UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 872

THE YUKON-TANANA REGION ALASKA

BY

J. B. MERTIE, Jr.

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1937

For sale by the Superintendent of Documents, Washington, D. C. - Price 70 cents (Paper Cover)

CONTENTS

ILLUSTRATIONS

THE YUKON-TANANA REGION, ALASKA

By J. B. Mertie, Jr.

ABSTRACT

For more than 35 years investigations of the geology and mineral resources of the great tract of country lying in the central part of Alaska between the Yukon and Tanana Rivers have been in progress. The present report aims to correlate and coordinate all the many observations thus gathered from many sources, so as to give a comprehensive and up-to-date summary of the significant features of the geography, geology, and mineral resources of the region. The geologic formations occurring in this region embrace members belonging to practically all the great systems and many of the epochs from the pre-Cambrian to the Recent. The sedimentary rocks show a wide range in lithologic character, from the highly metamorphic rocks characteristic of the Birch Creek schist to the slightly consolidated sand and gravel deposits of the Quaternary. In composition, too, they differ widely, some being conglomerates, others sandstones and shales, and still others limestones. Igneous rocks, some of effusive and others of intrusive origin, form notable components of the geologic sequence of rocks exposed in the region, and tuffs and volcanic agglomerates, which partake of the characteristics of both sedimentary and igneous rocks, are widely distributed.

The mineral deposits that have been most developed in the region are those in which the principal valuable mineral is gold, but deposits containing other valuable metallic minerals, such as tin and tungsten, as well as nonmetalliferous products, such as coal, have been found. In the accompanying report the aim has been not so much to enumerate and describe in detail each of the many places at which mining or prospecting has been done, but rather to set forth the broader problems associated with the occurrence of mineralization in the region and to attempt to trace the connection of certain types of deposits with certain geologic incidents and processes. By this treatment the author has aimed to direct intelligent prospecting toward those areas that are regarded as having most likelihood of containing mineral deposits of value and thus to prevent much loss of time and effort in searching in those areas where geologic conditions do not seem to have been favorable.

INTRODUCTION

LOCATION AND SUBDIVISIONS

The Yukon-Tanana region is an area of about 38,000 square miles in central Alaska that lies between meridians 141° and 152° west longitude and parallels 62° 40′ and 66° 35′ north latitude. (See fig. 1.) This area, lying almost entirely south of the Arctic Circle, is bounded on the north by the Yukon River, on the south by the Tanana River, and on the east by the international boundary between Alaska and Canada. The distance from the confluence of these two rivers eastward to the international boundary is about 320 miles; and the greatest north-south distance across the region, measured along the 146th meridian, is about 170 miles.

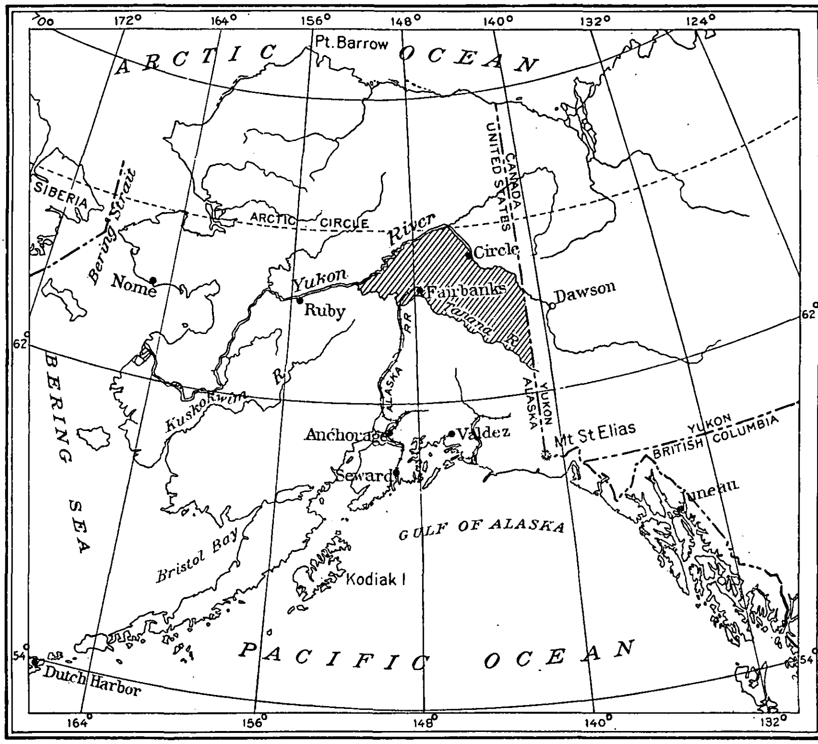


FIGURE 1.—Index map showing location of the Yukon-Tanana region.

When the systematic mapping of Alaska was begun it was found desirable to subdivide the Territory into quadrangles and map areas, the major boundaries of which were taken as the geographic meridians and parallels. In this way the Yukon-Tanana region was subdivided into five tracts, which are known as the Rampart, Fairbanks, Circle, and Fortymile quadrangles and the Dennison Fork district. The Rampart quadrangle includes that part of the region lying west of the 150th meridian; the Fairbanks quadrangle lies between the 150th and 146th meridians; the Circle quadrangle lies between the 146th and 142d meridians; the Fortymile quadrangle lies east of the 142d meridian and between the 64th and 65th parallels; and the Dennison Fork district includes that part of the Yukon-Tanana region south of the 64th parallel. A small triangular tract that lies east of the 142d meridian and north of the 65th parallel has received no formal designation. Another small map area in the central part of the Fairbanks quadrangle, known as the Fairbanks special district, was delimited for mapping on a larger scale.

EARLY EXPLORATIONS

The upper Yukon Basin in Alaska was first explored by officials of the Hudson Bay Co. According to Dawson,[1] the Hudson Bay post on the Peel River, near the mouth of the Mackenzie, was in charge of J. Bell, who from this station reached the Porcupine River in 1842 and descended it for 3 days' journey. Returning to the Porcupine in 1846, Bell descended that stream to the large river which the natives called the Yukon. In 1847 Fort Yukon, the oldest settlement of the upper Yukon, was established at the junction of the Yukon and Porcupine Rivers by A. H. Murray, another employee of the company. In the meantime, the upper Liard and upper Yukon were being actively explored by Robert Campbell, and in 1850 Campbell, starting from Fort Selkirk, at the junction of the Pelly and Lewes Rivers, continued downstream and finally arrived at Fort Yukon, thus proving that the Pelly and Yukon were in reality continuous. The Hudson Bay Co., however, did not extend its operations west of Fort Yukon, and the Russians, on the lower Yukon, had not worked that far upstream, so that the river below Fort Yukon remained unknown to the English until 1863, when Ivan Simonsen Lukeén, of the Russian-American Co., penetrated to Fort Yukon from the lower Yukon.

In 1866 the Western Union Telegraph Co. sent an exploring expedition up the Yukon from its mouth. This party, originally in charge of Robert Kennicott and after his death under the command of W. H. Dall,[2] ascended the Yukon to Fort Yukon. Two members of the party, Ketcham and Lebarge, continued up the river as far as Fort Selkirk, but that stretch of the river had already been explored 16 years before by Robert Campbell. The next year the ownership of Alaska passed from Russia to the United States, and in 1869 Dall's trip was repeated by Capt. C. P. Raymond,[3] of the United States Army, who determined for the first time the geodetic position of Fort Yukon and thereby established American ownership to this part of the river and the surrounding area.

During the next 25 years the Yukon and Tanana Valleys were visited at intervals by numerous men, with various motives. Some

[1] Dawson, G. M., Report on an exploration in the Yukon district, N. W. T., and adjacent northern portion of British Columbia, in 1887: Canada Geol. Survey Ann. Rept., new ser., vol. 3, pt. 1, p. 138 B, 1888.

[2] Dall, W. H., Exploration in Russian America: Am. Jour. Sci., 2d ser., vol. 45, pp. 97–98, 1868; Alaska and its resources, 1870.

[3] Raymond, C. P., Reconnaissance of the Yukon River, Alaska, Washington, Government Printing Office. 1871.

came in search of geographic or scientific information, some for adventure, and some for fur or gold. The results of some of these visits have been published, but many remarkable trips by early prospectors and traders have not been recorded and will therefore never obtain the recognition that they deserve. In the early seventies traders and prospectors, such as Arthur Harper, Jack McQuesten, A. Mayo, and George Holt, made numerous exploring trips in the Yukon Basin. Harper, McQuesten, and Mayo reached the Yukon in 1872 by the old Hudson Bay route from the Mackenzie River, and Brooks,[4] on the authority of E. W. Nelson, of the Biological Survey, states that Harper and Mayo in 1878 ascended the Tanana River between 250 and 300 miles, or as far as the present site of Fairbanks, and found alluvial gold on the bars of the river. Harper, with one companion, is also said by Schwatka[5] to have made an overland trip from Belle Isle, the present site of Eagle, southwestward to the Tanana River sometime prior to 1883. George Holt, on the other hand, was the first white man to cross from Lynn Canal to the headwaters of the Yukon in 1878. About 1881 a man named Bean opened a trading post on the Tanana River about 48 miles above its mouth, but this station was later abandoned when his wife was killed by the Indians. In 1882, according to Allen,[6] a missionary named Simms ascended the Tanana River as far as the mouth of the Toklat. The best compendium of information on Alaska up to 1881 is the volume by Ivan Petroff,[7] special agent of the Census Office. Petroff did not himself visit interior Alaska, but he made extended journeys in the more accessible parts of the Territory in 1880 and 1881.

In the summer of 1882 the Schieffelin brothers, according to Spurr,[8] ascended the Yukon in a small steamboat from St. Michael to Nuklukayet [Tanana]; and in the fall of the same year they prospected some small streams about 80 miles above Tanana, where they found auriferous bars that would yield $10 a day to the man. These streams probably included Minook Creek and the Hess River. The Schieffelin brothers returned to San Francisco in 1883 and do not seem to have followed up their discovery of gold.

In 1883 Lieutenant Schwatka,[9] of the United States Army, made a trip from the headwaters of the Yukon to its mouth. Schwatka

[4] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 25, 1911.

[5] Schwatka, Frederick, Along Alaska's great river, 1885.

[6] Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk Rivers, in the Territory of Alaska, in the year 1883: 49th Cong., S. Doc. 125, 1887.

[7] Petroff, Ivan, Report on the population, industries, and resources of Alaska: Tenth Census of the United States, vol. 8, pt. 2, pp. 1–189, 1884.

[8] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 103–133, 1898.

[9] Schwatka, Frederick, Report on a military reconnaissance in Alaska, made in 1883, Washington, Government Printing Office, 1885.

made the first reliable traverse map of the Yukon River, initiating thereby the era of exploratory mapping in interior Alaska. Two years after Schwatka's trip, Lt. H. L. Allen,[10] of the United States Cavalry, made a remarkable trip through interior and northern Alaska, in the course of which he descended the Tanana River from the mouth of the Tok River to the Yukon. Allen made the first reliable map of the Tanana River, as Schwatka had done for the Yukon. After Dall, the next geologist to visit interior Alaska was R. G. McConnell,[11] of the Canadian Geological Survey, who in 1888 crossed from the Mackenzie to the Porcupine, descended to the Yukon, and ascended that stream to the confluence of the Pelly and Lewes Rivers. Another early trip was that of I. C. Russell[12] in 1889, from St. Michael up the Yukon River to its headwaters. Russell devoted himself chiefly to geomorphic studies.

Meanwhile the gold placers of interior Alaska were beginning to attract attention. According to Spurr,[13] a miner named Franklin had found gold in 1886 at the mouth of the Fortymile River, and in 1887 and succeeding years the gold placers of the Fortymile district began to be mined. In 1893 two Russian half-breeds named Pitka and Sorresco made the first discovery of gold on Birch Creek, and in the following year most of the important placers of the Circle district were discovered and opened up. Similarly, farther down the Yukon, a Russian half-breed named John Minook found coarse gold in 1893 on Hess Creek and nearby streams, and in the spring of 1896 active mining began in the Rampart district. Finally, in 1896, the rich placers of the Klondike district, in Yukon Territory, were discovered, and the gold rushes began which culminated in 1898.

SYSTEMATIC SURVEYS

The next stage in the exploration of central Alaska was conducted mainly by governmental agencies, with the purpose of obtaining more exact information regarding the geography, geology, and mineral resources. The first expedition of this sort was headed by J. E. Spurr,[14] in 1896. Spurr, together with H. B. Goodrich and F. C. Schrader, crossed from Lynn Canal over Chilkoot Pass to the headwaters of the Yukon and descended that river as far as Nulato, visiting the Fortymile, Circle, and Rampart mining camps on the way. Spurr

[10] Allen, H. L., Report on an expedition to the Copper, Tanana, and Koyukuk Rivers in the Territory of Alaska, in the year 1885, Washington, Government Printing Office, 1887.

[11] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie Basins, Northwest Territory: Canada Geol. Survey Ann. Rept., new ser., vol. 74, pp. 134–139 D, 1890.

[12] Russell, I. C., Notes on the surface geology of Alaska: Geol. Soc. America Bull., vol. 1, pp. 99–156, 1890.

[13] Spurr, J. E., op. cit., pp. 115–117, 1898.

[14] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 87–392, 1898.

attempted a systematic classification of the rocks along this route and also presented the earliest published data regarding the character and extent of the gold placers of the Yukon Valley. Another geologic expedition similar to Spurr's was made in 1898 by A. H. Brooks [15] and W. J. Peters, who ascended the White River, portaged to the headwaters of the Tanana River, and descended that stream to its confluence with the Yukon. The next year Brooks [16] made another trip, starting from Lynn Canal and paralleling roughly on the southwest his trip of 1898. On this trip he reached the Tanana River near the mouth of the Tetling River and thence proceeded northward across the Yukon-Tanana region to Eagle.

In 1902 Brooks [17] made a trip from Tyonek, on Cook Inlet, across the Alaska Range to the Tanana River, and thence northward to Rampart, thus crossing the west end of the Yukon-Tanana region. In the same year A. J. Collier [18] and Sidney Paige made a geologic traverse of the Yukon from Dawson, Y. T., to its mouth, giving particular attention to the coal measures along the river. This trip was repeated in 1903 by Arthur Hollick and Sidney Paige for the purpose of making more complete fossil collections.

In July 1903 a division of Alaskan mineral resources was organized in the Geological Survey under the leadership of Alfred H. Brooks, and in the same year a systematic study of the geology and mineral resources of the Yukon-Tanana region was begun. This work was undertaken by L. M. Prindle and with the cooperation of other Federal geologists was continued until 1911. Most of these surveys were of the reconnaissance type and were published on a scale of 1:250,000, but a detailed geologic map of the Fairbanks special district, on the scale of 1:62,500, and a report were also prepared. From 1911 to 1931 study of the Yukon-Tanana region has been for the writer a continuing project, on which he has worked intermittently during nine field seasons. This work was a continuation of the reconnaissance studies initiated by Prindle, but the surveys were more areal in scope than the earlier linear traverses. Many other geologists and engineers, however, have contributed to this work, as will be seen by the bibliography presented below. Still others have done important work in this region, which has not been published, and adequate acknowledgment of such contributions will be made at the proper places.

---

[15] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 431–494, 1900.

[16] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana Rivers: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 331–391, 1901.

[17] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

[18] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, 1903.

The topographic mapping of the Yukon-Tanana region may be regarded as having begun with the linear topographic surveys of the Yukon and Tanana Rivers by H. B. Goodrich and W. J. Peters, respectively, in 1896 and 1898. The Fortymile quadrangle was also surveyed in 1898 by E. C. Barnard. Systematic topographic surveys, however, were begun in 1903, coincidentally with the systematic geologic mapping, and in 1903 to 1910 reconnaissance topographic maps of the entire Yukon-Tanana region were prepared on a scale of 1:250,000. The topographic engineers who participated in this work were T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, J. W. Bagley, D. L. Reaburn, and G. T. Ford. An area of about 500 square miles in the central part of the Fairbanks quadrangle was also mapped on a scale of 1:62,500 by T. G. Gerdine, R. H. Sargent, and G. Neuner.

Another activity of the Geological Survey in the Yukon-Tanana region was a study of the surface waters and hot springs, which was carried on in 1907 to 1912. The engineers who participated in this work were mainly C. E. Ellsworth, G. L. Parker, C. C. Covert, E. A. Porter, R. W. Davenport, and G. A. Waring.

About 60 publications have been prepared by the geologists and engineers of the Geological Survey dealing with the geology, mineral resources, placer and lode mining, surface waters, and hot springs of the Yukon-Tanana region. Of these more than half treat of the progress of mining during the last 30 years and are largely of ephemeral interest. For the following bibliography, therefore, 28 papers have been selected, which include most of the published facts regarding the geology, mineral resources, and general mining conditions. The list is arranged chronologically.

Spurr, J. E., Geology of the Yukon gold district, Alaska, with an introductory chapter on the history and present condition of the district, by H. B. Goodrich: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 87–392, 1898.

Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann., Rept., pt. 7, pp. 431–494, 1900.

Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana Rivers: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 331–391, 1901.

Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, 1903.

Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: U. S. Geol. Survey Bull. 251, 1905.

Stone, R. W., Reconnaissance from Circle to Fort Hamlin; U. S. Geol. Survey Bull. 284, pp. 128–131, 1906.

Prindle, L. M., and Hess, F. L., The Rampart gold placer region, Alaska: U. S. Geol. Survey Bull. 280, 1906.

Prindle, L. M., The Yukon-Tanana region, Alaska; description of Circle quadrangle: U. S. Geol. Survey Bull. 295, 1906.

Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska, with a section on the Rampart placers, by F. L. Hess, and a paper on the water supply of the Fairbanks region, by C. C. Covert: U. S. Geol. Survey Bull. 337, 1908.

Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 255–314, 1908.

Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, 1909.

Johnson, B. L., Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district: U. S. Geol. Survey Bull. 442, pp. 246–250, 1910.

Brooks, A. H., The Mount McKinley region, Alaska; with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, 1911.

Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska; with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith: U. S. Geol. Survey Bull. 525, 1913.

Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, 1913.

Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, 1913.

Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 321–355, 1914.

Ellsworth, C. E., and Davenport, R. W., Surface water supply of the Yukon-Tanana region, Alaska: U. S. Geol. Survey Water-Supply Paper 342, 1915.

Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, 1916.

Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, 1917.

Mertie, J. B., Jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 221–277, 1918.

Mertie, J. B., Jr., Lode mining in the Fairbanks district: U. S. Geol. Survey Bull. 662, pp. 403–424, 1918.

Mertie, J. B., Jr., The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions: U. S. Geol. Survey Bull. 739, pp. 149–165, 1923.

Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, 1926.

Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, 1930.

Mertie, J. B., Jr., A geologic reconnaissance of the Dennison Fork district, Alaska: U. S. Geol. Survey Bull. 827, 1931.

Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 347–443, 1932.

Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849–B, 1933.

Mertie, J. B., Jr., Mineral deposits of the Rampart and Hot Springs districts: U. S. Geol. Survey Bull. 844, pp. 163–226, 1934.

To this bibliography should also be added the more important contemporaneous publications of the Geological Survey of Canada, which treat of contiguous parts of the Yukon-Tanana region in Yukon Territory, Canada, as follows:

McConnell, R. G., Report on the Klondike gold fields: Canada Geol. Survey Ann. Rept., vol. 14, 1905.

Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, 1914.

Cockfield, W. E., Sixtymile and Ladue Rivers area, Yukon: Canada Geol. Survey Mem. 105, 1921.

PRESENT REPORT

The present report is an eclectic summary of all the available information regarding the general and economic geology of the Yukon-Tanana region. Much of the information here presented has been given in earlier publications on various parts of this region, but the need was apparent for a general report, in which all the local information might be digested and coordinated and in which the older data might be reviewed and revised in the light of supplementary information of later date.

This project presented some difficulties. In certain areas, as in the Eagle-Circle and Rampart districts and the White Mountains, the character and distribution of the geologic map units are sufficiently well known to warrant their delineation on the reconnaissance scale of 1:250,000; and in the Fairbanks special district a detailed geologic map on the scale of 1:62,500 had already been published. In other areas, however—for example, in parts of the Dennison Fork district—geologic formations and boundaries have been extrapolated beyond their known limits, and the mapping is correspondingly weak. In still other parts of the region, particularly in the Fairbanks and Circle quadrangles, there are considerable areas which the writer has not visited and in which the mapping is based largely upon the field work of other men. Finally, there are tracts, mainly in the Circle quadrangle, which have not yet been visited by any geologist; and in such areas the mapping represents only the writer's best guess as to the general distribution of the major units. It should be pointed out, however, that these least-known parts of the Yukon-Tanana region appear to consist largely of metamorphic rocks and granitic intrusives, which will have to be studied in considerable detail before they can be classified and mapped as smaller units. In view of these variations in the actual and permissible accuracy of the work, it has seemed best to present the geologic map upon a scale of 1:500,000. This map and the accompanying report represent the present status of knowledge and opinion regarding the geology of the Yukon-Tanana region.

The present report may be said to terminate the era of reconnaissance surveys begun by Brooks and Prindle in 1903. The general types and distribution of the major geologic units are now fairly well known, but for detailed presentation of the geology much remains to be done. Therefore, the publication of the present report should more properly mark the beginning of a new era of detailed and semidetailed mapping in selected areas, where the answers to many unsolved geologic problems can best be found. Thus, the relations between the pre-Cambrian and the early Paleozoic metamorphic rocks can probably be deciphered by special studies in the southern part of the Circle quadrangle; the problems connected with the Pelly gneiss will require a detailed study of the eastern part of the Dennison Fork district; and the Cambrian and unmetamorphosed pre-Cambrian rocks can best be studied in the region north and northeast of Eagle. In fact, as will be shown in the following pages, important stratigraphic, structural, and paleontologic problems remain to be solved in nearly all the sedimentary formations so far differentiated; and the igneous rocks, particularly those of granitic character, present a broad and fertile field for research.

Another part of the present report is a summary of the economic geology of the Yukon-Tanana region, with particular reference to the character and origin of the placer and lode deposits of gold. The results of most of the economic work, which is of paramount interest and importance to the people of Alaska, have heretofore been promptly published in adequate detail. The present report therefore does not treat of individual mining properties, or even in detail of producing districts, but aims more particularly to present development of mining from a comparative point of view, emphasizing the general character of the mineralization and pointing out the similarities and differences in the mineral deposits of various districts in this region.

SOURCES OF INFORMATION

The present report is a selective summation of geologic facts and interpretations acquired by 25 or more geologists during a period of about 36 years, but more particularly in the years since 1903. It is not possible to show in detail the contributions made by individual workers, but the following sketch gives a general idea of the parts taken in this work by various geologists.

In 1903 to 1911, L. M. Prindle, with his assistants, F. L. Hess, Adolph Knopf, R. W. Stone, B. L. Johnson, and J. B. Mertie, Jr., mapped the Fortymile, Fairbanks, and Circle quadrangles, and Prindle and F. J. Katz mapped the Fairbanks special district. In 1911, H. M. Eakin mapped a portion of the Rampart quadrangle.

Another area of importance in this region is the zone along both sides of the Yukon, from the international boundary to Circle, which, though in reality part of the Fortymile and Circle quadrangles, could not be reached to advantage by pack horses. This strip was therefore repeatedly examined by geologists who traveled down the Yukon by boat. Starting with A. J. Collier and Sidney Paige in 1902, this work was continued by Arthur Hollick and Sidney Paige in 1903, by A. H. Brooks and E. M. Kindle in 1906, by G. C. Martin and R. M. Overbeck in 1914, by Eliot Blackwelder in 1915, by G. H. Girty in 1918, and by the writer in 1925. Reports by Collier, Brooks, and Mertie, listed in the above bibliography, give the sequence of geologic findings in this project.

The specific geologic activities of the writer in this region have been as follows:

1911. Assistant to L. M. Prindle, in the central portion of the Circle quadrangle.
1916. Areal and economic studies in the Tolovana and Fairbanks districts.
1921. Areal studies in the northern part of the Fairbanks quadrangle.
1922. Areal and economic studies in the Rampart quadrangle.
1925. Areal studies along the Yukon River between Eagle and Circle. Assistant, M. M. Knechtel.
1928. Areal and economic studies in the Dennison Fork district. Assistant, R. D. Ohrenschall.
1929. Areal studies in the northeastern part of the Fairbanks quadrangle and the northwestern part of the Circle quadrangle.
1930. Areal studies north of the Yukon River, contiguous to the international boundary. Assistant, A. E. Waters, Jr.
1931. Areal and economic studies in the Rampart quadrangle. Assistant, A. E. Waters, Jr.

Other important work has also been done in this region, including the work of Eliot Blackwelder along the Yukon River and in the White Mountains in 1915, the work of R. M. Overbeck in the Rampart and Fairbanks quadrangles in 1918, and the work of Philip S. Smith in the southern part of the Fairbanks quadrangle in 1920. For one reason or another the results of these investigations have not been published, and in the present report the writer has utilized so far as possible these unpublished data.

ACKNOWLEDGMENTS

The contributions of other workers have already been outlined. The writer wishes hereby to acknowledge the many sources of information to which he has had access, but particularly to mention the value of the fundamental geologic facts that were discovered and recorded by L. M. Prindle. The included bibliography is sufficient acknowledgment of the contributions of most of the other geologists and engineers who have worked in this country. The unpublished results obtained by Eliot Blackwelder, R. H. Overbeck, and P. S. Smith, mentioned above, are included in the present report, but where possible individual acknowledgment of their contributions will be made.

During several field seasons the writer has been materially aided by geologic field assistants—M. M. Knechtel in 1925, R. D. Ohrenschall in 1928, and A. E. Waters, Jr., in 1930 and 1931. The services of all these men are gratefully acknowledged. Another member of the writer's field parties to whom thanks are due is R. L. Phillips, who since 1921 has served as packer and who in this service has suffered one painful and dangerous injury.

It would be difficult indeed to acknowledge individually the help and hospitality that the writer has received from the people of the Yukon-Tanana region in the last 20 years. In respect to transportation and equipment special thanks are due to the officials and employees of the White Pass & Yukon Route and of the Northern Commercial Co., all of whom have always been willing and anxious to do everything possible to further the work of Federal scientists and engineers. The writer has never experienced any treatment other than hospitality among the prospectors, miners, and traders of this country, and to mention certain ones in particular would be to slight the others. The writer prefers therefore to thank these many friends of 10 to 20 years' standing as a group for their helpful understanding, cordial cooperation, and generous hospitality.

GEOGRAPHY

DRAINAGE AND RELIEF

YUKON VALLEY

The Yukon and its tributaries form one of the large drainage systems of the world. The main Yukon heads in the northwest corner of British Columbia and drains the southwestern part of Yukon Territory and most of central Alaska. It forms the northern boundary of the Yukon-Tanana region and drains three-fifths of that region. In east-central Alaska the Yukon receives two large tributaries—the Porcupine River, which enters from the northeast at the 145th meridian, and the Tanana River, which enters from the southeast at the 152d meridian. The Tanana River marks the southern limit of the Yukon-Tanana region and drains two-fifths of it. The Yukon and Tanana Rivers therefore constitute the master streams of the Yukon-Tanana region.

From the international boundary to the mouth of the Porcupine, an air-line distance of 180 miles, the general course of the Yukon River is about N. 45° W. At the mouth of the Porcupine the Yukon River veers abruptly southward, and from that point to the mouth of the Tanana, an air-line distance of 220 miles, its general course is about S. 60° W. With regard to direction, the Porcupine has somewhat the relation to the Yukon below Fort Yukon that the Missouri has to the Mississippi. Many minor variations from the general course of the Yukon, above and below Fort Yukon, are also apparent on the accompanying map. The course of the Yukon River has been controlled partly by the preexisting structure of the bedrock but has also been materially changed from time to time by local warping, by alluviation and superposition, and by other causes. The combination of these controlling factors has given rise to a long and intricate physiographic history, which as yet is only partly deciphered.

The principal tributaries of the Yukon that drain the Yukon-Tanana region, named in order downstream, are the Ladue River, a tributary of the White River, the Fortymile River, the Seventymile River, the Charley River, Birch Creek, Beaver Creek, and Hess Creek. The Fortymile River, the largest of these seven streams, drains about one-sixth of the Yukon-Tanana region, and Birch Creek, the second largest, drains about one-eighth. All these tributaries are nonglacial streams, which at ordinary stages discharge clear water into the Yukon. The Yukon River itself, however, is turbid, because it flows swiftly over fine sediments in parts of its course, and also because one of its large tributaries in Yukon Territory, the White River, heads in the Alaska Range and discharges a large volume of water that is loaded with glacial silt.

The Yukon Valley between the international boundary and the mouth of the Tanana represents only a small part of the entire valley, but this stretch is divisible into three rather distinct units. These may be designated the Eagle-Circle Canyon, the Yukon Flats, and the Fort Hamlin-Rampart Canyon. The air-line distance of the first section, from the international boundary to Circle, is about 120 miles, but the distance by river is considerably longer. Within this stretch and for a considerable distance upstream in Yukon Territory the Yukon flows in meanders of large amplitude and has banks that rise boldly from the river. The width ranges from half a mile to 1½ miles, and in the wider stretches numerous islands occur. The true elevation of the Yukon River above sea level at the international boundary is 879 feet, but on plate 1 the elevation is shown to be about 600 feet. The error is due to lack of precise vertical control when topographic mapping was first begun in this region. Between the boundary and Circle the fall of the river is about 135 feet, or somewhat more than 1 foot to the mile. The current of the river in this stretch ranges from 4 to 6 miles an hour. A short distance downstream from Nation a dangerous bedrock reef, known as Nation Reef, crosses the Yukon, but this is the only obstacle of this sort in this stretch of the river.

One of the characteristic features of the Yukon Valley within the Eagle-Circle Canyon is the prevalence of well-defined terraces that mark the various levels of the ancient valley floor. One of these terraces is from 75 to 100 feet above the level of the river and has been observed principally in the stretch between the Tatonduk and Nation Rivers, tributaries of the Yukon from the northeast. As a rule this terrace is not level but undulating, and it also rises gently toward the hills on both sides of the river. This terrace is nearly everywhere timber-covered and probably has an upper gravel surface. A second terrace, estimated to be about 500 feet above the level of the river, is also present at many places but has been specially noted below the mouth of the Tatonduk River, below the mouth of the Nation River, and at and below the mouth of the Kandik River, a tributary of the Yukon from the northeast. A third terrace, between 700 and 800 feet above the level of the Yukon, is visible at many places between the Tatonduk River and Circle. Still other terraces, both higher and lower than those above mentioned, are present in the valleys of tributary streams, both from the north and the south. The mapping and study of these river-cut terraces constitute an interesting geomorphic problem, and a proper understanding of the erosional history of this part of the Yukon is a necessary preliminary step in the solution of the more difficult geomorphic problems of the lower river.

The Yukon Flats constitute a great alluvial basin in which the Yukon River flows from Circle to Fort Hamlin, an air-line distance through Fort Yukon of about 180 miles. The greatest width of this basin, from north to south, in the vicinity of Fort Yukon, is about 75 miles, and the area is estimated to be at least 7,500 square miles. Within this stretch of the Yukon all the tributary streams on both sides are similarly aggraded in their lower courses, and in the Porcupine Valley these flats extend upstream from Fort Yukon for 80 miles in an air line.

The Yukon flows across the Yukon Flats as an intricately braided stream. Even at ordinary stages of water the river splits into many channels, but at flood stages the river overflows from its main channels into hundreds of higher sloughs, and the flats become a vast labyrinth of reticulating waterways, through which a stranger finds it difficult to keep to the main channels. The name Yukon Flats is somewhat misleading, for the valley floor, though devoid of relief, is far from approaching a horizontal plane. In fact, the fall of the river from Circle to Fort Hamlin is about 200 feet, or nearly 1 foot to the mile, and these "flats" are therefore a tilted alluvial surface, across which the river flows swiftly through a system of shallow braided channels. The current, which ranges from 3 to 6 miles an hour and averages perhaps 4 miles, is at least as swift as that above and below the flats, and this condition, together with many shallow and shifting gravel bars, makes navigation by river steamboats tedious and difficult.

The Yukon Flats have not yet been mapped, and even the main channel of the river is uncharted, except for sketches that have been prepared by the pilots on the river steamboats of the White Pass & Yukon Route. The two Yanert brothers, who have lived for many years in the lower part of the Yukon Flats, know more about the various channels of the Yukon within the flats than any other living men, and they have made some carefully prepared drainage maps of parts of the flats, but these have not been published and are therefore not generally available. The reconnaissance topographic map that accompanies this report covers the ridge country south of the flats; but here, as elsewhere close to the river, the lower hills are wooded, and the map gives little or no expression to important surface features, such as terraces along the marginal zone. The north side of the Yukon Flats is in the main unmapped. Nor do the main channels of the Yukon approach close to the hills anywhere in the flats. Therefore little is known of the surface configuration of the terrane bordering the flats, though observations that have been made from the adjoining hills yield some information regarding it. Thus, where Beaver Creek debouches into the Yukon Flats the hills break away suddenly in a steep unbroken slope, which descends to a poorly drained, lake-dotted gravel terrace that is distinctly higher than the outlying flats proper. This terrace extends northward from the hills for 10 miles or more, and across this bench Beaver Creek flows in a sharply incised, relatively narrow but flat-bottomed valley. The borderland of the flats has also been observed where the Chandalar River debouches from the hills to the north.[19] Here a gravel terrace, about 30 to 35 feet above the level of the Chandalar, extends northward to the hills as a gently rising foreland. Another terrace, about 600 feet above the river level, is also visible north of the lower Chandalar River. The general conclusion, then, to be drawn from the few available observations is that the Yukon Flats are also bordered by terraces, but that these terraces, particularly the higher ones, are less perfectly preserved than those in the Eagle-Circle Canyon and are not necessarily correlative in their elevations with those farther upstream.

The banks bordering the river channels within the flats vary in composition, height, and appearance. In general, they are composed of alternating layers of silt, sand, and fine gravel, but observations at low water show that the lowest visible strata and the surfaces of the river bars are largely coarse gravel, with individual cobbles as large as 6 or 8 inches in diameter. Most of these sediments show cross-bedding and other characteristics that require them to be classi-

---

[19] Mertie, J. B., Jr., The Chandalar-Sheenjek district: U. S. Geol. Survey Bull. 810, pp. 101–102, 1930.

fied as fluviatile deposits, but a minor proportion originated in small lakes and ponds and are therefore to be regarded as lacustrine deposits. All these sediments are overlain at the surface by a peaty stratum of vegetal material. No hard rock is known to crop out anywhere in the Yukon Flats, but a drill hole recently sunk at Fort Yukon showed that the depth to bedrock at that place is 237 feet. The swift current of the river and the presence of such banks of incoherent alluvial material combine to produce much lateral erosion, which results in the constant attrition of older banks and the building up of new bars and islands from the detritus thus obtained.

The banks of the older islands rise in general to a height of 15 to 30 feet above the mean water level and are usually bordered by a dense growth of spruce timber, as much as 2 feet in diameter. Wherever the river impinges against such banks, particularly on the outside of large meanders, the banks are caved and fringed by overhanging moss and by fallen trees, which project into the channel, forming dangerous snags and sweepers. The inner sides of such meanders are usually sandy beaches, and in places where the river is wide newly formed sand spits and low islands occur in midstream. Some distance back from the water's edge willows and alders grow on these low-lying sandy shores; a little farther back, on higher ground, poplars are found; and spruce is confined largely to the still higher banks above described.

The Yukon Flats, irrespective of their mode of origin, are believed now to be in the stage of destruction rather than construction. Several considerations support this belief. Many of the higher banks are clearly above the level of ordinary inundation by high water and are therefore not subject to alluviation by overflow. The absolute elevation of such islands is therefore not being increased. Another factor contributing toward the destruction of the flats is that the Yukon River, below the lower end of the flats, is cutting bedrock and is thereby lowering its channel. This results in an increase in the relative elevation of the islands with respect to the mean river level, but the absolute elevation of the newly formed islands can only be increased by alluviation up to the present level of high-water overflows, and this overflow level itself is also being lowered by the reduction of the baselevel of erosion. Therefore, as the older islands are destroyed by lateral erosion, islands of equal elevation are not being re-created by any fluviatile processes now acting in the flats. In the meantime the newly formed islands are themselves subject to destruction by lateral erosion. The magnitude of this lateral erosion may be gaged by the fact that the town site of Fort Yukon has been cut back several hundred feet in the last 15 years. The net result of these processes must certainly be the entrenchment of the Yukon and the subsequent dissection of most of the bordering alluvial deposits.

Another significant feature characteristic of the Yukon Flats is the backhand drainage of the tributaries of the Yukon in this stretch. On the north side of the river the Chandalar, Hadweenzic, Hodzana, and Dall Rivers enter the Yukon flowing in a southeasterly direction, whereas the Yukon flows southwest. These courses can hardly be ascribed to the control of rock structure, as the major cleavage of the rocks in this part of the Yukon Valley strikes parallel to the Yukon River. Moreover, these same courses also hold in the lower valleys of these tributary streams where they flow across the soft unconsolidated deposits of the flats. South of the Yukon the upper courses of the tributary streams show similar backhand drainage, but here the prevailing structure of the country rock may more properly be considered a causative factor. On the other hand, the smaller tributaries that rise in the hills north of Victoria Creek also flow across the flats in a northeasterly direction toward the Yukon. This backhand drainage suggests that the courses of these tributary streams have been materially affected by local unwarping to the west; but whatever the cause, this is a significant geomorphic feature that has a bearing on the origin of the Yukon Flats.

The lower stretch of the Yukon Valley, here called "the Fort Hamlin-Rampart Canyon", may be considered a valley of geomorphic anomalies. Toward the lower end of the Yukon Flats the various channels of the Yukon coalesce, and about 8 miles below the mouth of the Dall River the Yukon is reunited into a single channel and enters a narrow rock-cut gorge near the old site of Fort Hamlin, which continues downstream to the wide alluvium-filled depression of the lower Ray River Valley. About 7 miles below Fort Hamlin a rock-cut terrace is visible, about 60 to 75 feet above the river level, but the gradient of this terrace is steeper than that of the Yukon, so that it approaches the level of the river downstream. A higher terrace, about 300 feet above the river level, is also visible in this stretch. About 12 miles below Fort Hamlin the low rock-cut terrace has about disappeared, and its place is taken by a silt bench, about 75 feet high, which continues downstream for some distance and then veers off into the valley of the Ray River. Below the Ray River the Yukon turns abruptly southeastward and enters another rock-cut gorge, through which it flows for 10 miles or more, emerging at the mouth of Hess Creek into a wide valley that appears to have been originally part of the Hess Creek Valley. The river follows this wide valley to a point about 35 miles (air-line distance) downstream, but at that point it leaves this depression and turns again into the hills to the north, flowing for about 15 miles through another rock-cut gorge, called the Ramparts. The steep walls of this gorge rise abruptly from the water's edge to a height of 1,000 feet or more, before they merge with the surrounding hills. The low broad depression, however, which marks an older course of the river, continues to the south of these hills, and the Yukon flows back into it below the Ramparts. This is as fine an example of lateral diversion of a river as could well be found.

River terraces are visible both below and above the Ramparts. Between the Ramparts and Tanana two rather well defined terraces are developed. One of these is about 50 feet above the river level, but farther back from the river, a higher terrace, about 300 to 400 feet above the river, also shows on both sides of the river. A low hard-rock erosion level, about 30 feet above mean water level, was also observed about 20 miles above Tanana and at some other places. Between Hess Creek and the Ramparts remnants of many terraces can be identified along the river, but these are particularly well preserved in the lower courses of some of the tributary streams. In the lower valley of Minook Creek, for example, three well-defined terraces and several less perfectly developed ones are present. The highest of these terraces is from 900 to 1,000 feet above the level of Minook Creek, another is about 500 feet above the creek level, and a third is 90 feet high. These terraces are closely tied up with the geomorphic history of the Yukon.

It appears from the foregoing description that the geomorphic history of the Fort Hamlin-Rampart Canyon is complex, and that this history is also the key to the origin of the Yukon Flats. Between Fort Hamlin and the Ray River the Yukon evidently occupies the site of an older valley carved by a much smaller stream. Between the Ray River and Hess Creek the Yukon has been superposed upon a rock divide, which was not the site of any transverse stream, though it may mark the site where two small streams headed against one another. Both above and below the Ray River the Yukon therefore flows in a canyon cutting bedrock, but the Ray River enters this canyon in a wide, open alluvium-filled valley, the bedrock basement of which is as low as the bed of the Yukon and probably lower. This anomaly of a mature valley opening into a youthful canyon requires explanation. The Ray River, like the other streams that enter Yukon Flats from the north, flows southeastward, making a backhand drainage with regard to the Yukon. North of the Fort Hamlin Canyon is a wide alluvium-filled depression through which the Ray River formerly continued its southeasterly course to discharge somewhere in the Yukon Flats. The present mouth of the Ray River represents merely a meander of the older stream, which has been laterally intersected by the Yukon in the carving of the youthful gorge that it now occupies.

Below the mouth of Hess Creek the Yukon occupies a wide valley that is quite unrelated to its valley above Hess Creek. This older and more mature valley is the downstream continuation of Hess Creek, which appears at some time to have communicated with the drainage of the Yukon Flats. Yet even in this lower valley the Yukon has been diverted from its course into the hills to the north, to form the present Ramparts. It is evident, therefore, that the Yukon River from Fort Hamlin to Tanana occupies several older drainage courses, which were formerly independent streams; and it is equally apparent that the Yukon has been literally diverted at several places from an old valley to a new channel in bedrock. Finally, it is by no means certain that a river as large as the Yukon has discharged southwestward from the flats since late Tertiary time, for the flats may at some time have been drained northeastward through the Porcupine Valley to the Arctic Ocean. If the southwestern drainage from the flats has been in existence since the Tertiary, the ancient outlet was probably through the lower part of the valley of Hess Creek.

Any explanation of the various geomorphic anomalies in this part of the Yukon Valley would require the formulation of several hypotheses regarding the geomorphology of this valley since Pliocene time, and the lack of precise mapping and other requisite information renders such an undertaking at present of doubtful value. Simple upwarping, however, or even complex crumpling alone in the Fort Hamlin-Rampart area will not explain the facts, although local downwarping, particularly in the Yukon Flats, is very likely to have been an effective accessory factor during certain stages in this complex history. Lateral diversion on a grand scale, probably accompanied by stream piracy, appears to have been one of the chief factors, and it is difficult to see how this could have obtained without a marked elevation of the regional baselevel of erosion; and this in turn points either to extensive alluviation of this part of the Yukon Valley or to impounding of the river. It remains a problem for the future to acquire more precise data and therewith reconstruct the long chain of events that must have taken place in the Yukon Valley between Fort Yukon and Tanana.

TANANA VALLEY

The surface configuration of the Tanana Valley is not so well known as that of the Yukon Valley. Many observers, including the writer, have visited that part of the valley between Fairbanks or Nenana and Tanana; but for the upper valley, between the international boundary and Fairbanks, the notes and writings of A. H. Brooks are the principal sources of information.

The Chisana River, which is the largest headwater tributary of the Tanana, originates in the glaciers of the Alaska Range, near the international boundary, and after flowing northeast for about 60 miles turns at right angles to the northwest, and the stream from that point to the Yukon is known as the Tanana River. The Tanana flows in a general N. 60° W. direction for an air-line distance of 375 miles to join the Yukon. The actual length of the river is much greater than this, for the course is far from direct, and the direction of flow likewise departs materially at many places from the general course. The course of the lower Tanana is particularly sinuous, owing to the fact that it swings northward for miles into the aggraded valleys of the tributary streams from that side. The best information at present available indicates that the Tanana River flows at an elevation of about 1,900 feet at the mouth of the Chisana and at 350 feet at Tanana. The gradient is therefore much greater than that of the Yukon from the boundary to Tanana, and the distance is much less, so that the average current is correspondingly swifter. The Chisana and all the larger tributaries of the Tanana are glacial streams that drain the north side of the Alaska Range, and the Tanana is a silt-laden, turbid stream from its source to its mouth.

All the large tributaries of the Tanana River enter from the south, and most of the 15 to 20 rivers that constitute this drainage are mud-laden glacial streams that drain the north flanks of the Alaska Range. The tributaries from the north, which drain the Yukon-Tanana region, are smaller, clear-water streams. The larger of these northern tributaries, named in order downstream, are the Goodpaster, Salcha, Chena, and Tolovana Rivers and Baker Creek. The Tolovana River has the largest drainage basin; the Salcha, Chena, and Goodpaster Rivers and Baker Creek follow in order of areas drained. One of the singularities of this drainage system is that no tributaries of any size enter the Tanana from the north for 150 miles below the boundary. This is due to the fact that within this stretch the Yukon-Tanana divide lies close to the Tanana River; for 50 miles it is nowhere more than 10 miles and at one place only 2 miles from the Tanana.

The Tanana River is usually considered to begin at the junction of Mirror Creek with the Chisana River, where the latter stream abruptly changes its course from northeast to northwest. At this point the small stream called Mirror Creek enters from the southeast through a wide depression that is obviously out of all proportion to the size of the stream that occupies it. A low alluvium-filled divide separates the head of Mirror Creek from the Snag River, a tributary of the White River. A considerably larger stream than Mirror Creek must have once flowed though this wide valley, but it is by no means certain whether the course of this ancient stream was northwest or southeast. This is merely one of the prominent examples of drainage changes which the Tanana has suffered, perhaps to as great a degree as the Yukon.

From the mouth of Mirror Creek downstream for 50 miles (air line), the Tanana flows in a broad alluvial lake-dotted lowland that ranges in width from 20 to 40 miles. Within this stretch the river flows slowly in a tortuous meandering course, with occasional riffles. At the mouth of the Tetling River, a small tributary from the south, the hills close in from the south, terminating this broad lowland, although the valley floor still remains 5 to 8 miles wide and the river retains its meandering course for another 35 miles. A short distance below Tanana Crossing the river ceases to meander, and for the next 30 miles it is a swift stream, confined to a single channel, with a few rapids. Cathedral and Tower Bluff Rapids occur in this stretch, the former in a constricted part of the valley and the latter farther downstream, where the river follows close along the north side of a valley floor about 10 miles wide. At Tower Bluff Rapids the Tanana splits into many shallow channels with shifting sand bars, and thence it continues as a swift braided stream to a point within 20 miles of the mouth of the Nenana River. From this point downstream to the Yukon the Tanana River flows for the most part in one or two channels, with a current of 4 to 6 miles an hour.

The Tanana differs from the Yukon in many respects. Instead of being a continuous canyonlike valley, the upper Tanana Valley is constricted only for several short stretches, as, for example, above the Robertson River and below the Johnson River. Brooks [20] has aptly described this part of the valley as a system of connecting basins, which possess the general outline of parallelograms. Below the Little Delta River, however, this basinlike topography gives place to a broad alluvial lowland, which continues with minor interruptions to the Yukon. Throughout its course the Tanana River hugs the north wall of its valley, and this in turn gives rise to other variations in its course. In the upper Tanana Valley the tributary streams from the north, though much aggraded in their lower courses, have relatively narrow valleys. The lower tributaries of the Tanana from the north, however, such as the Chena and Tolovana Rivers, are very wide and have also been extensively aggraded, and the Tanana has been diverted northward into these broad depressions to form great arcs, which lengthen its course materially. In the Tolovana arc the Tanana also meanders tortuously in arcs of

[20] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 450, 1900.

smaller amplitude. Most of these features are connected genetically, in that all of them are phases of the diversion of the Tanana against or toward its north bank. Brooks and later observers are in agreement that this diversion has been caused by the dumping of extensive deposits of glacial or glaciofluviatile material into the Tanana Valley by the great glacial streams that drain the north side of the Alaska Range. The Tanana has been unable to transport this material downstream and has therefore deeply aggraded its valley, and by thus raising the baselevel of erosion it has caused its tributaries from the north likewise to aggrade their lower valleys. The upstream extent of this aggradation in these northern tributaries, as shown on plate 1, is a proper measure of the magnitude of this process.

Another interesting and perhaps significant feature of the Tanana Valley is the fact that the larger tributaries from the south, such as the Delta, Nenana, and Kantishna Rivers, enter the main stream opposite bedrock points that extend from the north side of the valley southwestward into the Tanana Flats; and in so doing the Nenana and Kantishna have developed a backhand drainage in their lower courses. Still another feature of interest is the right-bank erosion in the lower courses of most of the tributaries of the Tanana River that enter from the north, as exemplified by the Healy, Goodpaster, Salcha, Chena, and Tolovana Rivers. The causes of these peculiar features of both northern and southern tributaries are not apparent to the writer, though it is possible that they may in some unexplained way be connected with the alluviation of the Tanana Valley by the glacial outwash deposits contributed from the south.

The Tanana has river terraces, but not enough work has yet been done to give many details of their character, height, and distribution. Brooks [21] has recorded the fact that terraces at an elevation of about 200 feet above the river are present in the upper Tanana Valley, and among others he mentions in particular 200-foot bluffs of stratified sand and silt at the mouths of Robertson and Johnson Rivers. These bluffs indicate the upper level of the alluvial filling that was laid down in the Tanana Valley as the glaciers were dissipated and also gives a measure of the amount of material which the Tanana has excavated from its valley in postglacial time. Brooks [22] also observed rock-cut benches in the Tanana Valley, and calls attention to a local baselevel about 600 feet lower than the surface of the old plateau, which he was able to trace for 60 miles. As the average elevation of the old plateau above the Tanana is about 2,000 feet, this level would therefore be about 1,400 feet above the present river.

[21] Brooks, A. H., op. cit., pp. 456–457.
[22] Idem, p. 453.

YUKON-TANANA PLATEAU

The region lying between the Yukon and Tanana Rivers, which is part of the great central plateau province of interior Alaska, is a country of diversified topography and drainage. This province has no continuous chains of mountains, similar to the various ranges of the Rocky Mountains, but instead is a rolling upland characterized by discontinuous groups of higher mountains that diversify an otherwise monotonous sky line produced by ridge crests of more or less uniform height. (See pl. 2.) The valleys likewise lack uniformity. Some of the headwater streams have narrow, canyonlike valleys; some flow in wide open valleys that are disproportionately large in comparison with the streams that now occupy them; and some flow across aggraded headwater plains. Similar diversity exists in their lower courses, for some of the lower valleys are broad aggraded lowlands and others are narrow gorges. This marked topographic diversity is the result of a long and complex geomorphic history, which dates back to the Tertiary period.

The principal highlands of the Yukon-Tanana region during late Tertiary time were in the eastern half of that region. The present highlands have been created principally by differential erosion of this older land surface, and as the ancient highlands were underlain by granitic rocks, which are resistant to erosion, the site of the ancient highlands has been perpetuated in the present highlands. As these granitic rocks are neither bedded nor in any marked degree gneissoid, structural lines are weak, and the trends of the ridges and the courses of the streams are less markedly unidirectional than farther west. Even in this eastern area, however, two prominent structural directions are evident in the courses of the streams. One of these trends is about N. 60° W., and the other N. 60° E. The former is parallel to the course of the Yukon from Eagle to Fort Yukon and also to the Tanana River from its head to its mouth; the latter is parallel to the course of the Yukon from Fort Yukon downstream to and beyond Tanana. Within the granitic rocks of the present highlands these trends are doubtless due to a system of multiple jointing.

In the western half of the Yukon-Tanana region the production of highland areas by differential erosion is still more pronounced, although it is evident here, as elsewhere in this region, that differential warping has also been a factor in shaping the present land surface. In this western area the structural line that strikes N. 60° E. becomes dominant, and the ridges and valleys have a marked trend in that direction. There is, however, an older structural line, striking more nearly true northeast, that is developed in the area occupied by the early Paleozoic rocks and also is reflected in the courses of the streams. These structural trends are interrupted at places by isolated buttes or mountain groups, which owe their existence to the intrusion of bodies of Tertiary granitic rocks and probably also to local uplift. As a result of these conditions, elongate ridges and isolated buttes have been developed in the western half of the Yukon-Tanana region. These highlands, composed of the harder and more resistant country rock, are much lower in elevation than the eastern highland areas, but the neighboring valleys are also more deeply eroded, and the local relief is therefore pronounced.

One of the curious effects of the structural control of the regional drainage is a marked interdigitation of drainage channels, such that headwater streams on opposite sides of a divide tend to flow parallel to one another but in opposite directions. As a result, major ridges are not consistently higher than minor divides. The Yukon-Tanana divide, for example, may follow a high prominent ridge for some miles and then turn abruptly to the north or south across a low saddle, or it may even follow a low timbered ridge for miles until that ridge joins another prominent ridge. This divide is therefore marked by intermittent jogs, which give it a very sinuous course and may cause the inexperienced traveler inadvertently to leave the major divide and descend into some deep valley. It is evident that many of the streams have courses inherited from an earlier land surface on which drainage channels were controlled more by original slopes than by structure and took shorter routes to the Yukon and Tanana Rivers. These ancient channels lie athwart the structural lines of the country, and later geomorphic evolution has been a struggle between these conflicting trends.

This ridge country, however, was not evolved in a single geomorphic cycle but instead was carved intermittently throughout several such cycles, during which the dynamic characteristics of the streams changed greatly. The complete drainage history of this region is a worthy problem for an expert geomorphologist. Enough is known of these drainage changes, however, to afford ample evidence at many places of deep valley alluviation, stream superposition, stream piracy, and reversal of drainage channels. This complex history has imparted to the valleys of this region many curious and seemingly conflicting characteristics, which add further diversity to the topography.

The Yukon Valley between Fort Hamlin and Tanana has already been cited as a valley of geomorphic anomalies. It is therefore to be expected that the tributaries of the Yukon within this stretch and the streams that head against them and flow to the Tanana should also show drainage anomalies to a marked degree. Minook Creek and most of the other southern tributaries of the Yukon between Minook

Creek and Tanana flow in narrow canyonlike valleys to the zone where they join either the Yukon itself or the old Yukon lowland. Their headwaters are markedly precipitous. Most of the tributaries of the Tanana that head against them, however, have wide open valleys, with incompetent streams of relatively low gradient, and open headwater basins that in places grade imperceptibly into the enclosing hills. Low gaps are also prevalent where ancient watercourses once existed, as, for example, between the heads of Stevens Creek and the North Fork of Baker Creek. A still more striking example is the broad lowland between the heads of Cache and Baker Creeks, where the ancient channel of some large stream was once located. A third lowland between adjacent groups of hills is the one now occupied by Niggerhead and Uncle Sam Creeks. These lowlands serve to break up the extreme west end of the Yukon-Tanana upland into isolated small groups of hills, but here again differential erosion has been a powerful accessory factor, for such hills are grouped about intrusive bodies of granitic rocks or rocks of other lithologic types that have a relatively high resistance to erosion.

A little east of the Rampart district conditions again change. Hess Creek flows in a broad valley throughout its course, and its headwater tributaries, unlike the tributaries of the Yukon farther west, head in open alluvial basins quite similar to those of the southward-flowing tributaries of the Tanana. The upper valley of Fish Creek, one of the large tributaries of Hess Creek, opens in this way directly into the Yukon Flats, and there are good reasons for the belief that a major drainage channel once connected the valley of Hess Creek with the flats through this gap, although the direction of flow of this ancient stream is not now known.

South of the headwaters of Hess Creek are the headwaters of the Tolovana River, which flows to the Tanana. The underground gold placer mining operations in Livengood Creek, one of the tributaries of the Tolovana, have afforded an exceptional opportunity to see not only the alluvial surface but also the bedrock configuration of a typical headwater stream of the Tolovana system. Studies by the writer [23] in this area have shown a complex drainage history, one of the significant features of which is an example of repeated stream piracy, whereby Livengood Creek captured some of the headwater drainage of the South Fork of Hess Creek, and in a later geomorphic cycle the South Fork recaptured a considerable part of the drainage of which it had been robbed. Other alluvial divides between the headwater tributaries of Hess Creek and the Tolovana River suggest

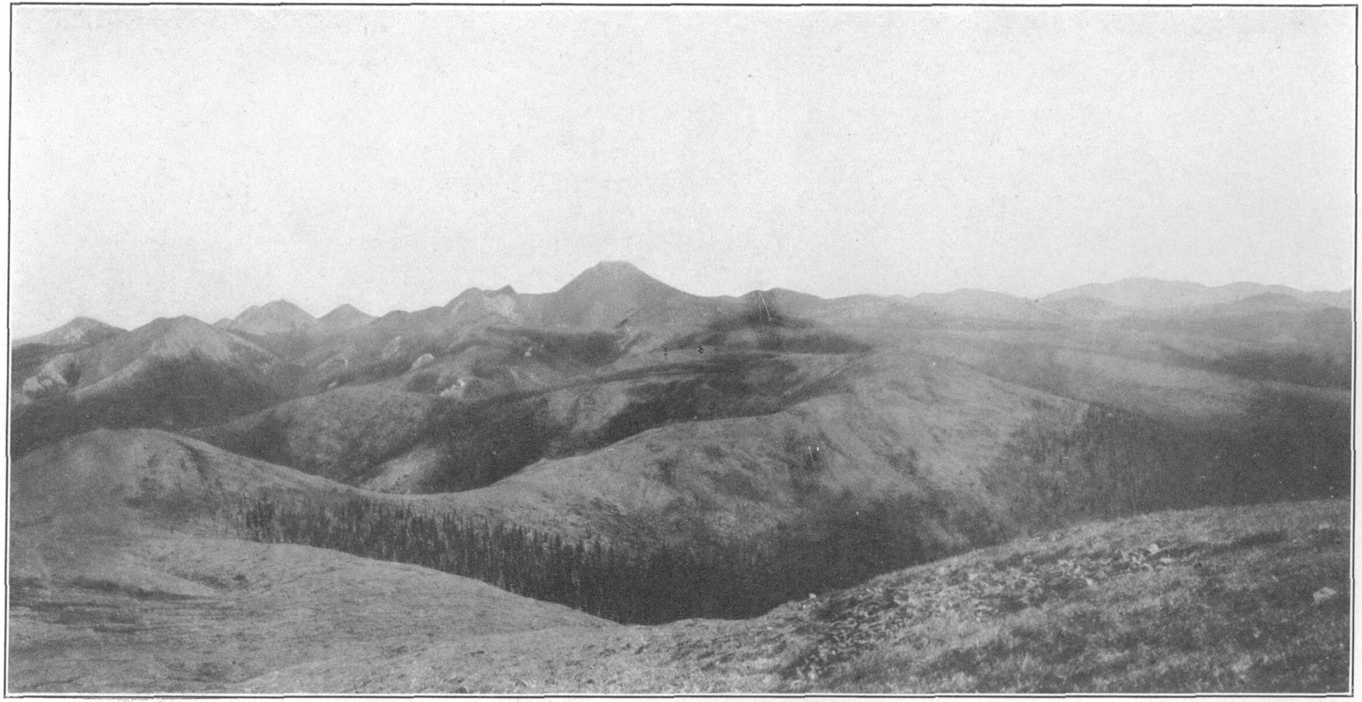
[23] Mertie, J. B., Jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 260–262, 1918.

that equally significant adjustments of drainage have taken place, but lack of underground data prevents a convincing demonstration. Such old water gaps constitute another of the drainage anomalies that characterize the topography of this region.

