams in black phyllites in close proximity to about the same kind of rock as that on Mosquito Fork. The placers of Chicken Creek have probably derived a part at least of their gold from this source. A locality on the ridge south of Kalamazoo Creek contains gold in brecciated vein quartz in quartzite schists within the zone of abundant intrusions. The alluvial deposits of the streams have been derived from the bed rock of the valleys in which they occur, and there has been no interference by glaciation in this area with the orderly deposition of material by stream action. The bed rock in some of these valleys, especially those of the Fortymile region, is composed of schists of

sedimentary origin containing many small quartz veins. Gold has been found in such small veins on Davis Creek, and on many creeks nuggets occur with quartz attached. It is probable that a large part of the gold of the Fortymile area has been derived from this source. The gold of the Eagle area is derived apparently from mineralized areas or quartz veins in bed rock that is composed of carbonaceous phyllites, limestone, and greenstone of Paleozoic age. The origin of the gold in the Seventymile area is not clear, as there are too many possible modes of origin. It has probably been concentrated to the present stream gravels from bench gravels that were derived partly from the conglomerates in which the streams are cut and partly from other sources. The placers of Woodchopper Creek are in conglomerates of the same age as those of the Seventymile and occur in the extension of the same belt to the west. They are believed by Brooks[a] to have originated from the conglomerate, where the gold had been deposited as alluvial gold contemporaneously with the constituents of the conglomerate.

Some of the minerals found associated with gold in the Fortymile quadrangle are barite, galena, native lead, argentite (silver sulphide), cinnabar (mercury sulphide), iron pyrites, hematite, limonite, magnetite, rutile, and garnet.

## GEOLOGIC HISTORY.[b]

In spite of the absence of detailed information, it will be well to outline some of the salient features of the geologic history of this area.

That the oldest sediments, including arenaceous, argillaceous, and calcareous material, were deposited in a pre-Ordovician sea seems probable, but no more definite assignment of the period when this deposition took place can be made. What is known of the geology of the adjacent regions makes it probable that this sea was of wide extent. Accumulation of sediments went on until a great but unknown thickness, probably to be measured in thousands of feet, was laid down, intrusions took place, and then, some time before the middle Devonian, an extensive crustal movement, which brought about a metamorphism of the entire mass, took place. Limestones recrystallized, sandstones changed to quartzites, and slates to phyllites and schists.

This disturbance was probably followed by erosion, of which, however, no records have been discovered in this quadrangle. In any event, possibly during Silurian and certainly during Devonian time, sedimentation was again in progress in this field. Sedimenta-

[a] Brooks, Alfred H., Bull. U. S. Geol. Survey No. 314, 1907, p. 199.

[b] This section was prepared in cooperation with Alfred H. Brooks.

tion during the latter period was accompanied by volcanic outbursts, which contributed the greenstones and tuffs so intimately associated with some of the Devonian terranes. The sediments deposited during Devonian time were not unlike those laid down during the preceding epochs. In late Devonian time the deposition of at least a thousand feet of argillaceous material in the northeastern part of the quadrangle took place. This material, now found as slate, which could not be differentiated from the older Devonian rocks in other parts of the quadrangle, belongs distinctly to the upper part of the system and may very likely be separated from the older terranes by an interval of erosion. Tectonically this uppermost Devonian member is to be grouped with the Carboniferous horizons, from which it is not separated by an erosional interval.

Carboniferous time began with an increase in calcareous matter and the appearance of a new fauna. Deposition of calcareous and argillaceous material continued until at least a thousand feet of strata had accumulated, called the Calico Bluff formation. It is probable that there was then a crustal movement which left a land mass exposed and inaugurated a period of erosion. In any event, the basal beds of the next series of sediments (Nation River formation) are made of coarse fragmental material, indicating a near-by land mass and probably an unconformity. The evidence therefore points to the conclusion that the oldest Carboniferous (Calico Bluff formation) was eroded before the deposition of the second member of the Carboniferous (Nation River). Sedimentation continued until at least 4,000 feet of arenaceous and argillaceous material was deposited. In adjacent areas, though not within the Fortymile quadrangle, there is evidence of another epoch of erosion following the deposition of the Nation River. This erosional interval was succeeded by deep-sea conditions, which continued throughout the latter part of Carboniferous and into Triassic time. There is no depositional record of the Mesozoic within the quadrangle, but the Lower Cretaceous sea probably covered it. The close of Lower Cretaceous time marked a period of mountain building and intrusion throughout most of Alaska, and some of the granitic rocks of the Fortymile quadrangle were probably intruded at this time.

Deposition during Tertiary time is represented by the fresh-water plant-bearing beds, here assigned to the lower Eocene. These were in part fluviatile, in part lacustrine, and probably never mantled any considerable part of the region. Their distribution indicates deposition in an extensive drainage system, possibly partly broken by lakes.

The later history of the province is a complex one which has not yet been fully deciphered. There was at least one extensive period of erosion, when much of the area was reduced to a peneplain. It

does not now seem likely that all the flat-topped topographic features can be assigned to this one period of erosion, as has been previously supposed, but the correlation and genesis of these varied topographic features must await further studies. The topographic records, such as flat-topped ridges, spurs, and well-marked stream benches, point to intermittent uplift since the first widespread period of erosion of which there is evidence in the even crest lines of the higher interstream areas. Glaciation has played no part in molding the topographic forms within the quadrangle, which lies entirely outside the glaciated area.