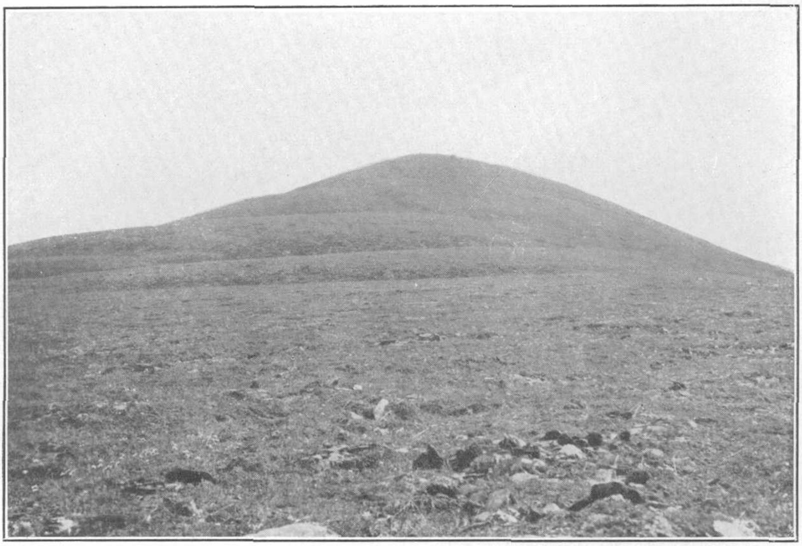
The lower Tolovana Valley is perhaps the most striking of the lowland features of this region. Debouching from the hills, the Tolovana and its parallel tributary, the Tatalina River, flow into valleys 5 miles or more in width, through which they pursue a tortuous meandering course for many miles. The Tolovana is a much larger stream than the Tatalina, but both are small in proportion to the size of the valleys that contain them. The valleys were surely carved by ancient streams that possessed both higher gradients and a larger supply of water than the present streams. One of the characteristic features of these streams in this portion of their courses is the presence of log jams. One great log jam in the Tolovana Valley has dammed the river for many miles upstream, and below this jam the bed of the river for miles is a mass of interlaced logs, from which many snags project upward to the surface of the water. At most places a 12-foot pole passed between logs will find no bottom.

A little farther downstream the Tolovana swings abruptly westward into the aggraded lower valley of Uncle Sam Creek and, returning to its own valley, is joined by the Chatanika River, into which the Tatalina empties a few miles upstream. From the mouth of the Chatanika to the Tanana the Tolovana River is a sluggish amber-colored stream that meanders even more tortuously than farther upstream, though in arcs of larger amplitude. The water is confined to a single very deep channel, and at normal stages of water the current is so slight that in many places it is imperceptible. In this stretch the valley opens to a maximum width of 25 miles and consists of a timbered silt plain, dotted with lakes, swamps, and marshes. Brooks crossed this swampy lowland with a pack train in the late fall of 1902, but earlier in the summer its passage with horses could be accomplished only with great difficulty and delay. The aggradation of this great silt plain by the Tolovana and its tributaries has been caused, as previously stated, by the elevation of the regional baselevel of erosion, due to extensive alluviation of the Tanana Valley with glaciofluviatile deposits. The great width of this plain, however, is another of the striking and unexplained topographic anomalies of the region.

Northeast of the Tolovana Basin is the valley of Beaver Creek, which drains into the Yukon Flats. The drainage of Beaver Creek is particularly anomalous. Heading against the North Fork of Preacher Creek, Beaver Creek flows in a general southwesterly direction for 35 miles (air line) and then turns abruptly around the

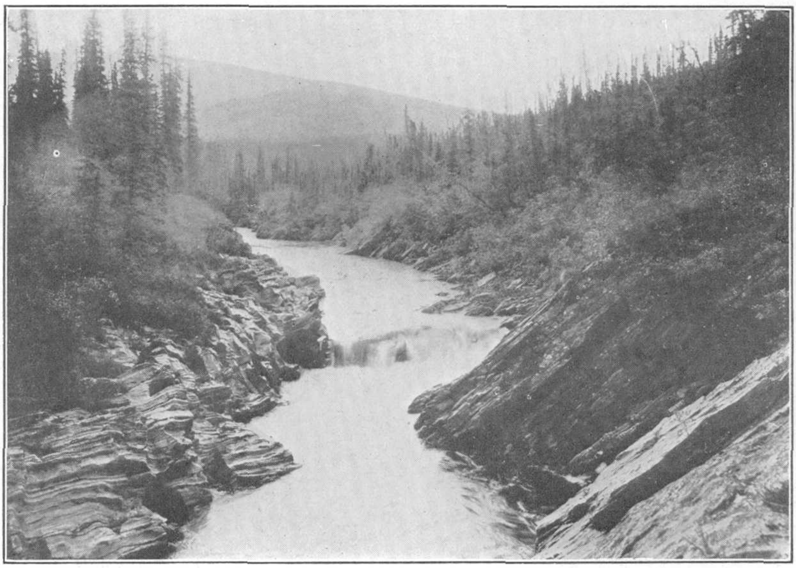


MOUNT SCHWATKA AND THE RIDGE COUNTRY NORTH OF VICTORIA CREEK.



A. HIGH TERRACES AT HEAD OF WOODCHOPPER CREEK.

Elevation 4,000 feet above sea level.



B. FALLS IN SOUTH FORK OF BIRCH CREEK.

Shows narrow, canyonlike stretch where stream flows across the cleavage of the Birch Creek schist.

southwest end of the White Mountains and flows in a northeasterly direction for 50 miles to the Yukon Flats. Its headwater tributaries are only about 10 miles from a point 70 miles farther downstream. High terraces are present in the valleys of both Beaver Creek and its tributary Fossil Creek. The White Mountains, which lie between Fossil and Beaver Creeks, are transected by two narrow gaps, of which the northern one is a wind gap through which Fossil Creek formerly drained into Beaver Creek. The southern gap now carries the water of Fossil Creek into Beaver Creek, but another small tributary of Beaver Creek is cutting back from the southeast and will ultimately rob the drainage of Fossil Creek and make of this southern water gap another wind gap. The complete drainage history of Fossil and Beaver Creeks is not known, but the recognized changes in drainage illustrate well how ancient consequent stream courses are now being adjusted to structural lines, in conformity with the requirements of differential erosion.

East of Beaver Creek are the valleys of Preacher and Birch Creeks. In its upper part, Preacher Creek shows no specially anomalous features, but in its lower valley it opens into a wide depression that follows around the south side of the Crazy Mountains and communicates on both sides of that range with the Yukon Flats. This lowland also extends southeastward for another 25 miles but has no recognizable outlet in that direction to the Yukon Flats. Preacher Creek, however, follows close to the hills along the west end of this lowland and continues northeastward through a gap 2 or 3 miles wide toward the Yukon. This gap which divides the Crazy Mountains on the east from another group of hills on the west that is the geomorphic and geologic continuation of the Crazy Mountains, constitutes another example of an ancient stream course that was established across the strike of the hard-rock formations. Beyond the hills both Preacher and Beaver Creeks are incised in a border terrane of gravel that extends for some miles out in the flats. The upper valley of Birch Creek is generally similar to that of Preacher Creek but shows to a more marked degree the contrast between the wide valley floors in these stretches where the stream was parallel to the cleavage of the Birch Creek schist and the narrow canyonlike stretches where it flows across the strike of this cleavage. Plate 3, *B*, shows one of the narrow stretches in the South Fork. After leaving the hills, however, Birch Creek follows a crooked, meandering course across the great lowland above described and continues around the east and north sides of the Crazy Mountains out into the Yukon Flats proper.

This great lowland that lies south of the Crazy Mountains trends about N. 60° W. and has a total length of 60 miles. It parallels the strike of the dominant structure of the country rock but has two wide outlets to the Yukon Flats, one on each side of the Crazy Mountains, occupied now by Preacher and Birch Creeks. This lowland, however, is not a late incision comparable with the strike valley of Fossil Creek, for it is now occupied by several sluggish streams, which are incompetent to have carved such a valley. The original sculpturing of this lowland may have been due to differential erosion, but the process was an ancient one that long antedated the recent valleys now being produced by differential erosion. The general appearance of this lowland suggests that it was an ancient course of some large master stream, perhaps the Yukon itself. This area in the vicinity of the Crazy Mountains is believed to be one of the critical localities for future geomorphic studies on the genesis of the Yukon Flats.

The Charley River, the next large stream southeast of Birch Creek, has fewer abnormal drainage features than the other main tributaries of the Yukon so far enumerated. Unlike those streams, it has a basin excavated largely within the area of a great batholith of granitic rocks. Its principal tributaries, which enter in the upper valley, tend to follow structural lines in the granitic rocks, and it is probable that the main valley also follows a complementary joint structure. The Charley River, however, like the other streams that enter the Yukon above the flats, has narrow canyonlike stretches, which appear to indicate a process of adjustment to a lower baselevel of erosion than formerly existed. Some of the highest country in the Yukon-Tanana region is found at the head of the Charley River, and here, as in other places in the region where the ridges exceed 5,000 feet in elevation, local alpine glaciation has taken place. Moraine Creek, a headwater tributary of Crescent Creek, occupies a U-shaped glacial valley and has a morainal deposit at its lower end.

The Seventymile River, which heads against the lower valley of the Charley River, is a typical strike valley, and this feature alone is adequate to account for its backhand drainage to the Yukon River. The upper valley is canyonlike, but the whole valley is deeply incised in the hills, though the floor broadens considerably in the lower valley. One characteristic of the Seventymile River worthy of special mention is a very well developed system of terraces. Just above the falls a low gravel bench about 12 feet high is present in the north side of the valley, and 4 or 5 feet above this is another gravel terrace that stretches backward to the valley wall. On the south side of the valley similar low gravel benches are also present, which are succeeded upward by two prominent terraces 125 and 500 feet above the level of the stream. The 125-foot terrace is very persistent and follows down the south side of the Seventymile River to the point where this valley opens out into the Yukon Valley, but there it veers eastward toward the south end of Calico Bluff. An alluvial depression between Calico Bluff and the hills to the south shows the old course of the Seventymile River to the Yukon. The 500-foot terrace is also very prominent and persistent. On the headwaters of the southern tributaries of the Seventymile River very well developed rock-cut terraces are found on the ridges at an elevation of about 2,500 feet above the river. According to the description given by Prindle,[24] these are flat-topped level benches, in places several acres in extent, which occur at elevations differing from one another by a few feet to about 50 feet. The character and structural attitude of the country rock appear to have exerted little or no controlling influence in the formation of these high terraces. Similar high terraces occur at other localities in the Yukon-Tanana region, one of which, along the divide between Woodchopper Creek and the South Fork of Birch Creek, is illustrated by plate 3, *A*. The winter snow often lies at the up-slope edges of these benches until late in the summer. It is possible that some of these forms are of fluviatile origin, but most of them are believed to be the result of certain leveling processes that are effective in high altitudes and high latitudes and are therefore particularly characteristic of the development of sub-Arctic topography.

The Fortymile River differs in several respects from any of the tributaries of the Yukon so far mentioned. To one not acquainted with the country the nomenclature of the tributaries of Fortymile River is very confusing. The two main branches of the river are its North and South Forks. About 21 miles above the main confluence the North Fork receives a large tributary from the west, which is called the "Middle Fork." The South Fork, on the other hand, is made up of Mosquito and Dennison Forks, and the term "South Fork" is applied only to that stretch below the junction of these two forks. Dennison Fork has two main tributaries called "forks", and local usage has therefore produced such undesirable names as "East Fork of Dennison Fork of South Fork of the Fortymile River." In general, as few of these phrases are used in this report as clarity of expression will permit, but at best the nomenclature is difficult to understand and utilize.

The main Fortymile River, the South Fork, and the North Fork for 10 or 15 miles above the main confluence are meandering streams that are deeply incised in canyons and cut bedrock on most of their riffles. Upstream from these meandering courses the tributaries are straighter and swifter but are still incised in deep valleys. Above these stretches, particularly in the tributaries that

[24] Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: U. S. Geol. Survey Bull. 251, p. 20, 1905.

head against the Tanana River, these streams are sluggish and flow across aggraded headwater plains. The upper valleys of Dennison Fork and its tributaries are specially good examples of such headwater lowlands. The old erosion surface that once connected with these lowland areas continues downstream into the lower parts of the valley as a high terrace, the slope of which is much less than the present stream gradients in the lower valleys, so that it gradually increases in height above the river downstream. This old surface now forms the top of the canyon in the main Fortymile River, at 500 to 600 feet above the level of the river. This feature is illustrated in plate 4, *A*. Remnants of still higher terraces and a well-marked system of lower terraces are also visible in this valley. The upper valleys of Dennison Fork and its tributaries are alluvial plains to the extreme headwaters, and these streams for the most part head in wide swampy divides. The distance from these headwater divides to the Tanana, as previously pointed out, is very short; but the tributaries of the Tanana, heading against these same saddles, have narrow precipitous headwater valleys.

The lower valley of the Fortymile River is easy to explain. The river consists essentially of entrenched meanders, inherited from an ancient valley that existed prior to the late regional uplift. This part of the valley is an excellent example of the rejuvenation of a stream valley that once was in adjustment to a mature topography. The upper valley of Dennison Fork, however, is distinctly anomalous, for it is surrounded by high mountains and yet has no steepened headwater gradients such as would be expected even in an area of mature topography. Moreover, this headwater drainage is entirely out of adjustment with the headwater tributaries of the Tanana, which, with their high gradients, are doubtless now in the process of extending their headwater valley to the north. The headwater gradients of the Dennison Fork must have been active mountain streams at the time when this drainage was extended southward so close to the Tanana; and conversely the headwater tributaries of the Tanana are likely to have been less actively eroding streams, in order to have permitted the Dennison Fork to extend its headwater drainage so far south. In an earlier publication [25] the writer has proposed, as an explanation of this anomalous headwater drainage, a hypothesis of differential warping, whereby a belt at the lower end of these flats was uplifted, thus locally raising the baselevel of erosion and causing extensive headwater aggradation in the southern tributaries of Dennison, Mosquito, and Middle Forks. This belt of upwarping appears to trend parallel to the general course of the

[25] Mertie, J. B., Jr., A geologic reconnaissance of the Dennison Fork district, Alaska: U. S. Geol. Survey Bull. 827, pp. 30–31, 1931.

Yukon and Tanana Rivers but does not extend northwestward into the valleys of the Salcha and Chena Rivers, for the streams show no responsive geomorphic features. The broader problem of the contemporaneous histories of the Yukon and Tanana Valleys still remains to be studied, in order to explain the original extension of the Yukon-Tanana divide southward to its present proximity to the Tanana River.

The western and northern tributaries of the Fortymile River show none of the anomalous features of the southern tributaries, but instead have valleys that are approximately in adjustment with the old erosion surface of the country. In general the valley floors are broader than that of the lower Fortymile, and it is apparent that the effects of the late rejuvenation have not yet progressed upstream into these upper valleys.

The Salcha and Chena Rivers and the smaller tributaries of the Tanana that lie between the Salcha and the headwaters of Dennison Fork require no special description in this paper, although they possess features of interest that should be discussed in a more detailed account. Their lower valleys are deeply aggraded, but upstream from points where the 1,000-foot contour crosses their valleys these streams in general show no very strikingly anomalous features.

The ridge tops in the Yukon-Tanana region rise to elevations of 2,000 to 5,000 feet, but the usual ridge level is from 2,500 to 3,000 feet. Within any one district there seems to be a rather uniform level of these crest lines, but if the tops of all the main ridges in the Yukon-Tanana region were joined, the resulting geometric surface would be a flat dome, highest in the east-central part and sloping gently therefrom in all directions, but sloping most toward the confluence of the Yukon and Tanana Rivers. Carving in this dome the ancient valleys that lie above the V-shaped drainage of recent date would produce a greatly diversified surface, characterized by rather open depressions of moderate depth. This ancient land surface, the predecessor of the present surface, has been classified by some of the earlier writers as an old peneplain. The ridge-top surface alone, without reference to its irregularities, might indeed be considered relatively featureless, but even this would show a variation in absolute elevation of 3,000 feet from the central areas to the two rivers. However, if any of the ancient erosion surfaces had any claim to be regarded as a peneplain, this old ridge-top surface was the one. Nevertheless, when the irregularities of this upper surface are also considered, it is evident that this classification is not altogether proper, for the ancient surface thus reconstructed was greatly diversified, and in no way approached a baselevel. Looking backward, therefore, as far as the relatively complete land surface warrants, we must conclude that this ancient surface was that of a mature but by no means old topography. Recent stream rejuvenation, together with local upwarping, has added the youthful valleys that are now incised in this older terrane.

There is another process, however, which will have to be carefully evaluated in future geomorphic studies. The ridge tops in many parts of the Yukon-Tanana region are abnormally flat, and many of the spurs leading laterally from the ridges are also flat-topped, as well as extraordinarily long. It is now well known that much of this abnormal flatness of crest lines and elongation of spurs is due to those same processes that have previously been mentioned in connection with the high terraces. Nivation, altiplanation, and related processes have undoubtedly produced many of these elevated plane surfaces, and other processes related to solifluction are equally certain to have been powerful factors in forming the long, smooth, gently sloping spurs. Little study of these processes has yet been made in Alaska, but in the Scandinavian countries, where similar forms exist, considerable literature on this topic has accumulated.

The present relief in the Yukon-Tanana region is marked. Tanana, the lowest point in the region, has an elevation above sea level of about 350 feet, and several mountains in the east-central part of the region rise to elevations in excess of 6,000 feet. The lower valleys in the vicinity of these high mountains, however, have elevations near 3,000 feet so that the local relief is not much more than 3,000 feet. In the western part of the region the highest mountains are lower but the valleys are corresponding lower, so that the maximum local relief still approximates 3,000 feet. Many of the higher mountains (higher in a relative sense) have received local names, as shown on the accompanying topographic map. Others, particularly in the more rugged and less frequented parts, have not been named. The highest mountain in this region is a peak that projects above the ridge separating the Healy River from the South Fork of the Goodpaster River and rises to an elevation of 6,515 feet. This mountain has received no local name.

SETTLEMENTS AND POPULATION

The principal settlements of the Yukon-Tanana region are located along the Yukon and Tanana Rivers and include Fairbanks, Nenana, Fort Yukon, Tanana, Eagle, Circle, Hot Springs, and Rampart. Fairbanks, Nenana, and Eagle are incorporated towns. A large part of the population of these settlements consists of white people, but some of them, particularly Fort Yukon, Tanana, and Rampart, have also a considerable native population. There are also many smaller settlements, some of which are essentially mining camps composed largely of white people, while others are primarily Indian villages. In the larger towns Territorial schools are maintained for the white children, and the Federal Government provides schools for the native children. Among the outlying mining camps may be mentioned Livengood, Jack Wade, and Chicken. There are also a number of mining camps close to Fairbanks, such as Cleary, Meehan, and Berry, which are now losing their identity because automotive transportation is rapidly making them suburbs of Fairbanks. Among the more prominent settlements that are inhabited mainly by Indians are Tanana Crossing, Eagle Village, Stephens, and Mansfield. In all, about 25 post offices are maintained in this region.

Fairbanks, the largest town in this region, is located on the flood plain of the Tanana River, along one of its sloughs, and is the center of mining, commercial, and industrial activity for the country. It was founded in 1905 as a mining camp but has now become a modern town, with public schools and a college, churches, a hospital, a national bank, stores, telephones, an electric power plant, a theater, newspapers, and a large aviation field. It is also the northern terminus of the Alaska Railroad and the center from which radiate roads, trails, and water and aviation routes to other parts of central, western, and northern Alaska. The University of Alaska (formerly the Alaska Agricultural College and School of Mines) is located at College, one of the smaller settlements close to Fairbanks. According to the Fifteenth Census, Fairbanks proper had in 1930 a population of 2,101, but at least 1,000 more people are distributed in nearby parts of the Fairbanks district, including those at Garden City and College and in the mining camps south of the Chatanika River.

Nenana and Tanana are essentially junction points in the transportation system of interior Alaska. Nenana is on the south bank of the Tanana River, just above the mouth of the Nenana River. The Alaska Railroad crosses the Tanana River at Nenana, and this point has therefore become the head of navigation for river steamboats, though before the railroad was built such boats plied upstream as far as Fairbanks. Tanana, on the north bank of the Yukon River opposite the mouth of the Tanana River, is the changing point for upper and lower Yukon River traffic, as different steamboat companies operate on the Yukon above and below this point. According to the Fifteenth Census, the population of Nenana in 1930 was 291 and of Tanana 185, but adjoining Tanana is a native village and mission containing an additional population of 96.

Fort Yukon is the center of the fur industry of interior Alaska. It is situated in the middle of the Yukon Flats, on the north bank of the Yukon River just above the mouth of the Porcupine River.

One of the points of interest at Fort Yukon is the Hudson Stuck Memorial Hospital, where the native people of the upper Yukon are cared for in sickness and are also taught the rudiments of sanitation and hygiene, as well as the fundamental principles of Christianity. This is the only well-equipped hospital in the upper Yukon Valley of Alaska and is therefore a great asset to both the white and the native people of the region. The population of Fort Yukon in 1930 is given in the Fifteenth Census as 304.

Eagle, Circle, Hot Springs, and Rampart are mining towns, with populations respectively in 1930 of 78, 50, 45, and 103. Eagle is a picturesque little settlement on the southwest bank of the Yukon River a few miles below the international boundary. It is built upon a terrace that stands well above the high-water level of the Yukon, even at times of severe flooding after the spring break-up, and has the best town site on the upper river. Eagle is the supply point for Fortymile, Seventymile, and American Creek mining districts and is also the port of entry in coming downstream from Yukon Territory.

Circle is on the southwest bank of the Yukon River at the east end of the Yukon Flats and is built upon the great flood plain of the river. It is the supply point for the Circle mining district and, being located at the north end of the Steese Highway, is a junction point for passengers coming up or down the Yukon River who wish to go by automobile to Fairbanks. About 35 miles in an air line southwest of Circle are the Circle Hot Springs, where a small watering place has been developed.

Hot Springs is built along a slough of the Tanana River, a few miles below the mouth of Baker Creek. It is the supply point for the Eureka and Tofty mining districts, which lie respectively to the northwest and northeast of the town. The Manley Hot Springs are located at this place but have not yet been successfully developed for visitors.

Rampart is on the southeast bank of the Yukon River a short distance below the mouth of Hess Creek. It is the supply point for the Rampart mining district, which lies to the south. Just across the river from Rampart the Department of Agriculture formerly maintained an experiment station, but this has been abandoned for 10 years.

TRANSPORTATION AND COMMUNICATION

Boats, steam trains, automobiles, airplanes, horses, and dogs are utilized for the transportation of people, freight, and mail in the Yukon-Tanana region. The Alaska Railroad, which connects Fairbanks with the south coast of Alaska, was completed in 1922 and since that time has been the quickest and most reliable route of entry into the southern part of this country. The trip from the coast takes two days and may be made by passengers both in summer and winter. The Alaska Railroad also maintains a reliable freight service and is equipped to handle all kinds of commodities, including perishable goods. Another route of entry is by automobile from Valdez to Fairbanks over the Richardson Highway, but this road is open only during the summer. A third route, which is the best for passengers and freight destined to points along the upper Yukon River, is by way of the White Pass & Yukon Route. This consists of a steam railroad from Skagway across the Coast Range to Whitehorse, which is the head of navigation on the Yukon River; and a steamboat service from Whitehorse to Nenana by way of the Yukon and Tanana Rivers. The steamboat service on this route is maintained from the 1st of June until the 1st of October. For more rapid transit, airplane service from the coastal cities to Fairbanks can also now be obtained, both in summer and in winter.

The navigable streams of this region are the natural routes for local travel in summer, and the stream valleys are also much used by horse and dog sleds in winter. Points on the Yukon River between Tanana and the boundary are served by one steamboat, operated by the American Yukon Navigation Co. on a reliable fortnightly schedule. This boat also plies up the Tanana River to Nenana, but most of the local traffic on the Tanana is handled by a steamboat operated by the Alaska Railroad, which also serves the settlements along the Yukon River below Tanana. Motor launches are also extensively used, both on the Yukon and Tanana Rivers and on their navigable tributaries; and upstream from the upper limit of navigation for power boats poling boats are used to a considerable extent. In winter the Yukon River is an arterial highway for horse and dog teams, but the Tanana is a treacherous stream in winter, and sled travel sticks mainly to the north shore, between Nenana and Tanana. Many trails from the two rivers inland to mining camps and trappers' cabins are also utilized in winter, mainly for the transportation of freight and mail. The longest of these is the 90-mile trail from Eagle to Chicken.

The Richardson Highway, from Valdez to Fairbanks, crosses the Tanana River at the mouth of the Delta River and from that point to Fairbanks serves as a local road for those who wish to enter the lower valleys of the Chena and Salcha Rivers or the ridge country on either side of those streams. From Fairbanks good automobile roads radiate to the surrounding mining camps on Ester, Goldstream, Cleary, and Fairbanks Creeks and the Chatanika River; and these are supplemented by wagon and tractor roads that lead to less frequented localities. An automobile road known as the Steese Highway has also been built from Fairbanks to Circle, and this serves both for local and through traffic; and a 6-mile automobile road has also been built to connect the Steese Highway with the Circle Hot Springs. Another road now connects Fairbanks with Livengood. The only other road of any consequence in this region is a 30-mile wagon road from Hot Springs to the Eureka mining district, which has recently been improved so that it is now suitable for travel by automobiles. Regular passenger schedules are maintained by automobiles in the summer on the Richardson and Steese Highways.

Many summer pack trails and winter sled roads have been built in this region, and some of these, for short distances from the river, have now been made into wagon roads. Thus, in good weather wagons may traverse the Eagle-Chicken road for 30 miles south from Eagle; a short road has been built from Nation, on the Yukon, to the Fourth of July Creek camp; the trail leading from Rampart up Minook Creek can be used by wagons for some distance; and a wagon road connects the lower end of the Hot Spring slough with Tofty. Considering the area of this region, however, established summer and winter routes of travel by land are as yet very meager.

The difficulties attendant on travel in this country have greatly favored the development of airplane routes, and at the present time many of the outlying towns and mining camps have aviation fields, so that rapid transit can be had when the occasion warrants it. Much of the mail is also now being carried by airplanes, though locally it must still be distributed by the older methods. Fairbanks, with its large aviation field, is the regional center of aviation, and several airplane companies offer service to all parts of Alaska. Outlying communities have been quick to avail themselves of these facilities, and there are now 16 regular landing fields in the Yukon-Tanana region.[26]

In the early days of the development of interior Alaska Fairbanks was connected with the south coast by a telegraph line, and the principal settlements on the Yukon and Tanana Rivers were likewise joined by telegraph lines. Most of these lines were later abandoned, but in their places radio stations were installed by the United States Signal Corps at Fairbanks, Tanana, Fort Yukon, Circle, Eagle, Hot Springs, and Livengood. Until recently these stations handled most of the long-distance and point-to-point communication, but in the fall of 1933 most of these stations, except Fairbanks, were abandoned, and commercial radiophones were introduced. Telegraph lines are still utilized, however, for communication between points along the line of the Alaska Railroad, as, for example, between Fairbanks and Nenana. For local communication telephones are much used, not only at Fairbanks but also at other places, as, for example, in the Livengood, Rampart, Hot Springs, and Circle mining districts.

[26] Taylor, I. P. (chief engineer, Alaska Road Commission), personal communication.

CLIMATE

The Yukon-Tanana region is part of the great interior province of Alaska and therefore has a typically sub-Arctic climate. The winters are long and cold, with short days in midwinter; and the summers are short but relatively warm and are characterized by nearly continuous daylight for 3 months in midsummer. Except in a small area near Fort Yukon, the sun is never below the true horizon at noon, even in the shortest winter days, and in the longest days of summer it is visible for nearly 24 hours. Unlike the Tropics, this region at sunset has a horizon that makes a small angle with the apparent path of the sun, which is consequently near the horizon long after sunset. This results in long hours of twilight, both in winter and summer.

Climatic records have been kept by the United States Weather Bureau at several localities in this region during the last 30 years or more, but only at Eagle, Fort Yukon, Rampart, Tanana, and Fairbanks are the records fairly complete. The mean temperature, precipitation, and snowfall for these five stations to the end of 1930 have been computed from the records of the Weather Bureau and are presented in the following tables:

Mean temperature in Yukon-Tanana region (°F.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Eagle	−13.5	−3.7	7.5	26.7	44.7	56.3	59.2	53.4	42.1	25.2	3.8	−10.4	24.3
Fort Yukon	−20.5	−13.6	−1.1	20.0	43.7	58.1	60.8	55.5	42.3	20.6	−6.1	−20.9	19.9
Rampart	−16.5	−7.7	4.1	22.9	44.9	57.8	59.7	55.0	41.2	21.7	−.9	−11.7	22.5
Tanana	−12.5	−4.7	5.4	23.5	44.5	57.1	58.5	53.5	40.8	23.0	.1	−10.5	23.2
Fairbanks	−10.8	−.1	10.2	28.5	47.3	58.5	60.3	55.1	43.5	26.4	3.3	−6.2	26.3
Mean	−14.8	−6.0	5.2	24.3	45.0	57.6	59.7	54.5	42.0	23.4	0	−11.9	23.2

Average precipitation in Yukon-Tanana region (inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Eagle	0.46	0.35	0.41	0.42	0.86	1.51	1.79	1.97	1.30	0.80	0.52	0.47	10.86
Fort Yukon	.42	.46	.34	.33	.52	.88	1.10	1.16	.69	.68	.32	.36	7.26
Rampart	.63	.63	.47	.22	.48	1.03	1.40	1.56	1.38	.97	.54	.64	9.95
Tanana	.72	.74	.69	.27	.82	1.10	2.42	2.34	1.47	1.08	.64	.69	12.98
Fairbanks	.81	.47	.79	.30	.57	1.42	1.88	1.92	1.47	.75	.66	.62	11.66
Mean	.61	.53	.54	.31	.65	1.19	1.72	1.79	1.26	.86	.54	.56	10.56

Average snowfall in Yukon-Tanana region (inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Eagle	8.5	5.2	5.6	3.6	0.5	0	0	0.2	1.6	7.8	8.9	10.3	52.2
Fort Yukon	7.2	7.4	5.5	2.2	.1	0	0	.1	1.3	7.8	6.4	5.3	43.3
Rampart	8.5	8.0	6.0	4.0	.3	0	0	0	1.2	8.2	6.8	7.2	50.2
Tanana	9.0	9.7	9.1	2.9	.6	0	0	0	1.0	6.8	5.1	9.4	53.6
Fairbanks	9.4	6.2	8.3	2.8	.4	0	0	.1	.8	5.5	6.3	7.8	47.6
Mean	8.5	7.3	6.9	3.1	.4	0	0	.1	1.2	7.2	6.7	8.0	49.4

Some interesting facts are shown by these records. In figure 2 the mean temperature, precipitation, and snowfall for the whole region have been plotted. From this diagram it will be observed

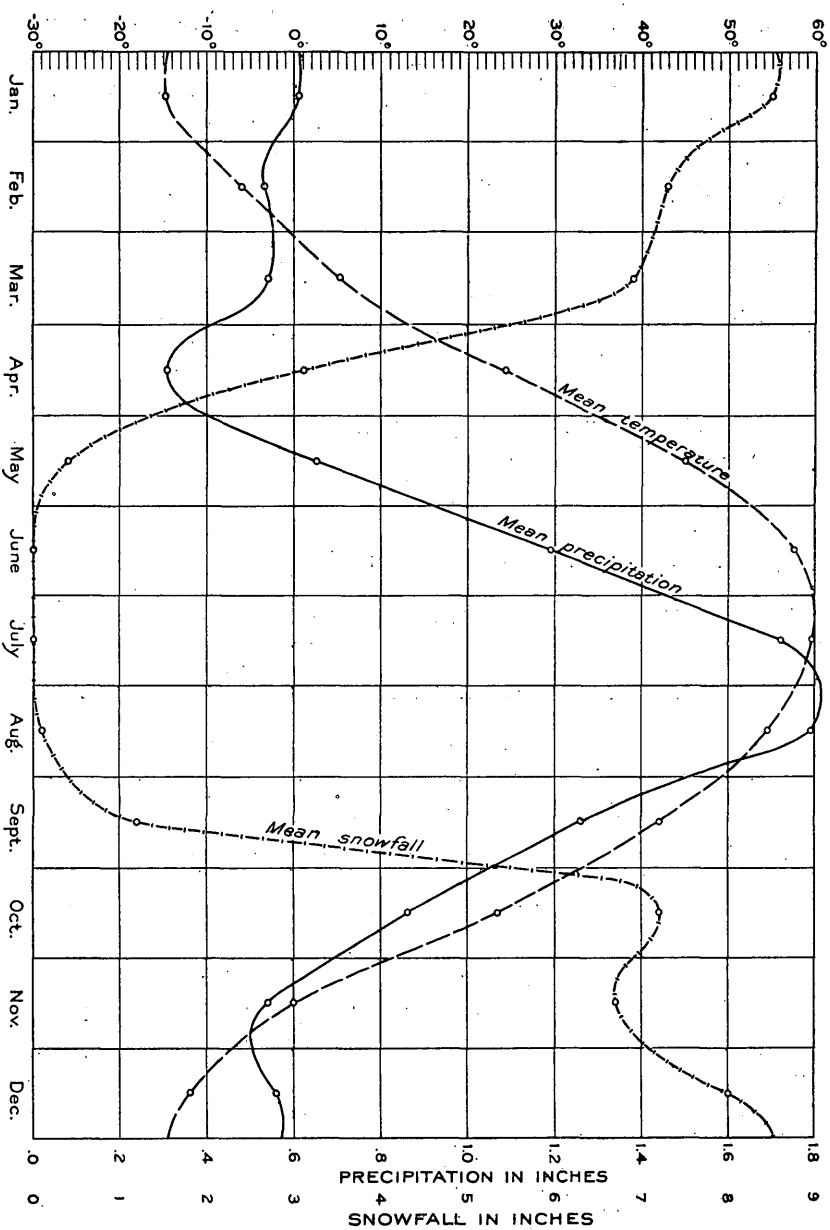


FIGURE 2.—Mean temperature, precipitation, and snowfall in the Yukon-Tanana region.

that the warmest weather occurs in the early part of July and the coldest in the middle of January. The mean precipitation is about 10½ inches, which classifies the region as semiarid, and most of this falls as rain during the summer, with a maximum in early August. The late summer may, therefore, be described as the wet season of this region. A sharp drop in the precipitation curve during April shows that that month is dryer than any other. The largest amount of snow falls in January, and practically none falls during June, July, and August. It is probable that no rain falls from November to March, inclusive, and on this assumption it will be seen that the average conversion factor of snow to water in this region is about 0.075—that is, it takes about 13½ inches of snow to make 1 inch of water.

The individual records from the five stations do not depart sufficiently from the mean to warrant separate charting, but they do show some deviations from the mean worthy of mention. Fort Yukon is the warmest of the five in summer and the coldest in winter. Moreover, the time of minimum winter temperature at Fort Yukon appears to be two or three weeks earlier than at the other four stations, and the period of extreme cold weather is longer. Fairbanks has the mildest climate of all the five stations, for it is appreciably warmer in winter and is also warmer in summer than any other station, except for a period of two months at Fort Yukon. Nevertheless, the mean annual temperature at Fairbanks is nearly 6° below the freezing point. The mean annual temperature at Tanana is the same as the regional average.

Tanana has the greatest precipitation, which exceeds the mean for the region by more than 2 inches, and the precipitation at Fairbanks also exceeds the mean by about 1 inch. The lightest precipitation occurs at Fort Yukon, where it is 3.3 inches below the average. Tanana differs from the other four stations in that its maximum precipitation occurs in July rather than in August. Eagle comes closer to representing the average conditions of precipitation than any other station. Tanana also has the greatest snowfall, but Eagle, though third in precipitation, has almost as great a snowfall as Tanana. At Fort Yukon nearly half the precipitation falls as snow, but at Fairbanks and Tanana only about a third is snow.

The means above tabulated and analyzed are based on figures that have a wide range between their maxima and minima, and the tables therefore do not give a very real picture of the actual existing climatic conditions. In summer a maximum temperature of 100° F. has been recorded at Fort Yukon, and in winter minimum temperatures of −76° and −75° have been recorded at Tanana and Eagle respectively, thus showing a possible annual range of 176° F. During the summer from 45 to 65 days may be expected when the temperature rises to 70° or higher, and in winter from 240 to 255 days may be expected when the temperature falls to 32° or less. Also from 120 to 160 days in winter have a minimum temperature of 0°

or less. It should be noted, however, that these figures are based upon the climatic records of stations along the Yukon and Tanana Rivers, at relatively low elevations above sea level; probably somewhat different conditions prevail in the hills that rise several thousand feet higher.

The Yukon River at Eagle breaks up in the spring sometimes between May 3 and May 18, usually about May 10, but at Circle, Fort Yukon, and Rampart the break-up is progressively later, by several days. The Tanana River at Nenana since 1917 has broken up at dates ranging from April 26 to May 17, with an average date of May 7. At Fairbanks the earliest and latest dates of the break-up on record since 1903 are April 26 and May 14, with an average date of May 6. It may therefore be seen that the Tanana River at Fairbanks and Nenana breaks 3 or 4 days earlier than the Yukon at Eagle. The Yukon and Tanana begin to freeze about the middle of October, but the smaller streams in general freeze earlier in the fall and open earlier in the spring than the main rivers. Steamboat navigation on the Yukon begins about June 1 and ends about the first week in October, thus giving a period of river navigation of about 4 months.

Most of the ground in this region is permanently frozen to great depths and thaws in summer only for a few feet below the surface. A marked exception to this condition, however, prevails along the larger streams, where circulating ground water has in places thawed the ground for several hundred feet back from the river banks. This frozen condition of the soil is believed to have originated during the ice age, when the regional climate must have been even more frigid than at present, but its perpetuation to the present day has doubtless been greatly aided by an insulating layer of sphagnum moss that covers much of the surface. The combination of a frozen subsoil and a spongelike layer of moss at the surface produces a condition that favors the growth of vegetation and seems to belie the semiarid nature of the country, for as a result of the frozen subsoil, there is slight circulation of ground water, and the scant precipitation soaks into the moss, where it is retained near the surface, thus favoring a dense plant growth.

The weather in the Yukon-Tanana region is generally pleasant, both in summer and in winter. The summer days are seldom oppressively warm, and except for the myriads of mosquitoes in June and July working conditions are very favorable. In the early summer thunderstorms are prevalent in some seasons, but a great variation exists in this respect. Though much of the summer weather is fair, few perfectly cloudless days occur, for the sky is usually characterized by isolated clumps of clouds, which make patches of sunshine and shadow over the landscape. This renders the photography of distant landscapes somewhat difficult. In winter still better weather prevails, and except when storms or periods of excessively low temperature occur, travel by foot and dog team along established trails is easy, and even cross-country travel on snowshoes is less laborious than summer travel in the valleys.

VEGETATION

The valleys and lower ridges of the Yukon-Tanana region have a heavy mantle of vegetation, which includes coniferous and deciduous trees, many kinds of flowering plants, ferns, mosses, lichens, and still lower forms of plant life. Little organized botanic work has yet been done in this region, but many travelers in the country have taken the opportunity to collect the more common plants; and there is available as a result of such collections a considerable amount of descriptive botanic data in the files of the United States National Museum and the Department of Agriculture. The flora of this country presents many interesting problems, particularly problems of ecology.

The common trees are the white spruce, the balsam poplar or cottonwood, and the quaking aspen, and at favored localities good stands of white birch are also found. Other trees that are more sparsely distributed are the black spruce, black birch, and tamarack. The white spruce constitutes a large part of the forest growth, ranging in size from trees 2 feet in diameter in the larger valleys to the scrubby stunted kind that grow near timber line. The poplars and aspen grow principally in the valleys, but where the spruce has been burned from the valley walls and lower ridges, poplars and birches are among the first trees to reappear in the course of natural reforestation. The natural habitat of the birch is on well-drained ridges and hill slopes. Black spruce grows as small scrubby trees in swampy places, and the tamarack or larch is found mainly in the valleys of the larger rivers.

Much of the country, particularly in the vicinity of mining camps, has at some time in the last 40 years been subjected to forest fires. Most of these fires, though due to carelessness or negligence, have not been intentional, but some of them have been deliberately set with the intention of obtaining dry wood quickly, or of killing mosquitoes, or perhaps with the erroneous idea of clearing off the vegetation so that grass would spring up for horse feed. For some years after a fire a burnt-over area is a desolate stretch that is useless for man or beast. Much fine timber and other useful vegetation is destroyed, and the country becomes a veritable no-man's land, devoid of vegetation, water, and animal life. The rainfall in this country is at best sparse, and when the surficial mantle of moss and other vegetation is thus destroyed, nothing remains to hold the moisture, and the run-off of the streams becomes torrential. This adversely affects placer-mining operations, for water then becomes available only during periods of rainy weather, and the excess run-off is wasted, instead of being conserved for periods of drought. Experience should have demonstrated by this time that no useful purpose is served by setting fires, even in a country as sparsely populated as interior Alaska.

Timber grows in this country up to an average elevation of about 2,500 feet above sea level, but local conditions cause considerable variation in the timber line. Where basic or ultrabasic rocks form the country rock, or on northward-facing slopes, timber may hardly extend up to an elevation of 2,000 feet; but in trunk valleys or on favored slopes, particularly where the bedrock is limestone, spruce timber may grow up to 3,000 feet or higher. Near timber line the spruce becomes smaller and above timber line gives place to low brush, of which the dwarf black birch and in moist ground the alder are the most common types. Above this are prostrate plants, such as the lichens and certain flowering plants, which continue to the top of the mountains, unless interrupted by slide rock.

A large variety of other vegetation grows in this country. Willows and alders, though essentially shrubby plants, grow at favored localities to 6 inches or more in diameter. Only one species of alder has been recognized, but several species of willows are present. The natural habitat of these plants is along stream courses, but they are widely distributed where the ground is damp enough to favor their growth. The flowering plants are particularly conspicuous in summer, and many types are found. The writer[27] in an earlier publication has given a list of 164 species that grow in the vicinity of Eagle, and probably as many more could be collected by a professional botanist. One of the most conspicuous and most attractive flowers of interior Alaska is the Iceland poppy, a yellow species whose natural habitat is on the upper slopes below and above timber line.

Many native grasses and sedges also grow in this country, and others which have probably been imported as seed in hay have become acclimated. Grasses that are suitable for horse feed grow in the valley bottoms and to a marked extent in the gulches near the upper limit of timber. Horses soon learn to like some of the horsetails, as well as certain other kinds of vegetation, such as some of the genera of the pea family. In the lower valleys grass for horses

[27] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 363–367, 1932.

is usually available by the end of the first week in June, but in late seasons adequate forage may not be obtained until after the middle of June. Similarly in the fall, the grass lasts until the early or middle part of September, or perhaps later. In the higher hills, however, forage is seldom available before the middle of June and is entirely dead by the first week in September. In general, therefore, horses can forage on the country for 3 or 3½ months, the time depending on the locality and the kind of season.

Several kinds of wild fruits grow in this region, of which the four most common and useful are the bog blueberry, the low-bush cranberry, the red currant, and the red raspberry. The high-bush cranberry, a member of the honeysuckle family, is also much used for making jelly, and the juice of this berry, when it is fully ripe, provides a fine substitute for vinegar for table use. Strawberries, though native to southern rather than interior Alaska, also thrive at some localities. At most of the settlements along the Yukon and Tanana Rivers, and even in the hinterland between the rivers, gardens are planted, and all the hardy vegetables, including potatoes, turnips, cabbage, lettuce, rhubarb, beets, carrots, and radishes, are grown without difficulty. Tomatoes and cucumbers are grown for the most part in hothouses. Agricultural experiment stations were started by the Department of Agriculture years ago at Rampart and Fairbanks, but the Rampart station was subsequently abandoned. The Fairbanks station, however, has continued to function and has recently been transferred to the University of Alaska. Much fine work has been done at these stations, and one of the important results of their work has been the development of hardy cereals that will ripen in the short sub-Arctic summers.

ANIMAL LIFE

The larger animals of this region are caribou, moose, bear, and mountain sheep. Many thousands of woodland caribou range throughout the region, and they form an important source of food for the white and native population. The caribou assemble in large bands in August, and one of the impressive sights of the country is a great herd of these animals migrating across rivers and over mountains, in such numbers that their transit past any one locality may take several days. From a mountain top surrounded by such a herd, one may see caribou on every ridge top in every direction, as far as the eye can reach. The caribou are more like cattle than wild game, and it is hard for the frontiersman to understand how the killing of caribou can be regarded by hunters as a form of outdoor sport.

54984—37——4

Moose are plentiful but do not assemble in large herds. Unlike the caribou, they are found mainly in low timbered valleys, particularly where lakes are plentiful. Sheep are found in the high mountains, but are relatively scarce. The largest number of sheep observed by the writer were in the hills near Mount Schwatka, north of Victoria Creek. Both the black bear and the brown grizzly bear are native to the country. The grizzly bear lives mostly in the higher mountains and is often met on the bare ridges at and above timber line. The fur-bearing animals include chiefly fox, lynx, marten, muskrat, squirrel, weasel, mink, land otter, wolf, and of recent years coyote. Other animals, such as porcupines, rabbits, tree and ground squirrels, marmots, and mice, are also found.

The native game birds are ptarmigan and grouse, but these birds, particularly the ptarmigan, appear to be nomadic and more or less periodically appear in numbers at different localities, and at other times are very scarce. In summer ducks, geese, and other waterfowl are plentiful along the streams and lakes. Many other birds, including the eagle, hawk, raven, owl, loon, tern, gull, kingfisher, swallow, sparrow, junco, thrush, warbler, jay, waxwing, and shrike, also inhabit this country.

The streams are amply stocked with fish. Grayling are found in nearly all the streams, and in some trout are also found. Salmon run up the Yukon and Tanana Rivers and constitute an important source of food, both for the people of the country and for their sled dogs. Other large fish, such as whitefish, pike, pickerel, and lake trout, are common in the lakes and larger streams.

DESCRIPTIVE GEOLOGY

GENERAL FEATURES

The Yukon-Tanana region and contiguous areas north of the Yukon River present one of the most complete geologic sections now known in Alaska. Bedded rocks of every geologic period except one have been identified, and a variety of igneous rocks, both intrusive and extrusive in origin, are also present. This diversified assemblage of rocks indicates that the region has had a long and intricate geologic history. The reconnaissance studies of the last 30 years have resulted in the accumulation of a great mass of information about this region, and although many of these data are even yet not thoroughly correlated, nevertheless they serve to indicate the major events in the geologic history. There remain, however, many unsolved geologic problems in this region, not the least of which is a better understanding of the regional structure.

The bedded rocks range in age from pre-Cambrian to Recent, and in the explanation accompanying the geologic map 22 map units of bedded rocks have been differentiated. The oldest sedimentary rocks are assembled in a group of crystalline schists, known as the Birch Creek schist, of pre-Cambrian age. Later pre-Cambrian rocks are also present, of which the least metamorphosed and best known are comprised in the Tindir group, of pre-Cambrian and Lower Cambrian (?) age, which is roughly correlative with the pre-Cambrian Belt series. The Tindir group, however, is typically developed in the contiguous area north of the Yukon River and therefore outside of the Yukon-Tanana region proper. South of the Yukon most of the younger pre-Cambrian rocks are assembled into a group of undifferentiated rocks, which also includes some rocks of early Paleozoic age. The calcareous members of the post-Birch Creek rocks are separately mapped, though few such rocks occur south of the Yukon. The Cambrian system is developed, so far as now known, only in the belt along the international boundary north of the Yukon, but the proximity of these rocks to the Yukon River renders it desirable to give a brief outline of their general character. Some of the rocks of Ordovician age are included with the pre-Cambrian in the assemblage here mapped as undifferentiated pre-Middle Ordovician rocks, but one formation of basic lavas, here designated the "Fossil Creek volcanics", has been differentiated and mapped. The Silurian system, so far as known at present, is represented by only one formation, which is composed of a great thickness of limestone and dolomite here named the "Tolovana limestone." The Devonian system, like the Ordovician, is largely undifferentiated, but one formation, composed largely of lavas and known as the "Woodchopper volcanics", has been differentiated and separately mapped. The undifferentiated Devonian rocks have been divided into a calcareous and a noncalcareous unit, which are separately delineated on the accompanying map.

The Carboniferous system includes a great diversity of bedded rocks. These have been divided into five well-defined mapable units and also into two less well-defined groups of undifferentiated rocks, one of calcareous and one of noncalcareous character. Three of the well-defined map units (the Livengood chert, the Rampart group, and the Calico Bluff formation) are of Mississippian age, and two groups of undifferentiated rocks are also Mississippian. The Rampart group is an assemblage of sedimentary rocks, lava flows, tuffs, and breccias, associated with which are masses of intrusive rocks. Another lithologic unit, known as the "Nation River formation", comprises a group of unique continental deposits, which are believed to be of Pennsylvanian age. The youngest of the Carboniferous rocks is a marine limestone of Permian age, the Tahkandit limestone.

The Mesozoic rocks include a series of Upper Triassic rocks, and also rocks of Lower and Upper Cretaceous age. No Jurassic sedimentary rocks have been recognized in this region, though some may be present, as a Callovian fauna correlative with the lower part of the Upper Jurassic of Alaska has recently been found on the Porcupine River, about 25 miles below the international boundary. The apparent absence of Jurassic rocks in the Yukon-Tanana region, however, is interpreted to mean that a great unconformity exists at the base of the Lower Cretaceous sequence. In an earlier report the writer [28] mapped the Lower Cretaceous rocks of part of this area as a separate unit, designated as the Kandik formation, but in the present report the Lower and Upper Cretaceous rocks are mapped as a unit, with no formal designations. The youngest of the consolidated rocks are a group of Tertiary rocks of estuarine and continental origin. Overlying all the hard rocks of the region are a variety of unconsolidated or alluvial deposits, which range in age from late Pliocene to Recent.

Many igneous rocks are present in the Yukon-Tanana region. Some of these, such as the meta-igneous rocks that are associated with the crystalline schists, are not separately mapped. Others, such as the Fossil Creek and Woodchopper volcanics and the Rampart group with its associated intrusives, are mapped with the bedded rocks. In addition to these, five units of igneous rocks are separately mapped. The two most important of these, from their economic relations, are the Mesozoic and Tertiary granitic rocks, which are the ultimate source of most of the metalliferous ores of this region. A group of Devonian intrusive rocks, mainly of ultrabasic character, has also been differentiated. Finally, two groups of lavas, one of early Tertiary and one of late Tertiary and Quaternary age, are mapped as separate units.

BEDDED ROCKS

ANCIENT ROCKS

The ancient rocks of this part of Alaska are here divided broadly into three units, based upon differences in age and lithology. The oldest unit, known as the "Birch Creek schist", consists largely of recrystallized sediments, with which are associated ancient meta-igneous rocks of both intrusive and extrusive character. The Birch Creek schist forms the base of the geologic section and is entirely of pre-Cambrian age. One of the two younger units, designated as the "Tindir group and associated intrusive rocks", is a group of little

[28] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 136–141, 1930.

altered rocks which are mainly of pre-Cambrian age, but may include some Lower Cambrian rocks. The second of the two younger units includes the major part of a group of partly recrystallized rocks, that were described by Prindle[29] in his report on the Fairbanks quadrangle as the †Tatalina group[30] and also similar rocks in the Circle and Fortymile quadrangles which have not received formal designations. In the present report the latter unit and certain undifferentiated early Paleozoic rocks are collectively designated "undifferentiated pre-Middle Ordovician rocks."

BIRCH CREEK SCHIST AND ASSOCIATED META-IGNEOUS ROCKS

DISTRIBUTION

The Birch Creek schist forms the bedrock surface of about one-fifth of the country between the Yukon and Tanana Rivers. This formation occurs in three general tracts. The largest of these is a triangular area of about 4,000 square miles, whose southern limit is marked by the valley of the Chena River. The northeast side of this triangle is delimited by the flats of Birch and Preacher Creeks, and the northwest side is formed by the flats of the Tolovana River and upper Beaver Creek. This area contains few intrusive bodies of the later granitic rocks, and those which occur occupy relatively small areas. It is also a significant fact that younger pre-Cambrian rocks lie along both the southern and northwestern sides of this triangular block of Birch Creek schist. The Fairbanks and Circle mining districts lie within this area.

A second area occupied by this formation is a belt lying along the northeast side of the Tanana River and extending from the headwaters of the Mosquito and Middle Forks of the Fortymile River northwestward to and somewhat beyond the Salcha River. This area comprises about 1,500 square miles. Along its north side this belt is adjoined by younger pre-Cambrian rocks and by Paleozoic greenstones, but along its east side the Birch Creek schist abuts against great intrusive bodies of granitic rocks, with an extremely irregular contact. A small mining camp, known as the Tenderfoot district, lies near the west end of this belt, at a considerable distance from the great granitic intrusive bodies.

The third area of the Birch Creek schist forms the eastern part of the Yukon-Tanana region and continues eastward beyond the international boundary into Yukon Territory. This area comprises

---

[29] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 37–39, 1913.

[30] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey. Quotation marks, formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

about 1,500 miles in Alaska and an undetermined area in Canada. Along its north side this block of the Birch Creek schist adjoins both the younger pre-Cambrian rocks and the granitic intrusives and interfingers with both of these formations; along its west side the boundary is determined by the great granitic intrusives, and the contact is likewise very irregular. A considerable part of the Fortymile mining district lies within this area, and just east of the boundary, in Yukon Territory, is the Sixtymile mining district. Still farther east is the Klondike mining district, whose bedrock is also composed of the Birch Creek schist and other pre-Cambrian rocks.

LITHOLOGY AND PETROGRAPHY

In describing the Birch Creek schist it should be stated at the outset that no intensive study has yet been made of these rocks. Many of the lithologic and structural data are based on the field work of L. M. Prindle, which was done in connection with rapid reconnaissance surveys. The petrographic examination of these rocks, which has been made mainly by Prindle and the writer, was likewise a part of this reconnaissance work and had for its principal objective the recognition of the constituent minerals, so that proper petrographic designations might be applied. The following data are therefore descriptive rather than genetic, and the application of modern methods for deciphering the history of these metamorphic rocks remains a task for the future.

The designation "Birch Creek schist", as now used, includes all the older pre-Cambrian metamorphic rocks that were originally of sedimentary origin. Associated with these metamorphic sediments are a considerable variety of schists and gneisses of igneous origin, which are not considered to be an integral part of the Birch Creek formation. In the Yukon-Tanana region, however, these metamorphic igneous rocks have for convenience been mapped with the Birch Creek schist, under the designation "Birch Creek schist and associated meta-igneous rocks. In Yukon Territory the Canadian geologists have applied the name "Yukon group" to all the older pre-Cambrian crystalline rocks of that region, irrespective of their sedimentary or igneous origin, but this usage has not been generally adopted in Alaska.

The Birch Creek schist consists of sediments which through many ages have been regionally metamorphosed to produce the more common types now seen over so much of this country. A minor part consists of similar rocks which have been metamorphosed, not only by repeated folding and compression but also by contact-metamorphic processes. Manifestly this additional metamorphism is not a function of the age of these rocks but is due entirely to their proximity to great bodies of intrusive granitic rocks, most of which are a part of the later geologic sequence. It should also be emphasized that a description of the Birch Creek schist cannot at present be attempted upon a stratigraphic basis, for the original bedding has in large measure been obliterated, and the stratigraphic sequence is known only in a most general way.

The Birch Creek schist consists principally of quartzite, quartzite schist, quartz-mica schist, mica schist, feldspathic and chloritic schists, and a minor proportion of carbonaceous and calcareous schist and crystalline limestone. Quartzite schist and quartz-mica schist appear to be the more common types. Most of these rocks are completely recrystallized, but in some of the more competent beds—for example, the quartzites—original detrital fabric and other evidences of their sedimentary origin are still preserved. In general, these rocks are characterized by a foliated or laminated structure, and many of them show a distorted foliate or crenulated fabric that indicates the superposition of one cleavage upon an older structure of similar type. In a broad way, the more quartzose metamorphic rocks are considered to represent the basement members of the sequence.

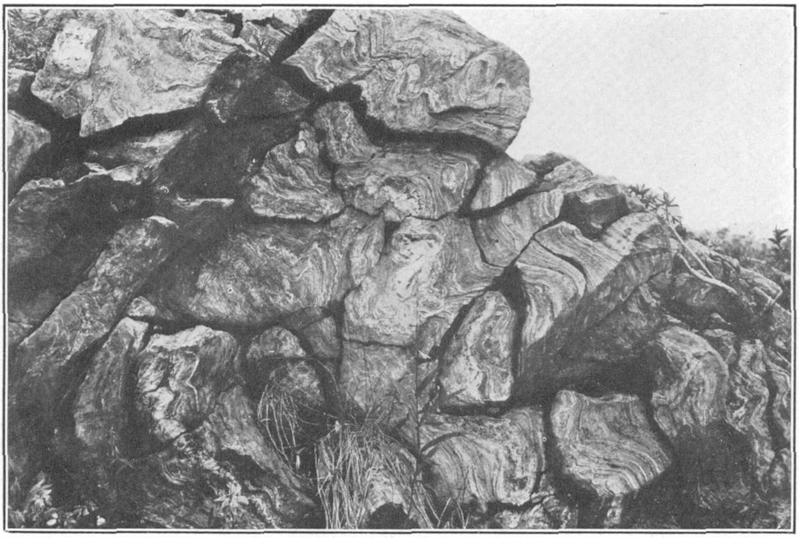
The quartzite schists occur in beds that range in thickness from a few inches to several feet. Most of these rocks contain sufficient mica to give them a definite cleavage, but they also grade into beds of almost pure quartzite in which the cleavage is hardly apparent. Most of these rocks are strongly jointed, and therefore in weathering they usually break down to form a blocky talus. This jointing also has an important effect where such rocks form the bedrock under gold placer deposits, in that it enables the gold to penetrate deeply into bedrock and necessitates the removal and cleaning by hand of a considerable depth of such rock, in order to obtain a high recovery of the gold. Where the quartzite schist and quartzite occur in higher country they usually make prominent topographic forms, owing to their superior resistance to weathering. Another characteristic of these quartz-rich rocks, particularly above timber line, is the prevalence upon them of a black lichen, which gives to their croppings a somber, forbidding appearance when viewed from a distance. The quartzite schists are typically developed in the area around the headwaters of Birch Creek but are also found in the vicinity of Fairbanks, in the Fortymile country, and at many other places.

The quartz-mica schists at many localities are interlaminated with the quartzite schists, but at other localities they appear to constitute most of the country rock. As might be expected, these rocks grade lithologically on one hand into the quartzite schists and on the other hand, with a decrease in quartz, into rocks that are more properly termed mica schists. The quartz-mica and mica schists, particularly the latter, are incompetent rocks, which have taken up most of the stresses induced by regional folding and differential compression, and their textures show to a marked degree the results of these processes. Crumpling, crenulation, and flow cleavage are characteristic features of these rocks, as shown in plate 4, *B*, and it is apparent that not only has the original bedding been entirely obliterated, but also at many places an older cleavage has been intensely deformed to produce the present cleavage planes. The textures, in short, are those which might be expected to occur in rocks that have been intensely deformed at great depth during several periods of diastrophism. In weathering these micaceous schists disintegrate to form soft, friable rocks, and where they have been subjected to the action of both air and water, as in the bedrock under placer deposits, they disintegrate to a soft clayey material. The quartz-mica and mica schists are found everywhere in the areas of Birch Creek schist and cannot be said to be specially characteristic of any one locality, though they are well developed in the Fairbanks, Circle, and Fortymile districts, both in the vicinity of the placer-mining operations and in the neighboring hills.

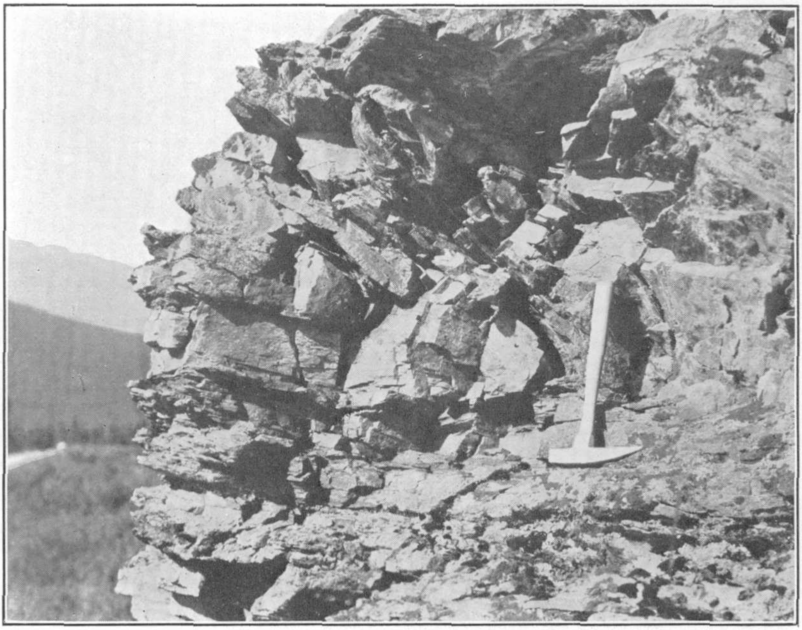
Calcareous schist and limestone appear to constitute a relatively small proportion of the Birch Creek schist and are restricted to the upper parts of the formation. Where observed, such calcareous rocks occur as elongated bodies of small thickness and horizontal extent, which are completely recrystallized, usually schistose, and at some localities silicated. The greatest amount of crystalline limestone in the Birch Creek schist is found along the Fortymile River from the mouth of Franklin Gulch downstream to the boundary. Here the limestone is interbedded with a variety of schists and gneisses in beds from a few inches to 100 feet or more in thickness, and at places the associated quartzites are themselves more or less calcareous. Similar calcareous members crop out as a group of lenses of crystalline limestone in the Fairbanks district, extending from the head of Pilot Creek S. 70° W. into the valleys of Dome and Vault Creeks. Other localities are in the valley of Goldstream Creek near Fox; at the mouth of Mastodon Creek, in the Circle district; and at several places in the headwaters of the Salcha and Chena Rivers, close to the succeeding pre-Cambrian rocks.

Schists on which the effects of contact metamorphism have been superposed are particularly prevalent at or near the borders of the great instrusive bodies of granitic rocks that characterize the eastern half of the Yukon-Tanana region; and in this process new minerals, such as garnet, staurolite, and albite, have been developed. No special study has yet been made of these contact-metamorphic phases of the Birch Creek schist, but garnetiferous schists have been observed at many places along these border zones, and staurolitic schists are

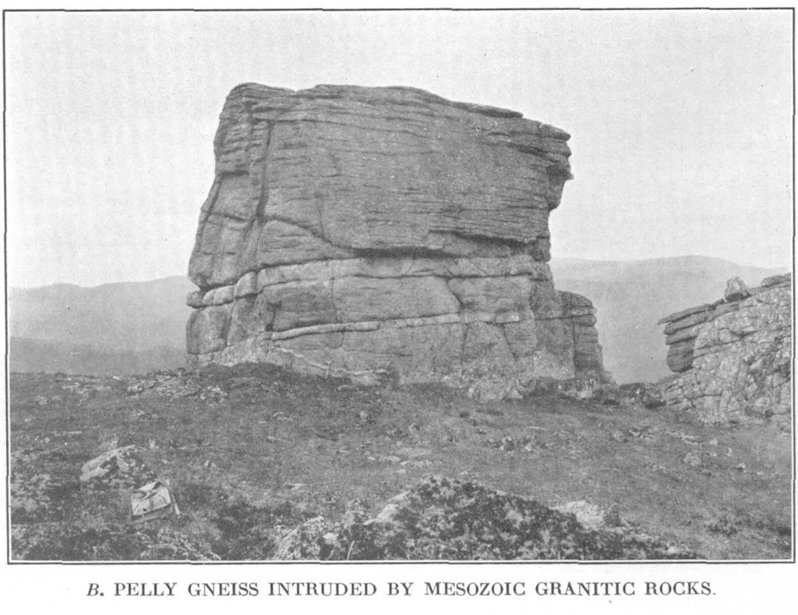
A. VALLEY OF FORTYMILE RIVER AT MOUTH OF STEEL CREEK.
Shows well-defined terrace about 500 feet above the river level.



B. CONTORTED SCHIST ON RIDGE NORTH OF MOSQUITO FORK OF FORTYMILE RIVER.



A. CONTORTED FELDSPATHIC QUARTZITE, SALCHA RIVER.



B. PELLY GNEISS INTRUDED BY MESOZOIC GRANITIC ROCKS.

known at the heads of Coal and Woodchopper Creeks and at other localities.

The essential minerals of the rocks composing the Birch Creek schist are quartz, biotite, and sericite, and the more common accessory minerals are albite or oligoclase, chlorite, calcite, garnet, iron oxides and hydroxides, apatite, and zircon. The less common accessory minerals, including those found in the contact-metamorphic phases and in the associated meta-igneous rocks, consist of epidote, zoisite, hornblende, diopside, augite, orthoclase, tourmaline, staurolite, andalusite, titanite, rutile, and pyrite. In some of these rocks certain of these accessory minerals are dominant, particularly the feldspars and chlorites in the schists and the hornblende among the igneous derivatives. The quartzites are massive rocks which consist largely of quartz with a little mica. Under the microscope the quartz is seen to consist of interlocking grains, usually showing strain shadows under crossed nicol prisms, though in some of these rocks the original rounding of detrital grains is still preserved. The mica occurs in unoriented flakes. The quartzite schists and quartz-mica schists differ from the quartzites in containing increasingly larger amounts of mica, which is oriented in parallel flakes and gives a resulting foliation. Of the micas, biotite seems to be more common than sericite, but the presence of both these micas has in places been utilized to distinguish the Birch Creek schist from highly altered Paleozoic rocks, which are likely to contain a larger proportion of the brittle micas and chloritic minerals. The increase in the proportion of mica is also usually accompanied by an increase in the number and variety of the more common accessory minerals above enumerated. Some of the quartzite schists contain oligoclase or andesine, and by an increase in the amount of these minerals there arises another fairly common rock type, the feldspathic schists. Some of the schists of this type may perhaps be of igneous origin, but many of them are believed rather to represent metamorphosed arkosic sediments.

A number of types of meta-igneous rocks are associated with the Birch Creek schist, but the most abundant of these are the intrusives grouped under the designation Pelly gneiss. This unit consists mainly of granitic rocks but locally includes darker varieties of monzonitic, dioritic, and even gabbroic character. A description of the petrographic features of the Pelly gneiss is given on pages 202–203. In addition to the Pelly gneiss, chlorite, albite, and sericite schists, amphibolites, and hornblende schists are also associated with the Birch Creek schist, and many of these rocks are considered to be the metamorphic derivatives of ancient igneous rocks. The chlorite, albite, and sericite schists, like the limestone members, are confined to the upper part of the Birch Creek schist, but in parts of the Yukon-Tanana region they constitute a considerable part of the mapped unit. They are light-colored foliated rocks, ranging from a dirty cream color to light green, and most of them are soft, friable, and lustrous. The essential minerals are chlorite, sericite, quartz, and acidic plagioclase, either albite or oligoclase, and the common accessory minerals are the same as those of the mica schists. These rocks have not been studied in any detail, but their general characteristics suggest that many of them may be igneous phyllonites, comparable with the metarhyolites associated with the Totatlanika schist, as described originally by Prindle.[81] The amphibolites consist essentially of hornblende, biotite, albite or oligoclase, quartz, and calcite, and by a decrease in the content of feldspar they grade into the hornblende schists. Other minerals found in these rocks include epidote, zoisite, garnet, titanite, apatite, and iron oxides.

Mention should also be made of the large amount of quartz found in the Birch Creek schist. Veins of quartz, of course, are present in nearly all the geologic formations of this region, but the Birch Creek schist, because of its great age, has been acted upon by vein-making processes of every period, and consequently contains more vein quartz than any of the other rocks. This quartz, as might be expected from its differences in age and mode of formation, is diverse in character. Much of it is a white vitreous quartz that ranges from small seams to veins and lenses several feet thick, but some of it, particularly in the smaller seams, is colorless and transparent. The quartz that characterizes the gold lodes of the Fairbanks district is inclined to be porous and to show some crystalline faces, but this variety occurs in veins that cut transversely across the cleavage of the schist and is more characteristic of mineralized areas. Locally any of the quartz veins may be mineralized with sulphides, such as pyrite, arsenopyrite, and stibnite, and with free gold, but in general most of the older quartz veins of the Birch Creek schist are barren. It was the presence of so much quartz in the Birch Creek schist and the additional fact that the mining camps first discovered, such as the Klondike, Fortymile, Koyukuk, Fairbanks, and Nome camps had a bedrock of schist that led mining men to believe that the Birch Creek schist was the source of the gold. It is now believed, however, that the granitic rocks are the source of most of the gold of the Yukon-Tanana region, and that the Birch Creek schist is a source rock for gold only where it has been mineralized by granitic intrusives.

---

[81] Brooks, A. H., The Mount McKinley region, Alaska, with descriptions of the igneous rocks, by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, pp. 148–150, 1911.

STRUCTURE AND THICKNESS

The structure of the Birch Creek schist is known to be very complex, but the reconnaissance studies so far made do not justify any finality of opinion regarding either the details of the structure or the processes by which the structure has been produced. In general, where the Birch Creek schist contains no large bodies of later intrusives, its cleavage tends to strike N. 60° E., or roughly parallel with one of the major structural directions of the region. Even where the structure is least irregular, however, considerable diversity of strike may be observed, particularly in the less competent rocks. In areas where the great Mesozoic granitic batholiths are found, the cleavage close to these intrusives tends to follow contact lines, but farther away it tends to be decidedly aberrant. The dip of the cleavage is even more irregular, for close folding is common, and many of the minor folds are closely appressed, with axial planes ranging from high angles to verticality. Shearing has also been a process of marked effect, and at places lenticular fragments of competent beds, such as quartzite and old vein quartz, are found as elongated inclusions in the less competent schists, sometimes closely simulating a detrital or conglomeratic fabric. The structure is further complicated, particularly in the Fortymile district, by the presence of many ancient intrusives, chiefly though not wholly of granitic character, that have ruptured and deformed the schists during their intrusion, have soaked them with magmatic juices so as to alter their chemical composition, and have subsequently been deformed and sheared along with the ancient country rock, in such a way that they are now welded into the schists and form with them a complex of metamorphic rocks that almost defies analysis.

The area of Birch Creek schist lying between Fairbanks and Circle includes less granitic rocks than any of the other areas of these rocks in the Yukon-Tanana region and may therefore be expected to yield the best information regarding the ancient metamorphism of these rocks. This block of schist is bounded both on the northwest and southeast by the younger rocks of the undifferentiated pre-Middle Ordovician assemblage and in a broad way the structure may be regarded as anticlinal. The accompanying geologic map shows that the younger pre-Cambrian rocks converge toward the southwest, suggesting a closure around the end of the Birch Creek schist in that direction; and it may therefore be inferred not only that the general structure of the Birch Creek schist is anticlinal, but that the axial planes of the folds plunge southwestward. The general structure is also indicated by the fact that in the central zone of this area, along the ridges between Fairbanks and Circle, occur many quartzite schists of the type which is believed to represent the basal part of this metamorphic complex. That the structure is far from simple, however, is plainly indicated by highly appressed and in places recumbent folds, which appear to be characteristic structural features. (See pl. 5, *A*.) As a result, massive beds of quartzite and quartzite schist are found at some localities in a nearly horizontal position. In general, however, the axial planes of the appressed folds dip 30°–45° SE., and the impression is gained that a considerable part of this deformation is due to lateral thrusting from the southwest.

The Fairbanks district lies in the central zone of this area of Birch Creek schist, and the detailed studies by Prindle[32] in that district have thrown additional light upon the structure of these older rocks. Prindle found two belts of crystalline limestone in the Fairbanks district, one in the valley of Goldstream Creek and the other about 3 miles south of and parallel with the Chatanika River; and he regarded these zonal croppings as evidence of closely appressed synclines, in which the limestones, which occur in the upper part of the Birch Creek schist, have been infolded with older rocks of the sequence. Carbonaceous schists are also associated with both of these belts of crystalline limestone, and these likewise indicate that higher horizons of the schists are here represented in the synclines. Moreover, if, as above inferred, the folds of the Birch Creek schist plunge southwestward, it would be expected, in synclines of this sort, that the higher rocks of the sequence would begin to appear at the Fairbanks end of this Fairbanks-Circle block, and that the very oldest rocks of the sequence would be found at the northeast end, in the vicinity of Circle. The lithology appears to bear out this interpretation.

In the eastern part of the Yukon-Tanana region the structure of the Birch Creek schist is complicated, not only by the presence of intrusives but also by the fact that the ancient granitic intrusives, here called the Pelly gneiss, and other ancient igneous rocks become increasingly prominent. The regional trend of the cleavage in the vicinity of Dennison and Mosquito Forks of the Fortymile River appears to be about the same as the general direction of these two streams—that is, about N. 15° E.—and the prevailing dip of the cleavage is 15°–20° E., although this attitude is by no means uniform. In fact, at some localities, as along the ridges south of Liberty Creek, the cleavage of the Pelly gneiss appears to be nearly horizontal. This regional trend of the cleavage may be due to the proximity of the Mesozoic granitic rocks, but it certainly extends for some distance east of them. Still farther east, however, in Yukon

[32] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz: U. S. Geol. Survey Bull. 525, pp. 74–75, 1913.

Territory, according to Cockfield,[33] the regional trend of the igneous schists, and presumably also the Birch Creek schist, is northwest with prevailing dips to the southwest. It should also be emphasized that both the intrusive Pelly gneiss and the igneous schists which are associated with the Birch Creek schist in this area partake of the same regional structure as the schist itself. When these facts are considered in conjunction with the belief that the present cleavage of this schist in this area is superposed upon an older cleavage, whose general trend is unknown, it will be apparent that the present state of knowledge regarding the structural history of the Birch Creek schist in this part of the Yukon-Tanana region is based more upon vague conjecture than upon accurate analysis, and much more work, of a very detailed nature, will be required to acquire any adequate understanding of that history. In fact, considering the geology of the Birch Creek schist in Alaska alone, without reference to Yukon Territory, the Fairbanks-Circle area is much the best district in which to begin any such detailed studies.

As the Birch Creek schist comprises the oldest rocks in this region, the base of this formation has not been observed, and the upper limit is also more or less indeterminate. The complex structure has already been outlined, and it need hardly be stated that the stratigraphic section has not yet been deciphered. These facts make it impossible to hazard any exact estimate of the thickness of these rocks. It is probable, however, from the width across the regional strike at Circle and the absence along that section of infolded beds of later age, that a thickness of many thousands of feet is represented by this metamorphic complex.

AGE AND CORRELATION

The age of the Birch Creek schist is now considered to be not only pre-Cambrian but early pre-Cambrian. McConnell,[34] who first examined these ancient crystalline schists along the Yukon River, correlated them by lithology with the †Archean rocks of Canada, but subsequent workers, attempting to utilize a classification based upon the fossil records, designated them first as pre-Devonian and subsequently as pre-Silurian and pre-Ordovician. Cairnes,[35] in 1912, discovered Upper Cambrian fossils in the rocks that lie above the crystalline schists, and on the basis of these fossils, together with the stratigraphy and structure of the underlying rocks, he was led to the conclusion that the crystalline schists are of pre-Cambrian age.

[33] Cockfield, W. E., Sixtymile and Ladue Rivers area, Yukon Territory: Canada Geol. Survey Mem. 123, pp. 14–26, 1921.

[34] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie Basins, Northwest Territory: Canada Geol. Survey Ann. Rept., new ser., vol. 74, pp. 13–14 D, 1890.

[35] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 61–65, 1914.

The facts upon which are based the assignment of the Birch Creek schist to the early pre-Cambrian are given herewith. North of Eagle and both east and west of the international boundary is a group of rocks, predominantly limestone, in which Cairnes found Upper Cambrian fossils and in which the writer[36] subsequently collected early Middle Cambrian fossils. Below these fossiliferous beds is a great thickness of noncrystalline, nonfossiliferous rocks, aggregating between 20,000 and 25,000 feet, which are considered on structural and lithologic grounds to be pre-Cambrian. These are known as the Tindir group. The Tindir group has not yet been observed in contact with the Birch Creek schist, but all the evidence indicates that the Tindir is younger than the Birch Creek. This conclusion is not based primarily upon the relative degrees of metamorphism of these two groups of rocks, although it is a striking fact that the rocks of the Birch Creek schist are completely recrystallized, whereas those of the Tindir group are little metamorphosed. The principal evidence is the fact that there are two groups of rocks which, though almost in contact along the Yukon, are totally different in their lithology, the Tindir group consisting of dolomite, limestone, shale, slate, quartzite, red beds, and basic lavas, whereas the Birch Creek schist contains few calcareous rocks and no red beds. It would be impossible by metamorphism to transform the rocks of the Tindir group into rocks similar to those which constitute the Birch Creek schist. The Birch Creek schist is therefore considered to be older than the Tindir group, and as the Tindir group is classified as pre-Cambrian and Lower Cambrian(?) the Birch Creek schist is considered to be early pre-Cambrian. The use of the terms †"Algonkian" and †"Archean" for subdivisions of the pre-Cambrian has been discontinued by the United States Geological Survey.

No attempts have been made in Alaska to differentiate and to map separately the meta-igneous rocks associated with the Birch Creek schist, because in no area that has yet been studied in detail do such rocks form an important part of the geologic sequence. The granite gneiss and the amphibolitic rocks were identified by Prindle[37] in the Fairbanks district, but they are sparsely distributed there, and the available exposures are poor, so that although these rocks were studied petrographically, they were not separately mapped. The Pelly gneiss and the chlorite, albite, and sericite schists form a considerable part of the stratigraphic sequence in the Fortymile Valley, but only rapid reconnaissance work has yet been done in that part of the Yukon-Tanana region, and the best available information re-

[36] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 392–401, 1932.

[37] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz: U. S. Geol. Survey Bull. 525, pp. 60–66, 1913.

garding these rocks is that given by Cockfield [38] in connection with his semidetailed mapping of the adjoining Sixtymile district, just east of the international boundary. In addition to this lack of cartographic work, these meta-igneous rocks have not been found in contact with the later pre-Cambrian or with the early Paleozoic rocks. The result of these circumstances is that little is really known of the age of the meta-igneous rocks associated with the Birch Creek schist.

The Pelly gneiss in the Dennison Fork district has been observed in an intrusive relation with the Birch Creek schist, and is itself intruded by the Mesozoic granitic rocks. (See pl. 5, *B*.) Its age, however, cannot be definitely stated, as it has not been found in contact with any younger pre-Cambrian or Paleozoic rocks. Cockfield,[39] who has given more study than the writer to the field relations between the Pelly gneiss and the Birch Creek schist, was convinced that this gneiss intrudes all the pre-Cambrian crystalline rocks of the Sixtymile district, but he was unwilling to hazard a guess as to its absolute position in the stratigraphic column. It seems likely, from what is now known of the pre-Cambrian sequence in interior Alaska, that the Pelly gneiss is a part of that sequence, but its time relation to the Tindir group is not known. In fact, it is possible that the Pelly gneiss is of early Paleozoic age, though its absence from the rocks mapped as undifferentiated pre-Middle Ordovician rocks, which also occur in the eastern part of the Yukon-Tanana region, is presumptive evidence against that interpretation.

Still less is known of the age of the chlorite, albite, and sericite schists and of the amphibolites, hornblende schists, and related rocks. Semidetailed studies of these rocks have been made by McConnell [40] in the Klondike district and by Cockfield [41] in the Sixtymile district, and the information contained in their reports is the best now available. Both McConnell and Cockfield regard all the meta-igneous rocks associated with the Birch Creek schist as part of the pre-Cambrian sequence. McConnell classified the pre-Cambrian rocks as follows:

Klondike series:
- Sericite and chlorite schists, derived from the alteration of acidic and basic porphyritic igneous rocks.
- Pelly gneiss, derived from the alteration of granite porphyry and quartz porphyry.

Moosehide group: Altered diabase, passing at some localities into serpentine.

Nasina series: Quartzite, quartzite schist, and quartz-mica schist, with some bands of chlorite and actinolite schist and crystalline limestone.

---

[38] Cockfield, W. E., Sixtymile and Ladue Rivers area, Yukon Territory: Canada Geol. Survey Mem. 123, pp. 16–26, 1921.

[39] Idem, pp. 21–26.

[40] McConnell, R. G., Report on the Klondike gold fields: Canada Geol. Survey Ann. Rept., vol. 14, pp. 10B–22B, 1905.

[41] Cockfield, W. E., op. cit., pp. 16–26.

In this tabulation the "Nasina series" corresponds closely with the Birch Creek schist, and the Pelly gneiss was considered to be a deep-seated intrusive that was not greatly different in age from the sericite and chlorite schists, which represented surficial phases of the same eruptive activity. Cockfield, however, presented a somewhat different section, as follows:

Granite gneiss.
Amphibolites.
Sericitic and chloritic schists, mainly of igneous origin.
Nasina series, at the base of the section, consisting of quartzite, quartz-mica schists, mica schists, sheared conglomerate, graphite schists, and crystalline limestone.

In this classification the sericite and chlorite schists are considered to represent a different period of igneous activity from the Pelly gneiss, which is stated to be intrusive into both the igneous schists and the amphibolites.

Little is known at present regarding the correlation of the Birch Creek schist and its associated meta-igneous rocks with similar rocks in other parts of Alaska. Ancient crystalline rocks have been recognized and mapped in the region south of the Tanana River and extending thence southwestward into the Ruby district; in the Koyukuk and Chandalar districts of northern Alaska; and in Seward Peninsula. South of the Tanana the work of Brooks,[42] Prindle,[42] and Capps [43] has resulted in the grouping of most of the metamorphic rocks and their mapping as a single cartographic unit, the Birch Creek schist. One significant fact, however, in connection with this work was the recognition and mapping of a group of augen gneisses and metamorphic igneous schists, to which the designation "Totatlanika schist" was applied. This formation was determined to be younger than the Birch Creek schist and older than the Carboniferous rocks. It is possible that the Totatlanika schist may be correlative with some of the meta-igneous schists that are associated with the Birch Creek schist north of the Tanana.

In the Ruby district and in northern Alaska the name "Birch Creek schist" has not been applied to the crystalline rocks, because such rocks are too far separated from the Birch Creek schist in its type locality. The lithology and metamorphism of these rocks, however, are much the same as those of the ancient crystalline rocks of the Yukon-Tanana region, and it is probable that further studies will justify their correlation. In Seward Peninsula the crystalline

[42] Brooks, A. H., The Mount McKinley region, Alaska, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, pp. 56–60, 1911.

[43] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 20–22, 1912.

rocks have been divided into a lower part known as the Kigluaik group and an upper part called the Nome group. The Nome group has been regarded as of pre-Ordovician age, but the Kigluaik group, which consists of schists, limestone, and gneiss, may possibly be correlative with parts of the Birch Creek schist.

From the facts and hypotheses above presented it is apparent that two lines of investigation are available in the future study of the Birch Creek schist and associated meta-igneous rocks. The petrology, stratigraphic sequence, and structure of the Birch Creek schist should first be investigated in the type locality, between Circle and Fairbanks, where the history of these rocks is least complicated by igneous activity. With such information in hand, the petrology and paragenetic relationships of the associated meta-igneous rocks may then be studied to advantage in the eastern part of the Yukon-Tanana region.

TINDIR GROUP

DISTRIBUTION

The Tindir group is sparsely distributed in the Yukon-Tanana region proper, but its lithology and stratigraphy form so integral a part of pre-Cambrian history that a summary description of its rocks must perforce be included in the present report. The type locality of the Tindir group is north of Eagle, in the valley of the Tatonduk River, a tributary of the Yukon that enters from the east about 30 miles by river below the international boundary. A detailed description of the distribution, lithology, structure, age, and correlation of the Tindir group north of the Yukon River has been given in an earlier publication.[44]

So far as known at present, the rocks of the Tindir group crop out at only one general locality south of the Yukon—for a few miles below the mouth of Fourth of July Creek. North of the Yukon, however, they form the bedrock in an area of about 200 square miles in Alaska and extend for an undetermined distance eastward into Yukon Territory. Still farther north, in the Yukon-Porcupine region, these rocks reappear at the surface and are believed to have a wide distribution. It is also probable that some of the rocks mapped as undifferentiated pre-Middle Ordovician, particularly in the area between Eagle and Circle, may be correlated later with the Tindir group, but the effects of metamorphism south of the Yukon, coupled with the small amount of work so far done on this problem, make it impossible to trace the Tindir group for any considerable distance south of the river.

---

[44] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 369–392, 1932.

LITHOLOGY

The Tindir group consists of a thick sequence of sedimentary rocks interbedded with basic lava flows and intruded by igneous masses. The intrusive rocks, however, are not properly a part of the Tindir group. The principal sedimentary rocks are dolomite, limestone, shale, slate, and quartzite, and the igneous rocks are mainly diabase and basalt of greenstone habit, together with an undetermined proportion of lavas and tuffaceous beds of hematitic habit. In the type locality few of these rocks are recrystallized and most of them are practically unmetamorphosed.

The general stratigraphic sequence, so far as known at present, is as follows:

A. Principally thin-bedded limestone (top of section). Thickness about 1,700 feet.

B. Principally siliceous dolomite and shale, with beds of dolomitic conglomerate near the base. Thickness about 2,500 feet.

C. Upper red beds, consisting of hematitic dolomite, shale, flint, tuff, and lava, with a red basal conglomerate. Thickness 2,200 to 2,600 feet.

D. Amygdaloidal and ellipsoidal lavas of greenstone habit. Thickness about 1,000 feet.

E. Thin-bedded dolomite, shale, argillite, and quartzite, with local beds of more massive dolomite and quartzite, also basic dikes and sills. Thickness about 10,000 feet.

F. Massive magnesian limestone and dolomite. Lowest horizon thus far recognized in Tindir group. Thickness not less than 1,000 feet.

G. Thin-bedded dolomites and argillaceous rocks not unlike those of unit E. Also contains a prominent series of lava flows and an equally prominent series of red beds. Thickness undetermined.

The general stratigraphic sequence of the Tindir group is fairly well known, but the upper part of the sequence is much better known than the basal part, and for this reason it seems best to describe the group from the youngest to the oldest rocks, or, in other words, from the best known to the least known.

The rocks of unit A, which form the top of the sequence, consist of thin-bedded limestone and argillite, with beds of limestone breccia and limestone conglomerate near the base of the unit. Some of the limestone, particularly in the upper half, is a black crystalline variety that emits a fetid odor when broken. The thin beds of limestone in the lower half are massive, porous, and cream colored and are known by chemical analysis to be somewhat magnesian.

The rocks of unit B are variable in composition and include numerous types, such as dolomite, shale, argillite, sandstone, limestone, conglomerate, and grit, with many intergradations. Dolomite and shale, however, form a large part of the sequence. The carbonate rocks of unit B appear to be more magnesian than those of unit A, chemical analyses showing ratios of MgO ranging from 7 to 14 percent. When recomputed into molecular ratios, the analyses show that the dolomite molecule forms from 27 to 60 percent of these carbonate rocks. It is believed that some of these rocks are still more magnesian, grading into almost pure magnesite. These carbonate rocks are also notably siliceous, the proportion of silica ranging from 26 to 37 percent, and the other rocks of this unit are also more or less siliceous. The unity of this sequence is further manifested by the abrupt appearance, at its base, of rocks of different character, which form unit C.

The rocks of unit C are best described collectively as red beds, but chemical and petrographic studies have shown that rocks of rather diverse character are thus grouped together. Argillaceous, dolomitic, cherty, quartzitic, tuffaceous, and igneous varieties compose the sequence, but most of these are mixed types of rocks to which it is difficult to affix simple descriptive names. Thus the dolomitic members are dolomitic mainly because they are composed largely of detrital grains of dolomite, cemented by a hematitic matrix, and the same matrix is found in the siliceous and tuffaceous varieties. The tuffaceous members, as shown by chemical analysis, are highly siliceous, the SiO_2 ranging from 36 to 72 percent and Fe_2O_3 from 4 to 27 percent, with CaO and MgO forming most of the remainder. The one distinguishing characteristic of all these rocks is a high percentage of Fe_2O_3, and some of them are in fact low-grade iron ores. Irrespective of their origin, all these rocks have in some manner been impregnated with hematite. At their base is a coarse red conglomerate composed of subangular to angular detritus, cemented by a hematitic matrix that looks argillaceous but may in varying degrees be siliceous, dolomitic, or even tuffaceous. The material that forms the cobbles and boulders of the conglomerate is largely dolomitic but also includes hematized greenstone and chert. The rocks of unit C are a distinctive and interesting group that merits much further field and petrographic study.

Unit D consists of basic lavas and associated pyroclastic rocks of greenstone habit, with many associated dike rocks of the same general character. Most of the lavas are amygdaloidal, and many of them are also ellipsoidal, thus suggesting for them a subaqueous origin. Where best exposed the lower beds appear to be massive flows of lava, and the upper beds contain a greater proportion of volcanic conglomerate and tuffs. Petrographically, the lavas consist of dark-gray to greenish-gray holocrystalline to partly glassy basalts, with a tendency toward a diabasic habit in the more coarsely crystalline varieties. The dikes and sills, which are associated with the lavas, are particularly diabasic in character and are also characterized by small amounts of orthoclase and quartz, showing that they belong at the acidic end of the diabase-basalt family. Although all these rocks are collectively described as greenstones, many of them are hardly sufficiently altered to merit that designation, and this small degree of alteration in rocks as old as these is particularly noteworthy when they are compared with the much younger greenstones that occur south of the Yukon River.

The rocks of unit E consist mainly of thin-bedded dolomite shale, argillite, and quartzite, with a few beds of more massive dolomite and quartzite, all of which are intruded by basic dikes and sills. These rocks, in the Tatonduk-Nation district, are not so well exposed as the four overlying units and also have a more complex structure, so that less is known of their lithology and stratigraphic limits. That these rocks are different from those described as unit B is clearly indicated, however, by the presence of the more massive members of dolomite and quartzite, by their content of igneous material, and by their much greater thickness.

Unit F may be described as the essentially dolomitic member of the Tindir group. These carbonate rocks are made up of both thin and thick beds, but the thin-bedded and laminated types are more characteristic than the massive beds, and even the more massive varieties cleave into thin slabs. These dolomites are cream-colored, buff, or light yellow, and in moderately rugged country they tend to form less ragged crest lines than the Paleozoic limestones of the same region. Some of them are also much silicified, and all of them partake of the more complicated structure that is characteristic of the rocks below unit D.

Unit G is in a sense a catch-all for the other rocks of the Tindir group that have not or cannot be allocated to any of the six preceding units. This unit includes many rocks that are similar to those of unit E but also includes one notable series of basic lava flows similar to those of unit D and at least one series of red beds somewhat like the red beds of unit C. Certain distinctive features of the lithology and stratigraphic sequence of this unit, however, indicate that it cannot be correlated with any of the preceding units, and it is believed that in general these rocks are a supplementary part of the sequence, although it may well be that parts of the preceding units are infolded in them.

Unit G includes the rocks that crop out along the south side of the Yukon below the mouth of Fourth of July Creek. Just below Fourth of July Creek these rocks project into the river for a short distance, forming a reef known locally as the "Rock of Ages"; and about 4 miles below Fourth of July Creek the same rocks form a more extensive reef that projects a considerable distance into the river. These rocks consist essentially of thin-bedded black to gray dolomite, in beds from half an inch to several inches thick, interbedded with argillite, slate, and a few beds of limestone conglomerate. Much of the dolomite shows very fine alternating black and gray laminae, in places as many as 50 to the inch. Most of these beds are more or less silicified, and some of the silicified argillite and slate are perhaps better termed chert. The fragmented limestone is of two types, of which the more common consists of rounded limestone pebbles in a limestone matrix. The other type is an oolitic limestone in which the oolites are largely silicified to little balls of chert. A little farther downstream these dolomitic rocks contain some altered intrusives that were originally of basaltic or diabasic character but now contain so much calcite and chloritic minerals that they are better classified as greenstone.

In the low hills a short distance southwest of the dolomitic rocks that line the river banks below Fourth of July Creek is a belt of limestone that trends parallel with the river. Some of this limestone is dark gray to black and noncrystalline, but other beds consist of a silicified or chert oolite, with local layers of limestone breccia. This band of limestone is also considered to belong in the Tindir group and is classified as a part of unit G.

STRUCTURE AND THICKNESS

The structure of units A, B, and C of the Tindir group, as exposed in the type locality on the Tatonduk River, is relatively simple, for these units appear to be part of a plunging anticline whose axial line pitches southwestward toward the Yukon River. (See pl. 6, *A*.) The river marks a zone of faulting, trending northwest, the details of which have not yet been deciphered, but this faulting is known to have disrupted and terminated the relatively simple structure of the rocks of the Tatonduk Valley; and south of this zone, not only the old rocks but also the Paleozoic, Mesozoic, and Tertiary rocks have a rather complex structure. The rocks of the Tindir group that underlie the red beds are not exposed in the Tatonduk Valley, but where they crop out to the northwest their structure becomes progressively more complex, owing to close folding, faulting, and igneous injection, so that no broad generalizations are yet warranted. The rocks below Fourth of July Creek belong in this category. They strike in general northwest, but the dip is variable both in degree and in direction, and the few available structural observations probably have little significance so far as the broader structural features are concerned.

The thickness of the several units that form the Tindir group is given in the stratigraphic table on page 60. The total thickness of units A to F has been computed as about 18,600 feet, but to this must be added a considerable but indeterminate thickness of rocks represented by unit G. These considerations lead to the belief that the total thickness of the Tindir group, as exposed north of the Yukon River between the Tatonduk and Nation Rivers, is probably somewhere between 20,000 and 25,000 feet. The base of the sequence has not yet been observed, however, and it may well be that a supplementary sequence of rocks will later be found in the Yukon-Porcupine region that will materially increase the total thickness.

AGE AND CORRELATION

The rocks of the Tindir group were first observed in the upper ramparts of the Porcupine River by McConnell [45] in 1888, but at that time he was unable to make any suggestion regarding their possible age. In 1907 Kindle [46] made a geologic reconnaissance along the Porcupine River and recognized the fact that these rocks probably underlie the Middle Ordovician rocks that crop out nearby. Kindle's estimate of their probable thickness was 50,000 feet. The term "Tindir group" was first applied by Cairnes,[47] in 1911 and 1912, in connection with his geologic studies along the international boundary. Cairnes observed that these rocks underlie the Cambrian and Ordovician sequence north of Yukon, and on the basis of structural as well as paleontologic data he concluded that they are of late pre-Cambrian age, correlative with the rocks of the Belt series in British Columbia and the western United States. This conclusion has been fortified by the discovery in the Tatonduk Valley of an early Middle Cambrian sequence of rocks underlain successively by units A, B, and C, the uppermost members of the Tindir group.

In spite of the data above presented, the pre-Cambrian age of the entire Tindir group, though strongly suggested, is not definitely proved. Cairnes postulated a structural unconformity between the Cambrian and Ordovician sequence and the Tindir group, but where his observations were made neither the oldest rocks of the Cambrian and Ordovician sequence nor the youngest rocks of the Tindir group were exposed, and an unconformity, even if definitely proved, would be inconclusive evidence. Where the oldest Middle Cambrian rocks overlie the youngest rocks of the Tindir group, as in the Tatonduk Valley, no structural unconformity has been recognized, though the writer does not state that none exists. The possibility therefore still remains that some of the Tindir group may be of Lower Cambrian age. Against this interpretation, however, is the

[45] McConnell, R. H., Report on an exploration in the Yukon and Mackenzie Basins, Northwest Territories: Canada Geol. Survey Ann. Rept., vol. 4, pt. D, pp. 129–132, 1891.

[46] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 320–322, 1908.

[47] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 44–58, 1914.

universal absence of fossils in these rocks, their great thickness, and their lithologic and structural similarity to the rocks of the pre-Cambrian Belt series. Well-preserved fossils are far from plentiful in the overlying Cambrian rocks north of the Yukon, but at most localities some remains of organisms, commonly inperfect but nevertheless recognizable as fossils, may be found. This condition stands in marked contrast to that which exists in the Tindir group, in which several geologists have searched carefully but fruitlessly for fossils. The great thickness of the Tindir group renders it unlikely that all these rocks could be of Lower Cambrian age, but it is still possible that the uppermost part, represented by unit A, may later be proved to be Lower Cambrian. The regional structure is no aid in solving this problem, for structural unconformities have not been observed either within the Tindir group or between the Tindir group and the overlying Cambrian rocks. This condition, however, instead of being unique, is exactly that found at many localities in Montana where the Belt series has been studied.

Regardless of unconformities, there nevertheless exists some basis for a major subdivision of the Tindir group. The three uppermost units have a relatively simple structure and, with the exception of the red beds (unit C), are remarkably free from the results of igneous activity. The red beds are also characterized by a very prominent conglomeratic basal member. The underlying units, on the other hand, contain basic lava flows at two or more horizons, are intruded by basic dikes and sills, and have a more intricate structure, though the last-named feature may possibly be only fortuitous. Unfortunately the red beds of unit C have not yet been found in direct contact with the underlying lavas of unit D, but further study in a more favorable locality may result in the discovery of an unconformity at the base of the red beds, which would serve as the basis for a major subdivision of the Tindir group.

UNDIFFERENTIATED PRE-MIDDLE ORDOVICIAN ROCKS

DISTRIBUTION

The rocks here mapped as undifferentiated pre-Middle Ordovician include rocks of Lower Ordovician, possibly Cambrian, and pre-Cambrian age and are found in two general areas. One area is in the Fairbanks district, where a belt of these undifferentiated rocks extends from the Tatalina River northeastward for more than 90 miles to the North Fork of Preacher Creek. At its southwest end a continuation of this belt is also found in the low hills west of the Tolovana embayment. The maximum width of this belt, in the vicinity of the White Mountains, is about 20 miles. The second belt of these rocks begins in the lower valley of the Chena River and extends eastward across the Circle quadrangle into the Fortymile quadrangle, but this belt is disrupted in its central portion by the great granitic batholiths of Mesozoic age. The total length of this second belt is about 160 miles, and its greatest width is about 30 miles.

These rocks as here mapped include the major part of the †Tatalina group of earlier reports.

LITHOLOGY

Most of the information pertaining to these rocks has been obtained northeast of the Tatalina River, and the best available section is in the zone extending from Champion Creek to the north end of the White Mountains. This section is good, not only because it crosses these rocks where their outcrop is widest, but also because the line of the section lies across fairly mountainous country, where exposures can be seen along the ridge tops. Even along this profile, however, the exposures are discontinuous, and this fact, coupled with the complex structure of the rocks, makes it impossible to present a measured section. This zone has been traversed by Prindle, Blackwelder, and the writer, and in addition three other partial sections of the rocks have been observed by the writer, one from the dome at the head of Wickersham Creek northward, a second from the Tanana River at the mouth of the Kantishna northward, and a third from the lower valley of Beaver Creek eastward. All these traverses were qualitative rather than quantitative in scope, and the result may best be described as a generalized geologic sequence, rather than a geologic section. It may further be observed that this sequence is based upon an interpretation, which the structure in places renders doubtful, that the rocks in general decrease in age from south to north.

This assemblage, as mapped, includes a considerable variety of rocks, some of which are so distinctive in their lithology and structure that they might well be discriminated as separate formations along the principal section, but such lithologic units could not be projected along the strike without much more detailed mapping than has thus far been done. The generalized geologic sequence that is found along the zone from Champion Creek to the White Mountains is given below.

A. Slate and quartzite (top of section).
B. Black argillite, slate, and chert.
C. Red and green slates, quartzose sandstone, and a little limestone.
D. Quartzose sandstone and grit, in part feldspathic arkose and graywacke, all interbedded with slate.
E. Phyllite and quartzite, overlain by somewhat less altered quartzitic rocks.

Unit E, the basal part of the assemblage, as seen between Champion and Bear Creeks, consists principally of phyllite and quartzite, which are distinguishable with difficulty from the uppermost beds of the Birch Creek schist. These rocks are more or less recrystallized and have acquired a flow cleavage, but the more competent beds still show distinctly their original detrital fabric. Together with the phyllite and quartzite occur some lenticular beds of crystalline limestone, and one fairly good-sized body of limestone is shown on plate 1. Altered basic intrusive rocks of greenstone habit also occur here and there in this part of the sequence, but they are relatively insignificant. The dominant structural feature of these rocks is cleavage, which, though variable to a considerable degree, strikes about N. 50° E. and dips rather uniformly northwest at low angles, the maximum being 15°. In fact, the cleavage of the crystalline limestone that lies between Champion and Bear Creeks is nearly horizontal.

Between the lower valleys of Bear and O'Brien Creeks the assemblage consists principally of quartzitic rocks, in which, however, the original detrital character is usually evident in hand specimens. These rocks occur mainly in thin beds, but, unlike those south of Champion Creek, they have a less perfectly developed cleavage, and the dip of the dominant structure, though northwestward, is in general steeper, reaching 50° or more.

Unit D, the next younger division of the assemblage, is exposed along the ridges bordering the upper valleys of O'Brien and Willow Creeks. This unit is composed of quartzose sandstone and grit, in part feldspathic, together with considerable slate. The quartzose rocks consist principally of rounded grains of clear quartz that show clearly their original detrital character, though in some of these rocks fracturing of the grains and incipient recrystallization are evident. The name "quartzite", however, cannot be properly applied to most of these rocks. In granularity they range from moderately fine grained rocks up to pebbly grits, with grains as large as one-fourth inch in diameter. Some of them are characterized by the presence of noticeably larger grains of a bluish milky quartz set in a finer matrix of clear quartz grains. Most of them also contain more or less iron hydroxides, derived probably from original iron minerals in the sediments, and for this reason they have a characteristically rusty appearance. The quartzose rocks are not in general feldspathic, but at certain horizons they are so markedly so that they are better described as arkoses and graywackes. These feldspathic rocks are generally massive and occur in beds from a few inches to several feet in thickness. In the coarser-grained varieties grains of quartz and feldspar as much as half an inch in diameter have been observed. The feldspar includes both microcline and plagioclase, and it is probable that these feldspathic rocks were laid down in areas where the sediments were derived in large measure from the gneissic rocks that are associated with the Birch Creek schist. The slates associated with the quartzose and feldspathic rocks constitute a considerable proportion of unit D and are particularly prominent in the upper part. They are mainly dark-gray thin-cleaving rocks, which are greatly appressed and folded. The general strike of the quartzitic, arkosic, and slaty rocks of unit D is about N. 60° E., but the dip of the dominant structure, the bedding, is 20°–45° S. This structure apparently places these rocks below those of unit E, but actually the reverse is believed to be true.

Along the ridge northeast of the southeast fork of Willow Creek the rocks of unit D extend northwestward to a saddle opposite a point in the creek about 2 miles above the forks. Here red and green slates suddenly appear, and these rocks, together with some quartzose sandstone and a little limestone, form the sequence for the next half mile northwestward. These rocks are segregated as unit C, and although they constitute a relatively small part of the whole assemblage, they form a conspicuous horizon marker. In places red and green layers of slate alternate with one another, but elsewhere the slates are mottled in shades of red and green, and there is a suggestion that one type may possibly have been derived from the other. The calcareous beds consist of scattered lenses, a few inches thick, of dark-gray noncrystalline limestones, that weather to an ocherous yellow or cream color. These lenses of limestone look favorable for fossils, but none were found. The structure of unit C is essentially the same as that of unit D, except that the southward dip is, if anything, a little steeper. This part of the assemblage, characterized by red and green slate, has been traced southwestward from Willow Creek for many miles, as these slates crop out at places along the southeast side of Fossil Creek, again in the area northwest of Wickersham Creek, and finally along the Tanana River below the Tolovana telegraph station.

Northwest of unit C, in the White Mountains, another formation begins and extends almost to the forks of Willow Creek. This formation, which is called unit B, consists largely of argillite, slate, and chert and at its northwest side consists of calcareous argillites, which contain fossils. The argillites of this formation are clay rocks, but some of them have been considerably silicified, and all varieties may be found from clay argillites and slates through silica argillites into true cherts. Some of the cherts are distinctly banded. Most of these rocks are black, but some of them are dark-gray flags and slates, and some of the chert is even light gray. Pyrite, in small veinlets and also as disseminated crystals, is rather plentiful, particularly in some of the argillites. The rocks of unit B strike N. 70°–80° E. and dip generally 30°–60° S. Some of these rocks, however, dip northward, showing that they are not a simple monoclinal sequence, and the presence of considerable close folding at some of the croppings on Willow Creek confirms their greatly folded structure. (See pl. 6, *B*.) The rocks of unit B continue southwestward into the upper valley of Fossil Creek, where they are likewise closely folded, with the axial planes of the folds dipping northeastward. Farther down Fossil Creek these rocks disappear.

The fifth division of the assemblage, designated unit A, crops out imperfectly along the northwest flanks of the White Mountains. This unit consists of black to drab slates interbedded with white, gray, and purple quartzite and apparently grades upward into the overlying Ordovician volcanic rocks (Fossil Creek volcanics). These rocks dip steeply southeastward under the Ordovician and Silurian rocks of the White Mountains.

At other localities along this belt of rocks the section is less complete than between Champion Creek and the White Mountains, but parts of the sequence above outlined have been recognized. Thus, at the dome at the head of Wickersham Creek sheared quartzites are found, which show remnants of their original detrital fabric, and interbedded with these are some banded slates. To the north of this dome appear less altered sandstones and grits. All these rocks have a dominant structure which strikes N. 50° E. and dips about 30° S., and this stands in marked contrast to the northerly dip of the lowest rocks of the assemblage which adjoin the Birch Creek schist north of Champion Creek. The rocks above mentioned are believed to be closely correlative with unit D of the standard section. The rocks at the head of Wickersham Creek are believed to be separated from the Birch Creek schist by a thrust fault, and the lower beds of this assemblage have probably been faulted out of the sequence. North of the grit and arkose there is a series of green, maroon, and purple slates, associated with fine-grained cream-colored to gray sandstone, and nowhere else in this section do such rocks appear. This series can surely be correlated with unit C of the type section. Above these slates to the north fragmental arkosic rocks appear which are interpreted as a part of unit D, and their repetition in the section without any marked change in the dominant structure of the country rock indicates the presence of isoclinal folding and the duplication of stratigraphic horizons. The next rocks to the north are fractured remnants of the Tolovana limestone, infolded or infaulted with the rocks of unit D, and the last rocks of the assemblage at the north end of the section are quartzites intruded by small bodies of granular greenstone. These quartzites are believed to be a part of unit A, and the greenstone is considered to be the subsurface equivalent of the Ordovician Fossil Creek volcanics. It will be observed that the black argillites, slates, and cherts of unit B do not appear in the section north of the head of Wickersham Creek, and, like the basal part of the assemblage, they also are believed to be faulted out.

West of the Tolovana embayment these rocks extend northward from the Tanana River for about 15 miles. Some good exposures of them are available along the bluffs of the Tanana. At the mouth of the Tolovana River, according to the original notes of Brooks,[48] the bluffs along the west side of the Tanana are made up chiefly of ferruginous sandstone, interbedded with red and green slate, and such rocks continue to crop out for half a mile downstream. The red slate is a clay slate colored with hematite, but some of the associated greenish slates are siliceous. In places, particularly near the massive beds of sandstone, the slate is greatly contorted and crenulated, giving a curly fracture, but in other places it has a smooth slaty cleavage. In this section two of the massive rocks were found by the writer to be quartzose sandstones, composed mainly of well-rounded grains of quartz, rather uniform in size, with a minimum of interstitial cementing material. The matrix consists of fine quartz and sericite, greatly stained by iron hydroxides. One of these two specimens shows incipient recrystallization. Three other specimens were found to be feldspathic sandstones, consisting mainly of quartz grains, with more or less plagioclase feldspar, in varying stages of alteration. Some of the least altered crystals were determined to have the composition of andesine, and some of the quartz grains are broken and recrystallized, particularly along their edges. The matrix consists of quartz, sericite, iron hydroxides, and fine-grained argillaceous material derived in part from the alteration of the feldspars. The green slate, under the microscope, was found to be composed of fine, well-rounded grains of quartz in a matrix of chloritic material, sericite, and quartz. Incipient recrystallization is apparent.

Northward from the Tanana River along the 150th meridian these rocks form the country rock for 15 miles, but the hills are low and wooded, and most of the croppings are merely rubble. The rocks appear to be the same as those exposed along the river banks below the Tolovana telegraph station, except that differential erosion has tended to localize the harder rocks to the ridge tops and to restrict the softer argillaceous varieties to valleys and swales, where they are less apparent. Under the microscope the more resistant rocks of the ridges are found to have the same fabric as those along the Tanana, but they are essentially nonfeldspathic and are best classified as quartzose and quartzitic sandstone. No red slates were

[48] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., p. 472, 1900; also original notes.

observed along these ridges, and most of the other slaty rocks were either dirty green or brown, owing perhaps to the high degree of residual weathering on their ridges.

The general trend of the rocks west of the Tolovana embayment is apparently about N. 70° E., and the few available observations of strikes on the hills range from east to N. 60° E. The dip is indeterminate. To judge from the lithology, both units C and D are represented in these hills. To the south, where unit E might be expected to occur, the country rock is concealed by the alluvial deposits of the Tanana River. Units A and B, on the other hand, have been removed either by erosion or by faulting.

Between the lower valley of Beaver Creek and the North Fork of Preacher Creek the rocks consist at the west side of sheared sandstone and slate, the dominant structure of which strikes northwest and dips about 45° NE. A high dome to the east consists largely of metamorphosed arkosic rocks, whose structure is indeterminate; and still farther east, close to the North Fork of Preacher Creek, the country rock is largely slate. Most of these rocks may probably be correlated broadly with unit D. The rocks lying between the North Fork and Preacher Creek and the main Preacher Creek have not been seen by the writer but are assigned to this assemblage on the basis of the earlier mapping by L. M. Prindle.

Few data are available regarding the other rocks of this area that are mapped as part of this assemblage. The Chena-Salcha belt and its eastward continuation in the valleys of the North and Middle Forks of the Fortymile River have not, in fact, been seen by the writer, and the present classification is based largely on the earlier traverses of L. M. Prindle, supplemented by the later mapping of P. S. Smith in 1920. Prindle included the rocks of this belt, west of the 146th meridian, as part of his † Tatalina group, but east of the same meridian he classified them merely as undifferentiated Paleozoic. According to Prindle's description,[49] these rocks consist of more or less metamorphosed quartz-feldspar sandstones, quartzite, shale, slate, phyllite, chert, chert conglomerate, greenstone, and limestone, of which the dominant types are derived from sandy and argillaceous sediments. The quartz-feldspar rocks are said to be composed of rather coarse grains of quartz and feldspar in a finely granular matrix composed of the same materials with the addition of some argillaceous material. These rocks are considerably metamorphosed, and in some of them the quartz and feldspar have been converted into augen, and considerable sericite has developed. Such rocks suggest the presence of underlying bodies of the Pelly gneiss

[49] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pp. 26–27, 1913.

and of the Birch Creek schist. Interbedded with these quartz-feldspar rocks at many places are fine-grained quartzites and purple, drab, and green argillaceous slates and phyllites, with a little limestone. This description tallies in a general way with that of the † Tatalina group in its type locality and justifies the inclusion of these rocks as a whole in the assemblage here mapped, but the cherts and chert conglomerate, as well as some of the greenstone, particularly the ultrabasic varieties, are probably of later Paleozoic age. Much work remains to be done in the Chena-Salcha area before these infolded later Paleozoic rocks can be separated from those of the undifferentiated pre-Middle Ordovician assemblage here mapped.

STRUCTURE AND THICKNESS

Little is known of the structure of these undifferentiated pre-Middle Ordovician rocks. The rocks of unit E, which are considered to represent the basal part of the assemblage, have a cleavage that strikes about northeast and dips northwest. This attitude differs little from that of the cleavage of the underlying Birch Creek schist but most of these rocks are not completely recrystallized, whereas the rocks of the Birch Creek schist are almost entirely recrystallized. This difference in degree of recrystallization cannot be ascribed to the effects of intrusive rocks, as such rocks are as prevalent in this undifferentiated assemblage as in the Birch Creek schist. No structural unconformity has actually been observed between the two, but an unconformity is indicated by the difference in the degree of recrystallization. The lithology of the pre-Middle Ordovician assemblage also suggests the unconformable relation, for these rocks appear to have been derived from the erosion of the Birch Creek schist.

The dominant structure of the rocks of units C and D strikes parallel to the cleavage of the rocks of unit E, but the dip of this structure is steeper and is principally to the southeast. Moreover, this dominant structure at many places has been identified as bedding rather than cleavage. Although the relation between cleavage and bedding has not been observed in units C and D, drag folds have in places been seen with such relations to the bedding as to suggest the presence of appressed folds overturned toward the northwest—that is, with axial planes dipping southeast. Such structure suggests that units C and D constitute in general an overturned sequence of rocks, which are younger than and therefore stratigraphically overlie the rocks of unit E. The differences in structure and lithology also suggest the presence of a depositional hiatus between the rocks of unit E and the overlying rocks, but the available facts are not adequate to prove this hypothesis.