## GOLD PLACERS.

### DISTRIBUTION.

The material concerning the placers is presented in the order of their areal distribution, and is followed by an account of mining methods and statistics of production.

The localities of productive placers are indicated on the geologic map (Pl. V, in pocket). It is not practicable to show the distribution of the auriferous gravels, because nearly all the alluvium carries at least a trace of gold, and prospecting has not gone far enough to disclose how much of it may carry workable placers. The area of the Fortymile and its tributaries contains the most localities and the widest distribution of gold known to be in quantities sufficient to be mined. The map shows that this distribution of gold corresponds with that of the pre-Ordovician metamorphic rocks and associated intrusives. These are the rocks that have proved most productive of placer gold in the Birch Creek and Fairbanks regions, and merit, wherever they occur, attention on the part of the prospector. They are not everywhere auriferous, but it is in association with them especially that placer areas are likely to be found. The occurrence on creeks in the vicinity of Eagle in Paleozoic rocks is more local, being limited thus far to small areas on American Creek and its tributary, Discovery Fork. The Seventymile area includes occurrences at several rather widely separated localities in a region where the bed rock is predominantly formed of Tertiary conglomerates. This suggests that the gold of Seventymile is a secondary concentration from Tertiary placers. It does not follow, however, that the gold in the Tertiary beds is sufficient to pay for the cost of extraction. As these beds are indurated, they could not be exploited by placer-mining methods.

### FORTYMILE AREA.

The discovery of gold on the Fortymile in 1886 was followed within the next ten years by the discovery of practically all the localities that have since been productive. These include Walker Fork with

its headwaters, Poker and Davis creeks, Wade Creek, Chicken Creek, and small creeks in the vicinity, Napoleon Creek, Franklin Creek, Canyon Creek and tributaries, the Fortymile itself, and a few small areas in the immediate vicinity of the Fortymile. Chicken, Lost Chicken, and Wade creeks yield at the present time the largest annual output of gold. Most of the localities were visited by the writer in 1903, a few of them were reexamined in 1905, and others in 1907. In the following descriptions of the creeks free use has been made of the writer's published statements.[a]

*Walker Fork, Poker Creek, and Davis Creek.*—The headwater drainage of Walker Fork includes a number of small streams having their sources in the divide within Canadian territory. Of these, Poker and Davis creeks, which carry gold placers, are deeply cut with narrow V-shaped valleys. The grade of the upper part of the Walker Fork valley is approximately 100 feet to the mile. Here the valley floor is a few hundred feet in width, gradually broadening downstream.

A bench about 400 feet high limits the upper part of the valley on the south, and on the north there is a gradual rise to a benched surface at a corresponding level. In the vicinity of Twelvemile Creek there is another bench, about 100 feet high, very prominently developed. The valley narrows and becomes a canyon below the great bend to the northwest about halfway from Twelvemile to the mouth. There is but little timber in the upper part of the valley, and the adjacent ridges are bare. The valley floor and slopes between Cherry Creek and Twelvemile are fairly well timbered, having produced some spruce of sufficient size for mining purposes. There is abundant timber for fuel purposes.

The bed rock of the upper valley is predominantly quartzite schist and carbonaceous schist. In the lower part of the valley there is a large amount of hornblende gneiss with quartzite schist and quartz-mica schist. Between Twelvemile and the mouth of Wade Creek granitic and pegmatitic intrusives are most intimately incorporated with the schists. Dikes and small sills occur from a fraction of an inch to several feet in thickness. These have in many cases been plicated with the schists and even reduced to lenticular fragments. All of these that have been examined under the microscope exhibit the effects of cataclastic action. There are occasional basaltic fragments in the alluvials, and at one locality a fresh basaltic dike was observed. Quartz veins are common, many of them being parallel to the predominant structures. The structure is complex, the attitude being in places nearly vertical and in places horizontal.

[a] Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. U. S. Geol. Survey No. 251, 1905, pp. 39–59.

The first mining was done in the upper part of the valley and on Poker and Davis creeks, the area of economic interest on the Alaskan side extending from the boundary nearly to Cherry Creek, a distance of about 4 miles. In 1907, however, a dredge was installed on Walker Fork about a mile above the mouth of Twelvemile, at a locality several miles below the point where the ground had been found hitherto sufficiently productive to be worked by open cut.

The material on bed rock in the upper part of the valley ranges from 4 to 12 feet in thickness and includes muck, sand, gravel, and in some cases clay. In places there is no overburden of muck and rarely no gravels are found under the muck. The thickness of the gravels generally exceeds 4 feet and the maximum is about 10 feet. The greatest proportion of the gravel is made up of more or less angular fragments of quartzite schist under a foot in diameter. The proportion of bowlders is small. The gold is found not only on the bed rock, but in the gravels above bed rock through a distance of 2 or more feet. It is found also to a depth of 1½ feet or more in the bed rock. Gravel has been worked in places over a width of 50 feet, but on the outer limits it carries only low values. Ground has been worked that is reported to have carried values of $2 or somewhat more to the cubic yard. The general run of gold is made up of small, flat pieces, but nuggets have been found worth as high as $20. Toward the head of the creek there is some gold of a blackish color.