The rocks of unit B also dip mainly southeastward and are probably overturned to the northwest, so that their proper stratigraphic position is above the rocks of unit C. Along their northwest limit this unit is in general terminated by strike faulting, so that the next higher beds are not exposed. The rocks of unit A, which lie along the northwest side of the White Mountains, dip steeply southeastward under the overlying Ordovician lavas and are therefore also slightly overturned. These rocks represent the top of the pre-Middle Ordovician assemblage, but between units A and B an unknown but probably not a great thickness of beds has been faulted out.

In general, therefore, these undifferentiated rocks comprise a great thickness of beds, overturned toward the northwest and dislocated by strike faults. Though the beds commonly dip to the southeast, the general structure is isoclinal rather than monoclinal, so that these rocks increase in age intermittently rather than continuously from south to north. In other words, beds at particular horizons are probably several times repeated at the surface by close folding, with the infolding of adjacent beds of older or younger age. With such structure the true thickness of the assemblage may be only a small percentage of the surface distance across the strike of these rocks. As so little is known of the details of the structure, no true measurement of the thickness has been made. It is the writer's opinion, however, that the thickness is not less than 10,000 feet, and it may be two or three times as great.

AGE AND CORRELATION

The only fossils that have yet been found in the rocks of this assemblage are a small collection of trilobites and brachiopods, which occur in the upper part of unit B. The exact locality and the faunal identifications are given below:

1519A. East bank of southeast fork of Willow Creek, about a quarter of a mile above the west fork; collected by Eliot Blackwelder, 1915:

- Lingulella sp.
- Agnostus sp.
- Bathyurellus? sp.
- Hemigyraspis? sp.
- Megalaspis? sp.

Edwin Kirk, of the United States Geological Survey, who identified these fossils, considered them to be of Lower Ordovician age, and E. O. Ulrich, of the United States National Museum, concurred in this opinion. L. D. Burling, of the Canada Geological Survey, however, considered this fauna to be of Upper Cambrian age.

These fossils determine the approximate age of the upper part of unit B. Unit A, which is believed to overlie unit B and is itself overlain by Middle Ordovician lavas, is therefore probably of Lower or early Middle Ordovician age. But most of the sediments comprising this assemblage lie below the fossiliferous part of unit B, and as no fossils have been found in these sediments, their age is largely a speculative question. This problem of age is further complicated by the fact that the fossils above listed are neither definitely Ordovician nor definitely Cambrian. The following considerations, however, may have some significance:

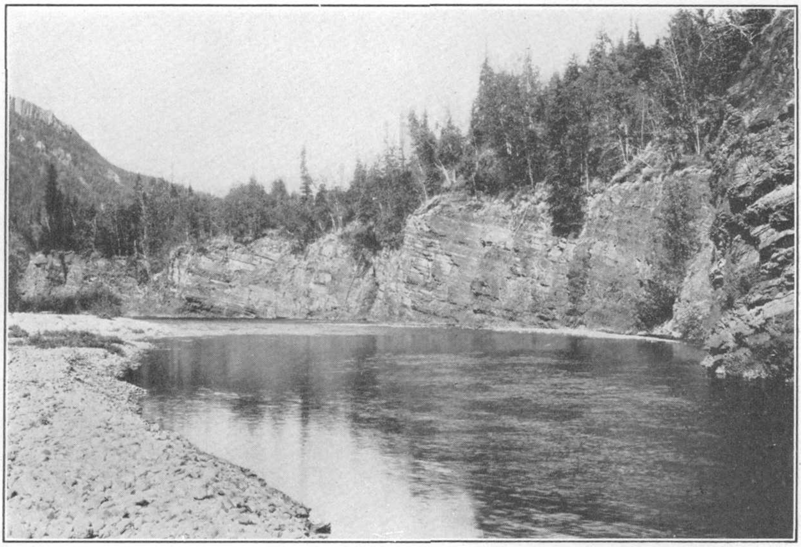
Unit B is decidedly a lithologic unit. The actual contact of this formation with the underlying rocks has not been observed, but all the field evidence is opposed to a downward lithologic gradation of these rocks into those which underlie them. This condition is in marked contrast to the stratigraphy of the Cambrian rocks found along the international boundary, where the writer [50] has recorded the gradual transition of the Cambrian into the Ordovician sequence without even a change in lithology. Walcott [51] reported that in British Columbia the Cambrian rocks grade into the "Ozarkian", and these in turn into the "Canadian" (Lower Ordovician) sequence, without a disconformity. Moreover, the rocks below unit B are so markedly different in their lithology from the Cambrian sequence along the international boundary and in British Columbia that it seems highly improbable that they belong anywhere in the Cambrian section. Hence they are more logically considered to be a part of the pre-Cambrian sequence. But the rocks of unit B are likewise dissimilar to the Upper and Middle Cambrian rocks exposed along the international boundary and, on the other hand, are very similar to the Lower Ordovician slates and cherts exposed along the boundary. The lithologic evidence therefore favors the paleontologic interpretation of Kirk and Ulrich, rather than that of Burling, and the writer is constrained to regard unit B as more probably Ordovician than Cambrian. This analysis also leads to the belief that the Cambrian system is probably absent in the White Mountain district, and that a stratigraphic hiatus and perhaps a structural unconformity exists at the base of unit B.

It is thus implied that units C, D, and E are pre-Cambrian. But these rocks are entirely different from the Birch Creek schist, and unit E at least shows lithologic evidence that it originated from the erosion of the Birch Creek schist. Units C, D, and E are therefore

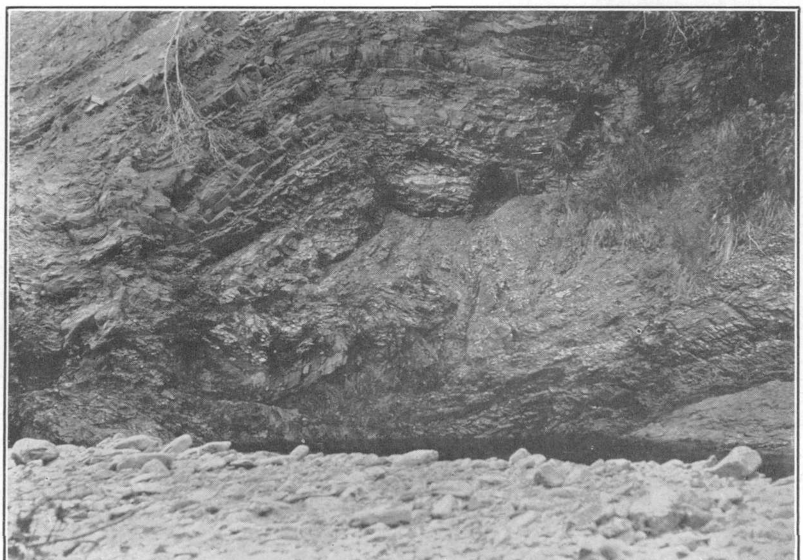
---

[50] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 392–401, 1932.

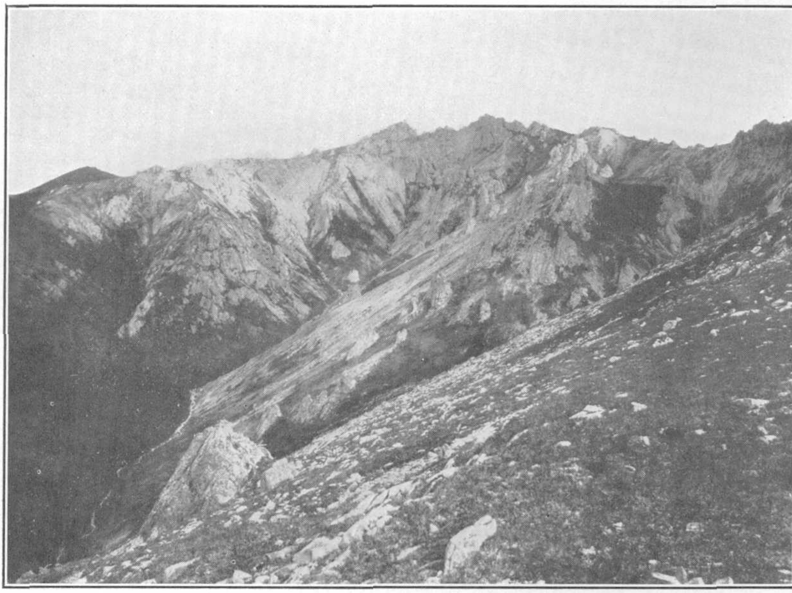
[51] Walcott, C. D., Pre-Devonian Paleozoic formations of the Cordilleran provinces of Canada: Smithsonian Misc. Coll., vol. 75, no. 5, pp. 259–368, 1928.



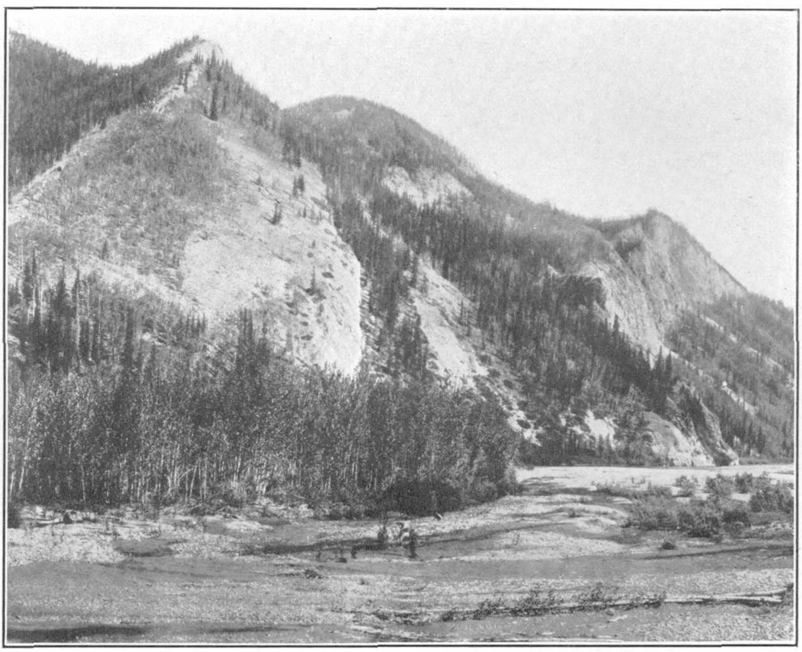
A. RED BEDS OF UNIT C, IN THE TINDIR GROUP, AS SEEN ALONG TATONDUK RIVER.



B. FOLDED BLACK CHERT AND SLATE OF UNIT B, IN THE UNDIFFERENTIATED PRE-MIDDLE ORDOVICIAN ROCKS, EAST FORK OF WILLOW CREEK, WHITE MOUNTAINS.



A. TOLOVANA LIMESTONE FROM THE SOUTH.



B. MIDDLE CAMBRIAN LIMESTONE, TATONDUK RIVER.

considered to be late pre-Cambrian. If this is true, they should be correlated with some part of the Tindir group. But the upper members of the Tindir group, as studied by the writer along the international boundary, contain a large proportion of thin-bedded dolomite, as well as red beds and extensive lava flows. The base of the Tindir group, however, has not yet been observed, though it is a significant fact that the lowest beds of that group yet recognized contain a greater proportion of quartzite and argillaceous rocks. These considerations suggest that units C, D, and E in the Fairbanks district may possibly be correlative with the basal part of the Tindir group. Under this interpretation, the rocks of this assemblage below unit B are likely to represent the basal section of the younger pre-Cambrian sequence. The upper beds were either eroded before the deposition of unit B or perhaps were never deposited. Under either interpretation, an unconformity is indicated at the base of unit B.

The rocks that are exposed in the low hills west of the Tolovana embayment have also been included as a part of this assemblage, but at this locality the Ordovician rocks appear to be absent. The rocks were originally described by Brooks [52] as the "Nilkoka beds", "Nilkoka" being the original name of the Tolovana River. Brooks assigned his Nilkoka beds to the Paleozoic, but this assignment had no paleontologic basis. These beds probably represent units C and D of this assemblage. The term "Nilkoka group" may later serve a useful purpose for a unit that does not include any Paleozoic rocks. It would be a fitting group name for the younger pre-Cambrian unit of this region.

If the correlation above outlined is accepted as a working hypothesis, the rocks of this assemblage must be described as pre-Middle Ordovician and late pre-Cambrian. If it were possible at the present time to map separately the Paleozoic and pre-Cambrian rocks of this assemblage it would doubtless be better to utilize at once the term "Nilkoka group" for the pre-Cambrian part. But such a differentiation, though possible in a small area in the White Mountain district, could not be extended elsewhere in the Yukon-Tanana region. The designation "undifferentiated pre-Middle Ordovician rocks" is therefore utilized for this assemblage until detailed mapping of this region can be done.

The rocks of the Tindir group have already been correlated with the Belt series, and units C, D, and E of the undifferentiated pre-Middle Ordovician assemblage must also therefore be correlated with

[52] Brooks, A. H., A reconnaissance of the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 472, 1900.

the same series of rocks. All these rocks were doubtless deposited in one or more inland bodies of water that occupied a basin from a few hundred to a thousand miles in width, extending from Mexico to Alaska. The fingering out of these deposits into two or three narrow basins in the Yukon-Tanana region and their apparent absence to the west, suggest that eastern Alaska represents the northwestern limit of this great basin of sedimentation, which subsequently became the Cordilleran geosyncline. The absence or scarcity of fossils in all these sediments and the abrupt appearance of a highly developed Cambrian fauna in the overlying beds has been considered by most investigators of pre-Cambrian geology to indicate that these sediments were not of marine origin but instead were deposited in shallow epicontinental seas of fresh or brackish water. This scarcity of fossils makes it necessary to correlate, if at all, by lithology, but all the previous experience of workers in the Belt series shows the difficulty and unsatisfactory results of this method. The very nature of the sediments probably precludes such correlation, except where certain horizon markers can be followed continuously. As the Tindir group and the undifferentiated pre-Middle Ordovician rocks are not known anywhere to be in contact, it is unlikely that any closer correlation between these two groups is possible.

CAMBRIAN SYSTEM

DISTRIBUTION

Rocks of the Cambrian system are not known to occur in the Yukon-Tanana region proper, but they are present a short distance north of the Yukon River on both sides of the international boundary, and for this reason a short description of these rocks is included. A more complete description has been given in a recent report.[53]

A few miles north of Eagle the Ogilvie Range crosses the international boundary, trending about east-west. The extent of this range in Yukon Territory is not known to the writer, but on the Alaska side of the boundary it disappears in a few miles. The Ogilvie Range is the site of the Cambrian rocks now known in Alaska, and the evidence so far available favors the belief that the Cambrian sedimentation was restricted to a relatively narrow trough that was approximately coextensive with the present range.

[53] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 392–401, 1932.

LITHOLOGY

The Cambrian sequence, so far as determined, is as follows:

1. Upper Cambrian limestone, which grades upward without any noticeable stratigraphic or lithologic break into Ordovician limestone. Thickness about 2,000 feet.
2. Upper plate of Middle Cambrian limestone. Thickness about 3,000 feet.
3. Slate and quartzite, also of Middle Cambrian age. Thickness about 300 feet.
4. Lower plate of Middle Cambrian limestone. Thickness between 600 and 800 feet.

The Middle Cambrian limestone, particularly the lower plate, is well exposed in the hills northeast of Calico Bluff, north of the Yukon River and also on the Tatonduk River. (See pl. 7, *B*.) It consists mainly of massive white finely crystalline rock, silicified to a greater or less degree. Some of the silica occurs as chert, but more commonly it is quartz, and some of this limestone is so thoroughly replaced by quartz that it resembles closely a granular white quartzite. Oolitic limestone also forms a part of the sequence, but this type is more common in the upper plate of the Middle Cambrian. Still another variety is limestone conglomerate, composed of subangular to rounded pebbles of limestone in a limestone matrix. Both the oolitic limestone and the limestone conglomerate are partly silicified.

Part of the upper plate of the Middle Cambrian limestone is exposed along the north bank of the Yukon, about 4 miles downstream from Calico Bluff, where it crops out at the water's edge. This is a massive light-gray crystalline limestone, which is not so greatly silicified as the lower plate. It also has oolitic and conglomeratic phases.

The Upper Cambrian limestone has apparently been eroded from the hills northeast of Calico Bluff, but about 10 miles to the north a sequence of Upper Cambrian and Ordovician limestone occurs along a high divide known as Jones Ridge. Here the Upper Cambrian limestone ranges from a massive white to cream-colored coarse-grained rock to a dense, fine-textured brownish-gray rock with prominent bedding planes. The coarse-grained limestone appears mainly in the lower part of the section, and the brownish-gray lithographic variety in the higher part. No stratigraphic hiatus has been discovered between the Upper Cambrian and Ordovician limestones.

STRUCTURE AND THICKNESS

The Middle Cambrian rocks occur in an anticline that pitches southwestward toward the Yukon River. The axial plane of this anticline meets the Yukon River at the first bend below Calico Bluff, and from this point one limb of the fold trends about east and the other north. The eastern limb is faulted near the international boundary, and the northern limb, which continues into the Tatonduk Valley, is likewise faulted a short distance north of the Tatonduk River. At the southwest end this fold is also terminated by a zone of faulting. The details of this faulted anticline have not yet been worked out.

The Upper Cambrian limestone crops out in a syncline, whose axial plane strikes about east and pitches in the same direction. This pitching syncline is north of the pitching anticline above described, to which it is structurally related. The south limb of this syncline forms the north limb of an anticline of major size that extends for some miles eastward into Yukon Territory.

The thickness of the several members of the Cambrian sequence is given in the tabulation above presented and aggregates about 3,300 feet. It should be emphasized, however, that the Upper and Middle Cambrian sections have not been measured as a continuous sequence, for they occur in this region at two different localities. The Middle Cambrian was measured at a locality where erosion has removed not only the overlying Upper Cambrian beds but also possibly some of the Middle Cambrian beds. The total thickness may therefore be greater than that above given.

AGE AND CORRELATION

Twenty-seven collections of Middle and Upper Cambrian fossils have been made in the vicinity of the international boundary, just north of the Yukon River. These collections, together with their localities and collectors, were presented by the writer [54] in an earlier publication, but some of them have recently been redetermined. These lists of faunas in their revised form are here reproduced on account of their bearing upon the general geology of the region. The Middle Cambrian fossils were collected in the course of work done by the United States Geological Survey, but the Upper Cambrian fossils were collected both by the Geological Survey of Canada and by the United States Geological Survey. The fossils of collection 25AMt148 were determined by G. A. Cooper, of the United States National Museum, but all the other Middle Cambrian fossils were determined by Edwin Kirk, of the United States Geological Survey. Eight Upper Cambrian collections, made by D. D. Cairnes,

---

[54] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 397–401, 1932.

of the Canadian Geological Survey, were determined by L. D. Burling, formerly of the same organization, but collections 4730, 4731, 4732, and 4733, made by Burling, were determined by C. E. Resser, of the United States National Museum. Of the five Upper Cambrian collections made by the United States Geological Survey, collections 30AMt146, 30AMt147, and 30AW22 were determined by Teiichi Kobayashi, of the Imperial University at Tokyo, and the other two by Edwin Kirk.

The Middle Cambrian fauna consists of 11 genera, of which two primitive corals, *Ethmophyllum* and *Archaeocyathus*, are said to be more closely related to forms hitherto known only in the Lower Cambrian. This statement indicates that some of the Middle Cambrian rocks north of Eagle are lower Middle Cambrian and also suggests that a Lower Cambrian sequence may possibly be present. The Upper Cambrian fauna contains 39 genera and also undetermined Foraminifera, corals, trilobites, and ostracodes. Of the 14 Upper Cambrian genera found by the United States Geological Survey west of the international boundary, only 5 also occur among the 30 genera represented by the Canadian collections along the zone close to the boundary. This suggests that different Upper Cambrian horizons are probably represented by the American and Canadian collections; and the stratigraphy bears out this interpretation, because the American collections are known to come from the uppermost Upper Cambrian, whereas the Canadian collections along the boundary are believed to have come from lower horizons. The tabular lists are given herewith:

Middle Cambrian fauna of region north of Yukon River, near international boundary

	25AMt148	28AMt263	30AMt47	30AMt77	30AMt136	30AMt214	30AW13	30AW58-59	30AW60	30AW62
Archaeocyathus sp			×	×	×	×	×		×	×
Archaeocyathus ? sp		×								
"Archaeocyathus" sp								×	×	
Ethmophyllum sp				×						×
"Cocinoptycha" sp				×						
Arctohedra minima Cooper	×									
Arctohedra mertiei Cooper	×									
Nisusia borealis Cooper	×									
Nisusia sp	×									
Eoorthis ? sp							×			
Stenotheca rugosa	×									
"Ptychoparia," 2 sp	×									
Albertella sp	×									
Ogygopsis sp	×									
Dorypyge, 2 sp	×									
Dorypyge ? sp										×

Upper Cambrian fauna of region along the international boundary

[Collected by Canadian Geological Survey]

	XX c 29	XX l 34	XX e 39	XIX j 9	XIX j 17, 18	XIX p 20	XIX j 31	XIX j 32	4730, 4731, 4732, 4733
Levisia sp				×					
Foraminifera		×					×		
Coral?							×		
Micrometra (Iphidella) pannula (White)		×						×	
Curticia? sp			×				×		
Obolus (Westonia) cf. O. stoneanus (Whitfield)					×		×		
Obolus sp	×			×		×	×	×	
Westonia sp									×
Lingulella sp				×	×		×		
Lingula sp						×			
Obolella? sp								×	
Acrothele cf. A. coriacea Linnarsson				×	×		×	×	
Acrothele sp									×
Acrotreta sp	×	×	×	×		×	×	×	
Schizambon cf. S. typicalis Walcott					×				
Eoorthis sp									×
Orthoid							×		
Stenotheca sp		×							
Dicellomus? sp							×		
Parabolus sp									×
Conularia sp		×							
Hyolithellus? sp		×							
Agnostus sp		×	×	×			×		
Eurycare? sp							×		
Ptychoparia sp	×	×		×					
Neolenus? sp		×							
Solenopleura sp	×	×							
Agraulos sp	×	×							
Asaphus? sp						×			
Illaenus? sp								×	
Dicellocephalus? sp			×						
Anomocare sp	×	×		×					
Dorypyge? sp		×							
Liostracus sp				×					
Trilobita (undetermined)		×			×		×		×
Ostracoda							×	×	

Upper Cambrian fauna of region north of Yukon River, near international boundary

[Collected by U. S. Geological Survey]

	28AMt262	30AMt146	30AMt147	30AW22	30AW61
Elkania hamburgensis (Walcott)		×		×	
Obolus tetonensis Walcott		×	×		
Obolus (Westonia) linguloides		×			
Obolus sp					×
Acrothele? burlingi		×	×	×	
Acrothele sp	×				
Acrotreta cf. A. curvata				×	
Acrotreta cf. A. sagittalis (Salter)		×			
Eoorthis sp					×
Eoorthis? sp			×		
Hyolites sp			×		
Dicellomus? sp				×	
Pseudagnostus (Plethagnostus) clarki			×		
Chuangiella intermedia			×		
Tatonaspis alaskensis			×		
Briscoia mertiei			×		
Briscoia robusta			×		
Briscoia septentrionalis			×		
Parabriscoia elegans			×		
Parabriscoia stenorachis			×		
Parabriscoia? tripunctata			×		
Hungaia? pacifica			×		
Eurekia sp				×	

The nearest Cambrian rocks with which this Alaskan sequence might be correlated are those of British Columbia and Alberta, which were studied for many years by C. D. Walcott. Walcott measured numerous sections of these rocks at different localities and studied the contained faunas in much detail. No such work has yet been done upon the Cambrian rocks of eastern Alaska and Yukon Territory, and it is therefore not possible to correlate the faunas above listed with those included in any of Walcott's standard sections. However, from the general similarity of the faunas and the strike of the rocks, it seems very probable that the Cambrian rocks along the international boundary were laid down in a part of the same basin of sedimentation as those of British Columbia; and the apparent absence of these Cambrian rocks farther west in Alaska also suggests that the international boundary is about the northwestern limit of that basin. Walcott [55] has shown that the Cambrian sediments in the Cordilleran province of Canada were deposited in several troughs, which form a part of the great Cordilleran geosyncline. The pre-Cambrian deposits have a much greater east-west extent in this geosyncline than the Cambrian rocks. The same is evidently true at the northwest end of this geosyncline, for the Tindir group occurs not only subjacent to the Cambrian rocks but also far to the north, in the Porcupine Valley; and the undifferentiated pre-Middle Ordovician assemblage as already seen, crops out well to the west and southwest, in the Fairbanks quadrangle. The Cambrian rocks along the boundary therefore probably represent the northwestern limit of Cambrian sedimentation in the Cordilleran geosyncline.

ORDOVICIAN SYSTEM

The Ordovician strata within the group of undifferentiated pre-Middle Ordovician rocks have already been considered. In addition to these, the Yukon-Tanana region contains a formation of Ordovician volcanic rocks that are separately mapped. The name "Fossil Creek volcanics" is here applied to this formation. Other Ordovician rocks, both older and younger than the Fossil Creek volcanics, are also found in interior Alaska but not in the Yukon-Tanana region proper. Reference to these rocks will be made in connection with the correlation of the Fossil Creek volcanics.

FOSSIL CREEK VOLCANICS

DISTRIBUTION

The Fossil Creek volcanics are typically exposed in the White Mountains, about 50 miles north of Fairbanks, where they crop out just north of Fossil Creek, in a belt about 40 miles in length. Northeast of the White Mountains these rocks are overlapped by younger

[55] Walcott, C. D., Pre-Devonian sedimentation in southern Canadian Rocky Mountains: Smithsonian Misc. Coll., vol. 75, no. 4, pp. 152–173, 1927.

Paleozoic rocks, and southwest of the White Mountains they are probably eroded, for they do not reappear in the hills west of the Tolovana embayment.

LITHOLOGY

The Fossil Creek volcanics consist of basic lavas, tuffs, breccias, and agglomerates of greenstone habit, together with a small proportion of granular basic intrusives. The lower part of the sequence consists mainly of bedded lavas and interbedded pyroclastic rocks. The lavas are diabase and basalt of greenstone habit, ranging from greenish gray to dark gray green. Amygdaloidal lavas are common, and at several places ellipsoidal flows occur. The massive lava has been much fractured by deformative stresses and usually breaks down into sharp angular pieces. In places, however, the rocks are mashed and slickensided, and some of the finer-grained basalt has developed a well-defined secondary cleavage, so that it is really an igneous slate. The fragmental rocks consist of laminae and beds of fine-grained tuffaceous material, welded together to form dense lithoidal rocks that do not differ greatly in appearance from the fine-grained basaltic rocks. Some of these also have a slaty cleavage. The coarser tuff-breccias and agglomerates are less common. The intrusive rocks of the sequence are speckled dark and light green granular gabbroic rocks, of greenstone habit, and are considered to be the deep-seated equivalents of the lavas. These rocks are found with the lavas in the White Mountains and, in fact, intrude them in places. They are best developed, however, along the ridge that lies west of the southwest end of the White Mountains, where they occur as small intrusive masses, invading the undifferentiated pre-Middle Ordovician assemblage.

The upper part of this volcanic sequence contains an increasing proportion of volcanic conglomerate, interbedded with tuffs. The conglomerate is made up of well-rounded, water-worn pebbles and cobbles, ranging from an inch or less to 12 inches in diameter and cemented by finer sediments of tuffaceous origin. Most of the pebbles and cobbles are greenstones, but small percentages of granitic rocks, quartzite, slate, and chert have also been observed. At the very top of the volcanic sequence is a reddish calcareous rock, which is probably a tuffaceous limestone, upon which the Silurian limestone rests. This tuffaceous rock, which is from 80 to 90 feet thick, contains brachiopods, trilobites, and other fossils, and it is on the basis of this fauna that the age of the volcanic sequence has been determined.

STRUCTURE AND THICKNESS

The trend of the Fossil Creek volcanics is about N. 50° E. over a distance of 40 miles. Together with the superjacent and subjacent rocks they are closely folded, but only in the high ridges of the White Mountains are the details of this structure apparent. There the dark-colored volcanic rocks and the adjoining white Silurian limestone crop out with diagrammatic clearness, and it is apparent that the strata are several times repeated. At the northeast end of the White Mountains, west of the head of Fossil Creek, the Fossil Creek volcanics occur in a compressed anticline, between two synclines of the Silurian limestone, and this anticline persists for 10 miles along the strike. The rocks of these folds stand nearly vertical, but the axial planes of the folds appear to dip steeply southeast, and the folds themselves pitch gently southwestward. Along the northwest flanks of the White Mountains the volcanic rocks reappear at the surface west of the Silurian limestone, but in these lower hills the details of the structure are not apparent. Along the southeast flanks of the White Mountains, at the head of Fossil Creek, the volcanic rocks also appear east of the limestone, but here the structure is more complex, for the volcanic rocks and limestone interfinger in a complex manner. Thus in one of the upper tributaries of Fossil Creek the limestone may be seen in a recumbent fold, wrapped around a central core of the volcanic rocks. The more complex structure along the southeast flank of the White Mountains is probably due to readjustments in the rocks, attendant upon the thrust faulting that was localized in the valley of Fossil Creek, as previously described in connection with unit B of the undifferentiated pre-Middle Ordovician assemblage. The pitching character of the folds brings the volcanic rocks to the surface at the northeast end of the White Mountains, where they constitute all of the country rock. Conversely this structure causes the volcanic rocks to disappear toward the southwest. The ellipsoidal lava that crops out in the water gap of Fossil Creek is probably in a small closely compressed anticline, squeezed into the Silurian limestone.

No structural unconformity has been observed between the Fossil Creek volcanics and the superjacent Silurian limestone, but the fossils found in the tuffaceous limestone at the top of the volcanic sequence are so greatly different in age from those found in the overlying limestone that a stratigraphic hiatus must exist between the two formations. It is very fortunate that these two faunas are so entirely dissimilar, for otherwise it might be difficult to prove that the calcareous tuff was not the base of the Silurian sequence. In reality, however, a great disconformity is present at the top of the Fossil Creek volcanics in the White Mountains. This disconformity may be due either to lack of original deposition of the later Ordovician rocks, or to their removal by subsequent erosion, but the progressive pre-Silurian denudation of the undifferentiated pre-Middle Ordovician assemblage to the southwest suggests that the latter interpretation is more probably correct.

No precise measurement of the thickness of the Fossil Creek volcanics has been made, but to judge from the structure of the central anticline of these rocks in the White Mountains, the thickness cannot well be less than 2,000 feet; and the distribution of these volcanic rocks at both ends of the White Mountains, particularly at the northeast end, indicates that the thickness may be considerably greater than 2,000 feet.

AGE AND CORRELATION

Several collections of fossils have been made from the uppermost member of the Fossil Creek volcanics. This fauna, which consists largely of brachiopods and gastropods, comprises 22 genera. All the fossils were examined and determined by Edwin Kirk, of the United States Geological Survey. A list is given below.

Middle Ordovician fauna of Fossil Creek volcanics

	5AS80	9AP87	9AJ70	1519C4	1519C6	1519C7	1520D1
Streptelasma rusticum (Billings)		×					
Streptelasma sp			×				×
Streptelasma? sp						×	
Columnaria (Paleophyllum) thomi (Hall)			×	×			
Columnaria? sp			×				
Halysites gracilis (Hall), var			×				
Halysites sp						×	
Crinoid columns					×		
Calymene sp				×			
Rhombotrypa sp		×	×	×			
Lingula sp				×			
Platystrophia sp				×			
Dalmanella sp				×			×
Dinorthis sp		×		×			
Leptaena near L. unicostata (Meek and Worthen)				×	×		
Plectambonites sericeus (Sowerby), var			×	×			
Plectambonites sp		×	×				
Rafinesquina sp		×					
Triplecia sp			×	×			
Rhynchotrema increbescens (Hall and Clarke), var		×	×	×			
Rhynchotrema sp							×
Liospira cf. L. progne (Billings)			×				
Maclurea? sp			×				
Maclurina sp	×						
Raphistomina sp			×				
Cyclonema sp			×				
Dyeria? sp		×					
Isotelus sp		×	×	×	×		

5AS80. About half a mile west of 4,000-foot mountain that forms the crest of White Mountains, west of forks of Fossil Creek; elevation on spur about 3,400 feet. Collector, R. W. Stone, 1905.

9AP87, 9AJ70. About 56 miles N. 10° E. from Fairbanks, saddle at extreme head of west fork of Willow Creek; elevation about 3,300 feet. Collectors, L. M. Prindle and B. L. Johnson, 1909.

1519C4, 6, 7. Southeast flank of White Mountains, at extreme head of west fork of Willow Creek; probably same locality as 9AP87 and 9AJ70. Collector, Eliot Blackwelder, 1915.

1520D1. Southeast flank of White Mountains, about 5 miles northeast of the mouth of Fossil Creek. Collector, Eliot Blackwelder, 1915.

These fossils were originally considered to be of Upper Ordovician (Richmond) age, but subsequent studies by Kirk convinced him that the entire fauna is best assigned to the Middle Ordovician (Mohawkian), approximately correlative with the fauna collected by Kindle [56] from the lower ramparts of the Porcupine River. A somewhat similar Middle Ordovician fauna has recently been collected by the writer [57] from the belt near the international boundary, about 7 miles north of the Yukon River. This fauna is considered by Kirk to be approximately of Trenton age. These three faunas, from the White Mountains, the Porcupine River, and the international boundary, comprise all the Middle Ordovician fossils of littoral facies now known in Alaska. Several Ordovician graptolite facies, however, are widespread in Alaska. Thus, Upper Ordovician (Utica) graptolites have been collected by Brooks [58] and Prindle in the Alaska Range; Middle Ordovician graptolites have been recorded by Cairnes [59] and by the writer [60] from the international boundary belt; and Lower Ordovician (middle or lower Deepkill) graptolites have been collected by L. D. Burling from a locality close to the site of the Cairnes collections. Buddington [61] and Kirk [62] have also found Middle and Lower Ordovician graptolites at several localities in southeastern Alaska.

In addition to the Middle Ordovician rocks from which the faunas above listed were obtained, Upper and Lower Ordovician rocks are also well known in Alaska. Upper Ordovician (Richmond) fossils have been found by Eakin [63] in the Sulukna Valley, about 50 miles west of Lake Minchumina, and by Brown [64] somewhat farther southwest in the same general region. In Seward Peninsula numerous collections of Ordovician fossils have been made in earlier years by Collier, Washburne, Knopf, and Kindle and more recently by Steidtmann and Cathcart.[65] These Ordovician rocks of Seward Peninsula

[56] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, p. 323, 1908.

[57] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, p. 403, 1932.

[58] Brooks, A. H., The Mount McKinley region, Alaska, with a description of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle: U. S. Geol. Survey Prof. Paper 70, p. 72, 1911.

[59] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 65–66, 1914.

[60] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, p. 50, 1930.

[61] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800 pp. 75–77, 1929.

[62] Kirk, Edwin, An Ordovician fauna from southeastern Alaska [abstract]: Geol. Soc. America Bull., vol. 29, pp. 143–144, 1918.

[63] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, p. 25, 1918.

[64] Brown, J. S., The Nixon Fork country: U. S. Geol. Survey Bull. 783, pp. 103–105, 1926.

[65] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. 733, pp. 23–26, 1922.

were originally referred to various horizons from the Upper Cambrian to the Upper Ordovician, but Edwin Kirk has found from recent studies that they fall into two well-defined groups, representative of the Upper and Lower Ordovician. The Middle Ordovician appears to be absent on Seward Peninsula, but this may be due to lack of extensive collecting.

It thus appears that Ordovician rocks, unlike those of Cambrian age, are widespread in Alaska, but in interior Alaska the work so far accomplished indicates that the Middle Ordovician rocks are restricted to a relatively small area in the east-central part. Only in the White Mountains of the Yukon-Tanana region, however, has the result of Ordovician volcanic activity yet been recognized, but there is a strong probability that the equivalent of the Fossil Creek volcanics may also exist farther southwest in the Kuskokwim Valley.

SILURIAN SYSTEM

The Silurian system is represented by one well-defined formation of middle Silurian (Niagaran) age and possibly in part by a group of undifferentiated rocks that are considered to be largely of Devonian age. The middle Silurian rocks are here described as the Tolovana limestone. No formal designation has been assigned to the overlying group of undifferentiated rocks, because this group may represent rocks of two different ages, which will ultimately be separately mapped.

TOLOVANA LIMESTONE

DISTRIBUTION

The Tolovana limestone is named for its outcrop in the Tolovana Valley, but its best exposures are in the White Mountains, about 50 miles north of Fairbanks. This formation is there infolded and essentially coextensive with the Fossil Creek volcanics. Farther southwest the same limestone is also present on the end of the ridge lying between the Tatalina and Tolovana Rivers; and still farther southwest it reappears in the low hills west of the Tolovana embayment. The total length of the belt within which the Tolovana limestone is recognized is therefore more than 60 miles.

LITHOLOGY

This formation is composed entirely of carbonate rocks, without any important admixture of argillaceous or arenaceous members. Both limestone and dolomite are present, but the proportion of each has not been determined, and in the following description the term "limestone" is applied in a generic sense. In the White Mountains these rocks are dark to light gray, have a crystalline texture of medium grain, and characteristically weather white on exposed surfaces, though in places this weathered rind is yellowish or buff. Like other limestones in the mountainous parts of Alaska, this formation weathers out in pinnacles and castellated forms that make rugged and picturesque sky lines. Plate 7, *A*, shows the general appearance of this formation. This limestone formation is in general massive so that the bedding is not apparent, but at some horizons there are also thin beds, ranging from a few inches to several feet in thickness. The fossils found in this formation in the White Mountains come from the lower 500 feet of the section; and in the later part of Tolovana time animal life may have been absent, or perhaps evidence of it has been destroyed by subsequent recrystallization. The limestone on the spur between the Tatalina and the Tolovana Rivers has been visited only by Brooks and Prindle, in 1902. Brooks [66] described this limestone as a massive white semicrystalline siliceous variety, containing corals.

West of the Tolovana embayment the Silurian limestone crops out in a band about 1½ miles wide, with a general trend N. 70° E. This limestone appears in low hills, where it has been subjected to more residual weathering and chemical solution than in the high hills of the White Mountains, and therefore it forms yellowish brown croppings that from a distance would scarcely be identified as limestone. At close range it is seen to be a bluish-gray crystalline limestone, ranging in granularity from a cryptocrystalline lithographic variety to finely crystalline types. The formation was not extensively sampled, but all the specimens collected are limestone rather than dolomite. Fossils are not distinguishable in freshly broken samples of this rock, but on the exposed surfaces corals weather out in recognizable forms.

STRUCTURE AND THICKNESS

In the White Mountains the structure of the limestone is similar to that of the Fossil Creek volcanics. At the northwest end of this range, the limestone forms the trough of two parallel synclines, separated by the Ordovician volcanic rocks. Both of these synclines are closely compressed, but the beds dip steeply away from the axial plane in each direction. The axial planes, however, are not vertical but dip steeply to the southeast. The southeastern of these two synclines is more complicated in structure, rendered so by the thrust faulting that was localized in the valley of Fossil Creek, and at its

[66] Brooks, A. H., field notes, Sept. 7, 1902.

northeast end the limestone is infolded with the Ordovician volcanic rocks in minor flutings. A third belt of limestone flanks the Ordovician volcanic rocks on the southeast in the valley of the west fork of Willow Creek. This appears as a thin persistent band, standing about vertical. It appears to be a faulted wedge lying on the southeast flank of the volcanic rocks.

The folds of the Silurian limestone and Ordovician volcanic rocks pitch steeply southwest, so that the volcanic rocks disappear in that direction; and as the contact between this light-colored limestone and the dark-colored volcanic rocks gives the best clue to the regional structure, the structure of the limestone becomes less apparent toward the southwest end of the White Mountains. The southeastern one of the two Silurian synclines trends into Fossil Creek and disappears, presumably against the fault zone in that stream. The northwestern syncline, however, continues southwestward and is believed to be the dominant structural feature of that part of the White Mountains, although the minor anticline of volcanic rocks that is exposed in the water gap of Fossil Creek shows that this major structure is modified by minor folds. At the extreme southwest end of the White Mountains the Silurian limestone alone appears at the surface, and the distance across its cropping, about 1½ miles, gives evidence of a considerable stratigraphic thickness. No accurate measurement of the thickness has been made, but the writer's interpretation of the structure suggests a possible thickness of as much as 3,000 feet.

Still farther southwest the Silurian limestone crops out in isolated patches along the divide between Beaver Creek and the Tatalina River, but in this lower country the major structure is not apparent. On one of the higher buttes along this divide, overlooking Beaver Creek, this limestone is a blue-gray crystalline variety, the beds of which dip 45°–60° SE., thus suggesting a continuation of the major structure of the southwest end of the White Mountains. Upon the lower end of the spur between the Tatalina and Tolovana Rivers Brooks found the limestone dipping about 70° SW., but at this locality the strike was about N. 75° E.

West of the Tolovana embayment the general trend of the Silurian limestone is N. 70° E., but at the west end of this band the limestone appears to strike about N. 30° E. The dip of the bedding in these lower hills is indeterminate from direct observation, but the pre-Middle Ordovician rocks border the limestone on the south. A strong joint structure, striking north and dipping steeply east, was observed, and this is believed to have a structural relationship to the cleavage observed by Brooks in the older rocks along the Tanana River. The distance across the limestone band at this locality is comparable with that at the southwest end of the White Mountains, and this constitutes a further indication that a considerable stratigraphic thickness is represented.

It has already been shown, on page 83, that a disconformity exists between the top of the undifferentiated pre-Middle Ordovician rocks and the base of the Silurian rocks. This stratigraphic hiatus, in the White Mountains, is inferred more from faunal than from structural evidence, but in the hills west of the Tolovana embayment the hiatus is emphasized by the absence of the Fossil Creek volcanics below the Silurian limestone, as the base of the Silurian is in direct contact with the rocks that lie below the Fossil Creek volcanics. Additional evidence is afforded by the fact that early Silurian rocks, though present as a graptolite facies in southeastern Alaska, are unknown in interior and northern Alaska. All the available evidence therefore points to a stratigraphic discontinuity at the base of the Tolovana limestone, and subsequent studies may show that this hiatus represents one of the major features of Paleozoic history in this region.

The top of the Silurian sequence is not exposed in the White Mountains, nor have late Silurian rocks been identified definitely elsewhere in the Yukon-Tanana region, and it is possible that such rocks are absent in this region. In any event, the accompanying geologic map shows strikingly the difference in trend lines between the Ordovician and Silurian rocks of the White Mountains and the Devonian and Carboniferous rocks farther north, the former trending about northeast and the latter nearly east. With little doubt these younger rocks overlap the Ordovician and Silurian sequence, and this leads to the inference that a great unconformity exists between the Tolovana limestone and the later Devonian rocks. This unconformity has also been inferred in other parts of interior Alaska, particularly in the Porcupine Valley [67] and in northern Alaska,[68] and it is now believed to represent one of the major periods of diastrophism in the Paleozoic history of this region.

AGE AND CORRELATION

A considerable fauna has been collected from the Tolovana limestone by Stone, Prindle, Johnson, Blackwelder, and the writer, of which some of the best material was obtained by Blackwelder. These fossils are listed below:

---

[67] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, p. 327, 1908.

[68] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 138–139, 1930.

Fauna of Tolovana limestone

	2AB25	4AP240	4AP241, 242	4AP243-246	4AH186	4AH193-195	9AP94, 9AJ82	9AP99, 9AJ84	1519B1	1519B2-4	1520A1	1520A2	1520B	1520D2	21AMt33	21AMt54	21AMt55	22AMt156
Zaphrentis sp		×																
Cyathophyllum sp	×	×				×				×								×
Diphyphyllum sp										×								
Crinoid columns									×			×						
Favosites cf. F. favosus (Goldfuss)		×	×					×										
Favosites cf. F. niagarensis Hall			×					×										
Favosites sp					×	×								×				×
Cladopora sp		×			×													
Trimerella sp										×								
Conchidium sp										×								
Conchidium? sp				×			×				×					×	×	
Clorinda? sp													×		×			
Atrypa? sp										×								
Megalomphala? sp										×								
Modiomorpha sp										×								

2AB25. Crest of hill 39 miles N. 63° W. from Fairbanks. Collector, A. H. Brooks, 1902.
4AP240–246. White Mountains, 40 miles north of Fairbanks, 1.47 miles N. 86° E. from junction of Fossil and Beaver Creeks. Collector, L. M. Prindle, 1904.
4AH186. White Mountains, 1.67 miles S. 67° E. from junction of Fossil and Beaver Creeks. Collector, F. L. Hess, 1904.
4AH193–195. White Mountains, 1.62 miles S. 31° E. from junction of Fossil and Beaver Creeks. Collector, F. L. Hess, 1904.
9AP94, 9AJ82. White Mountains, Brachiopod Gulch, N. 25° W. from Cache Mountain and 53 miles N. 9½° E. of Fairbanks. Collectors, L. M. Prindle and B. L. Johnson, 1909.
9AP99, 9AJ84. White Mountains, Limestone Gulch, about 48 miles N. 6° E. from Fairbanks. Collectors, L. M. Prindle and B. L. Johnson, 1904.
1519B1–4. White Mountains, spur west of forks of Willow Creek, about 700 feet above creek. Collector, Eliot Blackwelder, 1915.
1520A1, 2. White Mountains, Brachiopod Gulch, same general locality as 9AP94 and 9AJ82. 1520A1 lies 135 feet stratigraphically above 1520A2. Collector, Eliot Blackwelder, 1915.
1520B. White Mountains, northwest (?) bank of Fossil Creek, about 3 miles below Brachiopod Gulch. Collector, Eliot Blackwelder, 1915.
1520D2. White Mountains, southeast flank, about 5 miles northwest of mouth of Fossil Creek and about 1 mile north of site where collections 9AP99 and 9AJ84 were made. Collector, Eliot Blackwelder, 1915.
21AMt33. North bank of Beaver Creek about 11,000 feet upstream from mouth of Fossil Creek. Collector, J. B. Mertie, Jr., 1921.
21AMt54. White Mountains, Brachiopod Gulch, about 300 yards from Fossil Creek. Collector, J. B. Mertie, Jr., 1921.
21AMt55. White Mountains, Brachiopod Gulch, about 350 yards from Fossil Creek. Collector, J. B. Mertie, Jr., 1921.
22AMt156. Hills west of Tolovana embayment, 5.55 miles S. 73½° E. from junction of Hutlinana and Hutlitakwa Creeks. Collector, J. B. Mertie, Jr., 1922.

All these fossils have been identified and their age determined by Edwin Kirk. Originally determined as Niagaran, this fauna is now considered to represent a late horizon in the Niagaran epoch. This conclusion is based on the general aspect of the collections as a whole, for some of the collections, taken alone without reference to the others, are inadequate for a close determination of age. *Conchidium* and *Clorinda* may be considered the type forms, for these and related brachiopods are widely distributed in the middle Silurian elsewhere in Alaska; but in interior Alaska, at least, they have not been identified in late Silurian beds. Some of these collections, which did not include these type forms, were originally considered to be of late Silurian or even of Devonian age, so that it was thought that the Tolovana limestone might represent continuous sedimentation from mid-Silurian to Middle Devonian time. This interpretation was also favored by the fact that all the fossils above tabulated have been found in the lower part of the formation. Subsequent studies in this region, however, have shown that the lithology and fauna of the Devonian rocks are markedly different from those of the Tolovana limestone, and the continuity of Tolovana sedimentation into Devonian time is no longer considered even as a possibility. It is possible, however, that the uppermost part of the Tolovana limestone may be of late Silurian age, for similar massive limestone formations in interior and northern Alaska have been found to range upward into the late Silurian. Nevertheless, on the basis of the present knowledge the Tolovana limestone is assigned to the middle Silurian (Niagaran).

The Tolovana limestone is merely one phase of a great belt of middle and late Silurian limestone that has been traced in the form of an arc from Cape Krusenstern, on the Arctic coast, eastward to longitude 146°, thence southeastward to the Porcupine River, southward to the Yukon River, westward to the White Mountains, and finally southwestward into the Kuskokwim Valley. In northern Alaska [69] this middle and late Silurian limestone has been described as the "Skajit limestone"; it has also been observed and mapped on the north and east forks of the Chandalar River,[70] in the Porcupine Valley,[71] and along the international boundary.[72]

The southwestern extension of this Silurian limestone belt into the Kuskokwim Valley has also been recorded.[73] The Silurian limestones are therefore traceable intermittently for more than 1,000 miles in northern and central Alaska, and this belt constitutes one of the major stratigraphic and structural features of Alaska.

DEVONIAN SYSTEM

The Devonian system of the Yukon-Tanana region is less well known than either the older or the younger rocks of this region, and it is therefore more difficult to represent cartographically. The principal rocks of this system comprise a group of undifferentiated

[69] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 124–132, 1930.

[70] Mertie, J. B., Jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, pp. 229–233, 1925; The Chandalar-Sheenjek district: U. S. Geol. Survey Bull. 810, pp. 113–115, 1930.

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

[72] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 58–73, 1914. Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 404–407, 1932.

[73] Brown, J. S., The Nixon Fork country: U. S. Geol. Survey Bull. 783, pp. 102–105, 1926.

54984—37——7

rocks which, though essentially Devonian, may possibly include some rocks of late Silurian age. This group includes both sedimentary rocks and lava flows, and in order to present all available information, the limestones and lavas, which are the most striking members, have where possible been separately mapped. The remaining members are shown on the geologic map as an undifferentiated group. This method of separation yields three map units.

There is also in this region a group of basic and ultrabasic intrusive rocks which are considered to be of Devonian age. Further reference to these rocks will be made in the description of the igneous rocks of the region.

DISTRIBUTION

The undifferentiated sedimentary rocks that are considered to be largely of Devonian age crop out in several areas. One of the largest of these areas comprises the low hills that lie in the southwestern part of the valley of the Tolovana River and its tributaries. This band, which has a general trend of N. 60° E., extends northeastward into the valley of Beaver Creek and southwestward into the low hills that flank the south side of Hutlinana Creek, a tributary of Baker Creek. This area is about 95 miles in length and at its widest point is more than 20 miles in width, but part of this width is occupied by a large mass of granitic rocks, and the intrusive action of this mass may have had such an effect upon the structure of the surrounding sediments as to explain this great width of outcrop.

These rocks also occupy a somewhat wedge-shaped area that lies north of Victoria Creek. This area includes several bands of the differentiated limestone and one band of the differentiated greenstone, all of which are here considered to be a part of this sequence of rocks.

East of the lower valley of Beaver Creek is a third area of Devonian rocks, which extends eastward as a relatively narrow band for 60 miles or more to the flats of Birch Creek. This strip ranges in width from 1½ to 15 miles and also includes several elongate bands of limestone, one of which is very persistent.

A fourth area of these undifferentiated rocks lies in the upper valley of Troublesome Creek. This is a small area, about 5 miles from east to west and about 6 miles from north to south. Small lenses of differentiated limestone are also mapped in this area.

Undifferentiated Devonian rocks of about the same lithologic character, though much more metamorphosed, occupy two other areas in the eastern part of the Yukon-Tanana region. The larger of these two areas is a belt that begins at the southeast end of the Birch Creek flats and extends S. 60° E. for 100 miles to the international boundary and for an undetermined distance eastward into Yukon Territory. This belt, throughout most of its length, is from 5 to 10 miles wide, but it broadens to twice that width near the boundary. Similar rocks occupy a small area in the vicinity of Chicken.

The differentiated Devonian greenstones occupy an area along both sides of the Yukon River, from Coal Creek downstream to Thanksgiving Creek. This is the type area for these rocks, which have been designated the "Woodchopper volcanics." [74]

LITHOLOGY

Little is known of these rocks in the low hills of the southwestern part of the Tolovana Valley, for the croppings are poor, and these hills have not been examined by the writer and have been little visited by other workers. In crossing the end of the spur, between the Tatalina and Tolovana Rivers, Brooks saw no rocks exposed at the surface other than the massive Silurian limestone. West of the Tolovana embayment and south of Hutlinana and Niggerhead Creeks, the croppings are also poor, but one exposure of rocks in place and a considerable amount of surface rubble indicate that the rocks in this part of the belt consist of clay slate, siliceous slate, chert, quartzite, and a variety of nondescript sheared rocks. Similarly on the ridge between the Tolovana River and its West Fork the traverses of Brooks and Prindle in 1902 and of Brooks in 1906 indicate the presence of rocks which are dominantly quartzite and slate. No structural observations are available for any of these low hills.

Within this same general area, however, particularly in the vicinity of the Tolovana mining camp, these rocks crop out in some higher hills. Thus, south of Livengood the upper part of this sequence of rocks has been observed [75] to consist largely of sandstone, quartzite, shale, slate, argillite, and some thin beds of finely crystalline dark to light gray limestone, associated with and probably intruded by serpentine and other types of greenstone. These rocks near Livengood contain fossils of Middle Devonian age and except the Woodchopper volcanics are the only rocks of this sequence whose age has been definitely determined from the included fossils.

North of Victoria Creek, in the wedge-shaped area above mentioned, rocks similar to those south of Livengood are found, and in addition certain other types. Thus at the heads of Grouse and Bear Creeks the differentiated limestones of this group are asso-

[74] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 75–80, 1930.

[75] Mertie, J. B., Jr., Gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 232–236, 1918.

ciated with sandstone, shale, slate, quartzite, conglomerate, and chert. Some of these rocks are similar to others farther west that are referred to the Carboniferous, and as fossils are relatively scarce some doubt must remain as to the final assignment of the noncalcareous rocks that lie near the west end of the area between Victoria Creek and the Yukon Flats. Farther east in this same area the noncalcareous rocks are dominantly vitreous quartzite or quartzose sandstone and slate, with little chert or other types of rocks; and in fact, this paucity of chert away from the contact with the Carboniferous rocks is one of the distinguishing characteristics of this Devonian sequence.

Within this same area are found large bodies of limestone and basic lavas of greenstone habit, both of which are separately mapped. The largest of these bodies of limestone is composed of dark-gray to blue-black finely crystallized rock, but some of this mass is coarsely crystalline and marbleized, and along its south side it is noticeably brecciated. The limestone is closely folded and crumpled, and beds at different stratigraphic horizons are evidently repeated several times across the strike. Poorly preserved corals and crinoids were observed at several localities, but the best of these do not give conclusive evidence of the age of the containing rocks. South of this large mass of limestone are two narrow but persistent bands of limestone, one of which has been traced and mapped for 35 miles. The more persistent of these two bands is a crystalline limestone, at most places completely marbleized. These smaller bands of limestone are greatly sheared and may perhaps be faulted outliers of the main limestone mass to the north, but their linear persistence and their reappearance farther east in the Crazy Mountains suggest that they represent separate and lower horizons in the Devonian sequence.

The differentiated greenstones of this same area are closely intermingled with the massive limestone. On the hill north of Mount Schwatka the contact between the two formations is well exposed, and although it appears to be a fault contact, the general relations suggest that the greenstone lies stratigraphically below the limestone. Directly below the limestone is a black slate of volcanic origin, and this is followed downward by sheared purple and green tuffs, which in turn give place to lava flows. The relations are very similar to those which exist between the Silurian limestone and the Ordovician volcanic rocks in the White Mountains, but here the fossils of the limestone point to a Devonian rather than a Silurian age, and the tuffs, so far as observed, are not fossiliferous. The best stratigraphic interpretation at present available is that these volcanic rocks are correlative with the Woodchopper volcanics along the Yukon River and that the overlying limestone is correlative with the limestone interbedded with the Woodchopper volcanics. The faulted and irregular character of the contact between the limestone and the volcanic rocks east of Mount Schwatka is shown in plate 8, *A*.

Eastward from the lower valley of Beaver Creek, the same group of rocks again crops out, extending eastward to include most of the Crazy Mountains. In this band the large mass of limestone with its associated volcanic rocks is absent, but in the Crazy Mountains one thin band of limestone, similar to those north of Victoria Creek, has been recognized and mapped as extending for a distance of 22 miles. Between Beaver Creek and the North Fork of Preacher Creek little is known of these rocks, for they have been observed in place only at one locality, on the dome about 5 miles S. 67° E. of the confluence of Victoria and Beaver Creeks, where they were found to consist of sheared sandstone and slate. In the zone north of the North Fork of Preacher Creek these rocks also consist of sandstone and slate, with two thin bands of limestone along the north side, near the Livengood chert. The noncalcareous rocks of the Crazy Mountains consist mainly of quartzose sandstone, quartzite, and slate. The slate is chiefly drab to yellow but includes some zones of red and green slate. A little chert and chert conglomerate are also found, but the chert conglomerate is dissimilar to that of the Livengood formation in that the matrix is sandy and not cherty. This chert conglomerate more closely resembles the conglomerate of the Devonian rocks in the Troublesome Creek area and is thought to represent the basal part of that sequence of rocks. The limestone in the Crazy Mountains consists of crystalline limestone, similar to that of the narrow bands north of Victoria Creek, and has yielded one small collection of imperfect fossils. Three small lenses of limestone also crop out north of this main band.

In the fourth area these rocks appear along the east and west sides of the upper valley of Troublesome Creek, extending also a short distance up the valley of Quail Creek. These rocks are believed to lie in an anticlinal basin, surrounded by the younger rocks of the Carboniferous sequence. A continuous section across this basin cannot be given, for the rocks are more than ordinarily metamorphosed and are so thoroughly kneaded and distorted that the superficial succession of beds does not correspond to the stratigraphic sequence. Between upper Quail Creek and Nugget Creek, however, the rocks along the north side of Quail Creek consist mainly of phyllites, succeeded at the mouth of Nugget Creek by a crystalline limestone. The limestone contains fossils of Devonian (?) age, and the phyllites are believed to underlie the limestone stratigraphically. At the head of the spur between Nugget and Quail Creeks, on the other hand, is a tremendously sheared conglomerate, composed largely of chert pebbles and cobbles, but containing also detritus of sandstone, greenstone, limestone, and vein quartz. The pebbles and cobbles are flattened and elongated to so great an extent that in places the original fragmental character of the rock can hardly be recognized. This conglomerate is believed to underlie the fossiliferous limestone above described and may mark the base of the Devonian sequence. West of Troublesome Creek, between Nugget and Miller Creeks, the rocks consist of slate, graywacke, sheared greenstone (including more serpentine), and one band of crystalline limestone. Similarly the rocks on a spur on the east side of upper Troublesome Creek and south of Blizzard Creek are first massive diabasic greenstone, followed eastward by slate and phyllite, which in turn are succeeded by diabasic greenstone, serpentine, and finally by the same sheared conglomerate that occurs on the spur between Nugget and Quail Creeks. Still farther east more Devonian slate crops out, and finally this is succeeded by the black cherty rocks of the Carboniferous. All the Paleozoic rocks in the Rampart district are much more than ordinarily metamorphosed, and these Devonian rocks are no exception to the general rule.

Several miles downstream on Troublesome Creek, at the mouth of Union Creek, is a small body of rocks that are markedly different from the Devonian rocks of the upper valley. These are a group of mica schists, mostly light-colored but including also darker members containing biotite and carbonaceous material. These schists have been invaded by stringers of pegmatite, and near these stringers the schist contains well-developed crystals of quartz and feldspar and some grains of garnet and tourmaline. These rocks resemble altered sandstones or quartzites. So far as their general appearance is concerned, they resemble closely some of the rocks of the Birch Creek schist, but they are many miles from the nearest area of the Birch Creek schist and are not believed to belong to the old crystalline complex. Instead, they are considered to be the contact-metamorphosed equivalent of later Paleozoic rocks and are here assigned tentatively to the undifferentiated Devonian.

The Woodchopper volcanics along the Yukon River consist essentially of basaltic lavas of greenstone habit and associated pyroclastic material, interbedded with massive limestone and more or less shale, slate, and chert. The lavas at many places are clearly bedded, and numerous ellipsoidal flows are also present, in which some of the ellipsoids are as much as 6 feet in diameter. Much volcanic agglomerate or flow breccia and more or less tuff and tuffaceous sediments are also interbedded with the lavas. The lava is basaltic, and some of it is amygdaloidal, with vesicular fillings of calcite. The original rock minerals, essentially plagioclase and augite, are now altered to chloritic products, and the original iron minerals are now completely oxidized. More or less secondary pyrite and pyrrhotite are also distributed in these lavas.

From Woodchopper Creek downstream massive beds of limestone, which appear to be interbedded with the lavas, crop out at intervals in the bluffs on both sides of the river. Two of these masses of limestone, which are fossiliferous, occur along the north side of the Yukon, above Woodchopper Creek. These are shown in plate 8, *B*. The limestones themselves vary somewhat in appearance, the differences apparently depending more on their degree of metamorphism than on original differences in composition. Some are light to dark gray dense noncrystalline or cryptocrystalline limestone; others are partly recrystallized.

The belt of rocks that parallels the Yukon River from the Birch Creek Flats to the Canadian boundary and the other area in the vicinity of Chicken are included in this group with considerable doubt as to the correctness of their correlation. They are more metamorphosed than the other rocks of this group, but on the other hand, both Prindle and the writer have found imperfect fossils in these rocks, south and southeast of Eagle, which appear to justify their inclusion with the Devonian sequence. Little recent work has been done on these rocks, and the writer is dependent largely upon the description of them given by Prindle.[76] According to this description, these rocks consist of green and black phyllites, cherty slates, cherts, greenstones, serpentine, quartzites, and limestones. The larger bodies of greenstone have been separately mapped on plate 1, and are elsewhere described; and one small body of limestone, a short distance northwest of Eagle, has also been separately mapped. A partial section of these rocks northeast from Glacier Mountain is given by Prindle. Glacier Mountain is composed of granitic rocks and is bordered on the northeast by pre-Cambrian quartzite, which is succeeded stratigraphically by 500 feet of carbonaceous phyllite, 600 feet of limestone, 50 feet of quartzite, black and gray slaty phyllites exposed at intervals for half a mile or more, and finally meager croppings of limestone. Still farther northeast are greenish slates. As the rocks over part of this distance are nearly vertical in attitude, these distances may represent closely the true stratigraphic thickness, but only a part of the sequence is represented, as these

[76] Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, pp. 18–19, 1909.

rocks at the northeast end are overlapped by younger rocks. The first band of quartzite was considered by Prindle to be a part of the old crystalline complex and is so mapped in the present report, but it may in reality be only a part of the later Paleozoic sequence. The later rocks, beginning with the 500 feet of carbonaceous phyllite, were mapped by Prindle as Devonian, and this mapping also is followed in the present report. Rocks of essentially the same kind are found in the smaller area in the vicinity of Chicken.

STRUCTURE AND THICKNESS

The rocks here classified as essentially Devonian extend more or less continuously from the month of Baker Creek northeastward to the lower valley of Beaver Creek, thence eastward to the flats of Birch Creek, and thence southeastward along the south side of the Yukon River to the international boundary. The total length of this arc is about 200 miles, but little is known in detail of the structure of these rocks throughout this stretch. This is due in part to the reconnaissance character of the mapping but more particularly to a dearth of well-exposed sections. In fact, nowhere in this stretch is it possible to observe these rocks continuously for any great distance across their strike, and any conclusions regarding their structure must necessarily be based on widely separated observations, which over so great an area are almost meaningless.

Little is known of the dip of these beds. Some of them stand nearly vertical; many appear to dip southward at high angles; and a few appear to dip northward. The cleavage dips consistently southward, and some of it may have been mistaken for bedding. The strike of these rocks, however, is tangent to the great arc along which they crop out, and the dip of the dominant structure is successively southeast, south, and southwest. Notwithstanding the apparent structure, this group in general is bounded on the north by younger rocks and on the south by older rocks. One notable exception to this generalization is evident in the area north of Victoria Creek, where the Devonian rocks appear to have the structure of an anticline that plunges southwestward and is bounded on both the northwest and the southeast by younger rocks. Evidently, therefore, the age of the rocks decreases in general from south to north, and with the structural evidence at present available, the conclusion seems warranted that these rocks have been deformed into a system of close folds, which in considerable part are overturned toward the north. Such duplication of beds by folding will also account for the great distance, at some localities, across the strike of these rocks.

The distribution of these rocks also brings to light another feature. It is believed that the Devonian sequence in this region consists of an early group of Devonian rocks and a later group which is known from the contained fossils to be of late Middle Devonian age. The rocks classified as late Middle Devonian comprise the Woodchopper volcanics and a part or all of the Devonian rocks north of Victoria Creek. Both these areas lie north of the main band of Devonian rocks, and this distribution also conforms with the general relation of a decrease in age from south to north. It is also worthy of note that both blocks of late Middle Devonian rocks appear to be deformed in general into anticlinal arches, for not only do Carboniferous rocks reappear northwest of the late Middle Devonian rocks north of Victoria Creek, but similarly the Livengood formation reappears north of the Woodchopper volcanics. The details of the structure at both these localities are little understood.

No stratigraphic section of these rocks has anywhere been measured, and from the writer's observations upon the nature of exposures in this country, particularly in the belt occupied by these rocks, it is doubtful if any complete section can be measured, although intensive detailed work in the future may render it possible, by piecing together partial sections, to arrive at a better understanding of the structure that exists. In view of this observed complexity and uncertain interpretation of the structure, it is not possible to state with any assurance what is the total thickness of this group of rocks. The width of the belt is from 1 to 15 miles, and taking into consideration the width of other belts of rocks in the same region, whose structure is better known, it seems safe to state that the total thickness must be at least 5,000 feet.

AGE AND CORRELATION

A considerable number of fossil collections have been made from these rocks in the last 30 years, but unfortunately the rocks are so compressed and folded that many of these fossils cannot be relied upon to determine the age of the rocks containing them. Two faunas are recognized, of which one is clearly of Middle Devonian age and the other is older. It seems best to present these two groups separately.

Undifferentiated Devonian fauna of Yukon-Tanana region

	Collier 4, 5, 6	2AC60	2AC62	2AC131	2AP26	3AP77	4AP46	4AP301	4AP303	5AS15	847	848	849	7AP82	7AP268	7AP277	1513A	1513B	22AMt133	25AMt52	25AMt53	29AMt54	29AMt64	31AMt172
Streptelasma? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Amplexus? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Zaphrentis sp	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zaphrentis? sp	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyathophyllum sp	--	--	--	--	--	--	--	--	X	--	--	--	--	--	X	--	--	--	--	--	--	X	--	--
Diphyphyllum sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	X	--	--	--	--	--	--
Acervularia sp	--	--	--	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spongophyllum sp	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Favosites cf. F. niagarensis Hall	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Favosites sp	--	X	--	--	--	--	--	--	--	--	X	--	--	--	--	--	X	--	--	--	--	X	--	--
Alveolites sp	--	--	--	--	--	--	--	--	--	--	X	--	X	--	--	--	--	--	--	--	--	X	--	--
Cladopora sp	--	--	--	--	X	--	--	X	--	--	X	--	--	--	X	--	--	--	--	--	--	X	--	--
Cladopora? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	X
Syringopora sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	X	--	--	--	--	--	--
Syringopora? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--
Halysites? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Stromatopora sp	--	--	--	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crinoid columns	X	--	--	--	--	X	--	--	--	--	--	--	--	X	--	--	X	--	--	X	X	--	X	--
Favositella? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--
Megalomus? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Pelecypod, indeterminate	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Lepetopsis sp	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Lepetopsis? sp	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Pleurotomaria? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--

Collier 4, 5, 6. Locality not recorded. Collector, A. J. Collier, 1902.

2AC60. Yukon River, east bank, 3 miles below mouth of Tatonduk River; pebble from river gravel. Collector, A. J. Collier, 1902.

2AC62. Yukon River, east bank, 7 miles below mouth of Tatonduk River; pebble from river gravel. Collector, A. J. Collier, 1902.

2AC131. Locality not recorded. Collector, A. J. Collier, 1902.

2AP26. About 1¾ miles N. 30° E. from mouth of Quail Creek. Collector, L. M. Prindle, 1902.

3AP77. Tributary of Boundary Creek, 13 miles south of Eagle. Collector, L. M. Prindle, 1903.

4AP46. 40 miles west of Eagle. Collector, L. M. Prindle, 1904.

4AP301. Valley of Troublesome Creek, 30 miles east of Rampart. Same as 2AP26. Collector, L. M. Prindle, 1904.

4AP303. 27 miles east of Rampart, 1½ miles S. 58° W. from mouth of Quail Creek. Collector, L. M. Prindle, 1904.

5AS15. Limestone on top of ridge between North Fork of Preacher Creek and Yukon Flats; longitude about 145°50′. Collector, R. W. Stone, 1905.

847. South bank of Yukon River 12 miles below Woodchopper Creek. Collector, E. M. Kindle, 1906.

848. Yukon River 2 miles below Calico Bluff, in ravine below bend. Collector, E. M. Kindle, 1906.

849. East bank of Yukon River 2 miles below Calico Bluff. Collector, E. M. Kindle, 1906.

7AP82. Fortymile River a quarter of a mile below mouth of Napoleon Creek. Collector, L. M. Prindle, 1907.

7AP268. Ridge between forks of Quail Creek, east of Wolverine Mountain. Collector, L. M. Prindle, 1907.

7AP277. About 1 mile west of mouth of Quail Creek. Collector, L. M. Prindle, 1907.

1513A. Southwest bank of Yukon River at west end of dolomite bluffs about 3 miles below the mouth of Thanksgiving Creek. Collector, Eliot Blackwelder, 1915.

1513B. Same as 1513A, but 500 to 1,000 feet higher in sequence. Collector, Eliot Blackwelder, 1915.

22AMt133. Rampart district, 1.1 miles S. 88° W. of mouth of Quail Creek. Same as 7AP277. Collector, J. B. Mertie, Jr., 1922.

25AMt52. Yukon Territory, Canada, 2.3 miles S. 40° E. of international boundary topographic station 112. Collector, J. B. Mertie, Jr., 1925.

25AMt53. Yukon Territory, Canada, 1.9 miles S. 40° E. of international boundary topographic station 112. Collector, J. B. Mertie, Jr., 1925.

29AMt54. Ridge north of Victoria Creek, 0.33 mile N. 82½° W. of Mount Schwatka. Collector, J. B. Mertie, Jr., 1929.

29AMt64. Ridge north of Victoria Creek, 0.75 mile N. 57° W. of Mount Schwatka. Collector, J. B. Mertie, Jr., 1929.

31AMt172. Rampart district, about 1 mile S. 88° W. from mouth of Quail Creek. Same as 7AP277 and 22AMt133. Collector, J. B. Mertie, Jr., 1931.

The undifferentiated Devonian fauna consists largely of coelenterates and includes only two pelecypods and two gastropods, and only one genus among the 18 here shown has been identified specifically. Moreover, all these collections are poorly preserved, and few if any of them contain enough diagnostic forms to warrant any close assignment of age. Edwin Kirk, who has identified most of these invertebrates, has therefore been constrained to refer these fossils either to the Devonian or late Silurian, with varying emphasis upon one or the other system, depending upon the material at hand. The writer has already shown, however, that an unconformity probably exists between the Silurian and Devonian rocks in this region; and he also believes that these fossils probably represent a single group of rocks, rather than two groups of diverse age. It therefore follows that these fossils are possibly either Devonian or Silurian but are not likely to be both Devonian and Silurian. But so far as known at present, the middle and late Silurian in interior Alaska are represented by massive limestone and dolomite, and inasmuch as the rocks from which these fossils were obtained are diverse in lithologic character and appear structurally to be more closely related to the late Paleozoic rocks of the region, the writer believes that they should be regarded as Devonian rather than Silurian.

Much doubt remains, however, as to their precise place in the Devonian system. No lower Devonian rocks have yet been found in Alaska, and therefore it would be inconsistent, without better evidence than now exists, to refer these fossils to that part of the period. Middle Devonian rocks at two or three horizons have been identified, however, and the rocks containing these fossils are believed to represent the lower part of the Middle Devonian sequence.

In addition to the invertebrates above listed, two collections containing plant remains have also been obtained as follows:

5AP319. Dennison Fork of Fortymile River, about 20 miles south of Chicken Creek. Collector, L. M. Prindle, 1905.

1521A. North bank of Beaver Creek, 5 or 6 miles above Willow Creek. Collector, Eliot Blackwelder, 1915.

The two plant collections are of little importance but are given to make the record complete. Collection 5AP319 consists of some striated plant stems, which were referred by F. H. Knowlton to *Calamites radiatus* and were said to indicate only a Paleozoic age. Collection 1521A consisted of fossil wood.

Middle Devonian fauna of Yukon-Tanana region

	2AC90	2AC96	2AC97	841	842	846	156	168	169	170	171	172	16AMt64a	2065
Zaphrentis sp		×												
Cyathophyllum caespitosum Goldfuss													×	
Cyathophyllum sp					×			×	×					×
Favosites cf. F. hemisphericus								×			×			
Favosites cf. F. limitaris							×			×	×			
Favosites sp			×	×					×					
Alveolites sp									×					
Chaetetes sp		×												
Actinostroma sp									×		×			
Crinoid columns	×	×	×	×		×					×			
Fistulipora sp		×												
Monilopora sp	×													
Dalmanella sp					×									
Schizophoria striatula				×										×
Schizophoria sp		×								×				
Stropheodonta cf. S. calvini				×										
Stropheodonta sp						×				×				
Orthothetes? sp										×				
Chonetes sp				×										
Gypidula comis				×										×
Camarotoechia sp				×		×							×	×
Rensselaeria? sp					×									
Atrypa cf. A. flabellata												×		
Atrypa cf. A. hystrix				×	×									×
Atrypa reticularis					×	×	×	×		×			×	×
Atrypa reticularis?		×												
Spirifer sp					×					×				
Reticularia fimbriata var.										×				
Reticularia sp														×
Ambocoelia cf. A. umbonata					×									
Conocardium sp					×	×								
Cyclonema sp					×									
Diaphorostoma sp					×									
Proetus sp				×						×				×
Bollia sp				×										

2AC90. Yukon River, north bank, opposite Woodchopper; upper end of a series of bluffs. Collector, A. J. Collier, 1902.

2AC96. Yukon River, southwest bank, 3 miles below Woodchopper Creek. Collector, A. J. Collier, 1902.

2AC97. Yukon River, southwest bank, 4 miles below Woodchopper Creek. Collector, A. J. Collier, 1902.

841. Yukon River, north bank, opposite Woodchopper Road House. Collector, E. M. Kindle, 1906.

842. Yukon River, north bank, 2 miles above Woodchopper Creek. Collector, E. M. Kindle, 1906.

846. Yukon River, southwest bank, 2 miles below Woodchopper Creek. Collector, E. M. Kindle, 1906.

156, 168, 169, 170. Yukon River, north bank, 2 to 3 miles above Woodchopper Creek. Collector, Eliot Blackwelder, 1915.

171. Yukon River, southwest bank, about 2½ miles below Woodchopper Creek. Collector, Eliot Blackwelder, 1915.

172. Yukon River, north bank, opposite Woodchopper Road House. Collector, Eliot Blackwelder, 1915.

16AMt64a. East fork of Ruth Creek, a tributary of Livengood Creek, 1½ miles south of Livengood. Collector, J. B. Mertie, Jr., 1916.

2065. Yukon River, north bank, opposite Woodchopper Road House. Collector, J. B. Mertie, Jr., 1925.

All the fossils identified as Middle Devonian, with the exception of those in collection 16AMt64a, have been collected from the limestones that form a part of the Woodchopper volcanics. This fauna contains 25 genera, of which about half are brachiopods, one-fourth coelenterates, and the remainder are echinoderms, bryozoans, mollusks, trilobites and ostracodes. Edwin Kirk, who also identified most of these fossils, regards them as representative of a high horizon in the Middle Devonian, closely related to the Upper Devonian. It is probable that collections 29AMt54 and 29AMt64, from the area north of Victoria Creek, which are tabulated among the undifferentiated Devonian fauna, may also come from the same stratigraphic horizon as the Woodchopper volcanics, but the fossils of these collections are not sufficiently well preserved or numerous to justify their inclusion in the Middle Devonian list, on paleontologic grounds alone. Collection 16AMt64a, from the Livengood district, on the other hand, is representative of rocks with a different lithology from that of the Woodchopper volcanics, but it is included in the Middle Devonian list because it was so determined by Mr. Kirk, on paleontologic grounds.

Devonian rocks are widely distributed in central and northern Alaska. All those of central Alaska, so far as now known, are of Middle Devonian age, though some of them represent horizons high in the Middle Devonian, which may be proved by subsequent work to be of Upper Devonian age. Several Middle Devonian formations, however, have been recognized in interior Alaska. The oldest of these is the Salmontrout limestone, which has been described by Kindle [77] and by the writer,[78] from the area lying between the Yukon and Porcupine Rivers. The Salmontrout limestone is a highly fossiliferous formation, and up to the present has yielded 53 different genera. Rocks at this horizon have not been recognized in the Yukon-Tanana region, though they may possibly be present. The next horizon, above the Salmontrout limestone, is widely known, not only in the Yukon-Tanana region but also in many other parts of Alaska. This horizon is represented by collection 16AMt64a, and it is probable that most, if not all, of the undifferentiated Devonian fauna above tabulated may be assigned to the same horizon.

The third and highest Middle Devonian horizon is represented by the Woodchopper volcanics and by certain siliceous and slaty beds that have been described by the writer [79] in an area north of the Yukon River and close to the international boundary. Upper Devonian rocks have not yet been recognized in central Alaska but are typically developed in northern Alaska.[80] These rocks are characterized by *Spirifer disjunctus* and other invertebrates. Upper Devonian rocks are also well developed in southeastern Alaska, particularly on Prince of Wales and Chicagof Islands. No Lower Devonian rocks have ever been found in Alaska, and in view of the unconformity between the rocks of the Silurian and Devonian systems, their absence is a significant feature.

---

[77] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 327–329, 1908.

[78] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 407–415, 1932.

[79] Idem, pp. 409–410.

[80] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 139–151, 1930.

CARBONIFEROUS SYSTEM

Several groups of rocks, representing thousands of feet of sediments and lavas, were laid down during the Carboniferous period in this region. The general sequence of these rocks is now known, but much remains to be learned of their local characteristics and correlation. Several difficulties present themselves. First, no area has yet been found where a complete stratigraphic sequence exists, and at most places either the top or the base of individual formations, or perhaps both, cannot be observed. Second, there is a good reason for the belief that the lithology changes materially along the strike, thus making it difficult to correlate sections that are widely separated. Third, the degree of metamorphism is variable, depending on whether these rocks occur in belts of metamorphism or otherwise. Finally, with the exception of the Calico Bluff formation and the Tahkandit limestone, which represent only a small part of the sequence, most of the sediments of this system are only scantily fossiliferous.

For the purpose of this report the Carboniferous rocks are divided into seven map units, as follows:

Tahkandit limestone (Permian).
Nation River formation (Pennsylvanian?).
Calico Bluff formation (Mississippian).
Rampart group (Mississippian).
Limestone beds (Mississippian).
Undifferentiated Mississippian rocks.
Livengood chert (Mississippian).

These map units are not mutually exclusive, and the above tabulation is not to be regarded strictly as a geologic column. In some areas more detailed work has been done than in others, and therefore formations have been recognized and mapped locally which cannot everywhere be differentiated. Thus, the undifferentiated Mississippian rocks include not only certain rocks of the Rampart area that are believed to underlie the Rampart group, but also younger rocks that lie above and just below the Calico Bluff formation in the Eagle area and have locally been differentiated as map units. Similarly, the more prominent limestones that are separately mapped are interbedded in part with the Livengood chert and in part with later Mississippian rocks. The Nation River formation and the Tahkandit limestone, on the other hand, have been observed only in the eastern part of this region; and the distinctive lithology of the Nation River and the highly fossiliferous nature of the Tahkandit render both of these formations so easy to recognize that it is improbable that either of them now exists west of Circle.

LIVENGOOD CHERT

DISTRIBUTION

The Livengood chert was discriminated and mapped by the writer[81] in 1916 in the vicinity of Livengood, as a group of rocks composed largely of chert. The name "Livengood chert" first appeared in print in 1926,[82] but without definition. The formation is here defined for the first time. In 1918 this formation was traced westward by R. M. Overbeck to the Sawtooth (Lynx) Mountains; in 1921 it was traced eastward by the writer into the valley of Beaver Creek; and in 1929 it was also recognized by the writer still farther east. In its type locality the Livengood chert is now known to extend from a point north of the Sawtooth Mountains to the valley of Beaver Creek, north of the White Mountains, a distance of about 65 miles. The maximum width of this belt, in the vicinity of Livengood, is 8½ miles. An eastern extension of this belt is found in the hills that overlook the Yukon Flats, between the lower valleys of Beaver and Preacher Creeks. The length of this belt is 30 miles. The Livengood chert has also been recognized and mapped in a narrow belt crossing Woodchopper and Coal Creeks a short distance south of the Yukon River. Isolated beds of this formation have been recognized at other places, particularly in the vicinity of the Sawtooth Mountains, and the metamorphosed equivalents of these rocks have been observed farther west in the Rampart district, but these occurrences have not been mapped.

LITHOLOGY

The Livengood chert consists dominantly of chert, with which are interbedded minor proportions of limestone and argillaceous rocks. Numerous small bodies of basaltic or diabasic greenstone are also found with the sedimentary rocks, but these igneous members are believed to be largely intrusive and therefore of later origin. The chert of this formation has been studied in more detail in the vicinity of Livengood than elsewhere in the region. Observations of the rock from the bottom of 25 or more shafts on the bench north of Livengood Creek and other observations in the surrounding hills show that the rock is in large part a chert, ranging in color from a light smoky gray to black, in places much brecciated, and with a comparatively small proportion of other rock types. Below the gravel that constitutes the gold placers on Livengood Creek the

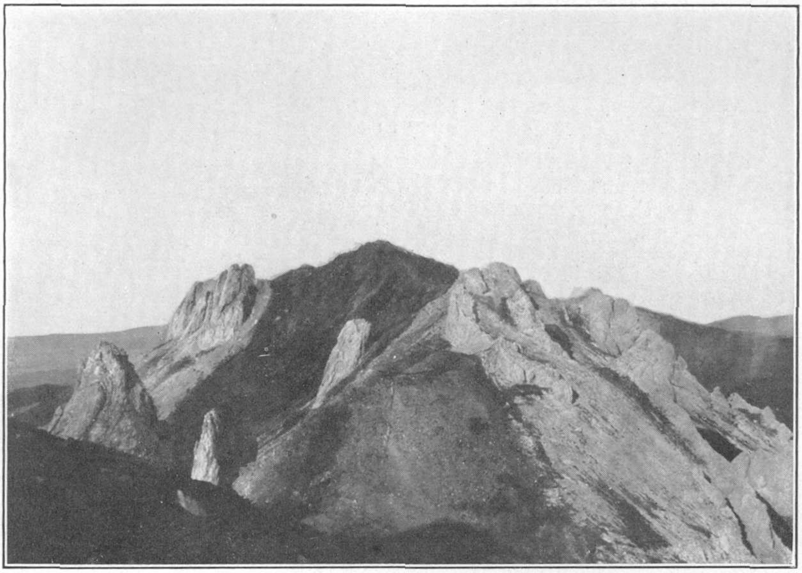
[81] Mertie, J. B., Jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 239–244, 1918.

[82] Mertie, J. B., Jr., The Paleozoic geology of interior Alaska [abstract]: Washington Acad. Sci. Jour., vol. 16, p. 79, 1926.

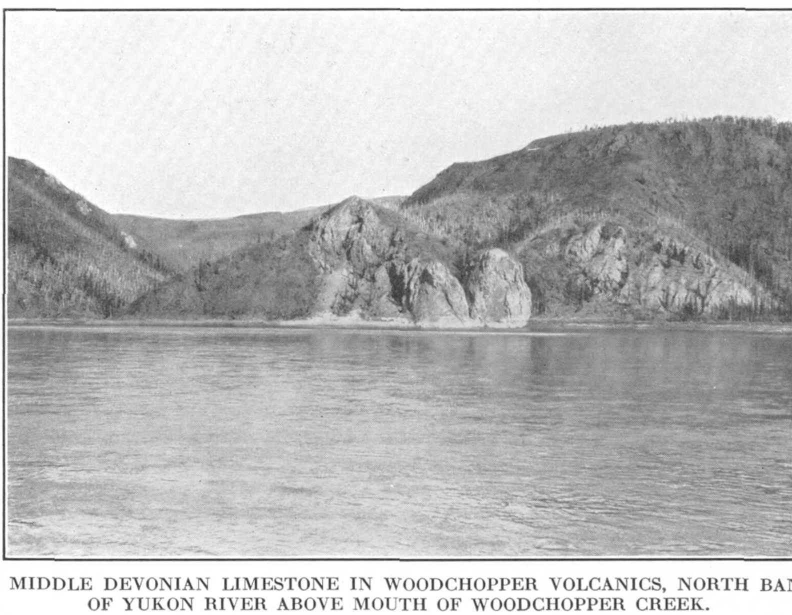
chert is deeply weathered to a red to black siliceous clay, which includes numerous particles of angular chert fragments, but in the nearby hills the chert is fresh and unaltered. Thus at Livengood Dome and on the ridge extending northward from it the chert appears as a dark-gray rock, in beds from a few inches to several feet thick, all of which are much fractured and brecciated. Locally some of the beds of chert are laminated.

The chert is highly resistant to erosion, and it might therefore be expected that even though it forms the principal type of rock along the ridge tops, rocks of less resistant types might be found to constitute an important part of the sequence in the valleys. That is apparently not true, however, because in the bedrock underlying the placers of Livengood Creek argillaceous rocks were observed in only 4 of 25 shafts, and there only as a minor proportion of the bedrock. Such argillaceous beds as were observed are either shale or argillite, and some of them are distinctly carbonaceous. Similar argillaceous rocks were also observed on Amy Creek, a tributary of Livengood Creek, on the South Fork of Hess Creek, and at other localities.

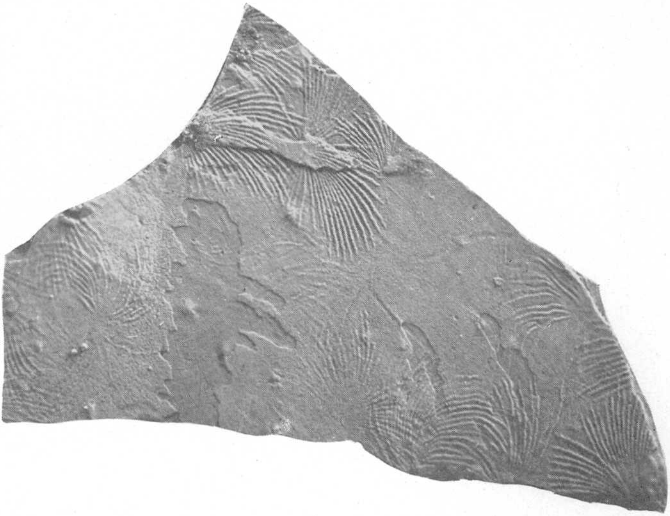
Two kinds of limestone are associated with the chert of the Livengood chert. The less plentiful type occurs as thin beds of noncrystalline and little silicified dark-gray limestone. Several beds of such limestone were observed along the walls of Amy Creek and in some of the smaller tributaries of Livengood Creek west of Amy Creek. The more common type is a crystalline white limestone, in varying stages of silicification. Several bodies of this limestone are differentiated in the vicinity of Livengood, and it was also observed as the bedrock below the placers of Livengood Creek in 8 of 25 shafts. This more or less silicified limestone is a white to cream-colored rock in the hills but weathers to tones of yellow and brown below the gravel. Also in places underground the limestone has been dissolved from the partly silicified rock, leaving a rock that resembles a siliceous sinter. In places—for example, along the ridge southeast of Martin Creek—this limestone is almost completely silicified and closely approximates in appearance and composition a pure-white granular quartzite. Other bodies and lenses of this siliceous limestone have also been observed both east and west of the Livengood district, and in one of these small lenses, in a western tributary of Lost Creek, some imperfect fossils were found by R. M. Overbeck. In most of these siliceous limestones the siliceous matter is chalcedonic quartz, but in some, as in the Martin Creek occurrence, the silica is granular quartz, and gradational types appear to exist. It seems probable that the silicification of these limestones within or contiguous to the Livengood chert has resulted from the



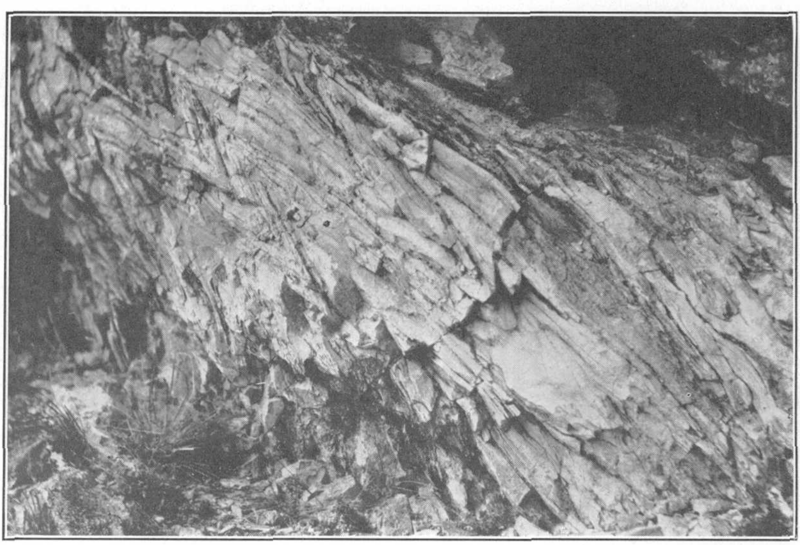
A. DEVONIAN LIMESTONE AND ASSOCIATED VOLCANIC ROCKS ALONG RIDGE EAST OF MOUNT SCHWATKA.



B. MIDDLE DEVONIAN LIMESTONE IN WOODCHOPPER VOLCANICS, NORTH BANK OF YUKON RIVER ABOVE MOUTH OF WOODCHOPPER CREEK.



A. OLDHAMIA? FROM CARBONIFEROUS ROCKS IN NORTHERN PART OF FAIRBANKS QUADRANGLE.



B. CLOSE FOLDING IN LIMESTONE NORTH OF RUBY CREEK, RAMPART DISTRICT.

circulation of heated waters charged with silica derived from the contiguous cherts.

Another prominent rock type of the Livengood formation is chert conglomerate. This rock crops out at intervals along the south side of the Livengood chert in the Livengood district and at other localities both to the east and west. It is well developed at the west end of the area occupied by the Livengood chert, northeast of the Sawtooth Mountains, and is equally prominent along the north side of the hills that border the Yukon Flats, between the valleys of Beaver and Preacher Creeks. It is also found along the south side of the Livengood area in the valleys of Woodchopper and Coal Creeks, southeast of Circle. This conglomerate appears to lie at or near the base of the Livengood chert, though similar intraformational conglomerates may also be present higher in the sequence. This rock is a unique horizon marker, because it differs lithologically from any other conglomerate in the Yukon-Tanana region, and where it is observed one may be sure that it and the cherty rocks associated with it are a part of the Livengood chert. This chert conglomerate is composed essentially of chert pebbles in a matrix of chert. The pebbles are usually small, seldom exceeding an inch in diameter, and vary in shape from rounded to subangular. As a rule, the pebbles are of much the same color as the matrix, usually gray, and are so perfectly welded into the matrix that in unweathered croppings the conglomerate nature of the rock may not be readily apparent. At other localities the pebbles have different colors and stand out in marked contrast to one another and to the matrix. So firmly are the pebbles cemented to the matrix that surficial alteration does not cause the rock to disintegrate, allowing the pebbles to separate. On the contrary, in both fresh and altered specimens of this rock the pebbles are permanently attached to the matrix, and when the rock is broken it fractures directly across both matrix and pebbles. This chert conglomerate is therefore a rigid rock, and the movements attendant upon regional metamorphism were registered in the form of extensive brecciation, with the development at some places of myriads of small cracks which have been recemented by chalcedonic silica.

The chert of the pebbles and of the matrix of this conglomerate has been examined under the microscope and has been found to be a microcrystalline rock composed of chalcedonic quartz, which shows only aggregate polarization. In some places, however, particularly where extreme brecciation and recementation by silica has taken place, the conglomerate itself has also been partly recrystallized to a fine-grained quartzitic rock. The result of this process is particularly noticeable in the Rampart district, where some of this chert is included among the undifferentiated Mississippian rocks.

The origin of both the chert conglomerate and the chert of the Livengood chert presents some puzzling features. The widespread occurrence of these rocks, their obvious lack of genetic relationship to siliceous intrusive rocks, the lack of internal evidence of replacement, and the occurrence of entirely unsilicified argillite and limestone interbedded with the chert at various horizons have convinced the writer that this chert and chert conglomerate are of primary origin. But these rocks are almost devoid of fossils, and therefore it is hardly likely that the chert was derived from siliceous organisms such as diatoms, though possibly it may have been formed as a result of the secretion of silica from sea water by the action of certain types of algae. Possibly it may have resulted from the original sedimentation of fine-grained or colloidal siliceous silts, or perhaps the silica was precipitated from aqueous solution by chemical action. The exact mechanism by which these rocks were produced is not yet understood, but in any event the chert is believed to be primary.

If its primary origin is admitted, the chert conglomerate then presents an additional problem, for a question naturally arises as to the reason why the pebbles of the chert conglomerate at many places are exclusively chert. The pre-Mississippian formations include many other kinds of rocks and relatively little chert, and it would therefore be expected that the pebbles of a basal conglomerate should be composed dominantly of the various other types of country rock. The explanation might be suggested that these chert pebbles originated by prolonged residual concentration at the surface of a relatively few cherty rocks, while the less resistant rocks were chemically disintegrated; but the region is permeated with vein quartz, which is as resistant to chemical disintegration as the chert, yet little or no quartz is found in the chert conglomerate. These considerations suggest that the pebbles, in some manner, were formed essentially at the same time as the matrix that contains them, and that both pebbles and matrix had a common origin. The process may have been similar to that by which the limestone conglomerate and limestone breccia in the Cambrian rocks were formed—that is, by the submarine erosive and sorting action of oceanic currents. Or perhaps the formation of deposits of chert in shoal water, where atmospheric agencies might act at intervals, might have resulted in the denudation and sorting of siliceous fragmental debris by atmospheric agencies. Or again, such siliceous deposits in shoal waters may have been broken and rolled by tidal currents. In any event, the subangular character of some of the chert pebbles, indicates that the comminution of the fragments of chert must have occurred after the source rock had attained a considerable degree of cohesive strength, and that this comminution was accompanied by little subsequent transportation or assortment. The exact process cannot be exactly visualized, but the writer is convinced that the pebbles and angular fragments of chert in this conglomerate are essentially contemporaneous with the matrix itself—not precisely contemporaneous, as the source rock probably antedated the pebbles, but essentially contemporaneous in the sense that both pebbles and matrix were formed during the same geologic epoch, and in fact during a single geomorphic cycle.

STRUCTURE AND THICKNESS

Although the chert of the Livengood chert is highly resistant to erosion, few good structural observations are available, as these rocks occur mainly in a part of the region where the ridges are low and the croppings are mainly rubble. To generalize from a very few observations, the strike of these rocks is about N. 60° E., and the dip steep to the south. These rocks are closely folded, however, and all evidence indicates that in the type locality the same beds are probably duplicated several times in crossing this belt from south to north. The few fossils so far collected in the Livengood chert are considered to be Carboniferous, but this formation is adjoined on the south by fossiliferous Middle Devonian rocks. Moreover, the chert conglomerate that crops out along the south side of the Livengood belt is much more likely to be a basal conglomerate than one formed at the top of the sequence, for transgressional conglomerates have many more chances for survival than recessional conglomerates. Finally, the fossils found in the next group of rocks, north of Livengood, include forms that were originally determined as Pennsylvanian, though now referred to the upper Mississippian. Hence all evidence indicates that the Livengood chert, in its type locality, is bounded by older rocks on the south and by younger rocks on the north, and the conclusion is therefore justified that the structure of these rocks is that of a closely folded sequence, overturned from south to north.

With this type of structure and few data for detailed interpretation, no measurement of the thickness of these beds is possible. The type locality, though the best place for fossil evidence of the limits of the formation, is a poor place wherein to determine the thickness, for at this point there is a marked break in the structural trend from N. 60° E. to about east, which is reflected not only by an increase in the width of this belt of rocks but also in divergent stream courses, as shown by the headwaters of the South Fork of Hess Creek and by the Tolovana River above the mouth of Livengood Creek. This divergence in regional trend is probably an effect produced by the intrusion of Tertiary granitic rocks, some of which appear at the surface on and about Amy Dome. This localized intrusive activity has apparently added additional complexity to a structure already too complex for ready analysis. Obviously, there would be much duplication of beds in a section of the Livengood chert drawn N. 30° W. through Livengood; on the other hand, the absence of any considerable area of infolded younger rocks within this area indicates a considerable thickness of beds, perhaps several thousand feet, but no closer estimate than this seems warranted.

AGE AND CORRELATION

Fossils are very scarce in the Livengood chert, and none have been found at the type locality, near Livengood; but the small collection listed below was obtained in the valley of the West Fork of the Tolovana River.

18AOF8. Second western tributary of Lost Creek above its mouth, 2.4 miles N. 21° W. from junction of Lost Creek with the West Fork of Tolovana River. Collector, R. M. Overbeck, 1918:

Crinoid stems.
Batostomella sp.
Athyris sp.

These fossils were identified by G. H. Girty, of the United States Geological Survey. They were examined together with several other collections that were obtained from the undifferentiated Carboniferous rocks to the north, and Mr. Girty accepted the whole group of collections as Carboniferous, and probably upper Mississippian, but with certain reservations. The more diagnostic fossils, upon which the determination of upper Mississippian age was based, do not occur in collection 18AOF8, and it is doubtful if this collection alone, considered without reference to the others, even justifies a definite assignment to the Carboniferous. On the other hand, this collection does not contain *Spirifer disjunctus*, which is characteristic of the Upper Devonian elsewhere in Alaska, and the best estimate of the geologic age of the Livengood chert that the writer is able to give is that it probably represents the base of the Carboniferous sequence in this region, and it is therefore classified as Mississippian.

The only counterpart to the Livengood chert is a formation that crops out at the head of the Anaktuvuk River, in northern Alaska, which was originally described by Schrader [83] as the "Stuver series" but was subsequently included by Smith and Mertie [84] as a part of the Noatak formation, of Mississippian age. The general stratigraphy of Schrader's Stuver "series", however, does not correspond closely with that of the Livengood chert. Other groups of

---

[83] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Prof. Paper 20, pp. 60–62. 1904.

[84] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 151–168, 1930.

rocks containing considerable chert occur elsewhere in central and northern Alaska, but the best information now available indicates that most of the cherty rocks of northern Alaska are of Triassic age. Certain cherty rocks from the Ruby district were doubtfully referred by the writer[85] to the Mesozoic (?), upon the basis of an obscure fossil imprint that was found by G. L. Harrington along the border of these rocks. These cherts resemble very much the Livengood chert and are also associated with lava flows similar to those of the Rampart group. These cherty rocks from the Ruby district, as stated in the report cited, may eventually be proved to be of Carboniferous age and more or less correlative with the Livengood chert.

UNDIFFERENTIATED MISSISSIPPIAN ROCKS

DISTRIBUTION

The rocks here mapped under the Mississippian blocks designated "limestone" and "noncalcareous rocks" crop out mainly in the Rampart district and northeastward therefrom. Beginning near Tanana, these rocks extend 140 miles N. 60° E. in a band of variable width to the confluence of Grouse and Bear Creeks, in the upper valley of Hess Creek, and then continue as two bands, the southern of which takes the direction of the main belt, and the northern branch extends northeastward up the northwest side of Grouse Creek and on to the Yukon Flats. Within the same belt are many bodies of limestone, most of which are separately mapped, though their age is no more certain than that of the noncalcareous rocks. Most of these limestones occur in the Rampart district, between the North Fork of Baker Creek and Minook Creek, though two other conspicuous areas of limestone also occur to the east—one at the head of Lost Creek and the other along the ridge north of Beaver Creek.

In addition to the Mississippian rocks above mentioned, there are certain other rocks along the Yukon River a short distance downstream from Eagle which lie stratigraphically below the Calico Bluff formation. These rocks are best exposed along the west bank of the river north of Calico Bluff, but they crop out also along the northeast bank below the mouth of Shade Creek, along the northeast bank between Calico Bluff and the Tatonduk River and on the west bank opposite the mouth of the Tatonduk. Other Mississippian rocks that may lie stratigraphically above the Calico Bluff formation are found in a zone between Eagle and the mouth of the Seventymile River, overlapped in part by younger Carboniferous and Tertiary rocks. Another occurrence of this sequence that may overlie the

[85] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 22–24, 1924.

Calico Bluff formation is found along the northeast bank of the Yukon below the mouth of Fourth of July Creek. All these rocks are in this report considered to be a part of the undifferentiated Mississippian sequence, though only those south of the river are mapped.

In the extreme southeastern part of the Yukon-Tanana region there is a group of rocks which were called by Brooks[86] the "Wellesley formation." These rocks crop out on the east side of the Chisana River, south of Mirror Creek, and also for some distance on the west side of the Chisana. The rocks of the Wellesley formation are here included with the undifferentiated noncalcareous Mississippian rocks.

LITHOLOGY AND STRUCTURE

Most of the information regarding these Mississippian rocks has been obtained in the Rampart district, as that part of the belt lies in a mountainous area where good croppings are available. On the other hand, the Rampart district is an area where the country rock has been more than ordinarily metamorphosed, with the result that the structure is complex and difficult of analysis. This group includes rocks of many varieties, which probably represent several horizons in the Carboniferous. Lithologically, these rocks comprise shale, slate, phyllite, sandstone, quartzite, several varieties of schist, chert, chert conglomerate, limestone, greenstone, and their metamorphic equivalents. Local conditions, however, render it impracticable to divide these rocks into formations, based either on differences in lithology or on faunal evidence, for where the exposures are best the rocks are so highly metamorphosed that faunal evidence is obliterated; and where fossils are found, particularly east of the Rampart district, the hills are low and exposures are poor. Although complete data are lacking, partial sections and a number of fossil collections yield considerable information as to the lithologic sequence and age. These data may best be given by a presentation of local details.

A section from the head of Russian Creek, in the Rampart district, southeast to the mouth of Chapman Creek will illustrate the variation in lithology and degree of local metamorphism. On the ridge between Russian and Ruby Creeks are found quartz-mica schist, quartzite schist, quartzite, garnet and staurolite schist, phyllite, hornblende schist, and chert schist. In the midst of this sequence is a band of crystalline limestone, bent into a hook, thus illustrating the character and intensity of the metamorphism that has locally

---

[86] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 470–472, 1900.

occurred. Intermingled with these metamorphic rocks, particularly near the limestone, are bodies of sheared greenstone. Prindle[87] noted the same zone of highly metamorphic rocks, for he refers specifically to the garnetiferous mica schists and marbles of Ruby Creek. All these rocks have evidently developed flow cleavage under great dynamic stress, and are now completely recrystallized. The type of structure is illustrated in plate 9, *B*. The strike of the schistosity is best determined by the elongation of certain prominent beds, such as the crystalline limestone, which trend N. 60° E. Between Ruby and Slate Creeks, along the same section, the rocks are not well exposed, but toward the heads of these two creeks, particularly on and about Baldry Mountain, the sequence consists of phyllite, sheared chert, quartzite, quartzite schist, and several varieties of green schist. It is characteristic of the siliceous schists of this group that under the influence of the atmosphere they weather to form smooth surfaces that simulate a chert and suggest that these rocks were cherty, in the same way and for the same reason that the imprints of bryozoans and coelenterates often weather out of crystalline limestone which if broken reveals no trace of fossils. It is therefore the writer's belief that most of the quartzites and quartzite schists around Baldry Mountain, no matter how coarse-grained they now appear to be, were not derived from sandstones but instead are the highly altered derivatives of a chert formation that has been kneaded and recrystallized to a surprising extent. Similarly the green schists are probably derived in large measure from basaltic and ultrabasic greenstones, which appear elsewhere in the Yukon-Tanana region as little-altered rocks. The general strike of the schistosity remains about N. 60° E. and the cleavage dips 30°–60° NW., in marked contrast to the regional cleavage farther east in the Fairbanks quadrangle, where it dips in general southward or southeastward.

The section from the head of Slate Creek to the mouth of Chapman Creek was not directly observed but was seen indirectly by means of an oblique section up Minook Creek, starting from the mouth of Slate Creek. The rocks consist of quartzite, chert, chert conglomerate, phyllite, slate, and argillite. Two bands of brown-weathering siliceous limestone also form a part of the sequence. All of these rocks are less altered than those farther northwest, and it is a noticeable fact that the metamorphism decreases progressively upstream. Opposite the mouth of Goldpan Creek, along the west wall of the valley of Minook Creek, is a massive white quartzite; and two similar but smaller croppings may also be seen at the mouth

[87] Prindle, L. M., The Rampart gold placer region, Alaska: U. S. Geol. Survey Bull. 280, p. 20, 1906.

of Goldpan Creek. A close examination of this rock discloses the fact that it is, in part at least, the metamorphosed product of a chert conglomerate; that is, a conglomerate like that of the Livengood chert. From the mouth of Goldpan Creek upstream on Minook Creek the rocks, though of the same general character as those below Goldpan Creek, appear to include a greater proportion of argillaceous rocks. The strike of the cleavage, from Slate Creek to Chapman Creek, is nearly northeast, and the dip, as before, is northwest.

Supplementary to the section between the head of Russian Creek and the mouth of Chapman Creek, certain observations on the ridges north and south of Granite Creek are also instructive. Between Granite and Boulder Creeks a thick band of crystalline limestone crops out, which continues in diminishing width northeastward almost to Minook Creek and extends in an increasingly wide zone southwestward to Wolverine and Orum Creeks. This is the most persistent belt of limestone in the Rampart district and probably corresponds to the limestones noted on Minook Creek between Slate and Goldpan Creeks and also to the limestones at the head of Hoosier and Little Minook Creeks. Between Granite and Boulder Creeks this limestone is greatly sheared, grading into calcareous schist, with a cleavage striking N. 60° E. and dipping 60° NW. On the north side of the limestone the country rock is all derived from original chert. Some of it is still massive, and some is slaty chert and pencil chert, but much of it is sheared. Micaceous minerals have developed in some of these sheared cherts, producing rocks that are best described as cherty phyllite and chert schist. The limestone on this ridge is split for about 2 miles in such a way as to include a thin wedge of sheared chert, greenstone, and quartzite.

South of Granite Creek, on the ridge between Granite Creek and the head of Minook Creek, the country rock is sheared chert and black slate, with a cleavage striking as elsewhere N. 60° E. and dipping 60° NW. Though sheared, these rocks are less altered than those north of Granite Creek. It is of interest to note that a deposit of stibnite was observed along this ridge. The stibnite is altered and is covered by red and yellow oxides, by means of which it was first observed.

The limestone bodies of the Mississippian northeast and southwest of Minook Creek have been separately mapped, so far as practical. In the zone from 92 Hunter to Troublesome Creek, the ridges are low and croppings are too scattered and incomplete to permit separate mapping of the limestones, although they are probably as much a part of the sequence here as they are in the high hills southwest of Minook Creek. All the limestones from Minook Creek to the north fork of Baker Creek have been recrystallized. They include coarsely crystalline white marble, phanerocrystalline, massive, and banded light-gray marble, and many varieties of finely crystalline limestone, mostly light gray but grading into darker varieties. Some of the more strongly metamorphosed types of crystalline limestone, particularly impure varieties, have developed later minerals such as mica, garnet, and epidote. Silicification is not as common in these limestones as might be expected if they are the metamorphic equivalents of the siliceous limestones about Livengood. Dolomitic varieties were observed only among some of the finer-grained lithographic types.

Northeast of Minook Creek, in this same northern belt, an interesting section of rocks is exposed in the valley of 92 Hunter and on the ridge east and west of this creek. The rocks here are believed to be the stratigraphic equivalents of those that crop out on Minook Creek upstream from Ruby Creek, but they are much less metamorphosed and are fossiliferous. This section and also those on Huron Creek, Mud Fork, and Erickson Creek have been studied by Overbeck,[88] from whose notes the following data are taken. The north end of the ridge west of 92 Hunter is composed of greenstone and greenstone schist. Succeeding this to the south, and apparently underlying the greenstone, is a blue-gray, light-weathering limestone, followed farther south by impure light and dark cherts. Still farther south on the same ridge are black slates and dark phyllites, the latter containing some thin beds of conglomerate and grit. Mississippian fossils were found in a limy grit composed of grains of chert and quartz cemented by calcite. South of the fossiliferous beds are slates and quartzites. The section up 92 Hunter supplements the sections along the west ridge. South of the greenstone there crop out for a mile the following beds, named in order from north to south: Dark-blue argillite, in part calcareous, in beds 6 inches to 2 feet thick, weathering rusty brown; highly carbonaceous schist, much crumpled; black and greenish-gray slates; platy phyllite; and argillaceous beds streaked with sandy layers. At the north end of the ridge east of 92 Hunter is a dark-blue limestone that is believed to be correlative with the similar limestone found west of the creek. About a mile to the south on this ridge are argillites containing bands of chert, and these are followed to the south by bluish slates with conglomeratic and gritty beds containing Mississippian fossils. Still farther south are dark-gray phyllites, becoming darker in color, which abut against the massive Cretaceous quartzites.

---

[88] Overbeck, R. M., unpublished data on work done in 1918.

The rocks thus described in and on both sides of 92 Hunter are also found on the ridge between Miller and Willow Creeks, from the northeastern limit of the Cretaceous quartzite down the ridge to Troublesome Creek. The general sequence toward the northeast is micaceous sandstone followed by brecciated light-gray chert of unknown thickness. A mile farther to the northeast is a reddish rock of unknown character, followed successively in the same direction by brownish shale, dark slate, and bluish-green limestone. At the end of this ridge, along the west wall of Troublesome Creek, the same fossiliferous grit is again exposed. Dark-blue brecciated limestone is also exposed in the valley bottom of Willow Creek, and one of the streams that enters Willow Creek from the north shows light and dark impure chert, together with some dark-blue slate and phyllite.

The Mississippian rocks are also exposed along the spurs leading west from the Sawtooth Mountains. Here they include siliceous slate and argillite, chert, chert conglomerate, and sandstone. Close to the intrusive rocks that form this massif the shale and argillite are hardened and altered, with the development of contact-metamorphic minerals such as andalusite and cyanite. At one locality near the contact with the monzonitic rocks some chert conglomerate, in a greatly sheared condition, was also observed. The cleavage of these rocks, dips steeply northward, but the bedding appears to strike about east, and to dip both north and south.

North of the Sawtooth Mountains a lithologic though not necessarily a stratigraphic sequence is fairly well exposed in Union Creek. At the head of the creek, near the monzonite of the range, is a sheared conglomerate made up of pebbles of light-colored granitic rock and quartz, set in a dark argillaceous matrix. North of this is a considerable thickness of dark-colored argillaceous rocks, which in turn are followed by a variety of multicolored thin platy phyllites, with some satiny slate. North of these is some dark-greenish and reddish pencil slate, and this, after a concealed interval, is succeeded by a coarse grit or conglomerate made up chiefly of closely cemented dark-gray, black, and bright-green chert pebbles but containing also a little quartz and well-rounded nearly white grains of a feldspathic rock. The rocks in the lower 2 miles of the creek are concealed. Most of the rocks exposed on Union Creek dip 20°–80° N.

Still farther east, on the East Fork of Mud Creek, the first rocks that crop north of the Livengood chert are greenish-gray slates. Farther downstream is a greenish-gray, red-weathering phyllite, which is followed by greenish-gray slate and by a massive cream-colored quartzite of medium grain. East of Mud Fork Overbeck also obtained several incomplete sections in the various tributaries of Erickson Creek, which when assembled give a lithologic sequence from south to north about as follows:

Livengood chert, south side of section.
Greenish-gray phyllite.
Greenish sandstone.
Phyllite.
Dark-blue impure limestone.
Phyllite.
Dark slate.
Impure limestone.
Quartzite.
Brecciated limestone.
Purple slates.
Red and greenish-yellow phyllite.

Insufficient information is available to state whether this sequence of rocks is overturned, but in any event the rocks are so greatly folded that the lithologic sequence does not correspond with the true stratigraphic sequence.

The locality where Carboniferous fossils were first found in this western part of the Yukon-Tanana region is a low rounded hill southwest of the confluence of Hess Creek with its South Fork. These rocks were described by Prindle [89] as greenish, grayish, and black slates, with siliceous material. Other rock rubble on the slopes of this hill shows that there are also present in this vicinity a light-colored, brownish-weathering limestone, yellowish and greenish shale and slate, black chert, and dark-colored carbonaceous and micaceous sandstones. These rocks also dip to the southeast, but the sequence is probably overturned to the north.

From these observations it is apparent that a well-defined sequence of argillaceous and arenaceous rocks, with some limestone and little chert, lies north of the Livengood chert, in the zone between Rampart and Livengood, but so much of the sequence is concealed that it is not possible to say what relations exist between these two groups. An unconformity, a fault, or some other structural or stratigraphic relation might easily exist, but in any event it is believed that these rocks are younger than the Livengood formation.

On the northwest side of Grouse Creek the rocks of the lower valley are largely argillite and sandstone, with dikes and small intrusive bodies of basaltic greenstone, but farther upstream the country rock changes to argillite, slate, and chert with much greenstone, which may possibly be a part of the Rampart group, though here mapped as

[89] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 337, pp. 22–23, 1908.

noncalcareous Mississippian rocks. Between the head of Grouse Creek and the Yukon Flats there are two short ridges that trend northeast. These are composed of shale, slate, and quartzose sandstone, and from fossils collected nearby they are also considered to be a part of the Mississippian sequence. These rocks are probably the less metamorphosed equivalents of those on Union Creek, Mud Fork, and Erickson Creek. They also dip dominantly southeastward.

The rocks that form the ridge between Victoria and Beaver Creeks are likewise composed of shale, argillite, and quartzite, with some chert, although the argillaceous rocks predominate. There is also on this ridge a large body of limestone, which is highly siliceous and resembles most closely some of the silicified limestones in the Livengood chert. All these rocks are intruded by small bodies of greenstone. One coelenterate was found by Blackwelder in this limestone, but the specimen was too imperfect to warrant a stratigraphic assignment of the included rocks. Both this limestone and the other rocks along the ridge to the west of the limestone are assigned to the Mississippian mainly on the basis of lithologic similarity.