*Wade Creek.*—The valley of Wade Creek is narrow and V-shaped toward the head, the lower portion is more open and there is a floor a few hundred feet in width that merges finally into the valley of Walker Fork. The fall from the upper limit of placer mining to the mouth, a distance of about 8 miles, is approximately 600 feet. The quantity of water during dry seasons is insufficient to meet the demand. There is considerable timber on the northwest slopes of the valley and a light growth of spruce on the southeast. The valley floor near the mouth of the creek is fairly well timbered with spruce and aspen.

The bed rock in which the valley of Wade Creek has been incised is predominantly schist with some interbedded ferruginous limestone. The schists are in places intruded by granitic rocks, and a small basaltic dike was observed near the head of the creek. Quartz veins are common in the schist. The schist and quartz veins are in places pyritiferous. The gravels range from 1 foot to 3 or more feet in thickness and are overlain by a bed of muck that in places attains a thickness of about 20 feet. Gold is rarely found more than 1½ feet above the bed rock in the gravels. Most of it is on bed rock and in crevices and along joint planes of the bed rock to a depth in places of about 4 feet. The values are rather irregularly distributed. Values were first found on the river at the terminations of the spurs, and these

became favorite localities for prospecting, as the gravel was shallow and the values were frequently greater than in the valley floor.

Much of the gold is coarse and several nuggets have been found ranging in value from $216 to $437. The nuggets are all well worn, contain very little quartz, and are valued at $17 an ounce. The largest of them have been found in the part of the valley about midway between the source and the mouth. The general run of the gold is made up of small flat pieces, and a considerable proportion of that found near the head of the creek is rusty. A small amount of gold has been found in the lateral gulches, and this differs from that in the main creek in being but slightly worn and somewhat rusty. Very little fine gold is found. As so large a proportion of the gold is in the nuggety form and as nuggets are of irregular distribution, the values are extremely variable. The ground is reported to average about $100 to the box length of 12 by 12 feet. The proportion of black sand associated with the gold is small. Barite is abundant, and the rounded pebbles of this mineral are characteristic associates of the gold. Hematite pebbles are also abundant.

The alluvial deposits have been derived from the bed rock of the drainage area. Pieces of gold with quartz attached are common, and an assay of quartz from a vein near the head of the creek was found to carry 0.06 of an ounce of gold to the ton. It seems probable that the gold has been derived from quartz veins and stringers in the schist, and possibly also from mineralized areas in the schists, which are in places impregnated with considerable pyrite.

Mining developments are scattered along about 5 miles of the valley, commencing at a point about 4 miles above the mouth and extending toward the head. The gold is mined principally by open cut, but there is some ground sufficiently deep for drifting.

*Chicken Creek and vicinity.*—The drainage area of Chicken Creek includes about 20 square miles of a fan-shaped area which is only about 5 miles long from north to south. The tributaries converge from their sources in the divide between it and Franklin and give an amphitheatral form to the upper valley. The creek is a small one, and Stonehouse Creek and Myers Fork are the most important tributaries. The valley of Chicken Creek is open and the lower part has a grade of less than 80 feet to the mile. The valley has a flat on the west, which rises gradually to a broad, low spur, and southward merges into the broad, grassy meadows of Mosquito Fork. The ridge east of Chicken Creek shows a well-defined bench about 275 feet above the creek, where heads a small stream called Lost Chicken, which flows southeast to Mosquito Fork. Ingle Creek, a small tributary of Mosquito Fork about 2 miles west of Chicken Creek and just beyond the western edge of this quadrangle, is included in the productive area.

There is a considerable variety of bed rock in the Chicken Creek drainage area. There are schists in a part of the divide between Chicken and Franklin creeks. Phyllites, limestone, and greenstone occur, all regarded as Paleozoic; there is the northeastern extension of a large area of intrusives, mostly of the composition of quartz diorite, and there is an extensive area of basalt. The general distribution of these rocks is shown on the accompanying geologic map (Pl. V).

The alluvial deposits include the present stream gravels and bench gravels. The stream gravels are of a mixed character. There is a large proportion of greenish hornblendic rock, partly of tuffaceous origin, derived from the large body of this rock present in the hill east of Chicken Creek; there are evenly granular and porphyritic varieties of the quartz diorite; there is vein quartz, phyllite, schist, crystalline limestone and sandstone, coal and ferruginous nodules, which in many cases contain fragments of dicotyledonous leaves. The constituents are mostly under a foot in diameter and the proportion of bowlders is small. The depth to bed rock in the main valley ranges from about 6 to 45 feet. A layer of muck from a few feet to more than 20 feet thick covers the gravels, forming frequently more than half the alluvial deposit. The gravels range from about 6 to 20 feet in thickness and are mostly on the west side of the stream, to a distance of 1,000 feet from it. The lower portion of the gravels contains considerable clay, which often carries away the gold in the sluices.

The pay is found mostly on bed rock, but sometimes extends into it and often above it, where it is found through 5 feet or more of the gravels. Most of the work has been done on the west side of the creek, in places several hundred feet from it. Pay has been found nearly to the western limit of the gravel and over a width of about 80 feet. The values range from $50 to $175 to the box length, and a considerable portion of the ground has probably averaged about $1 to the square foot. The gold is rather fine, and much of it is granular. It is generally dark in color and some of it has quartz attached.