The rocks that lie along the west bank of the Yukon River north of Calico Bluff underlie the Calico Bluff formation. At the south end of this sequence the rocks directly below the Calico Bluff formation consist of carbonaceous and siliceous shale and argillite and grade stratigraphically downward into shale and chert and finally, at the north end of the exposure, become almost entirely thin-bedded chert. This chert is mostly black but weathers to a yellowish brown, probably owing to the formation of hydrous iron sulphates. The base of this sequence is not exposed, but the croppings show a thickness of about 1,700 feet. These rocks lie, along with the Calico Bluff formation, in an open synclinal basin that plunges gently N. 30° W., but this structure is modified along the sides and ends by faulting, so that these rocks may be said to lie in a structural island of fairly simple structure, surrounded by rocks of much more complex structure that is not well understood.

The rocks in the hills between Eagle and the mouth of the Seventymile River are thought to lie stratigraphically above the Calico Bluff formation, but croppings are so poor that little confidence can be placed in this assignment. These rocks consist of thin-bedded carbonaceous shale, weathering to gray and brown shale, calcareous shale, siliceous slate, siliceous limestone, chert, and some beds of conglomerate. On exposed hilltops and slopes, especially where old burns have bared the surface to view, they are considerably weathered, and the bedding and joint planes, particularly in the argillaceous varieties, are commonly covered with a thin red film of hematite or limonite. The effect of this weathered debris is to give to the hillsides occupied by such material a bright-red appearance when viewed from a distance on a sunny day. These beds are greatly disturbed and therefore irregular in strike and dip but appear on the average to strike northwest. The dips are high, ranging from 40° to 75°, both to the southwest and northwest, thus yielding little information regarding the structural relations of these rocks to the Nation River formation, which adjoins them on the northeast. On the basis of other data obtained on the north side of the Yukon they have been considered to underlie the Nation River formation, and this forms the basis on which they are considered to be younger than the Calico Bluff formation. Similar rocks, however, containing fossils of late Middle Devonian age, are known north of the Yukon River in the valleys of Shade and Eagle Creeks, and later work may prove that the rocks in the hills northwest of Eagle are older than they are now supposed to be.

According to the description given by Brooks,[90] the Wellesley formation consists in its lower part of coarse massive conglomerate, interbedded with some beds of clay slate, but the upper part is composed almost entirely of slate. Brooks estimated the thickness at 1,000 to 2,000 feet, but the top of the sequence was not recognized. Although the name "Wellesley formation" was used as a local designation by the writer [91] in an earlier report dealing with the geology of this southeastern part of the Yukon-Tanana region, it seems best in this report to include the formation in the undifferentiated noncalcareous Mississippian unit. From the reported lithology, it seems probable that this formation lies in the lower part of the Mississippian.

AGE AND CORRELATION

Fifteen collections of fossils have been made from the undifferentiated Mississippian rocks, most of which came from the great belt of these rocks that stretches from the Rampart district northeastward to the Yukon Flats. These fossils are listed below.

[90] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 470–472, 1900.

[91] Mertie, J. B., Jr., A reconnaissance of the Dennison Fork district, Alaska: U. S. Geol. Survey Bull. 827, pp. 25–26, 1931.

Invertebrates found in undifferentiated Mississippian rocks of Yukon-Tanana region

	Brooks 27A	4AP270	4AP277	4AP317	4AH213	7AP318, 320	1522A	18AOF2	18AOF3	18AOF4	18AOF5	18AOF7	21AMt128	21AMt152
Oldhamia?														×
Coral		×		×										
Coral?			×											
Zaphrentis? sp								×						
Lophophyllum sp											×			
Cyathophyllum?													×	
Lithostrotion? sp			×											
Syringopora? sp							×							
Stromatopora? sp		×												
Platycrinus sp						×								
Crinoid columns								×	×	×	×	×		
Batostomella sp								×	×	×	×	×		
Rhabdomeson? sp								×						
Archimedes? sp			×											
Stropheodonta sp						×								
Fistulipora sp		×	×					×	×	×			×	
Fistulipora? sp		×												
Delthyris? sp						×								
Stenopora sp					×				×			×		
Spiriferina? sp								×						
Fenestella sp					×							×		
Polypora? sp			×											
Rhombopora sp		×	×		×							×		
Rhipidomella? sp						×								
Lima? sp					×									
Chonetes? sp						×								
Productus cf. P. longispinus			×											
Productus? sp					×									
Camarophoria? sp						×								
Spirifer cf. S. arcticus												×		
Spirifer sp		×						×			×			
Hustedia cf. H. compressa		×												
Nucula sp	×													
Bellerophon sp	×													
Euomphalus sp			×											
Trilobite?	×													

Brooks 27A. Valley of Snag River, about 15 miles southeast of Mirror Creek. Collector, A. H. Brooks, 1898.

4AP270. 40 miles east of Fort Hamlin and about 12 miles N. 25° E. from the junction of Grouse and Bear Creeks. Collector, L. M. Prindle, 1904.

4AP277. 35 miles southeast of Fort Hamlin and about 1 mile S. 41° W. from forks of Hess Creek. Collector, L. M. Prindle, 1904.

4AP317. 8 miles east of Rampart. Collector, L. M. Prindle, 1904.

4AH213. 35 miles southeast of Fort Hamlin and about 1 mile S. 41° W. from forks of Hess Creek. Collector, F. L. Hess, 1904.

7AP318. Little Minook Creek, 5 miles S. 13½° W. from junction of Hunter Creek and 47 Pup. Collector, L. M. Prindle, 1907.

7AP320. Ridge at head of Dawson Creek, 3½ miles S. 21° W. from junction of Hunter Creek and 47 Pup. Collector, L. M. Prindle, 1907.

1522A. Ridge north of Beaver Creek, about 1 mile N. 27° W. from mouth of Willow Creek. Collector, Eliot Blackwelder, 1915.

18AOF2. About 2 miles S. 10½° W. from junction of Hunter Creek and 47 Pup. Collector, R. M. Overbeck, 1918.

18AOF3. About 2½ miles S. 10½° W. from junction of Hunter Creek and 47 Pup. Collector, R. M. Overbeck, 1918.

18AOF4. About 3 miles S. 16° W. from junction of Hunter Creek and 47 Pup. Collector, R. M. Overbeck, 1918.

18AOF5. About 1.6 miles S. 17½° W. from junction of Hunter Creek and 47 Pup. Collector, R. M. Overbeck, 1918.

18AOF7. About 3½ miles S. 58° W. from forks of Hess Creek, close to 4AP277 and 4AH213. Collector, R. M. Overbeck, 1918.

21AMt128. Lillian Creek, tributary of Livengood Creek, from bedrock 1,100 feet above sea level. Collector, J. B. Mertie, Jr., 1921.

21AMt152. About 15.4 miles N. 39° E. from junction of Grouse and Bear Creeks. Collector, J. B. Mertie, Jr., 1921.

Collection Brooks 27A was determined by Charles Schuchert, now of Yale University. The collections made by Prindle in 1904 and 1907 were determined by E. M. Kindle, now of the Canada Geological Survey, but were subsequently reexamined and in part redetermined by G. H. Girty, of the United States Geological Survey.

Mr. Girty also determined the collections made by Overbeck and the writer. Collection 1522A was determined by Edwin Kirk, of the United States Geological Survey, but was assigned merely to the Paleozoic. With the exception of collection Brooks 27A, which has not been reexamined, all these fossils are now accepted by Girty as a part of the Mississippian sequence, but they are fragmental lots, and the stratigraphic assignment does not have the same degree of certainty as that for the fauna of the Calico Bluff formation.

Some peculiar fossil forms were found in collection 21AMt152. These imprints resemble closely the genus *Oldhamia* as described by Kinahan [92] from the Cambrian of Ireland, but there is little doubt that the rocks in which these fossils are formed are an integral part of the Mississippian sequence. They are shown in plate 9, *A*. After being submitted to several paleontologists, none of whom were willing to name them, photographs were made and sent to Rudolf Ruedemann, of the State Museum of New York. Dr. Ruedemann agreed that they exhibit the structure of *Oldhamia* but thought that they showed some details suggesting that they may be hydrozoans. In addition to the so-called *Oldhamia*, there are some fine hairline imprints among the specimens, which Dr. Ruedemann thought were different, possibly being a bryozoan or hydrozoan.

The number and fragmental character of the 15 fossil collections from the undifferentiated Mississippian rocks illustrate the difficulties of reconnaissance geologic mapping in the Yukon-Tanana region. These collections were distributed over an area of at least 750 square miles and therefore represent an average of one collection for every 50 square miles. Where fossils are as scarce and poor as these, mapping must necessarily be based largely on the lithology of the rocks; and it must be admitted that many of these undifferentiated Mississippian rocks do not differ materially from the underlying Devonian rocks, and some of them, particularly the slates, are not unlike the Lower Cretaceous rocks. The present mapping represents the writer's best judgment as to what should be included in or excluded from the Mississippian sequence.

The correlation of these rocks with specific Mississippian formations in other parts of interior or northern Alaska is hardly warranted, for the rocks here described may include any and all horizons in the Mississippian. The Calico Bluff formation, for example, may well be represented in the belt of rocks that stretches northwest from the Rampart district, for the rocks of that formation are soft and little resistant to erosion, so that they might easily be present in the wide alluvium-filled valleys of Hess Creek and its tributaries.

---

[92] Kinahan, J. R., The genus *Oldhamia* (Forbes), its character, modes of occurrence, and a description of the nature of the localities in which it occurs in the Cambrian rocks of Wicklow and Dublin: Royal Irish Acad. Trans., vol. 23, pp. 547–561, 1858.

If they do so occur, they may never be recognized in this western province of the region. A somewhat similar condition was encountered in northern Alaska,[93] where Smith and the writer observed and described a great thickness of Mississippian rocks that were believed to underlie the more precisely determined Lisburne limestone, of upper Mississippian age. This great complex of rocks was called the Noatak formation, and in a broad sense the undifferentiated Mississippian rocks of the Yukon-Tanana region may be said to correspond with that formation, though the lithology is different in many respects.

RAMPART GROUP

DISTRIBUTION

The Rampart group is an assemblage of bedded volcanics and sedimentary rocks that crop out in a belt extending from Stevens Creek, in the Rampart district, northeastward to the Yukon Flats. They are well exposed along the Yukon River from Fort Hamlin to Rampart, but as the Yukon in this stretch flows about parallel to their strike, only a part of the sequence is there exposed. At Fort Hamlin the width of this belt southeast of the Yukon is 25 miles, but from the work of Eakin [94] the rocks of this group are also known to extend for an undetermined distance northwest of the Yukon, into the valley of the Ray River, and to reappear still farther northwest, in the valleys of the Melozi and Kanuti Rivers.

Another group of similar rocks are known farther up the Yukon Valley, extending upstream from Circle for 20 miles or more and cropping out also in the Crazy Mountains, west of Circle. These rocks, being so far separated from the locality of the Rampart group, were given a different designation ("Circle volcanics") by the writer in an earlier report,[95] though even at that time they were considered probably to be equivalent to the Rampart group. Subsequent work by the writer during the field season of 1929 further strengthened this belief, and although the two groups have not been traced directly into one another, their essential contemporaneity seems sufficiently established to warrant mapping the Circle volcanics with the Rampart group.

LITHOLOGY AND STRUCTURE

No complete stratigraphic section of the Rampart group in its type locality can be given. The Yukon runs in general parallel to the strike, but some of the wide meanders between Fort Hamlin and

[93] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 151–168, 1930.

[94] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 31–37, 1916.

[95] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 85–88, 1930.

Rampart yield partial cross sections. Minook Creek cuts through the southeastern half of the formation, but only discontinuous exposures are visible in its valley, and the hills near Rampart are low and to a considerable extent covered with gravel and timber, so that croppings on the ridges also are rare. Similar conditions prevail on Hess Creek, and in the smaller valleys between Hess Creek and the Yukon. Mining operations on Hunter and Little Minook Creeks have also exposed the bedrock at places, and there are numerous exposures on these creeks themselves, particularly on Hunter Creek. None of these localities, however, yields a complete section, but from all of them together a fair idea of the lithology may be obtained. The present description is based upon field observations on the Rampart group by the writer in 1922, 1923, and 1931 and upon the notes and published reports of Spurr in 1896, of Collier in 1902, of Prindle in 1907, of Eakin in 1911, and of Overbeck in 1918. The thin sections of these rocks made by earlier workers have also been reexamined, but those of Spurr and Overbeck furnish most of the data for the petrographic descriptions.

The Rampart group was first described by Spurr,[96] who gave a detailed account of its lithology and petrography. Spurr's description serves as a general picture of these rocks, but in the light of later work it requires considerable modification. For this reason, a new description of the Rampart group is herewith given, which will be found to differ in some important particulars from the original. A petrographic description of these rocks is presented in the section of this report devoted to the igneous rocks of the region (pp. 205–210).

Along the Yukon River from Fort Hamlin to Rampart the Rampart group consists of sediments, including chert, shale, slate, and sandy beds, interbedded with diabasic and basaltic flows, tuffs, and breccias of greenstone habit. Most of the igneous members are lava flows, with which are associated flow-breccias and subaerial and water-laid tuffs. In places dikes of diabase cut the Rampart group, and just above Hess Creek the associated igneous rocks are mainly coarse-grained greenstone intrusives. The cherts of the sequence are found as thin beds, ranging through gray, green, black, blue, and red and in places showing varicolored banding. They appear to be rather closely associated with the lavas and tend to weather to a dirty brown color. The shales and slates are for the most part black or dark gray, but green and red varieties are also found. The sandy beds include yellow and brown sandy shales and a few thin beds of yellow and brown sandstone. A few calcareous beds are

[96] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 155–169, 1898.

also found among the sediments, and about 12 miles above Rampart a lens of fossiliferous limestone about 200 feet thick crops out along the north bank. Interbedded with this limestone are several layers, from 10 to 20 feet thick, of calcareous grit, composed of pebbles of greenstone cemented with calcite. Down the beach from this limestone are greenstone, chert of various colors, argillite, black crystalline limestone, and basaltic tuff; and greenstone is found upstream, so that these calcareous beds appear to be an integral part of this group of rocks.

The rocks of the Rampart group are exposed at intervals on Minook Creek and its lower tributaries. Along Minook Creek the rocks are mainly bedded greenstone, but one prominent bluff just above the mouth of Hunter Creek is composed of greenstone tuff. On Hunter Creek more bedded greenstone is found, associated with yellow-brown weathering chert in thin beds. Much of the greenstone in this vicinity is greatly fractured and brecciated, and the cherty beds are closely folded. Similarly on Little Minook Creek the bedrock consists of several varieties of basaltic greenstone, slate, and chert.

East-northeast of the Rampart district Overbeck [97] has studied the rocks of the Rampart group in the valley of Hess Creek, and in the valleys between Hess Creek and the Yukon. The lithology in general is similar to that seen along the Yukon, except that the proportion of sedimentary rocks seems greater. Thus, on Richardson and Erickson Creeks, two tributaries of Hess Creek from the south, most of the rocks are coarse-grained greenstone, but fine-grained micaceous shale, argillite, and chert constitute an important part of the sequence; and on Mastodon Creek, a tributary of Hess Creek from the north, the rocks include greenstone and fine-grained red and green argillites and tuffs, in part calcareous. Still farther north, on Waldron Creek, an exposure about 2 miles above the mouth shows dark-blue argillaceous beds, thin bands of light and dark chert, and brown sandstone.

From these local details it will be seen that the Rampart group consists partly of bedded greenstones, tuffs, and breccias and partly of a variety of sediments that include chert, shale, slate, argillite, sandstone, and a few beds of limestone and calcareous grit. The coarser-grained basic intrusive rocks associated with the group are not separated on the map. Some of these intrusives appear to be much less altered than the lava flows, and it is possible that they are in part considerably younger. All the greenstones and many of the sediments on fresh fracture have a greenish color, due to the presence of secondary minerals such as the chlorites and serpentine. On

[97] Overbeck, R. M., unpublished notes, 1918.

weathering, however, these minerals are oxidized and produce limonite and related minerals that give a brown discoloration to many croppings. The sediments probably constitute from a third to a half of the sequence and appear to be more common along the south side of this belt than along the Yukon. As both the Rampart group and the undifferentiated Mississippian rocks that adjoin them on the south are greatly folded, it is likely that this prevalence of sediments along the southern border of the Rampart group may be due in part to infolding of the older rocks, which are dominantly sedimentary.

The structure of the rocks of the Rampart group is not simple. Wherever these rocks are exposed they are closely folded and locally faulted and brecciated. Slickensided surfaces are common. A good many readings of strike and dip have been made, but most of these were taken on incompetent sedimentary beds and therefore tell little of the general attitude of the beds at any one locality. The lower valley of Hess Creek is carved largely in these rocks, and its course, together with the general trend of the ridges in its valley, gives perhaps the best idea of the regional strike, which is N. 70° E. About 50 observations of the dominant structure have been plotted, of which two-thirds show dips to the north and one-third to the south. The average north dip is 47°; the average south dip is 36°. Most of these observations were made on the bedding, but some of them record the cleavage. These data in reality mean little but suggest a regional dip to the north for the Rampart group south of the Yukon. Geologic conditions north of the Yukon are not sufficiently well known to extrapolate structurally in that direction.

No estimate of the thickness of the Rampart group has been made, and with the present lack of knowledge regarding the structure and areal limits of these rocks, no exact estimate is practicable. It is obvious, however, that a formation which is closely folded and has a width across its strike of 20 miles may possibly have a stratigraphic thickness of as much as 5,000 to 10,000 feet.

In the Circle district the rocks equivalent to the Rampart group have been called "Circle volcanics." These rocks consist essentially of basaltic lavas of greenstone habit, not unlike the lavas of the Woodchopper volcanics. (See pl. 10, *A*.) They differ from the Woodchopper volcanics, however, in that they are cut by diabasic and gabbroic intrusive rocks. The formation also contains interbedded sedimentary rocks, mainly chert and argillite, with some tuffs and flow breccias. Along the Yukon River above Circle the interbedded sedimentary rocks appear to constitute only a minor proportion of the Rampart group. It is noteworthy that neither in the Circle district nor in the Rampart district do these rocks contain any massive limestones comparable with those found in the Woodchopper volcanics. Little is known of the structure of the Circle volcanics, but at their southward limit, 12 or 15 miles west of Thanksgiving Circle, they appear to dip northwestward, thus apparently overlying the Mississippian (?) rocks that adjoin them on the southeast. From this point downstream for 15 miles, to a point where the exposures on the east side of the river end, numerous reversals in dip were observed, and it is obvious that these lavas are much folded.

AGE AND CORRELATION

The Rampart group consists dominantly of bedded igneous rocks but has a considerable proportion (one-third to one-half) of interbedded sediments that give a clue to the geologic age. Some of these sediments are scantily fossiliferous, and it is probable that in time diagnostic fossils will be discovered. Organic remains have in fact already been found, but they are too few and too imperfect to warrant a positive statement regarding the age of these rocks.

The oldest reference to organic remains in these rocks is given by Spurr,[98] who reported a rock along the Yukon below Minook Creek that he determined to be a glauconitic jasperoid containing fish teeth. The original thin sections of this rock have been reexamined by the writer and by others, and the rock is found to be an ordinary diabase of greenstone habit consisting essentially of plagioclase feldspar, pyroxene, and magnetite, with some calcite, chlorite, and other secondary minerals.

Prindle in 1907, in the course of his boat traverse from Fort Hamlin to Tanana, found a fossil coral (?) along the southeast bank of the Yukon River about 14 miles by river below Fort Hamlin. This specimen, no. 7AP230, was never transmitted for paleontologic determination and has now been lost.

In September 1923 the writer made a boat trip from Beaver to Tanana, in the course of which the following collection of fossils was made from sediments that are believed to be a part of the Rampart group:

23AMt130. North bank of Yukon River about 12 miles N. 20° E. from Rampart. Collector, J. B. Mertie, Jr.

Stenopora sp.
Leioclema sp.
Fistulipora sp.

These fossils were identified by G. H. Girty, who assigned them to the Mississippian.

Spurr, believing that the Rampart group underlay rocks of known Carboniferous age farther up the Yukon, stated merely that the

[98] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, p. 168, 1898.

age of this group of rocks was pre-Carboniferous. Collier in 1902 and Kindle in 1906 collected Middle Devonian fossils from limestones interbedded with volcanic rocks along the upper Yukon opposite the mouth of Woodchopper Creek. Brooks[99] correlated these Middle Devonian volcanics with the Rampart group and thus accepted Spurr's assignment of pre-Carboniferous. It was subsequently shown by the writer[1] that the Woodchopper volcanics are not correlative with the Rampart group, which represents a distinctly later era of more widespread volcanic action.

Collection 23AMt130, above described, was taken from a lens of limestone that is probably a part of the Rampart group. Calcareous grits, interbedded with this limestone, also contain the same fauna, though in a very poor state of preservation. These calcareous grits suggest strongly the fossiliferous calcareous grits found by Overbeck on the ridges east and west of 92 Hunter, in the Rampart district, which appear to underlie the rocks of the Rampart group. The possibility that this limestone and its associated grits are older than the Rampart group must therefore be considered in determining the age of this group of rocks. In general, however, it may be stated that only one collection of determinable fossils has been made from the rocks of the Rampart group and that the stratigraphic position of these fossils is more or less doubtful. But if this collection does not properly belong in the Rampart group, it represents a horizon that is older and not younger than these rocks. The Overbeck collections, from beds underlying the Rampart group, are also assigned by Girty to the Mississippian. Therefore, all these collections, taken together, afford good evidence that the Rampart group is not older than Mississippian.

In the upper Yukon Valley, in the vicinity of Eagle, a rather complete sequence of Carboniferous rocks is exposed, but no Carboniferous volcanic rocks appear as part of the sequence. Farther down the river, however, but upstream from Circle, there is a group of volcanic rocks which have been described by the writer[2] as the "Circle volcanics." Although the relations of these volcanic rocks to the more precisely determined Mississippian section could not be determined, they were assigned to the Mississippian and were correlated with the Rampart group. In 1929, however, the writer was able to trace these volcanic rocks westward from Circle around the north side of the Crazy Mountains in such a direction as to suggest that they might

---

[99] Brooks, A. H., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, p. 277, 1908.

[1] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 86–88, 1930.

[2] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 85–88, 1930.

connect with the Rampart group. But the fact still remains that in their type locality near Circle, these volcanic rocks appear to contain a smaller proportion of interbedded sediments than the Rampart group. It is therefore possible either that the volcanic rocks near Circle can be correlated directly with the Rampart group, the lithologic differences being attributed to changing conditions of accumulation along the strike; or that these rocks represent a dominantly volcanic series overlying the partly marine rocks of the Rampart group and thus supplementing the Rampart sequence.

Irrespective of the precise stratigraphic relations that may exist between the Rampart group and the Circle volcanics, they are either equivalent or closely related to one another, and in the present report they are mapped together. The Rampart group in its type locality appears to overlie the undifferentiated Mississippian rocks. There still remains the problem, however, of correlating a great thickness of volcanic rocks with the sedimentary Carboniferous sequence in the vicinity of Eagle. The Calico Bluff formation, in that area, is definitely known to be of upper Mississippian age. It is believed to be overlain by a great thickness of continental deposits, the Nation River formation. Much then depends upon whether the Calico Bluff formation is represented among the undifferentiated Mississippian rocks of the Rampart district. If the Calico Bluff formation is at a distinctly higher horizon than the undifferentiated Mississippian rocks of the Rampart district, the latter may be dominantly lower Mississippian, with the Rampart group lying stratigraphically between them and the Calico Bluff formation. This interpretation of the stratigraphy explains the absence of the Rampart group in the Eagle area and the absence of the Nation River formation in the Rampart area. On the other hand, it is possible that the Calico Bluff formation is represented among the undifferentiated Mississippian rocks around Rampart. Such an interpretation would place the Rampart group stratigraphically above the Calico Bluff formation and would also suggest a correlation of the Rampart group with the Nation River formation. The first-named interpretation has been favored by the writer in an earlier report,[3] and in the absence of further evidence of a more decisive character it is also used in the present report.

The Rampart group may be correlated with a similar assemblage of volcanic and sedimentary rocks that occur in the Ruby district and extend southwestward into the Kaiyuh Range. This assemblage was referred by the writer[4] to the late Paleozoic, but the absence

[3] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 84–130, 1930.

[4] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 56–59, 1924.

of fossils made it impossible to state definitely that the rocks were of Mississippian age.

Another rather complete section of Carboniferous lavas and related rocks is exposed near the heads of Chisana and White Rivers, at the head of the Tanana. The geologic section in this area was studied by Capps,[5] who showed that the lowest rocks are of Devonian age, and the youngest Permian. At least three groups of basic volcanic rocks and associated sediments lie between these two fossiliferous formations, and the lower one of the three is very probably contemporaneous in origin with the Rampart group.

The study of the Rampart group also suggests its correlation with the Carboniferous volcanic rocks of southern Alaska. In the Copper River region Moffit and the writer[6] have described and mapped two formations of volcanic rocks, of which the lower is similar lithologically to the Rampart group and is likewise of Mississippian age. This is known as the Strelna formation. The upper, called the Nikolai greenstone, is now known to be of Permian or Triassic age. It is probable that the Rampart group is equivalent to all or possibly to the lower part of the Strelna formation. The Circle volcanics may also be equivalent to the Strelna formation, or perhaps to its upper part. It is hard to see how either the Rampart group or the Circle volcanics can be correlated with the Nikolai greenstone, as no evidence has yet been adduced in the upper Yukon region to show any marked volcanic activity in Permian time.

CALICO BLUFF FORMATION

DISTRIBUTION

The type locality of the Calico Bluff formation is at Calico Bluff, on the west bank of the Yukon River about 8 miles due north of Eagle. Calico Bluff, viewed from the southeast, is shown in plate 10, *B*. The rocks of this formation are also exposed in a narrow zone on the north bank of the Yukon north of Calico Bluff, and this zone strikes N. 30° W. and reappears on the north side of the valley of the Tatonduk River. Another narrow belt of the same rocks occurs just west of the mouth of the Seventymile River and also continues N. 30° W., cropping out again on the west bank of the Yukon about opposite the mouth of the Tatonduk River.

LITHOLOGY

The rocks at Calico Bluff consist essentially of alternating beds of limestone and shale, with some slate. The top of the sequence

[5] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 39, 1916.

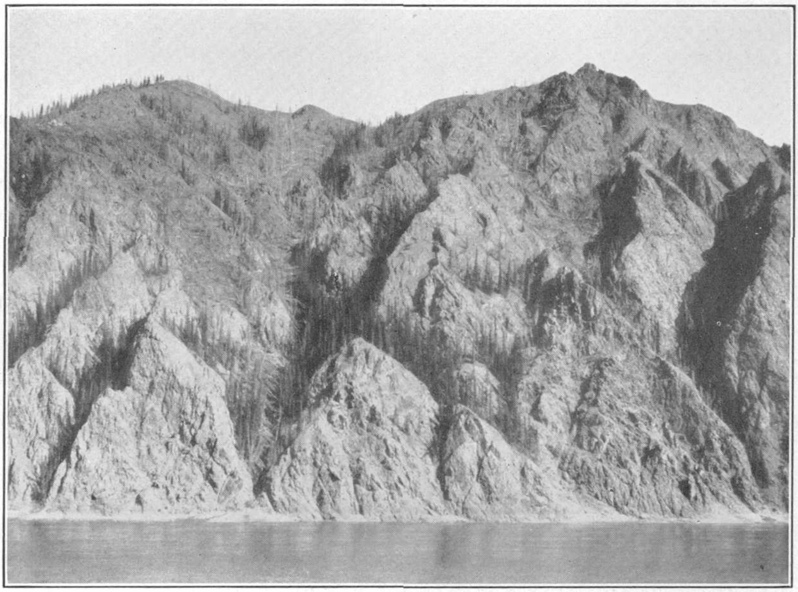
[6] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 54–67, 1923.

is not exposed. The formation grades downward without any stratigraphic interruption into argillaceous and siliceous rocks, and the base of the sequence is arbitrarily taken at that point in the section where, in going downward, the limestone and fossiliferous beds cease. Being only gently folded, the beds in this bluff afford an excellent opportunity for measuring a detailed section.

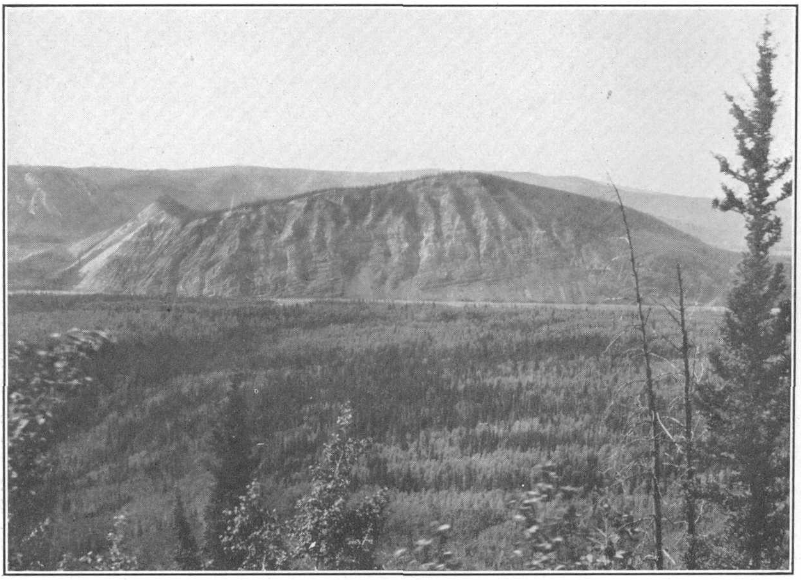
The beds of limestone and shale are thicker at the base of the section and become progressively thinner toward the top. As a result, the upper part of the section consists of a great number of thin beds of alternating limestone and shale, some of which are grouped together in the following section. It is doubtful whether any two sections of Calico Bluff made by different men would exactly match, for much of the variation in lithology is more apparent than real, depending to a considerable extent upon differences in color, which are due to weathering and do not persist laterally along the beds.

Section of Calico Bluff formation in south side of Calico Bluff, on Yukon River below Eagle

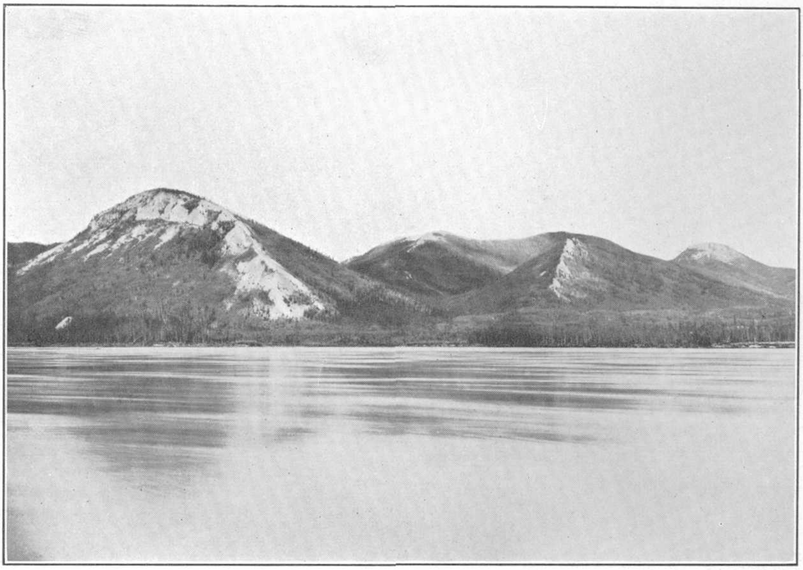
	Feet
Covered. Lower part composed of drab shale, with a few beds of limestone	60
Slope of gray shale, with a little limestone. Contains in the upper part 2 or 3 beds of sandstone that weathers a light ocherous yellow, each 3 or 4 feet thick	95
Calcareous shale, light gray or darker gray, weathering to a light gray. Upper 20 feet covered	194
Massive black limestone, noticeably carbonaceous. Weathers light gray	8
Thin beds of black shale and limestone, both of which weather light and dark gray. These rocks are fossiliferous, but the shale contains invertebrates of genera different from those found in the limestone, indicating an oscillating condition of sedimentation and of marine life	215
A cliff-forming group of beds. Consists of thin-bedded limy shale that weathers to chocolate brown at the top; a 2-foot bed of white-weathering limestone in the center; and black shale at the base	14
Thin, fissile black shale that weathers to a bronze color, except in the middle of the sequence, where it appears chocolate brown for 10 or 15 feet	119
Upper 56 feet is mainly thin-bedded limestone with some shale, weathering to a light chocolate-brown. Lower 27 feet is fissile black shale that weathers blackish brown	83
Fissile black shale, weathering brown at base and red and yellow farther up, giving a general bronze color to the beds	48
Alternating thin beds of white-weathering limestone and fissile black shale. Fossils occur in a thin band at the very top	10
Dark-gray fetid limestone that weathers light gray. Fossiliferous at the base	4



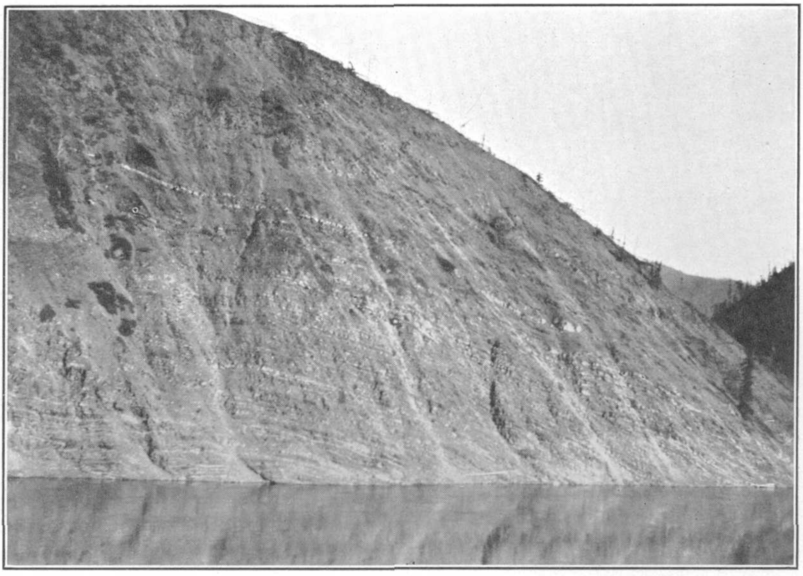
A. MISSISSIPPIAN VOLCANIC ROCKS ALONG YUKON RIVER UPSTREAM FROM CIRCLE.



B. CALICO BLUFF FROM THE SOUTHEAST.



A. FOLDED PERMIAN LIMESTONE ALONG YUKON RIVER ABOVE MOUTH OF NATION RIVER.



B. LOWER CRETACEOUS ROCKS ALONG YUKON RIVER ABOVE MOUTH OF KANDIK RIVER.

	Feet
Dark-gray fissile shale that weathers yellow brown	15
Beds of limestone as much as 3 feet thick, alternating with shale. Contains about midway of the sequence a 2-foot bed of fossiliferous limestone	26
Dark-gray fetid limestone that weathers light gray. Fossiliferous	14
Alternating thin beds of dark-gray limestone and thin, fissile black slate that is probably calcareous. Beds 2 to 8 inches thick	24
Black slate, somewhat siliceous. Near the top is a 6-inch bed of fetid black fossiliferous limestone that weathers white	39
Alternating beds of limestone and shale with some chert. Includes a thick zone of black siliceous slate	300

The lower 300 feet of this section is inaccessible and was not measured directly but was estimated by two roughly quantitative methods, which checked one another closely.

STRUCTURE AND THICKNESS

The structure of the rocks at Calico Bluff is that of an open syncline which plunges gently about N. 30° W. The other two belts of this formation to the northwest, one on the northeast side of the Yukon and one on the southwest side are interpreted in a broad way as the northeast and southwest limbs of this same syncline. Strike faulting, however, has materially modified the synclinal structure. On the north side of the Yukon, north of Calico Bluff, occurs a rapid alternation of Carboniferous and Tertiary rocks, standing practically on end. Similarly, farther downstream strike faulting is apparent on both sides of the Yukon, at the mouth of the Tatonduk River. None of the Mississippian localities northwest of Calico Bluff may therefore be expected to contribute much stratigraphic evidence about this formation. The rocks at Calico Bluff, for some unknown reason, constitute a little stratigraphic island of relatively simple structure, surrounded on all sides by beds that are more intricately folded, as well as faulted, and all the structural and stratigraphic information available is concentrated at this one locality.

The northwestward plunge of the syncline is indicated on the south side of Calico Bluff, where the strike of the rocks is east and the dip is 15°–35° N., averaging perhaps 20°, whereas the regional strike is N. 30° W. Minor crumpling is evident toward the east side of the bluff, but in general the rocks are little metamorphosed and show perfectly the original bedding planes, with incipient fracture cleavage only in some of the weaker beds.

The highest beds have been eroded at Calico Bluff, and it is therefore not possible to obtain a complete stratigraphic section.

The thickness of beds from the arbitrary basal line to the top of the bluff at its south end is about 1,270 feet.

AGE AND CORRELATION

Fossils are very plentiful at Calico Bluff, as well as at the other nearby localities where the rocks of this formation crop out, and nearly every geologist who has gone down the Yukon River, from the time of Collier's trip in 1902, has made collections from these rocks. The table presented below may be said to represent the intermittent collecting of seven geologists over a period of 24 years. The writer [7] also made additional collections of upper Mississippian fossils from the valley of the Tatonduk River in 1930, but the lithology of the containing rocks is somewhat different from that of the Calico Bluff formation, and it does not seem best at present to include these fossils with the fauna of the Calico Bluff formation, as above defined, though subsequent work may warrant the inclusion of these rocks as the upper part of the formation at its type locality.

A few of the earlier paleontologic determinations of these fossils were made by Charles Schuchert, now of Yale University, but the greater part of determinative work was done by G. H. Girty, of the United States Geological Survey. Girty himself made a trip down the Yukon River in 1918 and collected some of the best of the material tabulated below. The localities are arranged roughly in the chronologic order of the collections.

[7] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 421–423, 1932.

Fauna of the Calico Bluff formation

	5867	2AC56	2645	2646	2647	2644	2644A	2644B	2651	2651A	843	845	1796	1796A	1796B	1797	1797A	1797B	1797C	1797D	1797E	1797F	1798	1798A	5279	5302	5302A	5303	5304	5843	5843A	5843B	5843C	5843D	5843E
Coral					×																														
Cyathaxonia sp													×																						
Hadrophyllum? sp																									×										
Zaphrentis sp	×				×			×								×												×							
Zaphrentis? sp			×																																
Triplophyllum sp																			×						×					×					
Triplophyllum? sp																																	×		
Amplexus? sp																									×										
Campophyllum sp			×		×																				×			×		×		×			
Dibunophyllum? sp																			×																
Lithostrotion? sp																														×		×			
Favosites? sp																			×																
Michelinia cf. M. princetonensis																									×										
Michelinia sp			×																																
Aulopora? sp																																		×	
Cladochonus sp																			×						×			×							
Stromatopora? sp																									×										
Serpula? sp																									×										
Spirorbis sp																									×										
Echinocrinus sp								×																								×			
Fistulipora cf. F. excellens																									×										
Fistulipora sp			×																																
Fistulipora? sp																												×							
Batostomella sp													×	×		×				×	×			×		×	×				×	×	×	×	
Leioclema sp														×																					
Stenopora cf. S. carbonaria			×	×																															
Stenopora cf. S. ramosa																									×			×		×					
Stenopora sp			×					×																							×				
Stenopora? sp						×		×																											
Anisotrypa sp																									×										
Anisotrypa? sp																									×										
Fenestella sp	×					×		×	×				×	×						×				×	×	×		×		×	×	×	×		
Hemitrypa sp																×									×										
Polypora sp						×		×		×										×	×				×			×		×					
Pinnatopora sp								×						×																×					
Rhombopora cf. R. lepidodendroides			×	×																															
Rhombopora sp	×					×		×	×					×	×										×			×	×	×	×		×		
Coeloconus sp													×							×															
Ptilodictya sp																																×			
Cystodictya cf. C. lineata																									×						×	×	×		
Cystodictya cf. C. pustulosa			×										×												×			×	×			×			
Cystodictya sp	×					×		×	×					×	×									×											
Rhipidomella cf. R. permiana																									×										
Rhipidomella sp			×																																
Schizophoria sp								×																×	×										

Fauna of the Calico Bluff formation—Continued

	5867	2AC56	2645	2646	2647	2644	2644A	2644B	2651	2651A	843	845	1796	1796A	1796B	1797	1797A	1797B	1797C	1797D	1797E	1797F	1798	1798A	5279	5302	5302A	5303	5304	5843	5843A	5843B	5843C	5843D	5843E
Schizophoria? sp									×																										
Orthotetes sp																									×					×					
Orthotetes? sp																																	×		
Derbya sp																												×							
Derbya? sp						×							×																						
Chonetes capax																									×			×							
Chonetes cj. C. capax																														×		×	×	×	
Chonetes choctawensis											×																								
Chonetes cf. C. choctawensis						×		×		×							×						×		×	×									
Chonetes cf. C. levis																															×				
Chonetes sp			×		×			×	×															×			×								
Chonetes? sp																												×							
Productus cf. P. adairensis													×		×																	×			
Productus cf. P. adairensis var																									×										
Productus cf. P. adairensis?																								×				×							
Productus cf. P. cherokeensis						×		×	×	×																									
Productus cf. P. inflatus						×																			×										
Productus cf. P. inflatus?																																×			
Productus cf. P. ivesi					×																														
Productus ovatus																									×	×						×	×		
Productus ovatus var																																	×		
Productus ovatus?																				×	×														
Productus cf. P. ovatus					×			×	×	×			×			×																			
Productus cf. P. parviformis													×			×																			
Productsu cf. P. parvus			×					×					×													×			×						
Productus cf. P. scitulus														×										×											
Productus semireticulatus																			×			×			×			×				×	×	×	
Productus semireticulatus var			×		×																														
Productus semireticulatus?	×																				×			×											
Productus cf. P. semireticulatus								×		×																									
Productus cf. P. setiger						×			×				×																						
Productus cf. P. tenuicostus																													×						
Productus sp			×		×	×		×		×			×												×				×	×	×			×	
Pustula cf. P. alternata																									×							×		×	
Pustula cf. P. biseriata						×		×	×				×	×										×	×		×	×		×	×	×	×		
Pustula cf. P. concentrica								×																											
Pustula hirsutiformis																										×									
Pustula cf. P. hirsutiformis						×		×	×	×															×			×				×			
Pustula cf. P. hystrix	×																																		
Pustula cf. P. indianensis														×		×									×								×		
Pustula cf. P. indianensis?													×																						
Pustula cf. P. oklahomensis																									×										
Pustula cf. P. oklahomensis var																									×										
Pustula punctata															×																				

Pustula punctata?																				X				X											
Pustula cf. P. punctata						X																							X						
Pustula sp.																			X						X	X		X	X	X	X		X	X	
Avonia sp.																												X					X		
Strophalosia? sp.																									X										
Camarophoria cf. C. bisinuata																									X			X							
Camarophoria sp.																									X			X							
Leiorhynchus carboniferum	X	X					X			X	X	X													X			X				X	X		X
Leiorhynchus sp.						X																													
Leiorhynchus? sp.															X								X						X						
Moorefieldella eurekensis?																												X							
Pugnoides? sp.																									X										
Rhynchopora cf. R. beecheri																									X										
Rhynchopora sp.																																	X		
Rhynchonella sp.			X																																
Camarotoechia cf. C. metallica																									X			X							
Camarotoechia sp.								X																							X				
Camarotoechia? sp.								X																											
Dielasma sp.																									X										
Dielasma? sp.	X																								X										
Girtyella sp.																														X					
Spirifer cf. S. alatus			X																																
Spirifer cf. S. arkansanus																			X						X			X				X		X	
Spirifer cf. S. arkansanus var.																																X			
Spirifer cf. S. bifurcatus																									X										
Spirifer cf. S. bisulcatus						X		X		X																									
Spirifer cf. S. carinatus																									X			X							
Spirifer cf. S. keokuk						X		X																											
Spirifer cf. S. mortonanus																																X			
Spirifer cf. S. mosquensis																									X										
Spirifer cf. S. pellensis													X	X	X	X									X										
Spirifer cf. S. pinguis	X																																		
Spirifer cf. S. rowleyi																X																			
Spirifer cf. S. subrotundatus																										X		X				X			
Spirifer cf. S. sulcatus									X																										
Spirifer yukonensis																X									X			X							
Spirifer sp.			X		X	X			X															X	X							X	X		
Brachythyris cf. B. peculiaris																									X										
Brachythyris cf. B. suborbicularis																													X						
Reticularia cf. R. cooperensis																									X			X						X	
Reticularia cf. R. setigera						X		X					X																						
Reticularia sp.																										X									
Reticularia? sp.																																X			
Ambocoelia sp.																									X										
Ambocoelia? sp.								X																											
Martinia cf. M. rostrata										X																									
Martinia cf. M. sulcata																									X										
Martinia sp.																																X			
Martinia? sp.						X												X																X	
Spiriferina cf. S. spinosa																									X										
Spiriferina sp.																																	X		
Hustedia cf. H. mormoni																									X										
Hustedia cf. H. multicostata																									X										

Fauna of the Calico Bluff formation—Continued

	5867	2AC56	2645	2646	2647	2644	2644A	2644B	2651	2651A	843	845	1796	1796A	1796B	1797	1797A	1797B	1797C	1797D	1797E	1797F	1798	1798A	5279	5302	5302A	5303	5304	5843	5843A	5843B	5843C	5843D	5843E
Athyris? sp									×																										
Cleiothyridina cf. C. sublamellosa																									×								×		
Composita cf. C. trinuclea																									×								×		
Composita? sp			×																											×					
Composita sp	×												×																		×				
Sphenotus cf. S. brannerianus																									×										
Sphenotus cf. S. meslerianus																									×										
Sphenotus sp													×												×		×								
Edmondia? sp																												×							
Solenomya? sp																									×										
Cardiomorpha? sp																×																			
Nucula cf. N. randolphensis																									×										
Nucula cf. N. rectangula																												×							
Nucula sp																										×						×			
Nucula? sp																×																			
Leda cf. L. bellistriata																										×									
Leda? sp																																	×		
Yoldia sp																										×									
Parallelodon cf. P. carbonarius						×																													
Parallelodon sp								×																	×										
Leptodesma sp																									×								×		
Leptodesma? sp																					×														
Conocardium sp																									×										
Pteria? sp																												×							
Posidonomya sp			×																																
Caneyella cf. C. vaughani																									×										
Caneyella cf. C. wapanuckensis																	×								×										×
Myalina sp						×																													
Myalina? sp																									×										
Posidonella sp				×																															
Schizodus sp																									×										
Aviculipecten cf. A. batesvillensis																									×										
Aviculipecten sp						×		×		×							×								×	×		×						×	
Streblopteria cf. S. herzeri					×																														
Streblopteria similis?																									×										
Deltopecten cf. D. caneyanum																									×										×
Pleurophorus cf. P. subcostatus								×																											
Pleurophorus sp								×																											
Pleurophorus? sp					×																														
Cypricardinia cf. C. indianensis																														×					
Cypricardinia sp																									×			×							
Cypricardinia? sp													×																						
Cypricardella cf. C. nucleata																									×										

Cypricardella? C. oblonga																												X							
Miscellaneous pelecypods			X																																
Dentalium sp									X																										
Laevidentalium cf. L. venustum																									X								X		
Chiton sp								X																											
Patella sp																									X										
Oxydiscus? sp																									X			X							
Bellerophon cf. B. crassus			X	X																						X									
Bellerophon cf. B. sublevis																									X			X							
Bellerophon sp						X										X				X				X											
Bellerophon? sp									X																										
Euphemus cf. E. randolphensis																																X			
Euphemus sp																									X										
Bucanopsis cf. B. textilis																									X							X	X		
Pleurotomaria sp	X							X		X			X			X								X	X	X		X				X			
Pleurotomaria? sp									X																										
Phanerotrema? sp																									X			X							
Euconospira sp																									X										
Worthenia? sp																									X									X	
Bembexia cf. B. mcchesneyana																									X	X		X					X		
Bembexia sp																									X			X				X		X	
Bembexia? sp																														X	X				
Treposira sp																									X								X		
Straparollus cf. S. spergenensis																									X			X		X		X	X		
Euomphalus sp																											X				X				
Euomphalus? sp										X																									
Cyclonema sp																																X			
Cyclonema? sp																									X										
Holopea sp																												X							
Anomphalus sp																														X		X			
Naticopsis cf. N. carleyana																														X					
Naticopsis cf. N. *waterlooensis*																									X										
Naticopsis cf. N. wortheni																									X										
Naticopsis sp																X									X										
Naticopsis? sp																																	X		
Meekospira sp																									X					X			X		
Meekospira? sp																												X							
Bulimorpha sp			X																						X										
Zygopleura sp																																X		X	
Aclisina sp																																	X		
Aclisina? sp																									X										
Trachydomia? sp								X																											
Platyceras cf. P. acutirostre																									X										
Platyceras sp																												X							
Eotrochus cf. E. concavus																									X										
Sphaerodoma sp																									X										
Conularia sp	X																																		
Miscellaneous gastropods			X																																
Orthoceras cf. O. epigrus																																	X		
Orthoceras sp							X			X	X														X	X									
Nautilus? sp																	X																		
Gastrioceras sp																									X										
Gastrioceras? sp																														X					

Fauna of the Calico Bluff formation—Continued

	5867	2AC56	2645	2646	2647	2644	2644A	2644B	2651	2651A	843	845	1796	1796A	1796B	1797	1797A	1797B	1797C	1797D	1797E	1797F	1798	1798A	5279	5302	5302A	5303	5304	5843	5843A	5843B	5843C	5843D	5843E
Goniatites sp							×																					×							
Goniatites? sp																														×					
Phillipsia sp						×																						×							
Phillipsia? sp				×					×																										
Griffithides sp																									×	×						×	×	×	
Leperditia cf. L. carbonaria	×																																		
Paraparchites sp																			×																
Ostracoda																																×			

5867. West bank of Yukon River 6 miles above mouth of Seventymile River (Calico Bluff). Collector, A. J. Collier, 1902.
2AC56. South bank of Yukon River 2 miles above mouth of Seventymile River. Pebble in conglomerate. Collector, A. J. Collier, 1902.
2645. North bank of Yukon River about 5 miles above Seventymile River. Collector, Arthur Hollick, 1903.
2646. West bank of Yukon River just above mouth of Sheep Creek (Tatonduk River). Collector, Arthur Hollick, 1903.
2647. Calico Bluff, Yukon River. Collector, Arthur Hollick, 1903.
2644, 2644A, 2644B. Calico Bluff, Yukon River. Collector, A. H. Brooks, 1906.
2651, 2651A. North bank of Yukon River above island near Star (an abandoned settlement at the mouth of Seventymile River). Collector, A. H. Brooks, 1906.
843. Calico Bluff, Yukon River. Collector, E. M. Kindle, 1906.
845. North bank of Yukon River 1 mile above Seventymile River. Collector, E. M. Kindle, 1906.
1796, 1796A, 1796B. North end of Calico Bluff, Yukon River. Collector, Eliot Blackwelder, 1915.
1797, 1797A–F. North bank of Yukon River at big bend north of Calico Bluff. Collector, Eliot Blackwelder, 1915.
1798, 1798A. Calico Bluff formation, southwest of mouth of Sheep Creek (Tatonduk River). Collector, Eliot Blackwelder, 1915.
5279. North bank of Yukon River nearly opposite Seventymile River. Collector, G. H. Girty, 1918.
5302. South end of Calico Bluff, Yukon River. Collector, G. H. Girty, 1918.
5302A. Base of Calico Bluff, Yukon River. Float specimens. Collector, G. H. Girty, 1918.
5303. North end of Calico Bluff, Yukon River. Collector, G. H. Girty, 1918.
5304. West bank of Yukon River opposite mouth of Tatonduk River (Sheep Creek). Collector, G. H. Girty, 1918.
5843, 5843A. Calico Bluff, Yukon River. Just below base of zone B. Collector, J. B. Mertie, Jr., 1925.
5843B. Calico Bluff, Yukon River. Zone C. Collector, J. B. Mertie, Jr., 1925.
5843C. Calico Bluff, Yukon River. From 4-foot bed of limestone that lies 41 feet stratigraphically above top of zone C. Collector, J. B. Mertie, Jr., 1925.
5843D. Calico Bluff, Yukon River. In 215-foot zone about 450 feet vertically above river. Collector, J. B. Mertie, Jr., 1925.
5843E. Calico Bluff, Yukon River. Float specimens. Collector, J. B. Mertie, Jr., 1925.

The faunal list above given comprises 117 genera, and it is probable that more than 250 species are represented. The paleontologic determinative work on these collections has been of a general nature, with the purpose mainly of determining the geologic age of the fossils, rather than making a detailed study with specific determination and the description of new species. Girty believes that this fauna is more closely related to the marine Asiatic faunas described by Tschernyschew than to the Mississippian faunas of the Rocky Mountain region, and this fact, together with the presence of many new species, has deterred him from attempting to correlate closely with the standard sections in the States. This fauna is now considered by Girty to be of upper Mississippian age, roughly correlative with the Chester group of the United States.

North of the Yukon River and along the international boundary Cairnes [8] made 15 collections of upper Mississippian fossils, which, though they include some species different from those found at Calico Bluff, are, nevertheless, considered by Girty to be also of upper Mississippian age. The same is true of the fossils collected by the writer [9] from the valley of the Tatonduk River close to the Yukon. From these collections it is evident that the Calico Bluff formation has a considerable extension north of the Yukon River along both

[8] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 93–103, 1914.

[9] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 421–423, 1932.

sides of the international boundary. The upper part of this formation, which has been removed by erosion at Calico Bluff, will probably be found in this contiguous northern area.

Mississippian rocks are widespread in Alaska. One of the most persistent formations of Mississippian age is one in northern Alaska that is known as the Lisburne limestone, which extends from Cape Lisburne, on the Arctic Ocean, eastward almost if not quite continuously for 600 miles to the international boundary. This formation is composed of limestone and chert and therefore differs lithologically from the Calico Bluff formation; but the faunas of these two formations are similar and are considered to have originated at about the same time.

Mississippian rocks are also known to exist at many other places in Alaska, including Seward Peninsula, the Alaska Range, and southern and southeastern Alaska, but none of the formations appear to correspond closely with the Calico Bluff formation, although many of the fossils are similar.

NATION RIVER FORMATION

DISTRIBUTION

The Nation River formation is sparsely distributed in the Yukon-Tanana region. It crops out along both banks of the Yukon River a few miles below Eagle, forms the bedrock in an area between Boulder Creek and the lower Seventymile River, and extends northeastward from the Yukon to the international boundary. Farther down the Yukon it again crops out on both banks, above the mouth of the Nation River, and extends from that locality northeastward up the valley of the Nation River and southeastward along the northwest side of the Yukon to the Tatonduk River. It also is well developed along the northeast bank of the Yukon below the mouth of the Nation River.

LITHOLOGY

The Nation River formation is a thick sequence of continental deposits, consisting of well-indurated clay shale, sandstone, and conglomerate, and except for its higher degree of induration resembles greatly the Tertiary rocks that crop out along the south side of the Yukon. In the belt that crosses the Yukon below Eagle the Nation River formation consists mainly of dark-gray sandstone in beds from a few inches to 20 feet thick, interbedded with drab clay shale. The sandstone consists of grains of chert, decomposed feldspar, quartz, and more or less carbonaceous material. It weathers usually to a dark-brown color. The beds are commonly ripple-marked and also show various kinds of mud lumps and concretions, though cross-bedding is not common. Beds of dark conglomerate, 10 feet or more thick, are also interstratified with the sequence. These conglomerates are composed mainly of well-rounded pebbles of chert, usually light to dark gray but with some green cherts, set in a sandy matrix. Much comminuted plant debris occurs in all these rocks, and in some of them carbonized stems, as large as 2 inches in diameter and 2 feet in length, may be seen, but no plant remains of particular diagnostic value in determining the age of the rocks have been found.

The base of the formation is well exposed in the northeastern extension of this belt, near the international boundary. There the basal bed is a conglomerate about 80 feet thick, and 250 feet higher in the sequence is another bed of conglomerate, about 50 feet thick. At this point the Nation River formation rests upon beds of late Middle Devonian age. The formation therefore has not only a basal conglomerate but also an intraformational conglomerate, particularly in this lower part of the sequence exposed along the Yukon below Eagle.

From Trout Creek downstream to Nation River the rocks of the Nation River formation have the same general lithologic character, including shale, sandstone, and conglomerate, but the upper part of the formation, which is exposed along the southwest bank of the Yukon above the Nation River, is essentially a gray clay shale. This appears to grade upward into beds of sandstone and conglomerate that contain Permian fossils. The rocks here are faulted, and some of the sequence is probably missing, but the stratigraphic evidence indicates a gradual transition from the continental deposits to the overlying marine sediments of the Permian; and this relation constitutes the best datum at present available for the stratigraphic placement of the Nation River formation.

Below the mouth of the Nation River, along the northeast bank of the Yukon, occurs the same gray clay shale, interbedded with several thin beds and capped by one thick bed of conglomerate. The thick conglomerate forms the top of a bluff about 1,400 feet above the river and consists of gray, red, and green chert pebbles and a few pebbles of quartzite, as much as 4 inches in diameter, in a matrix of cherty and sandy material, with a white, possibly calcareous cement. This thick conglomerate may be near the top of the Nation River formation and probably corresponds to the conglomeratic beds exposed below the Permian limestone on the opposite side of the river.

A feature of special interest is the occurrence of a bed of bituminous coal in the Nation River formation on the southeast side of the Nation River about three-quarters of a mile from its mouth.

This has previously been described by Collier,[10] and it suffices here to state that this coal is of coking grade and was found by analysis to contain 55.55 percent of fixed carbon, with a rather high percentage of sulphur. The coal-bearing bed is now concealed by material that has slumped from above, but the coal is known to have occurred in a crushed bed, about 2 feet thick, standing nearly vertical, with foot and hanging walls of shale.

STRUCTURE AND THICKNESS

The major structure of the Nation River formation is not well known, but it is certain that these rocks in general are considerably deformed. Between Eagle and Calico Bluff the rocks are folded, in places closely folded—in fact, one recumbent fold was observed. The rocks appear to strike approximately parallel to the general course of the Yukon. The dip of the rocks is variable, owing to folding, and the structure is further complicated by a system of faults, which trend northwest. One of these faults probably passes along the southwest side of Calico Bluff, thus cutting through the rocks of the Nation River formation somewhere below the mouth of Boulder Creek. Stratigraphic interpretation of this structure, based on a few croppings along the river, is manifestly impracticable.

From the mouth of Shade Creek northeastward toward the Canadian boundary the structure is probably simpler and may approximate a monoclinal sequence dipping southwestward. On a high peak 3½ miles to the northeast and 3,200 feet above the river the basal beds of the Nation River formation dip 10° SW., but this dip evidently steepens toward the river. If the dip remains low nearly to the river, as seems probable, no considerable thickness of rock is involved, perhaps less than 1,000 feet. This interval, however, represents only a small part of the total thickness.

Near the mouth of the Nation River some larger structural features are suggested, but further work will be required in the hills along the northwest side of the Nation River, between the Yukon and the international boundary, before the major structure can be definitely determined. Apparently the rocks of the Nation River formation, striking northwest and dipping essentially southwest along the Yukon near Eagle, follow the northeast side of the Yukon in a narrow band and near the Nation River veer to the northeast, continuing in that direction up the Nation River toward the boundary. This distribution, together with the distribution of the Permian and Triassic rocks on the southwest side of the Yukon

---

[10] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 53–56, 1903.

between Trout Creek and the Nation River, suggest strongly the existence of a plunging anticline, whose axial line, dipping west-southwest, crosses the Yukon near the mouth of Trout Creek. This is not by any means a simple structure, for the central part is characterized by local folding, in which the Nation River formation, the Tahkandit limestone, and the Upper Triassic rocks are all involved. Plate 11, *A*, showing the Tahkandit limestone folded into an open anticline and syncline just southeast of the Nation River, exemplifies the local expression of the major structure that is suggested. This major structure is further complicated by faulting, the effects of which are visible in the rocks along the southwest side of the Yukon opposite the mouth of the Nation River. Also as a result of such faulting, there is an abnormal distribution of the rocks at the mouth of the Nation River, for if the folded structure were not thus modified, Triassic and younger rocks should appear along the northwest valley wall of the Nation River. Instead, the Nation River formation reappears along this side of valley, suggesting that a major fault, trending probably northeast, cuts the anticlinal structure at the mouth of the Nation River. The upthrown side of this fault is on the northwest. This fault probably intersects the country rocks close to the coal bed above referred to and accounts for the broken and complex structure of the rocks in the vicinity of the coal mine, in an area where the usual structure is open folding.

No complete section of the Nation River formation has yet been found. The rocks of this formation east and southeast of Calico Bluff undoubtedly form the basal part of the section, but only a small part of the sequence is represented. The rocks that extend up the Yukon for 12 miles or more above the mouth of the Nation River probably represent a considerable part of the sequence, including the uppermost beds, but as these rocks are folded and not continuously exposed, the thickness cannot be measured. Finally, no horizon markers are available that would enable the lower and upper sections to be pieced together. The precise thickness is therefore indeterminate. Estimates of the thickness ranging from 3,700 to 6,000 feet have been made by various workers, and all that can be said is that the thickness probably lies between these limits.

AGE AND CORRELATION

The Nation River formation, to judge from the character of its rocks, is of fluviatile origin. Much fragmental vegetal material is present in these rocks, but little of diagnostic value has yet been collected and identified. However, collections of such material have been made by various geologists in past years, and all of these were submitted to David White, of the United States Geological Survey, for identification, with the following results:

2970. Yukon River, east bank 2 miles below Tatonduk River. Collector, A. J. Collier. *Lepidodendron?* sp.

3AH7. Yukon River, west bank 3 miles above Nation River. Collector, Arthur Hollick. *Spirophyton* sp.

1655. Yukon River, northwest bank 5 miles north of Eagle. Collector, E. M. Kindle. Lepidophyte group.

Martin 81. Yukon River, east bank 2 miles below Tatonduk River. Collector, G. C. Martin. Specimens not identified.

Martin 89. Southeast bank of Nation River half a mile above mouth, at coal mine. Collector, G. C. Martin. Specimens not identified.

1501/19. Yukon River, 4 to 5 miles below Eagle. Collector, Eliot Blackwelder. Protolepidodendroid group. A variety of decorticated stems.

1507/I. Yukon River, north bank about 2 miles above Calico Bluff. Collector, Eliot Blackwelder. Indeterminate vegetal material.

1507/X. Yukon River, west bank 5½ miles above Nation River. Collector, Eliot Blackwelder. Indeterminate vegetal material.

1507/63. Yukon River north bank 1½ miles below Nation River. Collector, Eliot Blackwelder. Bothrodendroid? group.

25AMt127. Yukon River, northeast bank about 7½ miles N. 33° E. of Eagle. Collector, J. B. Mertie, jr. Specimens not identified.

Mr. White was inclined from the general appearance of these plant remains to assign them to the Mississippian, the possible alternative being Upper Devonian, but the material is so poor that little confidence can be placed in determinations of age that depend on this flora alone. The stratigraphic relations therefore become of considerable importance. The Nation River formation certainly underlies the Tahkandit limestone, of early Permian age, and is therefore not younger than early Permian. Along the international boundary it definitely overlies late Middle Devonian rocks and is therefore not older than late Middle Devonian. These two facts constitute all the definite stratigraphic evidence available, for the Nation River formation has not been observed in contact with the Calico Bluff formation at any locality where no possibility of faulting exists. The stratigraphic relations south of Calico Bluff, however, suggest that the Nation River formation lies stratigraphically above the Calico Bluff formation. It follows therefore, that the Nation River formation is probably of post-Mississippian age, for the Calico Bluff formation lies high in the Mississippian sequence, and the character of the basal beds of the Nation River formation suggests that this formation lies unconformably upon all formations older than itself. Hence the Nation River formation must be regarded either as Pennsylvanian or very early Permian. But the base of the Tahkandit limestone lies well down in the Permian sequence, and this fact makes it improbable that the Nation River formation is also Permian.

Therefore, the Nation River formation is here considered to be probably of Pennsylvanian age.

Quite apart from the local stratigraphic relations, this interpretation has much to support it, when considered in terms of the general Carboniferous sequence of Alaska. Marine sediments of Carboniferous age are widely distributed over Alaska, and all these rocks, though abundantly fossiliferous, have been found to belong either in the Mississippian or the Permian series. In other words, no marine Pennsylvanian rocks are known in Alaska. It is therefore not surprising but to be expected that continental deposits might somewhere be found in Alaska that would represent this period of nonmarine sedimentation. This formation appears to be a unique lithologic unit, though the possibility exists that plant remains may also exist elsewhere in interior Alaska, in estuarine rocks of the same age that have survived later cycles of erosion. A suggestion of this is found in the notes by Kindle [11] and by Maddren [12] on the occurrence of Carboniferous plants along the Porcupine River about 28 miles below the Coleen River.

However, an alternative conclusion should be stated. The plants of the Nation River formation and of the Porcupine Valley and also certain Carboniferous plants collected by Collier [13] from Cape Lisburne, in northwestern Alaska, have all been referred by David White to the lower part of the Mississippian. On the evidence of local stratigraphy and regional Carboniferous geology, the writer has concluded, in disregard of the botanic evidence, that the Nation River formation is probably Pennsylvanian. It is possible that the Nation River formation is lower Mississippian, as the fossils suggest. G. C. Martin,[14] formerly of the United States Geological Survey, holds this opinion. This interpretation must be admitted as a possibility, and if no other exposures were available than those along the international boundary, where the base of the Nation River formation rests upon Middle Devonian rocks, this interpretation would be hard to disprove. But the apparent upward gradation of the Nation River formation into the Permian limestone at the Nation River seems to contradict this hypothesis, under which an unconformity instead of a transitional zone must there exist, with the Calico Bluff sequence entirely removed by erosion. This difficulty seems insuperable to the writer, yet the question should not be regarded as definitely settled.

---

[11] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, p. 33, 1908.

[12] Maddren, A. G., unpublished notes, 1911.

[13] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 22, 1906.

[14] Oral communication.

TAHKANDIT LIMESTONE

DISTRIBUTION

The Tahkandit limestone is known at several localities, all of them along or contiguous to the Yukon River. The type locality is along the Yukon just above the mouth of the Nation River (the original Indian name for which was "Tahkandit"), where a belt of such rocks crosses the river, trending northeast. (See pl. 11, *A*.) Another belt on the south side of the Yukon crosses the valley of Trout Creek, about 10 miles south of the mouth of the Nation River, striking east. The continuation of this belt is found as an isolated limestone butte on the north side of the Yukon about 4 miles northeast of the mouth of the Tatonduk River. Along the south bank of the Yukon a short distance below the mouth of Coal Creek a small block of this limestone crops out.

LITHOLOGY

The Tahkandit limestone consists essentially of limestone but also includes in its lower part some beds of fossiliferous conglomerate, sandstone, and shale. The best section at present available is exposed along the southwest bank of the Yukon River opposite the Nation River, where not only the Tahkandit limestone but also the overlying and underlying rocks are also exposed. The stratigraphic section at this locality has been measured by the writer,[15] but later observations from midstream indicate that faults are present, which were not recognized when the section was studied at close range; and the section originally presented, though correct in general, may be erroneous in some of its details.

STRUCTURE AND THICKNESS

It was recognized by the writer in 1925 that the rocks of the Nation River formation and the Tahkandit limestone formed a pitching anticline, whose axial plane trended northeast, but the extension of this fold at that time was not known. The work of 1930, however, resulted in the recognition of the limestone butte northeast of the mouth of the Tatonduk River as the eastward continuation of the south limb of this major fold. At the same time the northeastward extension of the other limb was recognized in the valleys of Hard Luck and Waterfall Creeks, east of the Nation River. The general outline of this structure over an area of about 200 square miles is now recognized. The axial plane strikes east-northeast, and only the pitching end of the anticline crosses to the south side of the

[15] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, p. 122, 1930.

Yukon. Still farther northeast, toward the international boundary, along the strike of the north limb of this fold, Cairnes[16] recognized the same limestone near Ettrain Creek, as shown by its fauna, though he mapped it as part of the undifferentiated Carboniferous. On the south limb of the anticline most of this limestone has been eroded east of Trout Creek, but the limestone butte northeast of the mouth of the Tatonduk River represents the last outlying remnant of the formation in that direction.

The structure above outlined represents the major or regional structure of these rocks, but the Tahkandit limestone also has minor folds. These are illustrated by the open anticline and syncline along the north bank of the Yukon above the mouth of the Nation River, as shown in plate 11, *A*.

The total thickness of the Tahkandit limestone as measured in the section above cited is 527 feet, of which 373 feet is limestone. In view of the faulting now recognized at the site of the section, this section may be in error to some degree, but it gives an approximate idea of the thickness of the formation there exposed. It should be emphasized, however, that the top of the formation has not been recognized, and therefore the total thickness of the formation may be much greater.

AGE AND CORRELATION

The Tahkandit limestone, like the Calico Bluff formation, is very fossiliferous, and numerous collections have been obtained from it by geologists since 1896, when Spurr made his trip down the Yukon River. Other collections from the Tahkandit have been made by Cairnes and by the writer, but in the following tabulation only those fossils from the north side, which are close to the river, are included.

[16] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 93–103, 1914.

Permian fossils collected from the Tahkandit limestone along the Yukon River and its tributaries between Eagle and Circle

	2444, 2444a [1]	2AC55 [1]	2443 [1]	2445 [1]	Collier 1902 [1]	2441	Brooks 12	2446	2447	2448	427	428	Martin 82	Martin 83	1799	1799a	1799b	1800	1800a	1800b	1801	2437	2437a	2437b	2438	2439	2440	2440a	2442	2442a	2442b	2442c	2442d	2543 [2]	2549	5839	5839a	5839b	5839c	5840	5841	5842	6843a	6843b	6845
Globigerina? sp			X																																										
Zaphrentis sp								X					X	X																															
Zaphrentis? sp						X																																							
Triplophyllum sp																																					X			X					
Triplophyllum? sp																													X																
Amplexus? cf. A. zaphrentiformis	X																																												
Amplexus sp																										X																			
Lophophyllum sp																									X											X									
Lophophyllum? sp																																			X										
Acervularia? sp																																													X
Batostomella sp																				X	X	X							X						X	X									
Stenopora sp								X												X																									
Stenopora? sp											X										X																								
Polypora sp										X																																			
Phyllopora sp																					X																								
Phyllopora? sp																													X																
Rhombopora sp										X																																			
Coeloconus? sp																																													X
Cystodictya sp						X																																							
Lingula sp						X																X	X														X								
Lingulidoscina cf. L. utahensis														X																															
Lingulidoscina sp																								X							X														
Crania sp																																			X										
Crania? sp																																				X									
Orthotetes sp		X																																											
Derbya sp																													X																
Derbya? sp						X						X																																	
Modiola sp																																													X
Streptorhynchus cf. S. pelargonatus								X	X	X																X			X						X	X				X					
Streptorhynchus? sp											X									X																			X						
Meekella? sp																									X																				
Chonetes cf. C. geinitzianus																													X						X					X					
Chonetes cf. C. laevis			X																																										
Chonetes cf. C. morahensis								X			X												X	X		X		X		X	X	X			X	X		X		X					
Chonetes cf. C. ostiolatus var. impressus																																												X	
Chonetes sp						X																X			X																	X			X
Productus cf. P. aagardi																																											X		
Productus cf. P. cancriniformis																																											X		
Productus cf. P. cora			X											X		X									X	X									X		X								
Productus cf. P. cora var																																	X												
Productus cf. P. cora (of Tschernyschew)																											X		X								X		X						X

Productus cf. P. gruenewaldti														X				X																											
Productus cf. P. koninckianus								X	X	X													X		X				X	X	X				X	X	X	X	X	X		X			
Productus cf. P. koninckianus var																									X	X	X																		
Productus longispinus	X																																												
Productus longispinus?	X																																												
Productus cf. P. longus																									X	X	X		X				X		X		X		X						
Productus cf. P. longus?																																						X							
Productus cf. P. mammatus								X				X								X		X	X		X	X	X		X		X		X				X	X	X						
Productus multistriatus	X																																												
Productus cf. P. multistriatus		X	X	X		X																																							
Productus cf. P. phosphaticus var																																												X	
Productus semireticulatus	X																																												
Productus semireticulatus var		X	X																																										
Productus cf. P. semireticulatus			X	X		X																																							
Productus cf. P. transversalis										X																																			
Productus cf. P. undatus	X		X																																										
Productus sp						X		X							X			X	X						X				X																
Pustula cf. P. fasciata							X																																						
Pustula cf. P. horrida								X			X	X							X									X	X						X	X									
Pustula cf. P. humboldti			X																																									X	
Pustula cf. P. irginae								X															X		X	X	X		X	X	X		X		X	X	X		X	X					X
Pustula cf. P. punctata																																											X		X
Pustula punctata var	X																																												
Pustula cf. P. purdoni						X																																							
Pustula cf. P. wallaciana											X	X																																	
Pustula sp																													X						X	X							X	X	
Avonia cf. A. porrecta													X													X			X							X									
Avonia cf. A. porrecta?								X		X																																			
Avonia? cf. A. porrecta																																								X					
Marginifera cf. M. aagardi								X	X	X	X	X						X				X	X	X	X	X	X	X	X		X	X			X	X	X	X	X	X		X			
Marginifera cf. M. splendens								X																																					
Marginifera? cf. M. splendens									X	X																																			
Marginifera typica var. septentrionalis																																			X										
Marginifera typica var. septentrionalis?																										X			X				X			X									
Marginifera sp			X																																										
Marginifera? sp																			X																										
Aulosteges sp									X																				X						X		X								
Camarophoria margaritovi										X																																			
Camarophoria cf. C. margaritovi																										X	X								X				X						
Camarophoria cf. C. pinguis			X																																										
Camarophoria sp						X																														X	X								
Pugnoides sp																																				X			X						
Rhynchopora cf. R. nikitini			X			X		X			X	X			X	X	X			X		X	X	X		X	X	X	X	X	X				X	X	X		X	X		X		X	
Dielasma cf. D. elongata											X																																		
Dielasma? sp															X																														
Spirifer cf. S. cameratus						X				X																																			
Spirifer cf. S. fasciger																																			X					X					
Spirifer cf. S. marcoui						X		X				X								X									X																
Spirifer cf. S. scobinus	X																																												
Spirifer cf. S. striatus		X	X		X																																								
Spirifer sp																																			X										

[1] The fossils of these collections were determined by Charles Schuchert.

[2] Collection misplaced, but fossils known to be of Permian age.

Permian fossils collected from the Tahkandit limestone along the Yukon River and its tributaries between Eagle and Circle—Continued

	2444, 2444a	2AC55	2443	2445	Collier 1902	2441	Brooks 12	2446	2447	2448	427	428	Martin 82	Martin 83	1799	1799a	1799b	1800	1800a	1800b	1801	2437	2437a	2437b	2438	2439	2440	2440a	2442	2442a	2442b	2442c	2442d	2543	2549	5839	5839a	5839b	5839c	5840	5841	5842	6843a	6843b	6845
Spiriferella arctica			X	X		X		X	X	X		X	X		X						X																								
Spiriferella arctica var																										X																	X	X	
Spiriferella arctica?																				X																									
Spiriferella cf. S. arctica						X																																							
Spiriferella? arctica																									X				X						X	X	X			X	X				
Spiriferella? artica var																																	X						X						
Spiriferella cf. S. artiensis										X																																			
Spiriferella cf. S. saranae																																												X	
Spiriferella? sp																			X																										
Reticularia cf. R. lineata			X																																										
Squamularia cf. S. perplexa								X		X	X											X	X		X	X	X		X				X		X	X	X		X					X	
Squamularia sp																															X														
Squamularia? sp																												X																	
Martinia sp															X										X																				
Martinia? sp																										X			X														X		
Spiriferina sp																										X			X																
Hustedia cf. H. meekana						X																																							
Cleiothyridinia of C. incrassata																																											X		
Cleiothyridina sp								X																					X						X		X								
Composita subtilita?																				X																									
Edmondia? sp																										X			X																
Solenomya? sp																													X																
Pseudomonotis sp			X																																										
Pseudomonotis? sp																													X																
Schizodus sp								X																					X																
Aviculipecten cf. A. magnus																																													X
Aviculipecten sp	X					X		X		X												X							X						X		X							X	
Streblopteria sp			X																				X								X														
Streblopteria? sp																														X					X					X					
Deltopecten cf. D. occidentalis																									X																				
Deltopecten sp																		X																											
Pleurotomaria sp																						X			X						X					X	X	X							
Pleurotomaria? sp																										X			X														X		
Straparollus? sp															X																														
Schizostoma sp																									X	X			X						X										
Euomphalus? sp						X												X																											
Omphalotrochus sp								X																																					
Bulimorpha sp						X																																							
Bulimorpha? sp																																											X		
Gastrioceras? sp																																					X								

Ostracoda																																												×	×
Bairdia sp																										×																			
Fish tooth										×																																			

2444 and 2444a. Yukon River above Circle. (The description is inadequate but almost surely represents the Nation River locality.) Collector, J. E. Spurr, 1896.

2AC55. Yukon River, north bank 3 miles above mouth of Seventymile River. Collector, A. J. Collier, 1902. (No Permian rocks are known at this locality; either the locality is wrongly recorded, or the faunal and age determinations are incorrect.)

2443. Yukon River, west bank 3 miles above Nation River. Collector, A. J. Collier, 1902.

2445. Limestone mountain, 1½ miles northeast from mouth of Nation River. Collector, A. J. Collier, 1902.

Collier 1902. (Ambiguous wording in description of locality. Interpreted by the writer to mean float found along the Yukon at the mouth of Washington Creek.) Collector, A. J. Collier, 1902.

2441. Yukon River, west bank 3 miles above Nation River. Collector, Arthur Hollick, 1903.

Brooks 12. Yukon River, southwest bank 1 mile below Tatonduk River. Collector, A. H. Brooks, 1906. (No Permian rocks are known at this locality, and the writer is inclined to believe that this locality also is wrongly recorded.)

2446. Yukon River, south bank 6 miles above Nation. Collector, A. H. Brooks, 1906. (This collection probably comes from the Trout Creek locality.)

2447. Yukon River, north limb of anticline opposite station 14. Collector, A. H. Brooks, 1906. (This collection is undoubtedly from the north side of the limestone band at Nation River.)

2448. Yukon River, three-quarters of a mile below Coal Creek. Collector, A. H. Brooks, 1906.

427. Michigan Creek, west side about 6 miles from mouth. Collector, J. B. Mertie, Jr., 1911.

428. Michigan Creek, west side about 3 miles from mouth. Collector, J. B. Mertie, Jr., 1911.

Martin 82. Yukon River, south bank 2 miles above Nation River. Collector, G. C. Martin, 1914.

Martin 83. Yukon River, south bank 1½ miles above Nation River. Collector, G. C. Martin, 1914.

1799, 1799a, 1799b. Yukon River, southwest bank 8 miles above Nation River. Collector, Eliot Blackwelder, 1915.

1800, 1800a, 1800b. Yukon River, west bank above Nation River. Collector, Eliot Blackwelder, 1915.

1801. Yukon River, south bank just below Coal Creek. Collector, Eliot Blackwelder, 1915.

2437, 2437a, 2437b. Yukon River, west bank opposite mouth of Nation River. Lowest part of middle outcrop of Permian sandstone, with 15 feet of shales, but from several horizons. Collector, G. H. Girty, 1918.

2438. Yukon River, west bank opposite mouth of Nation River. Middle outcrop of Permian limestone, above lots 2437, 2437a, and 2437b, but in transition beds below main white limestone. Collector, G. H. Girty, 1918.

2439. Same general locality as 2438, but from a more shaly stratum just above 2438. Collector, G. H. Girty, 1918.

2440. Same general locality as 2438, but from base of a heavy limestone 10 feet above 2439. Collector, G. H. Girty, 1918.

2440a. Same general locality as 2438, but from the very top of the white limestone as exposed. Collector, G. H. Girty, 1918.

2442, 2442a–d. Yukon River, west bank opposite mouth of Nation River. Talus from several horizons. Collector, G. H. Girty, 1918.

2543. Yukon River, south bank three-quarters of a mile below mouth of Coal Creek. Collector, G. H. Girty, 1918.

2549. Yukon River, west bank opposite mouth of Nation River. Various horizons in lowest outcrop of Permian limestone. Collector, G. H. Girty, 1918.

5839, 5839a–c. Yukon River, southwest bank about 2¾ miles upstream from Nation. The positions of these four localities in the Permian stratigraphic section were closely determined. Collector, J. B. Mertie, Jr., 1925.

5840. Southeast side of valley of Nation River about 1 mile northeast of Yukon River. Collector, J. B. Mertie, Jr., 1925.

5841. Yukon River, southwest bank about three-quarters of a mile downstream from mouth of Coal Creek. Collector, J. B. Mertie, Jr., 1925.

5842. Southeast side of valley of Nation River about 5 miles northeast of Yukon River. Collector, J. B. Mertie, Jr., 1925.

6843a. Base of limestone that caps the mountain 4½ miles N. 45° E. from mouth of Tatonduk River, on west flank of mountain. Collector, J. B. Mertie, Jr., 1930.

6843b. Upper part of limestone that caps the mountain 4½ miles N. 45° E. from mouth of Tatonduk River. Collector, J. B. Mertie, Jr., 1930.

6845. Sandstone and conglomerate probably representing base of Tahkandit limestone, 2 miles east-northeast of mouth of Tatonduk River, along bluffs bordering valley floor. Collector, A. E. Waters, Jr., 1930.

The determinations of all these fossils, except a few of the earlier collections, have been made by G. H. Girty. As with the fauna of the Calico Bluff formation, Girty's work has been more in the nature of a rapid reconnaissance study, with the idea of learning the age of the fossils, rather than a detailed study involving the determination and description of new species. Many species, in fact, are new, and the fauna is apparently more closely related to Asiatic than to North American Permian faunas. Nevertheless, 58 genera and at least 135 species have been recognized. This fauna was believed originally to be of Pennsylvanian age, but is now assigned by Girty to a horizon low in the Permian. Farther north, along the international boundary, the higher portions of this formation are probably preserved and may be expected to yield a somewhat different fauna.

TRIASSIC SYSTEM

UPPER TRIASSIC SERIES

DISTRIBUTION

In the Yukon-Tanana region, as practically everywhere else in Alaska, the only part of the Triassic system present is the Upper Triassic, and even the Upper Triassic rocks are found only at two general localities. One of these is at the mouth of the Nation River, where the Upper Triassic rocks adjoin the Tahkandit limestone on both sides of the Yukon River. Twelve miles farther up the Yukon the Upper Triassic rocks also occur in the valley of Trout Creek, southeast of the Tahkandit limestone.

LITHOLOGY

At the Nation River locality the Upper Triassic rocks are exposed on the southwest bank of the Yukon, particularly at low water. The exposures at best, however, are intermittent, so that a precise stratigraphic section cannot be measured. A tape traverse was therefore made along the beach from the farthest point downstream at which such rocks are exposed upstream to the Tahkandit limestone. These horizontal distances are given in the following tabulation:

Upper Triassic rocks along Yukon River opposite mouth of Nation River

	Feet
Fossiliferous black shale. Strike N. 70° E.; dip 70° S. in downstream part of section but becomes gradually less upstream. This shale contains some thin beds of dense argillaceous limestone about 1 foot thick. Collection 13423	150
Covered	720
Shaly limestone or calcareous shale. Fossiliferous. Collection 13425	40
Covered	18
Shale and a 5-foot bed of highly fossiliferous limestone, from which a part of collection 13425 was made	12
Imperfectly exposed bituminous shale and limestone showing so many reversals of dip due to numerous small folds that it is difficult to tell whether the dip of the formation as a whole is dominantly southeastward or northwestward. Contains several fossiliferous beds from which collection 13426 was made	567

	Feet
Gray fossiliferous thin-bedded limestone. Strike N. 45° E.; dip 30° NW. Collection 13427	17
Mostly covered; black shale imperfectly exposed. Rocks adjoining to the southeast are the uppermost beds of the Tahkandit limestone (lower Permian)	100

From the foregoing traverse it may be seen that the Upper Triassic rocks consist essentially of black bituminous shale, interstratified with thin beds of gray to black limestone. Much of the shale at this locality is oil shale, but none of it was tested quantitatively for its content of oil.

At the other locality on Trout Creek the rocks are about the same as those opposite the mouth of the Nation River, but some of the oil shale consists of a mat of closely compressed shells of *Pseudomonotis* and *Halobia* in a shale matrix. The fossils are so numerous and so closely compressed that not even the thinnest sliver of shale can be discovered without the impression of a shell upon it.

STRUCTURE AND THICKNESS

The Upper Triassic rocks are soft and consequently present little resistance to erosion and occur mainly in valleys, with poor exposures. They are also incompetent rocks, which are particularly subject to deformation. Such conditions make it difficult to determine satisfactorily their structure. The traverse above given suggests to the writer that these rocks are welded into a number of small folds, with a general northwesterly dip. A narrow covered zone separates the lowest Upper Triassic rocks from the highest beds of the Tahkandit limestone, but the two formations appear to agree in strike and dip. Nevertheless a depositional hiatus exists between them, for not only the Middle and Lower Triassic but also the late Permian beds are missing.

The top of the Upper Triassic sequence is not exposed, and the total thickness cannot be ascertained. Even the thickness of the rocks here exposed cannot be accurately determined, owing to the intermittent croppings. Martin,[17] who examined these rocks in 1914, estimated the minimum thickness to be 400 feet, but Blackwelder,[18] in 1915, thought that the visible exposures indicated a thickness of 575 feet and possibly several times as much.

---

[17] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 701–702, 1916.

[18] Blackwelder, Eliot, unpublished notes.

AGE AND CORRELATION

Twenty collections of fossils have been made from these Upper Triassic rocks, most of which came from the Nation River locality. They are listed below.

Upper Triassic fossils from Yukon-Tanana region

	4054	8895	8896	8897	8898	8899	10266, 10267	9382	9383	9384	9385	9387	9388	9321	13423	13424	13425	13426	13427
Camarophoria? cf. C. crumena	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pugnax cf. P. osagensis	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pugnax sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhynchonella sp	--	X	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	X
Rhynchonella? sp	--	X	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Dielasma? cf. D. bovidens (Tschernyschew)	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Terebratula sp	--	X	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Martinia? sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spiriferina cf. S. laminosa	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spiriferina cf. S. simensis	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spiriferina sp	--	X	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	--
Nucula sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pseudomonotis subcircularis	--	--	--	--	--	X	--	X	--	--	--	--	--	--	X	--	X	--	--
Pseudomonotis subcircularis?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Pseudomonotis sp	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Pseudomonotis? sp	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Halobia cf. H. superba	X	--	X	X	X	--	X	--	X	--	--	--	X	--	--	--	--	--	--
Halobia sp	--	X	--	--	--	--	--	--	--	--	--	--	--	--	X	X	X	X	--
Halobia? sp	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--
Aviculipecten cf. A. parvulus	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aviculipecten sp	--	X	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Aviculipecten? sp	X	--	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	--
Pecten sp	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	X
Modiomorpha? sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pleurophorus? sp	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--
Plagioglypta? sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pleurotomaria sp	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pleurotomaria? sp	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--
Natica? sp	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orthoceras sp	--	--	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	--
Nautilus sp	--	X	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	X
Placites? sp	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Popanoceras (Parapopanoceras?) sp	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Trachyceras (Protrachyceras?) cf. T. (P.) leconti	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Trachyceras (Protrachyceras?) sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Clionites? sp	--	--	--	--	X	--	--	--	--	--	--	X	--	--	--	X	--	--	--
Monophyllites? sp	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	X
Nathorstites sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X
Ammonite of undetermined genus	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ostracoda	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bone fragment	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--

4054. Yukon River a quarter of a mile northeast of mouth of Nation River. Collector, E. M. Kindle, 1906.

8895. Yukon River, southwest bank about 1 mile above Nation River. From a 10-foot bed of dark noncrystalline limestone, which is probably not more than 50 feet above the crystalline Permian limestone. Collector, G. C. Martin, 1914.

8896–8899. Yukon River, southwest bank about 1 mile above Nation River. 8896 is about 31 feet stratigraphically above 8895; 8897 is about 10 feet stratigraphically above 8896; 8898 is from float along river bank between 8897 and 8899; 8899 is about 300 feet stratigraphically above 8897. Collector, G. C. Martin, 1914.

10266, 10267. Trout Creek about 3 miles from confluence with Yukon River. Collector, G. C. Martin, 1914.

9382. Yukon River, southwest bank southwest of Nation River. Collector, Eliot Blackwelder, 1915.

9383. Yukon River, southwest bank about 2 miles above Nation. Collector, Eliot Blackwelder, 1915.

9384. Yukon River, southwest bank opposite Nation River. Collector, Eliot Blackwelder, 1915.

9385, 9387, 9388. Hillside one-third of a mile northeast of mouth of Nation River. Collector, Eliot Blackwelder, 1915.

9321. Trout Creek about 3 miles from confluence with Yukon River. Collector, P. J. Hilliard, of Eagle, Alaska, 1915.

13423, 13425, 13426, 13427. Yukon River, southwest bank 2½ miles upstream from Nation. The relative positions of these four collections are given in the stratigraphic section. Collector, J. B. Mertie, Jr., 1925.

13424. Southeast side of valley of Nation River near Yukon River. Collector, J. B. Mertie, Jr., 1925.

These fossils have been determined by T. W. Stanton, of the United States Geological Survey. All of them are classified as Upper Triassic, but it is worthy of mention that certain genera of ammonites, such as *Placites*, *Popanoceras*, *Trachyceras*, *Clionites*, *Monophyllites*, and *Nathorstites*, occur only in the lowermost beds. These ammonites, though accepted by Stanton as an integral part of the Upper Triassic fauna, appear to represent a distinctly older faunal horizon.

Upper Triassic rocks occur at many places in Alaska. Martin,[19] in his general report dealing with these rocks, lists the Nizina, Kotsina, and Kuskulana Valleys, Cooper Pass, upper Susitna Valley, Kenai Peninsula, west coast of Cook Inlet, Iliamna Lake, Alaska Peninsula, and Kodiak Island in southern Alaska; Admiralty, Kupreanof, and Gravina Islands, in southeastern Alaska; and the valleys of the Firth, Canning, and Noatak Rivers, Cape Lisburne, and Cape Thompson, in northern Alaska. To these should now be added the numerous areas of Upper Triassic rocks recently recorded by Smith and Mertie in northern Alaska,[20] and a still later discovery of the same rocks by J. E. Owens, a prospector, in the upper valley of the Coleen River. These occurrences in northern Alaska indicate that a more or less continuous belt of Upper Triassic rocks crosses northern Alaska from the Arctic Ocean to the international boundary. These rocks, though correlative with those along the Yukon, differ in that they include a considerable proportion of chert.

CRETACEOUS SYSTEM

The Cretaceous system in the Yukon-Tanana region includes rocks of both Lower and Upper Cretaceous age, which are believed to be separated from one another either by an unconformity or by a depositional hiatus. The Lower Cretaceous series, as it also lies unconformably upon older rocks, is a fairly well defined group of rocks, particularly in its paleontologic aspect. The Upper Cretaceous series, on the other hand, is so closely associated with later rocks of early Tertiary age, both stratigraphically and paleontologically, that it has no well-defined upper limit. In this report, therefore certain rocks which, though possibly Upper Cretaceous in age, are in the writer's opinion more probably a part of the Tertiary sequence are described as Tertiary. It is also true, however, that relatively few Upper Cretaceous rocks are known to exist in the Yukon-Tanana region, and this fact, together with the intimate association of these rocks with those of the Lower Cretaceous sequence, renders it im-

---

[19] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 687, 1916.

[20] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 185–194, 1930.

practicable to describe and particularly to map these rocks separately. In the following pages, therefore, the Cretaceous rocks are described collectively, with individual references to localities where the rocks are believed to be of Upper Cretaceous age.

DISTRIBUTION

Lower Cretaceous rocks crop out along both sides of the Yukon River for 20 miles above and below the mouth of the Kandik River (known locally as Charley Creek). These rocks have previously been described by the writer [21] as the Kandik formation. These Lower Cretaceous rocks also are known to extend northeastward along both sides of the valley of the Kandik River to and beyond the international boundary. Lower Cretaceous rocks also crop out in the Hot Springs and Rampart districts to the southwest, as a wide band that extends from the lower Tanana River east-northeastward to the West Fork of the Tolovana River, in the Fairbanks quadrangle. The length of this band is about 70 miles, and its width ranges from 12 to 20 miles. Upper Cretaceous rocks may occur locally in this band.

LITHOLOGY

Along the Yukon the Lower Cretaceous rocks (Kandik formation) consist of a monotonous sequence of black slate and thin beds of sandstone. The slates are carbonaceous, argillaceous rocks, which in some of the thicker beds show little stratification or cleavage and are therefore more properly described as argillites. The usual argillaceous members are really slates, for most of them show a well-developed fracture cleavage. The sandstone interbedded with the slates is usually much jointed. Plate 11, *B*, shows a typical outcrop of the Kandik formation along the Yukon River above the mouth of the Kandik River.

The sandstone occurs for the most part in beds from a few inches to 2 feet thick, but some thick massive beds also are present. One thick bed of this type is exposed along the south bank of the Yukon just below the mouth of Glenn Creek. The thinner beds of sandstone are usually dark gray on a fresh break but weather to a dull-brown color, which is probably due to their content of ferrous oxide. They are composed essentially of grains of quartz, with little chert but more or less altered feldspar and ferromagnesian minerals. The thicker beds are inclined to be more purely quartzose, and some of them by partial recrystallization approach quartzite. In areas of complex structure these massive beds form excellent horizon markers.

[21] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 136–141, 1930.

A few miles upstream from the mouth of the Kandik River, on the north side of the Yukon, a great thickness of the Kandik formation is exposed at Kathul Mountain. The structure here is simple, and the elevation above the river corresponds roughly with the stratigraphic thickness, so that a sequence of 2,400 feet of beds may be observed. The lower fourth of this sequence consists mainly of slate and thin beds of sandstone, but the upper three-fourths is composed of sandstone, grit, and conglomerate, the conglomeratic beds becoming more noticeable toward the summit of the mountain. In the lower part of this section the interbedded slates, with a fracture cleavage, lie between the jointed beds of sandstone. This fracturing is well illustrated in plate 12, *A*. Higher in the section the conglomerate is fairly fine grained and might better be described as grit, though pebbles as large as 3 inches in diameter were noted. The pebbles are subangular to rounded and consist of quartz, chert, slate, and fragments of other dark-colored rocks, possibly in part of volcanic origin. Except for their fine grain, these conglomeratic beds do not differ essentially from some of the Tertiary conglomerates along the south side of the Yukon, and it is possible that they may in fact mark the base of the Tertiary sequence, though this seems unlikely.

In the Rampart and Hot Springs districts the Lower Cretaceous rocks occur in the vicinity of granitic intrusions, and therefore some of them show marked thermal metamorphism. Local dynamic metamorphism that is related genetically to the granitic intrusions has also extensively modified the character of these rocks at certain localities. The least-altered and structurally simplest of the Cretaceous rocks in this western belt are found in the country that lies between the headwaters of Hutlinana and Hutlitakwa Creeks.

In the headwater region of Hutlinana and Hutlitakwa Creeks Lower Cretaceous rocks form practically a monoclinal sequence, striking northeast and dipping southeast. At the head of Hutlinana Creek are three prominent exposures of the massive quartzite, two of them between the head of Bear Creek and Hutlinana Creek and the third forming the country rock of the high dome between the heads of Bear and Applegate Creeks. The last, which is also stratigraphically the highest of the three, extends southwestward down the ridge between Goff and Cairo Creeks. The two lower exposures occur on the ridge between Cairo and Hutlinana Creeks and extend southwestward to the northwest side of the Hutlinana Valley. A fourth outcrop of quartzite flanks Wolverine and Elephant Mountains on their southeast sides and appears on a prominent knob west of Deadwood Creek, extending thence southweastward down the ridge between Pioneer and Eureka Creeks. This is believed to be the lowest of these four quartzite outcrops and is close to the base of the Lower Cretaceous sequence.

These ridge-forming members form reliable horizon markers and could be separately mapped. These quartzites range in color from creamy white to very dark gray, but the gray appears to be the usual color of the unmetamorphosed and unweathered varieties. They are hard, vitreous rocks, composed of grains of quartz and relatively free of other minerals. Superficially, these rocks resemble quartzites, but except where they lie close to granitic intrusives they are not recrystallized to any considerable extent. Petrographically they might better be called well-indurated quartzose sandstones, but the term "quartzite" seems more applicable. In these quartzites marine fossils have been found. These rocks form the tops of ridges in this area and therefore constitute most of the visible croppings. Between the quartzites, however, argillites and slates crop out at favorable localities on the hillsides and in the valley bottoms. Such rocks, in the unmetamorphosed zone here considered, are dark-gray to black fine-grained argillaceous rocks, in which the original bedding is more likely to be marked by a banded structure than by any pronounced parting along the bedding planes. A slaty cleavage that cuts across the folded bedding planes is developed in places, but the rocks in general are not recrystallized.

Southeastward from the head of Applegate Creek to Niggerhead Creek the ridges become lower and croppings more scarce. Few rocks in place may be seen in the valleys, but on the ridges the country rock is sufficiently well exposed to show that the ridge-forming rocks change abruptly to soft dark-gray, brown-weathering micaceous or argillaceous sandstones. These rocks, as compared with the quartzites, are thin-bedded and grade into sandy shales. They do not resist weathering to the same extent as the quartzites, and the ridges which they form are therefore low, are relatively flat-topped, and show rubble rather than prominent rock ledges. These rocks probably lie stratigraphically above the quartzite and slate that occupy the stretch from the head of Applegate Creek to Elephant Mountain and are likely to prove to be Upper rather than Lower Cretaceous.

In a belt that extends southwestward from Quail Creek to the Tanana River the country rock has been intruded by granitic rocks and has been altered by both dynamic and contact metamorphism. This belt is but a few miles in width near Quail Creek but widens to 12 miles or more near the Tanana. It includes the granitic intrusive masses at Wolverine and Elephant Mountains, Hot Springs Dome, and Roughtop Mountain and the mineralized zones that constitute the mining areas of Quail, Eureka, Sullivan, Woodchopper, and American Creeks. Throughout this belt Lower Cretaceous rocks constitute most of the country rock, but some Upper Cretaceous rocks are known to exist in the vicinity of Wolverine and Elephant Mountains. All the Cretaceous rocks in this belt have suffered local dynamic and thermal metamorphism and therefore differ in general appearance and character from the rocks in the headwater region of Hutlinana and Hutlitakwa Creeks.

Wolverine Mountain is the dominating topographic feature of the Quail Creek area. The core of the mountain is an intrusive mass of granitic rocks, and the heat and pressure attendant upon the invasion of such rocks have produced marked changes in the Cretaceous rocks. The quartzose sandstones show a considerable degree of recrystallization to true quartzitic rocks, and the argillaceous rocks, particularly near the contact, are baked, hardened, and recrystallized to several varieties of hornfels and related rocks. Some of the altered argillaceous rocks are merely spotted or nodular, such spots appearing under the microscope only as carbonaceous clots in a fine groundmass showing incipient recrystallization. Closer to the granitic rocks are found hornfels in various stages of recrystallization, from fine-grained rocks to phanerocrystalline varieties with good-sized flakes of biotite. The common minerals of these hornfels and "knotenschiefer" are biotite and quartz, but andalusite and kyanite hornfels are also present to a small extent.

The Wolverine Mountain area is also worthy of special note because it is one of the two or three areas in the Yukon-Tanana region where Upper Cretaceous rocks have been identified. Such rocks occur on the south fork of Quail Creek, along the southeast side of Wolverine Mountain, but have also been identified by the writer on the north side of this mountain. According to Prindle,[22] the section along the southeast side of Wolverine Mountain consists of 10 feet of local conglomerate overlain by a few hundred feet of massive black sandy shale and fine-grained black shale. The conglomerate is composed of pebbles of quartzite and black slate. A small amount of similar conglomerate was also observed by the writer at about the same locality. On the north side of Wolverine Mountain at least six gulches drain into the main fork of Quail Creek, the largest of which enters Quail Creek about 1½ miles above its forks. On the spur just east of this gulch, beginning at an elevation of 3,200 feet and extending up to the intrusive contact, are found beds of black carbonaceous sandy argillite and shale, in part massive and in part thin-bedded, that also contain Upper Cretaceous plants and invertebrates. Below the elevation of 3,200 feet, however, massive

[22] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 47–48, 1913.

quartzite and slate, containing *Aucella* and other Lower Cretaceous invertebrates, extend northward down the slopes to Quail Creek. The rocks containing the Lower Cretaceous fossils also include some sandy beds, which are also in part carbonaceous, with irregular-shaped concretions and ripple marks. One thin layer of sandy shale was observed to have impressions of invertebrates on one side and ripple marks on the other. A few pebbles are also found on the hard vitreous quartzites. All the data therefore indicate that the *Aucella* of these Lower Cretaceous rocks lived in a near-shore, shallow-water habitat. It should also be emphasized that most of the Cretaceous rocks surrounding Wolverine Mountain belong to the Lower Cretaceous horizons.

The rocks about Elephant Mountain are essentially similar to the Lower Cretaceous rocks about Wolverine Mountain but also include plant-bearing beds that have been determined to be of Cretaceous age. The quartzite west of Deadwood Creek has already been described. This is believed to be of Lower Cretaceous age. At or near the base of this quartzite, at the head of Pioneer Creek, the country rocks are mainly argillite and black slate, but associated with these rocks are some quartzite and conglomerate, the latter a puddingstone with a quartzitic matrix. At the contact with the granitic rocks of Elephant Mountain more of this conglomerate is exposed. It consists of pebbles as much as several inches in diameter, of quartzite, chert, vein quartz, and limestone, cemented by quartzite. In the shaly rocks interbedded with this quartzite conglomerate, a rather poor collection (22AMt79) of Cretaceous plants was found. This quartzite conglomerate contains no pebbles of granitic rocks, and its contact with the granitic rocks is unquestionably that of a sedimentary bed invaded by an intrusive.

Between the southwest end of Wolverine Mountain and the head of Minook Creek the Cretaceous sequence consists mainly of a black graphitic argillite that changes in places to a black slate. About 3 miles southwest of Elephant Mountain, however, these argillaceous rocks give place to another band of quartzite that continues westward around the head of Boston Creek. A zone of displacement and shearing is believed to continue southwestward from Elephant Mountain, and as both argillite and quartzite lie to the northwest of this shear zone, they cannot be correlated exactly with any of the beds previously described. The quartzite dips steeply northward, however, and is therefore believed to be equivalent to one of the four southward-dipping quartzites southeast of Wolverine and Elephant Mountains.

Northwest and north from Elephant Mountain the dip of the Cretaceous rocks is reversed to the northwest, and some of the beds occurring southeast of Elephant Mountain are repeated. At least two well-marked outcrops of quartzite are present in this area, one of which extends northeastward as a prominent hogback as far as the head of Miller Creek. The general character of the rocks is the same as those in the valley of Hutlinana Creek.

Eureka, Pioneer, and Rhode Island Creeks and their tributaries constitute a large part of the Eureka mining precinct. These creeks lie in the zone of shearing that extends southwestward from Elephant Mountain, and the Cretaceous rocks in this area have been materially altered. Thus on Eureka and Pioneer Creeks the bedrock is largely phyllite and slate. At one place on Doric Creek, a tributary of Pioneer Creek, mining operations show a bedrock made up essentially of phyllite, in which are scattered reefs of dark-gray quartzite. One of these competent quartzite beds is closely folded into an almost recumbent fold, and another is cut by a quartz vein 8 inches thick, which was subsequently faulted. At other places on Pioneer Creek, where placer mining has bared the bedrock, it is found to consist of sheared sandstone, sandy phyllite, and slate, cut by quartz veins and notably pyritized and iron-stained. Again, on the point of the spur between Pioneer and Alameda Creeks the bedrock where exposed by placer mining is made up of phyllite and argillite in a highly altered condition, cut by quartz stringers and greatly fractured and iron-stained. A description of the bedrock on Rhode Island Creek would merely duplicate that above given. It is evident that the country rock in the Eureka precinct is more metamorphosed than that on the headwaters of Hutlinana and Hutlitakwa Creeks, but fragments of marine fossils found in the basins of Eureka and Rhode Island Creeks prove that this alteration is due not to a difference in geologic age but to local dynamic metamorphism. The mineralization that made Eureka and the neighboring creeks a gold placer camp was also related genetically to these dynamic disturbances.

West of Baker Creek the altered zone widens to include almost the entire width of the Cretaceous rocks. This is due to the fact that two granitic intrusive bodies, one at Hot Springs Dome and one at Roughtop Mountain, have invaded the country rocks, producing thermal and dynamic metamorphism from two centers. The hills in this area made up of Cretaceous rocks are low, and even the ridges are covered by residual talus, so that outcrops are few. Thermal alteration is best seen along the intrusive contact, near the summit of Hot Springs Dome, where the country rock consists mainly of spotted and nodular schists, in some of which andalusite has developed. Sheared quartzitic sandstone is also present at one locality along the north contact of the intrusive rock, and west of the summit of the dome some sheared conglomerate occurs, similar to that found near the intrusive contact at Elephant Mountain.

Along the north bank of the slough from the town of Hot Springs west to the Tanana River the altered Cretaceous rocks are well exposed. The contact with the intrusive rocks lies from half a mile to a mile of the slough, so that the alteration in these croppings is due more to dynamic than to thermal metamorphism. These rocks consist dominantly of phyllite, with somewhat less slate and argillite and a minor proportion of quartzite. The quartzite occurs in beds a few inches to 2 feet thick. Where this slough joins the Tanana River excellent exposures show that these beds are so closely folded and appressed that the folds themselves are hardly noticeable, the dominant structure being nearly vertical. Some of the phyllite, like the rocks closer to the granitic rocks is also nodular.

Few hard rocks appear at the surface in the mining area between Sullivan and Woodchopper Creeks, but scattered exposures and the observations made possible by drift and open-cut mining show that the Cretaceous rocks in this district are generally similar to those around Eureka and Pioneer Creeks. Phyllite, slate, and quartzite are the common varieties, and thermal effects are absent. Farther north, however, in the head of Boulder Creek, hornfels is developed around the margin of the Roughtop intrusive body, but the thermal effects appear to be much less than around the Hot Springs Dome.

Another occurrence of Upper Cretaceous rocks has been described by Martin,[23] along the southwest bank of the Yukon River a short distance below the mouth of the Seventymile River. These rocks consist essentially of alternating beds of sandy shale and sandstone, with some beds of conglomerate as thick as 10 feet. These rocks contain plant fossils that have been determined to be of Upper Cretaceous age. Not far west of these rocks, however, and probably adjoining them is a great thickness of Tertiary rocks. On the geologic map that accompanies the present report these Upper Cretaceous rocks are included with the Tertiary sequence, because their areal extent is too small and too indeterminate to warrant their separate delineation.

STRUCTURE AND THICKNESS

The Lower Cretaceous rocks along the Yukon River are considerably deformed, though most of the folds are of the open type and of large amplitude, so that for considerable stretches along the river the structure appears to be essentially homoclinal. In places, however, the rocks have a steep dip, which when considered in relation to the open folds suggests some unrecognized faulting. Along the

[23] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, pp. 387–390, 1926.

west side of Kathul Mountain these rocks dip southeastward, but at the east end they dip northwestward, suggesting that this mountain is the site of a gentle synclinal basin. As this mountain rises 2,400 feet above the river, and the dip of the rocks is low, the total thickness there exposed may be nearly 2,400 feet. The top of the sequence, however, is not exposed.

In the Rampart and Hot Springs district the structure is more complex, particularly so in the vicinity of the granitic intrusives. A section from the head of Niggerhead Creek to the mouth of Chapman Creek, passing through Elephant Mountain, shows one open anticline, which is invaded along its axial zone by granitic rocks. The structure is broadly symmetrical with respect to the zone of granitic intrusives but is areally unsymmetrical because a large part of the Cretaceous sequence on the northwest side has been removed by erosion. For this reason the stratigraphic horizons and structure that characterize the rocks at the head of Niggerhead Creek have no counterpart northwest of Elephant Mountain.

Although this structure is broadly anticlinal, in that the beds dip away in both directions from an axial zone, the arch is anomalous, for the dips are steepest in the axial zone and decrease progressively in either direction away from that zone. Thus on the southeast side of Elephant Mountain, where the stratigraphic sequence is best developed, the dips change from a range of 75° to 90° at Elephant Mountain to about 40° at the head of Applegate Creek. Extrapolating southeastward to Niggerhead Creek, the dips might be expected to become even lower, but the few scattered observations that are available in this low country do not appear to bear out this interpretation. Therefore, so far as can be learned by surface observations, the Cretaceous rocks appear to form a monoclinal sequence from Elephant Mountain to the head of Applegate Creek. The structure in the area southeast from the head of Applegate Creek is insufficiently well known to show whether this monoclinal sequence continues without interruption to Niggerhead Creek, or whether reversals in dip occur.

The present structure of the Cretaceous rocks has been produced by three different though related processes—general folding, faulting and shearing along a narrow zone, and intrusion of granitic rocks. The granitic intrusives lie along the zone of shearing but are not themselves sheared. It is therefore probable that the shearing preceded the intrusive action. The folding, however, is not so easy to place in the deformational sequence, but evidently it had some close genetic relationship to the shearing and intrusive processes, because these were localized along the axial plane of the folding. If it is assumed that the regional folding occurred principally during one deformational cycle, it seems that any one of the five following interpretations are possible:

1. The folding may have preceded the shearing.
2. The folding may have been contemporaneous with the shearing.
3. The folding may have followed the shearing but preceded the intrusion.
4. The folding may have been contemporaneous with and caused by the intrusion.
5. The folding may have followed the intrusion.

If the regional folding took place after the intrusion, without a causative relationship, the localization of the axial plane along the line of shearing and intrusion would have been a fortuitous and altogether unlikely event. On the other hand, the granitic intrusion can hardly be regarded as the cause of the folding, for this seems inadequate to account for the deformation observable in the Cretaceous rocks 10 miles or more to the southeast of Elephant Mountain. These considerations eliminate the fourth and fifth hypotheses. The second also seems improbable, for shearing and folding would hardly be expected to occur synchronously. The third hypothesis seems possible but implies that a long time intervened between the shearing and the intrusive, and this is doubtful. The most likely explanation is that the folding took place before the shearing and intrusion, and that the axial plane of the anticline became a zone of weakness along which subsequent readjustments took place.

Along the borders of the granitic intrusives the Cretaceous rocks have been greatly metamorphosed. The thermal effects of this contact metamorphism have already been described. In addition to such effects, the rocks have been greatly deformed. The more competent beds, such as the quartzites, have been tilted to a position approaching the vertical, and the less competent argillaceous beds have been compressed and sheared, producing close folding and secondary cleavage. The deformation of the argillaceous rocks is visible around the flanks of Wolverine and Elephant Mountains but can best be observed along the slough west of Hot Springs, where such border facies are well exposed. The dominant strike of the rocks along this stretch is east with a dip of 60° or more to the south. Cleavage and local bedding are usually parallel or nearly so. At the mouth of this slough the argillaceous beds are so closely folded and appressed that the folds are hardly discernible, only cleavage being prominent. The cleavage at this locality is about vertical.

The regional structure of the Cretaceous rocks in the valleys of Baker and Sullivan Creeks is indeterminate, as the country is low and the bedrock is largely concealed by alluvial deposits and vegetation. Scattered exposures along the north flanks of Hot Springs Dome indicate a general northward dip, thus suggesting that the present valleys of Baker and Sullivan Creeks may occupy a broad synclinal basin. The main zone of shearing and mineralization in this area appears to be localized in this presumed synclinal basin, several miles from the granitic rocks of Hot Springs Dome and Roughtop Mountain. This condition contrasts sharply with that which exists at Wolverine and Elephant Mountains, where the granitic intrusives lie along or near the main zone of shearing. This distribution of the intrusive rocks cannot be explained, but it corroborates the interpretation above given that the folding preceded the granitic intrusion.

The Lower Cretaceous rocks certainly extend without interruption from Elephant Mountain southeastward as far as the head of Applegate Creek, a distance of 7 miles; and if the sequence is really monoclinal a great thickness of rocks must be represented. More detailed work must be done in this belt, however, before any specific statement regarding thickness is justified, for the structure is possibly isoclinal, with many repetitions of the same beds. In any event, it seems probable that a great thickness of Lower Cretaceous rocks exists in this district, amounting at least to 5,000 feet and perhaps considerably more.

AGE AND CORRELATION

A considerable number of fossil collections have been made from the Cretaceous rocks of this region. The Lower Cretaceous fossils are dominantly of marine origin, but the Upper Cretaceous fossils include both invertebrates and plants. Several collections that were considered to be indeterminate were also obtained, and although this material adds nothing to the knowledge of this fauna, the locality descriptions are included as a matter of record.

Lower Cretaceous fossils from Yukon-Tanana region

	2764	2AP215	4AP338a	4AP339	4AP340	4AP341	4AP346a	4AH278	3783	3784	3785	11AE5	9389	18AO1	22AMt85	22AMt113	25AMt207	25AMt227	31AMt127	31AMt154	31AMt160
Alga, undetermined																					c
Chondrites heeri Eichwald		a												a							
Pentacrinus sp																b					
Pinna sp									b												
Inoceramus sp									b	b							b				
Inoceramus? sp													b								
Aucella crassicollis Keyserling	b										b	b				b					
Aucella cf. A. crassicollis																		b			
Aucella sp										b								b		c	
Aucella? sp									b						b						
Pecten sp									b												
Pecten? sp																b					
Pelecypods, undetermined												b			b				b		
Invertebrates, undetermined								x													
Perisphinctes? sp									b												
Belemnites sp																		b			
Belemnites? sp																	b				
Indeterminate			x	x	x	x	x														

a, Identified by F. H. Knowlton; b, identified by T. W. Stanton; c, identified by J. B. Reeside, Jr.