The bench between Chicken and Lost Chicken creeks is about 275 feet above the valley. Claims were located on this bench at the head of the Lost Chicken in 1901, and values were found at a depth of 33 feet. Further prospecting resulted in the discovery of ground carrying values of about $1 to the square foot of bed rock. A 45-foot hole was sunk through 23 feet of muck and 22 feet of gravel similar in character to the stream gravels, but somewhat finer and more rounded. The bed rock is similar to quartz diorite in character, like that at the head of Chicken and that on Mosquito Fork, where gold has been found in the bed rock. The discovery of gold on this bench led to great activity in bench prospecting throughout the region, but up to

1907 this was the only bench found to contain values workable under existing conditions. During 1907 values were found in bench gravels at a locality near the head of Chicken Creek, known as the Last Chance. The deposits at this locality are 18 to 20 feet deep and consist of 10 feet or more of muck overlying a thin bed of gravels resting on a hummocky surface of decomposed basaltic bed rock. These gravels are apparently on about the same level as those of the Lost Chicken bench. Insufficient work has been done to determine the extent of the values.

On the spur east of Stonehouse Creek, about 1 mile north of the junction of Stonehouse and Chicken creeks and about 500 feet vertically above the junction, gold has been found in place in dark phyllites lying on a surface of fine-grained quartz diorite porphyry dipping about 25 degrees. The only exposure at this point is in a hole 10 feet deep which has been sunk through the phyllite and about 2 feet of the underlying igneous rock and in a crosscut which has been carried to a distance of about 35 feet. In immediate contact with the igneous rock is about 10 inches of soft black material having the consistency of clay. The phyllites contain many thin calcite veins and some quartz veins; the thickest observed were hardly more than 2 inches in thickness. The quartz veins contain considerable pyrite, and the thinner calcite veins contain granular pieces and thin plates of gold. The alluvials on the slope below this locality adjacent to Stonehouse Creek, and those in Irene Gulch, which heads in similar phyllites only a short distance from this locality, have been mined for several years, and it is reasonably sure that a part, at least, of the placer gold found has been derived from these mineralized phyllites. The distribution of these rocks has not been determined in detail, but they have been found at several localities on both sides of Stonehouse Creek, where prospect holes have been sunk. The rock outcropping about the head of the Stonehouse is quartz diorite, and it is probably in the vicinity of the contact of this rock with the phyllite that the mineralized areas occur.

The problem of the immediate origin of the gold in the stream gravels of Chicken Creek and its tributaries is complicated by the facts that auriferous bench gravels occur in a part of the valley and that, besides the occurrence of gold in place in the phyllites, gold has also been found in place in the quartz dioritic rock like that forming much of the ridge at the head of the Chicken; but the only locality at which it has been found in this rock lies just beyond the drainage area of Chicken Creek, about 2½ miles up Mosquito Fork.

At this point Mosquito Fork is limited by a steep canyon wall of the quartz diorite, and about 200 feet above the stream is a mineralized zone about 6 feet thick striking approximately N. 25° W., which is very conspicuous by the brilliant red and yellow colors produced by

weathering. The rock has been brecciated and there has been considerable silicification. The surface rock within the zone is thoroughly decomposed and contains abundant fragments of quartz, which occurs in thin intersecting veins. This decomposed material yields fine flour gold by panning. Two assays of material collected in 1903 gave, in fine ounces per ton, for the one, gold 0.58, silver 0.10; for the other, gold 0.36, silver 0.10, or an average per ton of about $9.70 in gold. Since that time a small amount of drifting has been done and higher values have been reported, but no systematic work has been undertaken, and the extent of this occurrence has not been determined.

At a few localities on Chicken Creek, on Myers Fork, on Stonehouse Creek, and on Irene Gulch claims are worked by open cuts. The bed rock on Myers Fork is mostly basalt, and the gravels, from 8 to 20 feet in thickness, are composed largely of coarse fragments of this rock. Most of the gold is on bed rock and is coarser than the average of that on Chicken Creek. On Stonehouse Creek, where work has been done, there is a thickness of about 14 feet of gravels, of which about 4 feet carries values. Irene Gulch is a very small tributary of Stonehouse Creek and the gravels are shallow. While the creek heads in the phyllites above referred to, the bed rock near the mouth is slightly consolidated sandstone containing ferruginous nodules with plant remains. At all of these localities the water supply is limited.

On Chicken Creek most of the ground is suitable for drifting and considerable work has been done. Indeed, much of the ground that it would pay to work under present conditions has been already mined out, and, furthermore, the ratio of water to gravel in the Chicken area is so small that during a large part of most summers work is at a standstill. Several plans to bring water to the gravels of Chicken Creek from Mosquito Fork have been under consideration at different times, and during the summer of 1907 a dam was being constructed at Kechumstuk with that end in view.

Ingle Creek, a small tributary of Mosquito Fork west of Chicken Creek, just beyond the western limit of this quadrangle, has been mined to some extent. The gravel that was being worked here in 1907 was about 4 feet thick, and all was shoveled into boxes. The bed rock at this locality, like that from which a large proportion of the gravels of Chicken Creek has been derived, is mostly a green tuffaceous rock, and here it shows considerable mineralization with sulphides.

*Napoleon Creek.*—The valley of Napoleon Creek is deeply sunk below the steep slopes, and the valley floor is narrow, being about 300 feet wide at the mouth of the creek. The drainage area is small and the water supply is therefore limited. The valley, like that of Chicken Creek, has a variety of bed rock. The upper part of it is

cut in schists intruded by granitic rocks. In the lower part of the valley are Paleozoic rocks (Devonian?), principally greenstones and limestones, and fragmental rocks ranging from sandstones to conglomerates, regarded as Kenai (Eocene). There is also fresh basalt like that of Chicken Creek, and this occurs probably as dikes in the older rocks. Nearly every year since 1898 a small amount of work has been done on Napoleon Creek, and during 1907 work was in progress on Discovery claim and claim 1 above. The average depth to bed rock at the locality is about 11 feet. The ground ranges from 3 to 10 feet in thickness, and the width of workable ground is about 100 feet. The gold is practically all in the bed rock. It is coarse and of high grade, being reported to assay somewhat in excess of $19 to the ounce.

*Franklin Creek.*—That part of the valley of Franklin Creek adjacent to the Fortymile is narrowly V-shaped, with a stream flat of very limited extent, in places hardly 50 feet in width. The valley of the upper part of the creek is more open. The quantity of water carried by the stream is so small that in dry weather the water merely trickles through the gravel or stands in disconnected pools.

The bed rock includes micaceous, garnetiferous, and hornblendic schists and crystalline limestones that strike nearly east and west. They show much crumpling locally and are cut in places by granitic dikes. The gravels consist of more or less angular fragments of schist, crystalline limestone, granitic rocks, dark, heavy, rounded pieces of basalt reported to outcrop in the upper part of the valley, and brown and green pieces of rock composed of garnet, epidote, and quartz with considerable pyrite. The depth to bed rock ranges from 2 to 30 feet, with an average of 8 to 10 feet. Pay gravel is found mostly near bed rock and across the entire width of the creek bottom near the mouth, and some of the ground is reported to have carried as high as $5 to the cubic yard. Most of such ground, however, has been worked out. Of two of the largest nuggets found on the creek, one was worth $239 and the other $500. Much work was done on Franklin Creek in the early days, and at the present time it is affording a living to several miners, who are working partly by open cut and partly by drifting.

*Canyon Creek and its tributaries.*—The lower part of the valley of Canyon Creek is rather open, with a valley floor up to nearly a half mile in width. The valley is deeply sunk below the inclosing ridges, and the valleys of the tributaries are acutely V-shaped. The bed rock includes schists and limestones intruded by granitic rocks and greenstones partly fragmental in character. Considerable work has been done on Squaw Gulch. The stream is small, with a grade of about 150 feet to the mile. The gravels are predominantly quartzitic schist and crystalline limestone, with some granite and vein quartz

ranging in thickness from 3 to 10 feet. The proportion of bowlders is rather large. Gold has been found in about 1½ feet of gravel over a width of about 50 feet. It occurs as small flat pieces, with a considerable proportion of fine flaky gold; but coarse pieces have been found, up to nuggets worth as much as $43. The creek is reported to have produced a total of a few thousand dollars. Work has also been done on Camp Creek and Woods Creek, but the results attained are not available. The valley of the main creek has a large body of gravels, to which attention has been directed during the season of 1907 with the object of working the ground on a large scale.

Gold has been found in place in the ridge south of Kalamazoo Creek, a tributary of Canyon Creek, that heads in Steele Dome. At this locality there is a conspicuous outcrop of vein quartz and quartzitic schists about 1,000 feet in length and 50 to 100 feet or more in width. The rock is partly brecciated and cemented with ferruginous material. Specimens have been obtained showing specks of fine gold. It is not known, however, whether the gold is uniformly distributed through the rock or whether it is only of local occurrence. Placer gold found in creeks draining this area is believed by miners to have been derived from this locality.

*Bars and benches of the Fortymile.*—Many of the bars of the Fortymile proved very productive in the early days, and even in 1907 a few miners were found making wages with the rocker. The Fortymile follows a meandering course in a steep-walled canyon and, swinging from side to side, has left at more or less regular intervals considerable areas of the bed rock that have been reduced by the stream to a more or less level surface. The bed rock is predominantly closely folded, thin-bedded schists and crystalline limestone. The main structures are generally transverse to the course of the creek, and the attitude is for the most part nearly vertical. The process of downcutting is still in progress and bed rock is exposed along a great part of the stream in this quadrangle.

The bed rock on some of the bars slopes gradually from the stream, leaving an area several hundred feet in width at a distance of but a few feet above it. The thin mantle of gravels with which such areas were covered was easily removed and the cracks and crevices of the broken bed rock, composed of alternating soft and hard layers which afforded an excellent surface for retaining the gold, was most thoroughly cleaned by the miners. At the present time there is renewed interest in these shallow deposits that are under water at certain stages, and they are being investigated with reference to dredging. Where the Fortymile is sufficiently shallow it is possible in winter to sink holes through the ice to the frozen gravels and through them to the underlying bed rock without being troubled greatly by water. The gravel-covered flats that extend back from

the stream a distance ranging from a few hundred feet to half a mile or more are also being prospected.

The flat at the mouth of O'Brien Creek was being mined to a small extent in 1907 and was reported to carry some gold.

Work was being done in 1907 on gravels adjacent to the Fortymile at a locality on the right bank 1 mile above Canyon Creek. The depth to bed rock is from 18 to 22 feet. The gold is mostly on bed rock and to a depth of 1 to 2 feet within it. Water from adjacent creeks was stored in a small reservoir at a sufficient height above the gravels to afford a small head for the utilization of the water by means of a canvas hose and nozzle.

Discovery Bar, about 2 miles below Canyon Creek, was being worked by water from Discovery Creek, conveyed by a ditch about 4,500 feet long. One man was working at this locality with a portable set of short, narrow sluice boxes. The bar is reported to have yielded in the early days approximately $80,000 in gold.

The bar opposite the mouth of Smith (Davis) Creek was being worked in 1907 by water brought from Smith Creek. By taking water from a point about 7,000 feet up this creek a head of 120 feet is available, and two sluice heads are reported as the lowest amount. The water is piped across the Fortymile by means of a cable bridge having a span of 280 feet. The bar was first worked in 1887, and is reported to have produced in the early days approximately $500,000.

Another bar upon which much work was formerly done is located a mile above Moose Creek. In 1907 plans were being carried out to bring water to this locality, a distance of 3 miles, from tributaries of Moose Creek, by means of a combined ditch and flume. The amount of fluming necessary is approximately 7,000 feet. It was expected that 100 to 125 inches of water would be delivered with an available head of 100 feet. The deposit to be worked is 25 feet thick, the gravel being overlain by 6 to 9 feet of muck. The auriferous part of the deposit is 16 to 18 feet thick, half gravel and half broken bed rock. The muck was to be ground sluiced away and the rest of the deposit run through the boxes.

The gravels found on the benches of the Fortymile have in places been found auriferous and considerable attention has been directed to them. It is a slow process to prospect these deposits, and in many localities there is no available water. With the exception of the bench deposits of the Chicken Creek area, already described, no bench deposits have been worked extensively.

There has been considerable prospecting on the benches, and during the summer of 1907 bench deposits on the north side of the Fortymile about 2 miles above Steele Creek, in the drainage area of Flat Creek, were under investigation with reference to working by the hydraulic method. By the construction of a small reservoir and ditch

a small amount of water was made available, sufficient for testing the values to a certain extent. At this locality there is an overburden of 6 to 10 feet resting on about the same thickness of gravel. Work was being done at this locality, so far as the conditions would permit, and values were reported.

The stream that formerly occupied the old valley of the Fortymile, which is so perfectly preserved as the present high bench, was doing work similar to that which is now being done in the present valley. The older valley was wider than the present valley, the processes of concentration had extended over a longer interval of time, and if there was available at that time any considerable body of auriferous material the gold would have been concentrated in such localities as the form of the old valley, the position of the stream within it, and the character of the bed rock rendered most favorable. The amount in the bench gravels at the present time would represent the difference between that originally concentrated in the older valley and that reconcentrated from that older valley into the benches of intermediate height and into the valley of the present stream. Whether such amount proves to be of economic importance is a problem for the future.

*Other localities.*—There are a few localities where mining has been done that are of interest with reference to the distribution of the gold. Nugget Gulch, a short distance below Steele Creek, is an acutely V-shaped valley that is reported to have yielded in the past several thousand dollars. The stream floor is very narrow and has been worked for about a mile above the mouth over a width of about 30 feet. The valley is cut in an area of schists, limestones, and basic intrusives, and the gravels are similar to those of the other creeks.

The occurrence of gold on Miller Creek, a small tributary of Dome Creek, carries the extent of the possibly auriferous area to a considerable distance north of the Fortymile. Gold was discovered in 1893 and a small amount of work has been done. The bed rock is schist and the gravels are predominantly of the same material. No gold has been found in the other tributaries of Dome Creek or in Dome Creek itself, except immediately below the mouth of Miller Creek. The occurrence is apparently an isolated one.

### EAGLE AREA.

The most important gold-producing area in the vicinity of Eagle is that of American Creek and its tributary, Discovery Fork. These streams flow in acutely V-shaped valleys with a rather steep grade. The heads of the valleys are cut in carbonaceous schists and limestones. The bed rock of the lower parts of the valleys is mostly serpentine with basic dikes. The gravels are shallow—up to about 10 feet in thickness.

American Creek has been worked for several years and has produced a considerable quantity of coarse gold. In 1903 preparations were made to work the gravels on a large scale by the hydraulic process. A flume 7,200 feet in length, with a capacity of 1,200 miner's inches, was built and a hydraulic elevator installed. The quantity of available water, however, was limited and the plant could not be used to best advantage. On Discovery Fork an automatic dam had been constructed and found to work successfully, and in 1907 preparations were being made to work the ground on American Creek by the same method. The construction of the government wagon road by the road commission has brought these localities into close relation with Eagle, only about 10 miles distant.

### SEVENTYMILE AREA.

The valley of Seventymile Creek as far as the falls is located mostly in Kenai (Eocene) conglomerates. Above the falls as far as Barney Creek the Seventymile flows close to the contact of the Kenai rocks with schists. The valley is elaborately benched, and the surface of the lowest bench, about 20 feet above the stream, is covered with gravels several feet in thickness that are being prospected for working on a large scale. At the falls, about 20 miles from Eagle, the bench gravels have been mined to some extent and some gold has been extracted. Most of the mining, however, has been done on tributaries of the Seventymile, and those that have proved productive within the quadrangle are Broken Neck, Sonickson, and Nugget Creek.

Broken Neck Creek enters the Seventymile from the north, just above Mogul Creek. The Valley is deeply cut in Kenai conglomerate and shales, and where the stream leaves it the valley floor is only about 120 feet wide. The rocks dip 75° to the north and the shales contain many fossil leaves. The gravels are composed of the pebbles found in the conglomerate, pieces of shale and sandstone, a small proportion of quartzitic bowlders a foot or more in diameter, unlike the constituents observed in the conglomerate at this locality, and large bowlders of compact, fine-grained conglomerate, composed largely of chert pebbles. The creek has been worked to a width of 100 feet from the north to a point about half a mile upstream. The pay streak is reported to have been about 6 feet wide.

Sonickson Creek flows in a canyon whose slopes exhibit well-defined benching near the Seventymile. The bed rock at the mouth is a calcareous schist. The gravels contain bowlders of schist, conglomerate, greenstone, and granite. A small amount of work has been done near the mouth, but the results thus far obtained have not proved very encouraging.

Barney Creek enters the Seventymile from the north. The valley near the mouth is a very narrow cut in conglomerate and shales that range in dip from 55° S. to vertical. The gravels in the creek bottom are from about 1 to 3 feet thick and are composed of pebbles from the conglomerate, pieces of bowlders, and vitreous quartzite up to 3 feet in diameter. At a level of 50 feet above the mouth of the creek are bench gravels about 6 feet thick resting on the edges of the upturned conglomerate. These contain large quartzite bowlders like those observed in the creek gravels and similar also to those observed in Broken Neck Creek. These bench gravels on Barney Creek are auriferous and it is probable that part, at least, of the gold in the creek gravels has been derived by reconcentration from them.

The occurrence of gold on Nugget Creek and Flume Creek, both tributaries of the Seventymile to the west of the Fortymile quadrangle, indicates the extension of the auriferous area westward.

In conclusion it may be said that a few of the tributaries of Seventymile have produced in the past fairly good pay, Barney and Broken Neck creeks having been most productive, with several thousand dollars probably to the credit of each, and that there are extensive deposits of gravel along the main stream that in places have been found auriferous.

## MINING METHODS.

Mining in the Fortymile quadrangle has been done by the rocker, by open-cut work, by hydraulic methods, by drifting, and, during the season of 1907, by dredging. Various accessory means for the utilization of water have been brought into service, such as ditches, small reservoirs, automatic dams, etc.

Much work was formerly done by the rocker on the bars of the Fortymile, and even in 1907 a few instances of reversion to this original type were observed. The prevailing low stage of water was especially favorable for this kind of work. With the exception of the mining on Chicken Creek, most of the work has been done by open cut. The ground is generally stripped first of all by ground sluicing; then a cut of sufficient width for one or two sets of boxes is opened, and a bed-rock drain several hundred feet in length is constructed. The pay gravels have generally been shoveled into the boxes by hand work, but steam scrapers and bucket conveyers have also been used for this purpose. The hydraulic method has been used only to a small extent. Drifting is the most common method in the valley of Chicken Creek. The process includes the sinking of a shaft to bed rock, a distance of 20 to 40 feet, the timbering of the shaft, the opening up of the ground by drifts from which crosscuts are driven, the extraction of the few feet of auriferous gravels, and the hoisting of this material to the surface, where the gold is recov-

ered by ordinary sluicing. The method of thawing by steam points is the one most commonly employed.

The most recent development of method in the Fortymile region has been the introduction of dredging. The season of 1907 was an experimental one for this method, and while the results were perhaps incommensurate with the expectations, a considerable body of experience was undoubtedly acquired regarding the conditions under which dredging has to be carried on in this region. A dredge was installed an Walker Fork, about a mile above the mouth of Twelvemile, in the spring of 1907; a dredge was in the process of construction on Pump Bar of the Fortymile, about 2 miles below the mouth of Franklin Creek, during the summer of 1907; a dredge was in operation on the Fortymile at the Boundary, and another was working Sour Dough Bar of the Fortymile about 4 miles above the mouth, in Canadian territory.

The dredge on Walker Fork was freighted up the Fortymile and Walker Fork to its present position during the winter of 1906–7. The valley floor where the dredge is located is several hundred feet wide. The bed rock in this part of the valley includes schists, gneisses, and granitic intrusions, partly parallel with the main structures and partly cutting them. The alluvial deposits are reported to range from 6 to 14 feet in thickness, with an average of about 9 feet. The muck ranges from 1½ to 4 feet in thickness. The gold is said to be mostly on bed rock or within it to a depth of a few inches. The deposits are frozen. Insufficient ground had been previously prepared by ground sluicing for the operation of the dredge and it was necessary to use steam points for thawing the gravels. The dredge is a bucket open-connected steam dredge, the buckets having a capacity of 5 cubic feet. It was reported capable of working about 3 acres a month to a depth of 14 or 15 feet. The dimensions of the dredge are 36 by 76 feet and it draws about 4½ feet of water. It was held in position by two cables on each side and one in front, all held by deadmen. Three men are required to run it—a winchman, an engineer, and a fireman. The working season can commence from the 10th to the 15th of May and continue till the middle of September, giving about 120 days. The great difficulty encountered is the frozen character of the ground. It has been found necessary to prepare ground by stripping at least a year in advance in order to give the greatest opportunity possible for thawing by natural processes and thus for saving to a great extent the extra expense of thawing by steam points. Bucket lips that have a life of perhaps nine months under such conditions as are found in the dredging areas of California are worn down completely in a few weeks where they have to encounter frozen ground.

The machine in process of installation on Pump Bar below the mouth of Franklin is a dipper dredge. The machinery had been freighted up the Fortymile and was being assembled on a scow 42 by 80 feet, built of native spruce lumber. The capacity of the dipper was 2½ cubic yards and the machine was expected to handle about 1,000 cubic yards in ten hours. The ground to be worked is a shallow portion of the bed of the Fortymile, ranging from 6 to 12 feet in thickness, and is all unfrozen. It was reported that ground carrying 25 cents to the cubic yard would pay the cost of working.

The dredge on the Fortymile at the boundary is similar to that of Walker Fork but of less capacity. It was working on a bar of the Fortymile where the average depth to bed rock is about 8 feet. While bowlders are somewhat troublesome there, necessitating frequent stopping of the machine, the ground is for the most part unfrozen.

The dredge on the Canadian side of the boundary is a much larger machine with a capacity of 3,000 cubic yards per day, and a capacity for depth of 35 feet. This dredge also was working on a bar of the Fortymile where the ground was unfrozen and the bed rock soft.

There are many factors to be taken into consideration in any plan involving the installation of a dredge, and the neglect of any one of them may be fatal to the success of the undertaking. This is not the place for a detailed statement of the dredging problem, but inasmuch as some of these factors are overlooked so frequently with apparent indifference by those in charge of operation attention may be drawn to some of them. There is, for example, the problem of the determination of values in the ground. It might seem superfluous to insist on the importance of a thorough preliminary investigation of the ground, but those familiar with the conditions will recall cases where this vital factor has been practically neglected. There are also to be considered the dimensions and character of the alluvial deposits, the vertical and horizontal distribution and the character of the gold; the bed-rock surface, its hardness, receptivity for gold, and adaptability for dredging; the water and fuel supplies; the length of the working season; the costs of material, labor, and transportation; and the selection of a dredge best adapted to the conditions presented by the ground under consideration.

## PRODUCTION.

The production of placer gold of the Fortymile quadrangle, inclusive of 1907, has been approximately $5,000,000. Most of the gold is taken out of Alaska by way of Fortymile River, and from records furnished the Survey by the office of the United States Customs Service at the subport of Fortymile, Alaska, the following table showing the production of the Fortymile area for the years 1904 to 1907 has been prepared. These statistics do not include the pro-

duction from the Eagle and Seventymile areas, for which very incomplete data are at hand. The production of the entire Fortymile quadrangle for 1907 was approximately $150,000.

*Production of the Fortymile area for the years 1904 to 1907.*

| Creeks. | 1904. | | 1905. | | 1906. | | 1907. | |
|---|---|---|---|---|---|---|---|---|
| | Fine ounces. | Value. | Fine ounces. | Value. | Fine ounces. | Value. | Fine ounces. | Value. |
| Chicken, Lost Chicken, Myers Fork, Stonehouse, and Ingle. | 6,819.74 | $140,964 | 5,368.11 | $110,959 | 4,269.32 | $88,247 | 2,377.74 | $49,147 |
| Franklin | 494.29 | 10,217 | 581.47 | 12,019 | 783.79 | 16,201 | 100.34 | 2,074 |
| Wade | 5,233.24 | 108,171 | 4,521.00 | 93,449 | 3,094.87 | 63,971 | 3,381.90 | 69,904 |
| Walker Fork, Poker, and Davis | 1,222.11 | 25,262 | 1,124.28 | 23,239 | 1,184.32 | 24,480 | 484.42 | 10,013 |
| Squaw, Camp, and Woods Canyon | 156.27 | 3,230 | 103.62 | 2,142 | 63.32 | 1,309 | 123.36 | 2,550 |
| Napoleon, Montana, Buckskin, Dome, Eagle, and Twin | 51.00 | 1,054 | 46.06 | 952 | 13.11 | 272 | 11.51 | 238 |
| Fortymile bars and commercial dust | 886.60 | 18,326 | 637.40 | 13,175 | 437.54 | 9,044 | 266.47 | 5,508 |
| | 14,863.25 | 307,224 | 12,381.94 | 255,935 | 9,846.27 | 203,524 | 6,745.74 | 139,434 |

## SUMMARY.

The topographic features of this quadrangle comprise numerous ridges, of approximately uniform height, separated by deep, relatively narrow valleys. The rocks include a complex of schists and limestones with altered intrusives; Paleozoic phyllites, quartzites, limestones, and greenstones, both intrusive and extrusive, with associated tuffs; Tertiary clays, lignite, sandstone, shale, and conglomerates; bench gravels and stream gravels; and unaltered igneous rocks. The structure is exceedingly complex. The dominant trends in the northern part of the quadrangle are northwest-southeast; in the southern part, northeast-southwest to east-west. Igneous rocks are abundant and have been an important factor in the geologic history. The gold deposits are probably to be referred indirectly to them. The age of mineralization is not definitely established, but some of the auriferous material originated subsequent to the intrusion of comparatively fresh granular rocks of intermediate composition, which may have been as late as the Upper Cretaceous.

The quadrangle has produced approximately $5,000,000 in placer gold, and while the decreasing annual production indicates that the ground which it would pay to work under present conditions will soon be exhausted, there are still considerable bodies of low-grade ground that, under a lower cost of mining due to improvement in the facilities of transportation and cheaper methods of handling material, could probably be profitably mined. No workable deposits of coal have been found, but a small amount of local coal has been used for blacksmithing purposes.

# INDEX.

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