2674. Washington Creek 6 miles above mouth. Collector, A. J. Collier, 1902.
2AP215. Ridge about 2 miles east of head of Little Minook Creek. Collector, L. M. Prindle, 1902.
4AP338a. Head of Rhode Island Creek. Collector, L. M. Prindle, 1904.
4AP339. Head of Glen Gulch, between Eureka and Rhode Island Creeks. Collector, L. M. Prindle, 1904.
4AP340, 341. Head of Gold Run, tributary of Rhode Island Creek. Collector, L. M. Prindle, 1904.
4AP346a. Between heads of New York and Minook Creeks. Collector, L. M. Prindle, 1904.
4AH278. Gravel from Eureka Creek, near mouth of Boston Creek. Collector, F. L. Hess, 1904.
3783. Yukon River, southwest bank, about 400 yards below Glenn Creek. Collector, E. M. Kindle, 1906.
3784. Yukon River, south bank, about 1½ miles below Sam Creek. Collector, E. M. Kindle, 1906.
3785. Yukon River, north bank, about 6 miles above Charley Village. Collector, E. M. Kindle, 1906.
11AE5. Divide between Little Minook and Quail Creeks. Collector, H. M. Eakin, 1911.
9389. Yukon River, 8½ miles above Washington Creek. Collector, Eliot Blackwelder, 1915.
18AO1. Peak east of upper Hunter Creek, about 3 miles southeast of the mouth of 47 Pup. Collector, R. M. Overbeck, 1918.
22AMt85. About 5.3 miles N. 79° W. from mouth of Quail Creek. Collector, J. B. Mertie, Jr., 1922.
22AMt113. About 3.7 miles S. 78° W. from mouth of Quail Creek. Collector, J. B. Mertie, Jr., 1922.
25AMt207. Yukon River, southwest bank, just below Glenn Creek. Collector, J. B. Mertie, Jr., 1925.
25AMt227. East side of Woodchopper Creek, about 1 mile from Yukon River. Collector, J. B. Mertie, Jr., 1925.
31AMt127. Gravel on McCaskey Bar, between Eureka and Alameda Creeks. Collector, J. B. Mertie, Jr., 1931.
31AMt154, 160. About 3.7 miles S. 78° W. from mouth of Quail Creek. Same as 22AMt113. Collector, J. B. Mertie, Jr., 1931.

Upper Cretaceous invertebrates from Yukon-Tanana region

[Identified by T. W. Stanton]

	7AP271	7AP278	7AP279	8900	22AMt105a
Hemiaster? sp.	X	X		X	
Nucula sp.				X	
Nemodon sp.				X	
Cucullea sp.	X	X			
Inoceramus cf. I. labiatus Schlotheim	X				
Pecten sp.	X			X	
Pleuromya sp.	X				
Lucina sp.	X				
Natica sp.				X	
Pachydiscus sp.	X	X	X		
Pachydiscus? sp.	X	X		X	
Undetermined ammonite					X

7AP271. Southeast spur of Wolverine Mountain, 2.6 miles S. 53° W. of mouth of Quail Creek. Collector, L. M. Prindle, 1907.
7AP278. Ridge on west side of South Fork of Quail Creek. Collector, L. M. Prindle, 1907.
7AP279. East side of South Fork of Quail Creek. Collector, L. M. Prindle, 1907.
8900. South Fork of Quail Creek, about 1 mile above forks. Same as 7AP278. Collector, G. C. Martin, 1914.
22AMt105a. About 3.1 miles S. 69° W. from mouth of Quail Creek. Collector, J. B. Mertie, Jr., 1922.

Upper Cretaceous plants from Yukon-Tanana region

	1555	2973	3243	4AP306	7AP263	7AP271	6815	7407	7408	22AMt79	22AMt105b
Fern, undetermined	----	----	----	----	----	----	----	----	----	----	a
Podozamites lanceolatus	----	----	a	----	----	----	a	a	a	a	----
Ginkgo sp	----	a	----	----	----	b	----	----	----	----	----
Sequoia reichenbachi	----	----	----	----	----	----	----	----	----	a	----
Taxodium sp	----	----	----	----	----	b	----	----	----	----	----
Cephalotaxopsis sp	a	a	----	----	----	----	a	a	a	----	----
Nymphaeites sp	----	----	a	----	----	----	----	----	----	----	----
Castaliites sp	----	----	----	----	----	----	----	----	a	----	----
Menispermites sp	a	----	----	----	----	----	----	----	----	----	----
Platanus sp	----	----	----	----	----	----	----	a	a	----	----
Credneria? sp	----	----	a	----	----	----	----	----	----	----	----
Protophyllum? sp	a	----	----	----	----	----	----	----	----	----	----
Pseudoaspidiophyllum sp	----	----	a	----	----	----	a	----	----	----	----
Pseudoprotophyllum sp	----	----	a	----	----	----	----	a	----	----	----
Hedera platanoidea	----	----	----	----	----	----	a	----	----	----	----
Populus sp	----	----	----	b	----	----	----	----	----	----	----
Viburnum sp	----	----	----	----	----	----	----	----	----	a	----
Fragments of dicotyledonous plants	----	----	----	b	----	b	----	----	----	----	----
Indeterminate vegetal material	----	----	----	b	b	----	----	----	----	----	----

a, Identified by Arthur Hollick; b, identified by F. H. Knowlton.

1555. Yukon River, 25 miles below Mission Creek. Collector, J. E. Spurr, 1896.
2973. Yukon River, southwest bank, 2 miles below mouth of Seventymile River. Collector, A. J. Collier, 1902.
3243. Yukon River, southwest bank, just below mouth of Seventymile River. Collector, Arthur Hollick, 1903.
4AP306. Southwest spur of Wolverine Mountain, 2.9 miles S. 58° W. of mouth of Quail Creek; elevation about 3,200 feet. Collector, L. M. Prindle, 1904.
7AP263. Near Wolverine Mountain (?). Collector, L. M. Prindle, 1907.
7AP271. Southeast spur of Wolverine Mountain, 2.6 miles S. 53° W. of mouth of Quail Creek. Collector, L. M. Prindle, 1907.
6815. Yukon River, southwest bank, at mouth of draw 1½ miles below Seventymile River. Collector, G. C. Martin, 1914.
7407. Same as 6815. Collector, G. C. Martin, 1919.
7408. Yukon River, southwest bank, half a mile below next gulch below Seventymile River. Collector, G. C. Martin, 1919.
22AMt79. Southeast flank of Elephant Mountain, 7.7 miles N. 44° E. of Glen. Collector, J. B. Mertie, Jr., 1922.
22AMt105b. About 3.1 miles S. 69° W. from mouth of Quail Creek. Collector, J. B. Mertie, Jr., 1922.

Among the Lower Cretaceous fossils several require explanation. *Chondrites heeri* Eichwald is a form that has been loosely referred to the Eocene, but in reality its age is unknown. It may perhaps have a considerable stratigraphic range. In this district it happens to occur in rocks that are definitely known to be Lower Cretaceous in age and has therefore been included with the other Lower Cretaceous fossils. Collections 4AP338a, 339, 340, 341, 346a, and 4AH278 are listed as indeterminate, owing to the fact that so little was known of the local stratigraphy 30 years ago. In reality, these collections appear from original notebook data to have been obtained from the quartzites of the Lower Cretaceous rocks and probably represent the macerated remains of small pelecypods like *Aucella*, similar to those found in some of the later collections. Hess states in his notebook that collection 4AH278 was taken from "boulders of calcareous sandstone carrying many fragments of shells." Material similar to these collections was observed by the writer on McCaskey Bar, in the Eureka district, and constitutes the undetermined material of collection 22AMt127. No one familiar with the habitat and appearance of *Aucella* in the Lower Cretaceous of this district would doubt, however, that the latter collection, though specifically indeterminate, represents these *Aucella*-bearing beds. The conclusion that is derived from these so-called indeterminate collections is that the country rock on Eureka Creek and its tributaries is really of Lower Cretaceous age. No fossils have been found in the country rock of Baker, Sullivan, and Boulder Creeks, nor on Bean Ridge, but the assignment of the country rock in these areas to the Cretaceous is materially strengthened by the preservation of *Aucella* sp. as far west as Eureka Creek.

The Upper Cretaceous fossils present the greatest problem, because the occurrence of rocks of this age along the flanks of Wolverine and Elephant Mountains is not in accord with the apparent regional structure. The invertebrates of collections 7AP271, 278, and 279, supplemented by similar fossils in 8900, form the basis for the recognition of Upper Cretaceous rocks in the Rampart district. With regard to the Prindle collections, Stanton in 1907 made the following statement:

> These fossils evidently all belong to practically a single horizon, which is confidently referred to the Upper Cretaceous. My first impression that several of the fossils were specifically identical with forms that have been collected on the Yukon River at Bishop Rock and near Nulato is not confirmed on closer examination, but I believe that they are of practically the same age. The species of *Inoceramus* is very likely one that has been previously found on the Yukon, but the specimens in the present collection are too imperfect to serve as the basis for a positive identification. The most important forms are ammonites, which make up the bulk of the collection and which I have referred, in some cases doubtfully, to the genus *Pachydiscus*. These are unquestionably Upper Cretaceous types.

The plant fossils are very indefinite. Collections 4AP306 and 7AP271 were originally referred doubtfully to the Eocene, and collections 7AP263 and 22AMt105b were not considered to justify an age assignment. Collection 22AMt79, from Elephant Mountain, was definitely assigned to the Cretaceous but not specifically to either the Upper or Lower Cretaceous. These plants come from the same beds that yielded the Upper Cretaceous invertebrates and are therefore here assigned to the Upper Cretaceous, though in reality this assignment is based more on lithologic than on paleontologic grounds.

If the age of the invertebrates is as certain as stated by Stanton, it is necessary to conclude that Upper Cretaceous rocks form part of the sequence around Wolverine Mountain. It has previously been shown, however, that the sediments at Wolverine Mountain strike nearly east and dip steeply north on the north side of the mountain and steeply south on the south side. Such structure would appear to indicate that the oldest rocks of the Cretaceous series might be expected at this locality, but the fossils, on the contrary, appear to indicate that Upper Cretaceous rocks flank the mountain on both sides and are overlain by Lower Cretaceous rocks. Upper Cretaceous rocks must therefore be infolded or infaulted at Wolverine Mountain, if the fossil determinations are to be accepted. Prindle's original mapping, also based upon fossil evidence, shows a rim of Upper Cretaceous rocks encircling the granitic rocks of Wolverine Mountain. The structure above outlined makes this symmetrical distribution of the Upper Cretaceous rocks improbable, but, on the other hand, it is difficult to present a generalized delineation of the Upper Cretaceous rocks that would be compatible with the structure. For this reason and also because the Upper Cretaceous rocks in the vicinity of Wolverine Mountain are a minor part of the Cretaceous sequence of this district, the whole Cretaceous sequence has been mapped as a single unit.

Cretaceous rocks are known at many places in Alaska, and their distribution, character, and fauna have been described in detail by Martin.[24] The best-known section is on the Alaska Peninsula, where the Lower Cretaceous is divided into two and the Upper Cretaceous into three mappable formations. The lower of the two Lower Cretaceous formations, known as the Staniukovich shale, consists of shale, sandstone, and conglomerate and therefore resembles to some extent the Lower Cretaceous rocks of the Hot Springs district. The upper of the two Lower Cretaceous formations of the Alaska Peninsula, called the Herendeen limestone, has no lithologic counterpart in the Hot Springs district, but its type fossil, *Aucella crassicollis*, is the form most commonly found in the Hot Springs district. It is probable that *Aucella crassicollis* had a wide geographic range and existed in the Hot Springs district under near-shore conditions contemporaneously with the formation of the Herendeen limestone. The Lower Cretaceous sea probably invaded interior Alaska from the southwest, and Lower Cretaceous sedimentation on the Alaska Peninsula had already been in progress a long time before the upper Yukon Valley was inundated. It is therefore likely that no marine Lower Cretaceous rocks contemporaneous with the Staniukovich shale are present on the upper Yukon.

North of the Yukon River, along the international boundary, the Lower Cretaceous rocks have been identified by Cairnes.[25] These rocks, as previously stated, probably connect by way of the Kandik

[24] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, pp. 286–476, 1926.

[25] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 105–107, 1914.

River with those along the Yukon. Cairnes made five collections of fossils from these rocks, in which the type fossil appears to be *Aucella crassicollis* Keyserling. Still farther north in northern Alaska Schrader [26] found Lower Cretaceous rocks on both the south and the north sides of the Brooks Range, and he gave to these two groups of rocks the designations Koyukuk and Anaktuvuk "series." In the recent work in northwestern Alaska [27] the Lower Cretaceous rocks north of the Brooks Range, roughly equivalent to the Anaktuvuk group, were shown to continue westward more or less continuously from the Anaktuvuk River to the Arctic Ocean. This group is probably closely correlative with the Lower Cretaceous rocks of the Yukon-Tanana region.

In the Chitina Valley of southern Alaska two formations, the Kotsina conglomerate and the Kennicott formation, both believed to be in part at least of Lower Cretaceous age, were described originally by Rohn.[28] *Aucella*-bearing shales were found by Capps [29] at the head of the Chisana River and are also known to exist to the east, at the head of the White River. They were also found by Mendenhall [30] in the valley of the Nelchina River, a stream that heads against the Matanuska River and flows eastward to the Copper River.

In southwestern Alaska, east of Kuskokwim Bay, rocks of Lower Cretaceous age are included in the group differentiated by Spurr [31] as the "Oklune series." Lower Cretaceous rocks are also known on Admiralty and Etolin Islands, in southeastern Alaska.

The Upper Cretaceous rocks of the Yukon-Tanana region present some unsolved problems. Their lower limit is fairly well known, as they appear to lie unconformably above the Lower Cretaceous sequence, but their upper limit has not been determined. Unlike the Lower Cretaceous sequence, they appear to contain a considerable fossil flora, indicating the near-shore origin of most of them, and possibly a terrestrial origin for some. The overlying Tertiary rocks are entirely terrestrial, and the close association of these rocks with the Upper Cretaceous rocks along the Yukon River below the Seventymile River suggests that the so-called Tertiary rocks may contain a considerable unrecognized Cretaceous sequence at their base, or that

[26] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, 1904, pp. 74–77.

[27] Smith, P. S., and Mertie, J. B., Jr., Geology and geography of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 196–207, 1930.

[28] Rohn, Oscar, A reconnaissance of the Chitina Valley and the Skolai Mountains, Alaska: U. S. Geol. Survey 21st Ann. Rept., pt. 2, p. 431, 1900.

[29] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 52, 1916.

[30] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 309, 1900.

[31] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 167, 1900.

54984—37——12

perhaps the so-called Cretaceous rocks below the Seventymile River are really a part of the Tertiary sequence. Similarly in the Rampart district, in the vicinity of Wolverine Mountain, the Upper Cretaceous sequence is by no means well defined stratigraphically, and it is even possible that some of the so-called Upper Cretaceous rocks may in reality be of Lower Cretaceous age.

TERTIARY SYSTEM

Two general types of Tertiary rocks are found in the Yukon-Tanana region. The older of these is a coal-bearing series, the fossil flora of which is considered to be of Eocene age. In reality, this series may possibly also include rocks of Oligocene or Miocene age, and the sequence is therefore better designated as early Tertiary. The younger Tertiary series consists of unconsolidated deposits, whose age has not been determined from fossil evidence, but on geomorphic grounds they are believed possibly to be of late Tertiary age, perhaps Pliocene. In addition to the later Tertiary gravel, there are high terraces, with or without veneers of gravel, which also were formed in this late Tertiary epoch. The distribution of these late Tertiary gravel deposits is definitely known only at a few localities where they have been explored by mining operations, and the known areas are so small that it has not been feasible to map them separately. They are therefore included on the accompanying map with the unconsolidated deposits of Quaternary age.

EARLY TERTIARY ROCKS

DISTRIBUTION

The early Tertiary rocks are found in different parts of this region. The greatest area is a belt, from 1 to 15 miles wide, which extends from the international boundary west-northwestward to Woodchopper Creek and beyond. In the opposite direction this belt continues east-southeastward into Yukon Territory for an unknown distance. This belt, in Alaska, follows the south side of the Yukon, but the rocks crop out along the river only at a few places. At the west end of the Yukon-Tanana region the early Tertiary rocks crop out intermittently along both sides of the Yukon River, from the mouth of Hess Creek to the Tanana River. Near the mouth of Minook Creek they are not only found on both sides of the Yukon but also extend for 2 miles up the valley of Minook Creek. Throughout the remainder of the Yukon-Tanana region early Tertiary rocks occur only here and there as isolated remnants. One such small area is known along the ridge north of the North Fork of Preacher Creek. A smaller area occurs about a mile northeast of the confluence of Fairbanks and Fish Creeks, in the Fairbanks district. Several small areas have also been recognized in the vicinity of Chicken, in the Fortymile district, and at the heads of the Charley and Goodpaster Rivers, about halfway between the Yukon and Tanana Rivers. Two small areas are mapped along the north side of the Tanana, just west of the mouth of the Tok River.

LITHOLOGY

Where seen south of the upper Yukon River, these rocks consist of impure greenish-gray to almost black sandstone, graywacke, and sandy shale, in beds ranging from grit to coarse conglomerate. A short distance above the international boundary, in the hills north of the Yukon, the conglomerate consists of pebbles from a quarter of an inch to 3 inches in diameter in a brownish matrix. The pebbles here are mainly vein quartz and chert, with some quartzite, quartzite schist, graphitic phyllite, and decomposed granitic or dioritic material. This is about the average character of the conglomerate. At some places, however, the conglomerate is coarser, and boulders as large as 3 feet in diameter have been observed. At most localities all these rocks are loosely consolidated and therefore, by weathering, form on top of the ridges gravel deposits that simulate high bench gravel. In places, however, as, for example, in the valley of the Seventymile River, these rocks have been more than ordinarily indurated and occur as hard sandstone and conglomerate. The sequence of rocks in this series, as observed by Prindle,[32] comprises shale and sandstone with beds of lignite at the base of the formation, overlain by sandstone, shale, and conglomerate, with thick beds of conglomerate at or near the top.

The conglomeratic beds appear to be the direct though not the original source of a part of the gold in the placers of the Seventymile River and of Fourth of July, Coal, Woodchopper, and other creeks along the south side of the Yukon River between Eagle and Circle. This does not indicate that all the streams cutting these rocks contain workable gold placers, and no better examples of the variations in distribution of placers from this source can be found than the adjacent streams known as Fourth of July and Crowley Creeks, which head in the Tertiary rocks. The former has workable gold placers, but the gravel of the latter contains little or no gold. No reason exists for believing that gold is universally distributed in these conglomerates, for here as elsewhere only certain streams or even certain parts of some particular stream draining from a mineralized area contain auriferous gravel. Moreover, these rocks

[32] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pp. 32–34, 1913.

have been highly folded at many places, particularly in the zone south of the Yukon, so that even if the conglomerate beds had originally carried equally distributed deposits of gold, the gold in the deposits derived from these rocks would no longer be equally distributed.

Between Hess Creek and the Tanana River the Tertiary sequence shows the same general character. These croppings have not been examined at close range by the writer but were visited by earlier workers in this district, notably Spurr [33] and Collier,[34] from whose descriptions the following information is largely drawn.

Just below the mouth of Hess Creek (originally called the Whymper River) the Yukon abruptly changes its course from southeast to west-northwest, thus making a pronounced bend or loop, on the inside of which the Tertiary coal-bearing rocks are exposed. Directly opposite the mouth of Hess Creek and for about a mile upstream the early Tertiary rocks are exposed intermittently along the west bank of the Yukon, but downstream and on the opposite side of the river they are covered by recent alluvium. At the north end of the section the early Tertiary rocks rest without apparent unconformity upon siliceous slates and tuffs of Paleozoic age. This relation, however, is accidental, for other exposures farther down the Yukon and elsewhere in this region show a pronounced unconformity between the Tertiary and Paleozoic rocks. The early Tertiary rocks strike N. 30° E. and dip 70° SE., so that the coal-bearing beds opposite the mouth of Hess Creek are near the top of the exposed Tertiary sequence. The lower four-fifths of the section is composed of fine-grained sandstone, shale, and a small amount of conglomerate, throughout which are distributed fossil leaves, mainly of dicotyledonous plants.

Another section is exposed from the mouth of Minook Creek up the east bank of the Yukon for a distance of 2 miles. The base of the sequence is coarse conglomerate, which is overlain by finer-grained conglomerate, grit, and interbedded shale. The pebbles in the basal conglomerate are from 2 to 3 inches in diameter and consist mainly of material derived from the underlying Paleozoic rocks. The beds near the top of the sequence have the same lithologic character as those at the base but are noticeably less indurated and in places consist of almost incoherent sand and gravel. Impure lignites occur at several horizons in these rocks upstream from Rampart. These beds strike about N. 75° E. and vary in dip from 20° N. at the north end of the sequence to 60° N. at the south end. (See pl. 12, *B*.) The

[33] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 186–188, 1898.

[34] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 36–43, 1903.

section may be at least as thick as that exposed upstream from the Drew mine, but the two sections are not necessarily correlative.

North of the North Fork of Preacher Creek the early Tertiary rocks are poorly exposed along the crest of the ridge. The rubble at the surface consists mainly of conglomerate and grit, composed mainly of pebbles of chert but including also some dark-gray quartzite and vein quartz. Pebbles as large as 4 inches in diameter are visible along the ridge top. These rocks are well indurated, and the conglomeratic beds naturally form the crest of the ridge, with shaly beds probably lying farther down the slopes to the north and south. The early Tertiary rocks in the Fairbanks district, according to the description given by Prindle,[35] consist of brown micaceous sandstone and conglomerate. The conglomerate is composed largely of pebbles and fragments of schist and vein quartz, and the sandstone contains ferruginous nodules and indeterminable plant remains. Those rocks are not well indurated.

In the two small areas at the head of the Charley and Goodpaster Rivers the rocks are largely conglomerate and arkosic sandstone, of varying degrees of coarseness. The coarsest conglomerate is made up largely of granitic boulders, 6 feet or less in diameter. Beds of finer-grained conglomerate were seen, which alternated with beds of shale containing plant remains. Most of these rocks, however, are arkosic sandstones, along the bedding planes of which there is considerable carbonized plant material. These are well-indurated gray rocks composed of about equal amounts of quartz and feldspar with some mica.

In the vicinity of Chicken, in the Fortymile district, the early Tertiary rocks consist of fine-grained cream-colored to yellowish-brown sandstone, drab shale, and beds of conglomerate. The sandstone is loosely consolidated and contains numerous carbonaceous streaks, ferruginous nodules, and here and there angular to subangular pebbles of chert as much as an inch in diameter. The shale is soft and disintegrates rapidly to clay on exposure to the atmosphere. This sequence also includes beds of lignitic coal.

On Napoleon Creek, likewise in the Fortymile quadrangle, these rocks unconformably overlie the undifferentiated Paleozoic rocks. At the base is a 15-foot breccia, composed of fragments 4 inches or less in diameter of the underlying green phyllitic rocks, with a sandy matrix. Above this is 4 feet of bluish argillaceous rock, overlain by 20 feet of breccia, which in turn is followed by alternating beds of shale and conglomerate.

Along the north side of the Tanana River below the Tok River these rocks, according to the field notes of A. H. Brooks, consist of

---

[35] Prindle, L. M., op. cit. (Bull. 538), pp. 66–67.

8 feet of fine yellow sandy shale, which is exposed on the river bank and is overlain by coarse feldspathic sandstone and conglomerate. The grains of the sandstone are rounded, but otherwise the sandstone closely resembles an arkose and must be close to granite, which is believed to be the parent rock. The fine yellow sandy shale contains a few obscure vegetal remains.

STRUCTURE AND THICKNESS

The Tertiary rocks south of the Yukon probably present a much more complete section than those farther down the river, but no studies have yet been made that are sufficiently detailed to warrant a structural section across this sequence of rocks. In general, however, these rocks south of the Yukon are everywhere folded, and at some localities they seem to be more greatly deformed than the Lower Cretaceous rocks in the vicinity of the Kandik River and northeastward, notwithstanding the greater age of those rocks. This apparent anomaly is due to the fact that the region south of the Yukon is a province of great intrusive and metamorphic activity, and the Tertiary rocks lie within or along the edge of this province. The same condition of great deformation south of the upper Yukon and little deformation north of the river also holds for the Paleozoic and pre-Paleozoic rocks. This condition suggests strongly that the volcanism and accompanying metamorphism that were produced in Mesozoic time by the batholith in the Charley River Basin were renewed in the Tertiary and caused the deformation now observable in these Tertiary rocks. This hypothesis is also borne out both by the presence of granitic rocks of Tertiary age in the Rampart district and by the evidences of Tertiary mineralization in many parts of the Yukon-Tanana region, including the Seventymile district.

Evidence of the intense deformation of the early Tertiary rocks is found at numerous localities, particularly along the Seventymile River, where these rocks lie near the intrusive rocks to the south. On Barney Creek, a tributary of the Seventymile, the conglomerate beds stand nearly vertical at places, and even farther north, in the valley of Fourth of July Creek, they are nearly vertical at one exposure. Along the south side of the Seventymile River below the falls, where these rocks strike about N. 55° W., they dip consistently south at angles of 30° to 70° and are highly indurated. They consist here largely of sandstone and conglomerate, with some lignitic beds, but farther up Crooked Creek from the Seventymile the bedrock changes by degrees to soft shale and sandstone. This sequence indicates, if Prindle's interpretation of the order of deposition is correct, that these beds along the Seventymile River, though highly deformed, are at least right side up, the conglomerate resting normally upon the stratigraphically underlying shale and sandstone.

The beds of heavy conglomerate, however, are apparently duplicated by folding and crop out repeatedly in the area between the Seventymile and Yukon Rivers. This duplication of beds by folding and perhaps also by faulting unquestionably explains the great distance across the strike of these rocks from the falls of the Seventymile to the Yukon. It is therefore entirely possible that no great thickness of rocks exists in this belt, even though the greatest distance across the strike is nearly 15 miles. On the other hand, all of the sequence may not be present in that portion of the belt where the distance across the strike is the least. Prindle[36] estimated the thickness of the sequence between the Seventymile and Yukon Rivers at 3,000 feet. This, it seems to the writer, is a minimum estimate. In fact, opposite the mouth of Hess Creek, where the sequence is by no means as complete as in the Seventymile district, Collier[37] estimated the thickness of the Tertiary rocks at 5,000 feet. In view of the lack of detailed work upon the Tertiary sequence, it hardly seems worth while to hazard another estimate.

The rocks at the head of the Charley and Goodpaster Rivers were hastily visited by Prindle and the writer in 1911, and little study was given to their structure. They are only slightly tilted, and their total thickness is estimated not to be in excess of 1,000 feet. In the Fairbanks district the early Tertiary rocks are found only in one small area, and the exposures are mainly surface rubble. In the Fortymile district the early Tertiary rocks occupy a few small areas, and although they are fairly well exposed in places, their structure is complex, and the stratigraphic sequence and thickness are indeterminate.

AGE AND CORRELATION

The age of these rocks is not surely determined. There seems to be little doubt that most of them are of early Tertiary age, but as already shown, Martin,[38] relying upon the paleobotanic determinations of Hollick, is inclined to regard some of these rocks, particularly those along the Yukon River below the Seventymile River, as of Upper Cretaceous age. It is possible that both Upper Cretaceous and Tertiary rocks are included in the sequence here assigned dominantly to the early Tertiary.

In all, more than 30 collections of plant fossils have been made by various geologists from this sequence of rocks, but most of these have been obtained incidentally, in connection with other geologic

[36] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, p. 33, 1913.

[37] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, p. 37, 1903.

[38] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, pp. 387–390, 1926.

work. Fossils are plentiful, and many and more complete collections could and should be made, for a final settlement of this problem. The available material has in recent years been reexamined and studied by Hollick,[39] and the results have recently been published. In view of this fact, no good purpose would be served by publishing the older botanic determinations, as many of them have been extensively revised. It seems advisable, however, to place on record the localities where these fossils have been collected, and these data are presented below.

Spurr 4. Drew coal mine, Yukon River opposite mouth of Hess Creek. Collector, J. E. Spurr, 1896.

Spurr 6. Southeast bank of Yukon River just above mouth of Minook Creek. Collector, J. E. Spurr, 1896.

Spurr 7. Yukon River between Minook Creek and Tanana. Collector, J. E. Spurr, 1896.

2AC27. Coal Creek about 12 miles from Yukon River. Collector, A. J. Collier, 1902.

2AC40. American Creek 100 yards below crossing of Eagle-Valdez trail. Collector, A. J. Collier, 1902.

2AC140a. Drew coal mine. Collector, A. J. Collier, 1902.

2AC146. Northwest bank of Yukon River 4 miles upstream from Rampart. Collector, A. J. Collier, 1902.

2AC161. Southeast bank of Yukon River about 3 miles downstream from Rampart; dump from old tunnel. Collector, A. J. Collier, 1902.

3AH9a, b, c. Drew coal mine. Collector, Arthur Hollick, 1903.

3AH10. Southeast bank of Yukon River about 2 miles upstream from Rampart. Collector, Arthur Hollick, 1903.

3AP224½. McDowell claim, Chicken Creek. Collector, L. M. Prindle, 1903.

3AP251. Chicken Creek. Collector, L. M. Prindle, 1903.

3AP330. Wolf Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP336. Branch of Wolf Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP348–350. Bryant Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP355. Mogul Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP432. Mission Creek 2 miles above junction with Excelsior Creek. Collector, L. M. Prindle, 1903.

5AP178. Liberty Creek, tributary of O'Brien Creek. Collector, L. M. Prindle, 1905.

Kindle 11h. Yukon River 1½ miles above Seventymile River. Collector, E. M. Kindle, 1906.

Kindle 20. Coal mine, Washington Creek, 16 miles from Yukon River. Collector, E. M. Kindle, 1906.

Bennett, 1906. Drew coal mine. Collector, V. H. Bennett, 1906.

Kindle, 42. Northwest bank of Yukon River about 20 miles above Tanana. Collector, E. M. Kindle, 1906.

Atwood 10. Seventymile River half a mile below mouth of Mogul Creek. Collector, W. W. Atwood, 1907.

Atwood 11. Bryant Creek 3 miles above its mouth. Collector, W. W. Atwood, 1907.

Atwood 14. Drew coal mine. Collector, W. W. Atwood, 1907.

Atwood 15. Southeast bank of Yukon River upstream from Rampart. Collector, W. W. Atwood, 1907.

Atwood 16. Northwest bank of Yukon River about 10 miles below Rampart. Collector, W. W. Atwood, 1907.

11AE1. Southeast bank of Yukon River about 1½ miles upstream from Rampart. Collector, H. M. Eakin, 1911.

11AE2. Southeast bank of Yukon River about 1½ miles upstream from Rampart, about 500 feet stratigraphically above 11AE1. Collector, H. M. Eakin, 1911.

---

[39] Hollick, Arthur, The Tertiary floras of Alaska: U. S. Geol. Survey Prof. Paper 182, 1936.

In addition to the plants, a river mussel (11AE3) was also collected by Eakin from the same beds as lot 11AE2. This fossil was determined by W. H. Dall as *Unio athleos* Mayer.

From an examination of Hollick's paper, it appears that this ancient flora includes extinct species of poplar, buttonwood, maple, hazelnut, oak, hickory, walnut, hawthorn, and persimmon trees, as well as a marked percentage of subtropical Asiatic plants. Thus in one flora, from a relatively small part of Alaska, there appear a temperate North American facies and a subtropical Asiatic facies. This assemblage is in marked contrast to the relatively few species of spruce, poplar, birch, willow, and alder that now grow in this region, under present sub-Arctic conditions.

According to both Knowlton and Hollick, most of the Tertiary flora of Alaska is of †Arctic Miocene (late Eocene) age. According to the same authorities, this flora, while admittedly mixed both in climatic and geographic aspects, has a more marked kinship with the Fort Union flora than with any other of the Tertiary floras of the western United States and Canada. The biologic relationships are indisputable, but the geologic interpretation that all the rocks in Alaska containing this flora are Eocene may be questioned. A variety of Tertiary rocks, some obviously younger than others, are present in interior Alaska, but all are assigned by the paleobotanist to the Eocene. Some of the inconsistencies attendant upon this geologic interpretation in the Alaska Range have already been discussed by the writer.[40] In the interior of Alaska several Tertiary horizons are probably represented, and it seems entirely possible that indurated terrestrial deposits ranging in age from Eocene to late Tertiary are present in this region.

This ancient flora throws considerable light, however, on geologic conditions that prevailed in the Yukon-Tanana region in early Tertiary time. The assemblage of temperate plants similar to our eastern United States flora, together with subtropical plants of Asiatic aspect, certainly indicates a temperate climate with a precipitation several times as great as the present precipitation in this region.

The early Tertiary rocks of interior Alaska, unlike the older marine sediments of the Mesozoic and Paleozoic, tend to have a linear type of distribution, suggestive of ancient drainage channels, and in some areas such linear distribution coincides roughly with major stream valleys of the present day. Thus, along the Yukon early Tertiary rocks are distributed as belts and patches, first on one side of the river and then on the other, from Yukon Territory, Canada, downstream into the lower Yukon Valley. With little doubt,

[40] Mertie, J. B., Jr., Mountain building in Alaska: Am. Jour. Sci. 5th ser., vol. 20, pp. 101–124, 1930.

these early Tertiary sediments were laid down in a wide valley that may be the remote ancestor of the present Yukon. Topographic and climatic conditions, however, were very different from those of today. The present plateau of interior Alaska was not dissected then as now, the relief was probably small, and the trunk valleys were open and swampy. The stratigraphy indicates a thickness for these early Tertiary rocks of the order of 3,000 to 5,000 feet, and such a thickness of fluviatile deposits seems incomprehensible without the assumption of regional subsidence during the period of alluviation. The coal measures in the early Tertiary rocks likewise point to wide marshy valleys that were developed by regional subsidence. It is therefore concluded that early Tertiary time in the Yukon Valley was characterized by a gradual raising of the regional baselevel of erosion.

LATE TERTIARY DEPOSITS

DISTRIBUTION AND CHARACTER

In the description of the present topographic relief in the Yukon-Tanana region, reference was made to a system of high terraces that are found along the Yukon River and some of its larger tributaries. The higher of these river terraces are from 500 to 1,000 feet above the present drainage levels and are believed to be of late Tertiary rather than Pleistocene age. Beyond their approximate elevations, little is known of these old erosion levels, for no detailed information is available regarding the direction and magnitude of their gradients, their subsequent deformation, and other significant data. All these rock-cut terraces were probably overlain at some period in their history by ancient gravel, but most of these gravel deposits have been removed by subsequent erosion, and the terraces are now either bare or are covered only by thin veneers of gravel. Little can therefore be learned of the character and age of these late Tertiary unconsolidated deposits, except in some particular areas where they have been partly preserved. The Rampart district is such an area.

Unconsolidated deposits of this type, which are regarded as late Tertiary, crop out along the ridge tops east of Minook Creek, from Hoosier Creek northward to Hunter Creek; and remnants of the same gravel also exist on some of the ridge tops between Hunter Creek and the Yukon. On these relatively low ridges, where both residual overburden and vegetation occur, it is difficult to determine the true limits of these gravel deposits, and their extent as mapped is based largely upon geomorphic interpretation rather than upon observed boundaries. Fortunately these ancient deposits of gravel are gold-bearing and have therefore been prospected to such an extent that local information is available regarding their major distribution and general character.

Four of the principal occurrences of these deposits have received local names. The largest and economically the most important deposit forms the crest of the ridge between Hunter and Minook Creeks. This is called Idaho Bar. A second deposit, called California Bar, forms the divide between Little Minook and Little Minook Junior Creeks and continues around the head of the latter stream. A third, known as Florida Bar, rests on top of the ridge between Hoosier and Minook Creeks. About 2 miles up Minook Creek from the mouth of Hoosier Creek is a small creek known as Florida Creek. On the ridge south of Florida Creek, another small body of such gravel forms what has been called Macdonald Bar.

Idaho Bar (pl. 13, *B*) is typical of these older deposits. It has an elevation of about 1,600 feet above sea level and is about 1,000 feet higher than the mouth of Little Minook Creek. Little Minook Creek, however, has a high gradient, so that the elevation of Idaho Bar above the bend in upper Little Minook Creek is from 600 to 800 feet. California and Florida Bars have about the same elevation, but the bedrock beneath them is probably higher than that under Idaho Bar, as these bars are believed to have been formed upstream from Idaho Bar, in the old drainage system that produced all of them. Therefore the thickness of these late Tertiary gravel deposits on California and Florida Bars might be expected to be somewhat less than on Idaho Bar.

As these gravel deposits are nowhere exposed to advantage, their character is known only from what has been found in the prospect shafts and tunnels that have been driven. Idaho Bar has been prospected and mined sporadically for 30 years but unfortunately little of the mining data have been preserved. Hess[41] mentions one shaft near the middle of the divide between Hunter Creek and Little Minook Creek that was sunk in these gravels to a depth of 100 feet. He also states that in general the gravel of this high bench is frozen and consists of chert, diabasic and metamorphic rocks, vein quartz, heavy quartzite boulders, and some smaller pebbles. The quartzite boulders referred to are now known to be derived from the Lower Cretaceous rocks that crop out at the head of Minook Creek.

A favored locality for prospecting and mining in Idaho Bar has been along the south side of the ridge, at the head of a small gulch that enters Little Minook Creek at the bend. Here the miner can

[41] Prindle, L. M., and Hess, F. L., The Rampart gold placer region, Alaska: U. S. Geol. Survey Bull. 280, pp. 30–31, 1906.

prospect by means of a tunnel driven on bedrock, instead of sinking a shaft. One such short drift, driven during the winter of 1930–31, was examined by the writer. The bedrock at this point is chert of Carboniferous age, and the surface of bedrock is very irregular, with abrupt rises and drops. The gravel is of the type mentioned by Hess and is well rounded and fairly coarse. In the roof of the tunnel and also near bedrock, some boulders as large as 2 feet in diameter were observed.

From the mouth of this drift to the top of an old shaft at the crest of the divide the barometer shows a difference in elevation of 190 feet. This old shaft is said by the present miners to have been 90 feet deep and is probably the one mentioned by Hess. The obvious deduction from these observations is that the bedrock is about 100 feet higher at the crest of the ridge than at the south side, where the deposit is opened by drifting. Also the minimum thickness of the deposit on Idaho Bar is probably not much over 100 feet.

AGE AND CORRELATION

These high gravel deposits are the remnants of an old gravel sheet that extended northeastward from Florida Creek to the Yukon. Some of the miners in the Rampart district, recognizing this trend, have looked for a southwestward continuation of the high gravel along the ridge between Ruby and Slate Creeks, but no such extension has been found. In reality, the ancient upper channel of Minook Creek was about where it is now, but in its lower course, below the present site of Florida Creek, it drained northeastward to some master stream. This condition existed at a time when the regional base level was about 1,000 feet higher than at present. The gravel of Idaho, California, and Florida Bars was deposited in the lower course of this ancient predecessor of Minook Creek, and has been preserved because the lower course of this ancient stream was subsequently diverted westward to its present channel. The headwater gravel, corresponding to that on Idaho, California, and Florida Bars, has not been preserved, because it was eroded and dissipated in the recent entrenchment of Minook Creek.

The gravel deposits of Idaho, California, and Florida Bars are now assigned to the later Tertiary on the basis of geomorphology rather than on fossil evidence. These ancient deposits lie so far vertically above the Pleistocene deposits that form the lower benches in the present stream valleys that they can hardly be called Pleistocene without assigning to that epoch a duration of unwarranted length. Furthermore, the Pleistocene deposits of the Yukon Valley usually include, at least in their upper parts, more or less black carbonaceous silt, commonly called "muck", and such material is lacking or scarce in the high gravel. Another indication of the great age of the high gravel is its elevation with regard to the gravel of a lower terrace, only 90 feet above the present level of Minook Creek. This lower terrace extends up Hunter Creek, and its mantle of gravel and silt is the source of the Pleistocene mammal remains, later described. Other factors being equal, the gravel of Idaho Bar should be much older than the Pleistocene mammal-bearing sediments. These considerations lead to the belief that the high gravel deposits of Idaho, California, and Florida Bars are pre-Pleistocene.

These gravel deposits, on the other hand, are neither much indurated nor tilted, so that they bear little resemblance to the early Tertiary coal-bearing rocks of this district. Moreover, the folding of the coal measures implies a period of deformation following their deposition that must also be fitted into the Tertiary historical sequence. This period of orogeny has been considered by the writer [42] to have occurred either in Oligocene or Miocene time, but if the deposition of the coal measures extended into the Oligocene, as the Tertiary stratigraphy and flora suggest, it is more likely that the Miocene was an epoch of mountain building in this district. The high gravel of the Rampart district was, of course, deposited long after this period of mountain building. None of these facts prove definitely the age of the high gravel, but in the aggregate they suggest strongly the late Tertiary age to which it is here referred.

QUATERNARY SYSTEM

Unconsolidated deposits of Pleistocene and Recent age cover the surface of a considerable part of the Yukon-Tanana region. These alluvial deposits have not been studied sufficiently to warrant their separate delineations, and on the accompanying geologic map (pl. 1) they are shown as a single pattern.

Lack of critical data prevents a clean-cut separation and mapping of the Pleistocene and Recent deposits. First, there exist no marked differences in lithology that correspond to differences in age. The ancient gravel deposits of this region, so long as they are incoherent, look much the same as recent ones; and even the carbonaceous silt that characterizes the older alluvium has been reworked by modern streams and may be present as superficial deposits that are quite similar to the original material from which they were derived. Second, it is impracticable to observe stratigraphic sections of the alluvium in a region where such deposits have a considerable thickness. Where the older deposits are found as alluvial veneers on rock-cut terraces, their general character and age in relation to adjacent deposits may possibly be learned. But the Pleistocene

[42] Mertie, J. B., Jr., Mountain building in Alaska: Am. Jour. Sci., 5th ser., vol. 20, p. 123, 1930.

drainage of the Yukon-Tanana region has had a long and intricate history, during which there were developed old erosional channels that are now filled by both ancient and recent gravel. Sections of such deposits are not visible and can be observed only where underground placer mining is in progress. Indeed, a stratigraphic section of such deep deposits could be obtained only by being present during the entire time that a shaft was being sunk, for the walls of such shafts are cribbed as they are sunk.

The inexactness of the terms "Pleistocene" and "Recent", as applied to the alluvial deposits of interior Alaska, is a third barrier to a geologic classification. The term "Pleistocene", in the United States and southern Canada, is generally understood to be synonymous with the ice age, but this usage may not be applied in Alaska, for the ice age may have begun at an earlier date and certainly persisted longer in Alaska than in more southern latitudes. In fact, parts of southern Alaska are now ice-capped and may be said still to be in the ice age. But in interior Alaska even the term "ice age" is difficult of application, as most of the Yukon Valley, though begirt by ice on the north, east, and south, has not been regionally glaciated at any time during the Quaternary period, and glacial deposits occur only locally in the higher parts of the region, so that their relations to the early Quaternary deposits of the lower valleys cannot be determined.

If the alluvial deposits of the Yukon-Tanana region are to be assigned to epochs or smaller units, of different ages, it will have to be done largely on the basis of geomorphic study and interpretation and by extrapolation from facts determined locally to more widespread generalizations. The essential data for a sequential classification of the alluvial deposits have not been obtained, but certain of these deposits have evidently been and are still being laid down by recent streams during the latest geomorphic cycle. Such material, for purposes of description, may be called "late alluvial deposits"; and all Quaternary material deposited in preceding cycles of erosion may be called "older alluvial deposits." Certain of these older deposits, however, are of glacial origin, for local alpine glaciation occurred during Pleistocene time on the headwaters of some of the streams that drained the higher portions of the Yukon-Tanana divide. These deposits have been locally differentiated and mapped as glacial deposits. In this classification the older deposits represent an epoch whose duration may be several times that represented by the later deposits. But the classification may be refined by local descriptions of the older deposits that will give an inkling of their relative ages and may lead eventually to their proper subdivision.

GLACIAL DEPOSITS

The Pleistocene epoch in Alaska, as in many other parts of North America and Europe, was ushered in by a gradual lowering of the mean annual temperature, accompanied perhaps by changes in the amount or distribution of precipitation, but with the net result of regional glaciation on a large scale. The Alaska Range, together with southern and southeastern Alaska, was intensely glaciated during Pleistocene and probably during early Recent time. In fact, some of that part of Alaska is still covered with great ice caps. The Brooks Range, which crosses northern Alaska, was also glaciated, and small remnants of these glaciers still persist at some places. Finally, the upper Yukon and Tanana Valleys were extensively glaciated at the same time. Interior Alaska, however, including the Yukon-Tanana region, was not glaciated, except for the local alpine glaciation; yet all of this interior basin was girdled during the Pleistocene by great ice fields on the north, east, and south. These neighboring ice fields and the climatic and geomorphic processes that accompanied their development must have exerted a profound influence upon the processes of erosion and sedimentation that existed simultaneously in the Yukon-Tanana region. Quite apart from the regional lowering of the mean annual temperature, as compared with that of late Tertiary time, these ice fields probably served to depress still more the mean temperature of interior Alaska, yet not so much as to induce regional glaciation. The precipitation must have been as small as at present, or perhaps smaller. Yet the records preserved in the sediments show that vegetation grew, animal life existed, and, at least in the early stages of the glacial epoch, erosion and stream sedimentation were as active then as now. The same records also show that in the later stages of the glacial epoch, however, many of the vertebrates which then existed perished and that others were modified to new species that were better able to survive. Similarly in the late stages of the glacial epoch there came into existence throughout much of interior Alaska peculiar conditions of erosion and sedimentation, which are not yet fully understood. In fact, the whole Pleistocene history of the Yukon-Tanana region presents many difficult problems of erosion, sedimentation, and stream diversion, part of which are functions of climatic conditions, whereas others are further complicated by regional and local movements of elevation and depression. Moreover, most of these problems involve interdependent factors, like a complex mathematical equation of several variables and many functions of each of the variables, so that a partial solution of certain local geomorphic problems leads to more difficult regional problems. Underground placer mining has already supplied some of the essential data, but before a satisfactory general explanation of Pleistocene geomorphology can be presented, much further information will be required, particularly the type of information that may be obtained from detailed investigations.

Six small areas of glacial deposits are shown on plate 1, though undoubtedly other areas of morainal material are present in this region. These deposits were mapped by Prindle and the writer during the field season of 1911, and although the occurrence of alpine glaciation in this region had been surmised prior to that time, these moraines presented the first definite evidence of it. Similar morainal material may be expected elsewhere in the vicinity of the higher mountains along the Yukon-Tanana divide, but this part of the region has been little explored.

The glacial deposits occur entirely in the central part of this region, on both sides of the Yukon-Tanana divide. In this part of the region the Yukon-Tanana divide has been controlled largely by differential erosion and is formed by the harder and more resistant rocks. Next to quartzite, the granitic rocks of this region are most resistant to erosion, and therefore the position of the granitic intrusives has to a considerable extent determined the localities of glaciation. Five of the areas of morainal deposits occur in or near the two large batholiths of granitic rocks at the heads of the Charley and Goodpaster Rivers, and the sixth lies in a small area of granitic rocks in the valley of the North Fork of the Salcha River. The western part of Yukon Territory is similarly unglaciated except for local alpine glaciers.

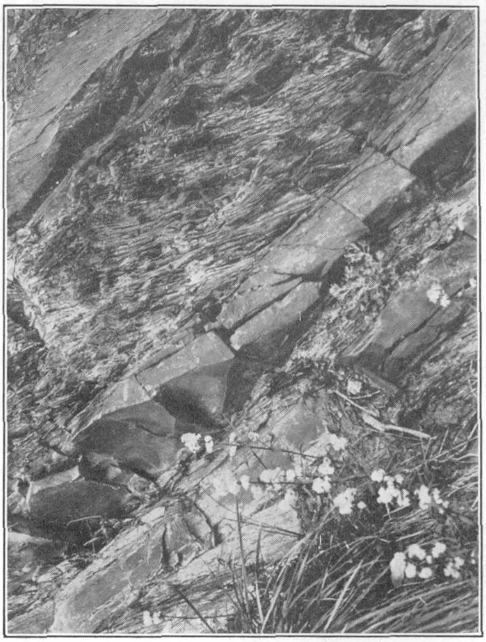
Only the headwater streams along or near the Yukon-Tanana divide have been modified by moving ice, but at such localities all the characteristics of alpine glaciation are evident, including cirques, hanging valleys, U-shaped lower valleys, and moraines.

The largest glacial deposit shown on plate 1 lies near the head of Crescent Creek, a western tributary of the Charley River. This deposit is a moraine about 1¼ miles long and half a mile wide, which occurs at the confluence of two forks of Crescent Creek. The deposit is about 400 feet thick at its upper end and about 100 feet thick at its lower end and is arranged in three or more concentric ridges, of which the outermost, away from the present creek, is the largest. The age of this deposit and of the others that resemble it, in comparison with the older alluvial deposits in the lower valleys, cannot be stated with assurance.

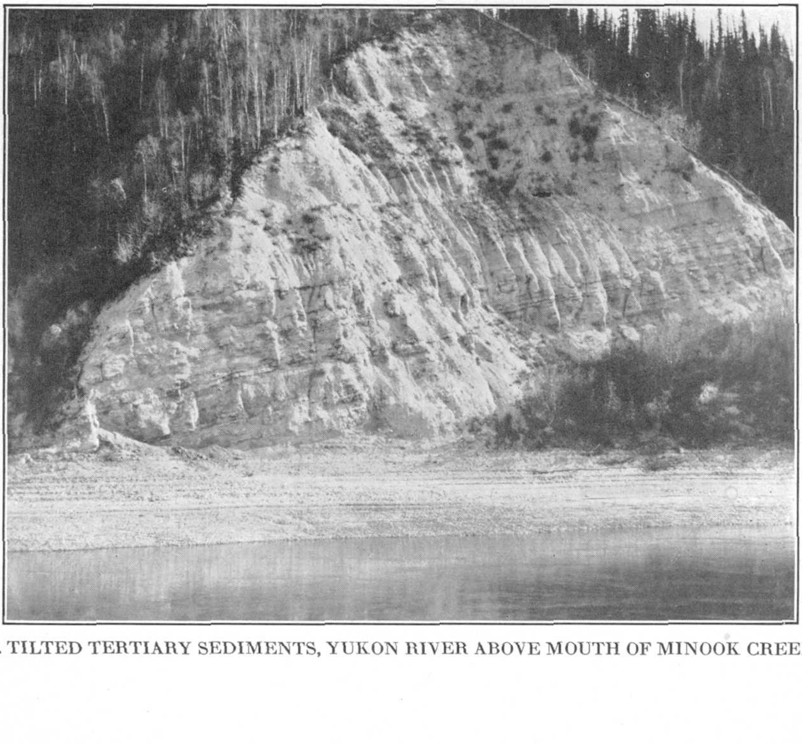
OLDER ALLUVIAL DEPOSITS

DISTRIBUTION AND CHARACTER

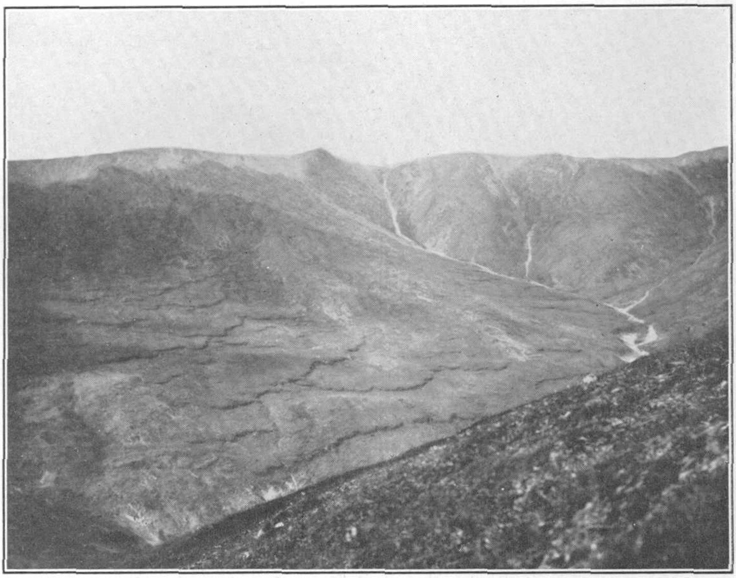
During the glacial epoch the Yukon and Tanana Rivers were both glacial streams. This is not to say that either or both of these rivers



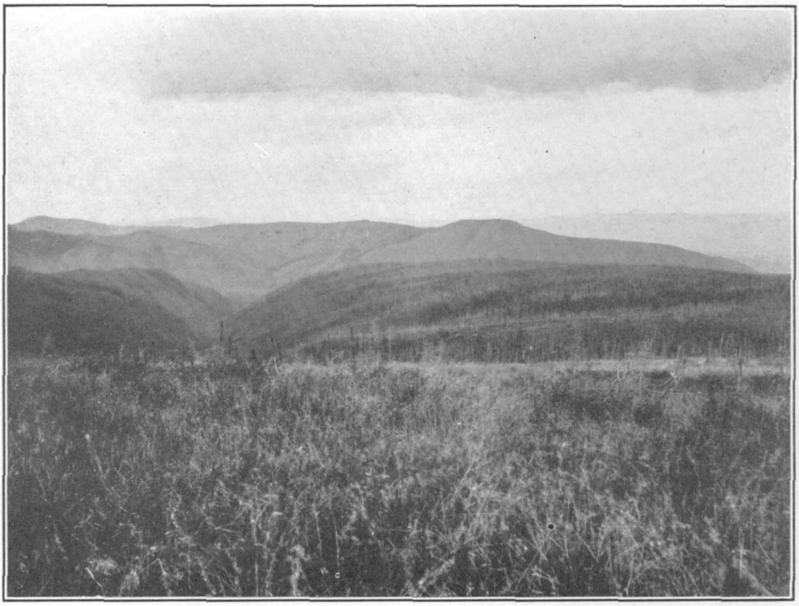
A. LOWER CRETACEOUS ROCKS, YUKON RIVER.
Shows fracture cleavage in slate and jointing in beds of sandstone.



B. TILTED TERTIARY SEDIMENTS, YUKON RIVER ABOVE MOUTH OF MINOOK CREEK.



A. SOIL FLOWS, HEADWATERS OF PREACHER CREEK.



B. IDAHO BAR FROM HEAD OF LITTLE MINOOK CREEK.

occupied throughout the ice age the same channels that they do at present, for much evidence is available to show marked changes in their drainage systems. But their valleys, at least, were drained by major rivers, flowing probably in the same direction as at present. Both these streams drained glaciated areas, the Yukon heading in the glaciers of Yukon Territory and northern Alaska and the Tanana in those on the north slopes of the Alaska Range. The tributaries of the Tanana River from the south, particularly in the late stages of the glacial epoch, when the glaciers of the Alaska Range were retreating, handled and reworked great volumes of outwash deposits from the glaciers, moving this material northward and subsequently redepositing much of it to form the great alluvial plains that now lie south of the river.

These glaciofluviatile deposits greatly altered the character of sedimentation in many streams that flowed southward to the Tanana. The lower valleys of such streams were extensively aggraded, thus decreasing their lower gradients, causing the deposition of their coarse detritus farther upstream, and making great silty swamps of their lower valleys. Though much of these deltalike deposits has since been removed, these lower stream valleys still show the effects of this process, in great embayments at their mouths. One of the most striking examples is the Tolovana embayment. The present depth of the alluvial deposits, both in the Tanana Valley and in the lower valleys of its tributaries, shows also that the base level of erosion for the Tanana was lower in preglacial time than at present.

The Yukon River likewise drained a glaciated region in its upper valley, and the headwater glaciers likewise produced a considerable volume of glaciofluviatile material which was transported downstream by the river. The volume of outwash material was much smaller, however, the glacial sources were a considerable distance upstream, and the excess of glaciofluviatile deposits, which the stream could not handle, remained upstream in Yukon Territory and therefore produced no aggradational effects in Alaska similar to those produced by the Tanana. In fact, this outwash material, by the time it was transported into Alaska, had been reworked, assorted, and mixed with nonglacial alluvium to such an extent that it was practicaly normal stream detritus.

While the Tanana and Yukon Rivers were thus functioning during the glacial epoch, their tributaries in the Yukon-Tanana region continued to exist as normal nonglacial streams. Many of the present valleys are disproportionately large in comparison with the streams that now occupy them; and the amount of alluvial material is also disproportionately large. These conditions suggest a period

54984—37——13

of active erosion prior to the glacial epoch, and the volume of the early Pleistocene alluvial deposits shows that this stream activity continued for a considerable time into the glacial epoch. Possibly an antecedent period of deep residual decay of the country rock might account in part for the volume of material in these old channels, but the streams themselves must have been erosionally active to handle this material.

These earliest Pleistocene deposits consist of silt, sand, and gravel, but where they have been available for underground observation they are dominantly gravel. These deposits occur in many different sites in the present valleys. Some of them lie 200 feet or more below the present surface, only 200 or 300 feet above sea level. Others occur on stream terraces, well above the present valley floors. At some places they lie deeply buried in old channels, separated from the present stream channels by bedrock reefs; and at other places the old and the new valleys have nearly the same courses, so that the present streams are now dissecting the older gravel. Many of the richer gold placers in the Yukon-Tanana region occur in these older deposits, but as all the placer deposits of this region have been described in considerable detail in earlier reports, they will not be further described here. These older deposits occur in all the principal mining areas of the region, including the Fairbanks, Hot Springs, Rampart, Circle, Seventymile, and Fortymile districts. One of the problems of Pleistocene geology is the correlation of all these older deposits, particularly the explanation of their varying elevations above sea level in regions where the present streams have nearly the same elevation. Hypotheses have been presented, both by the writer and by others, to explain the local relations that exist between the older alluvial deposits and those of more recent date, and at some places the Quaternary history of the streams has been deciphered. But a general correlation of these older Pleistocene deposits cannot yet be made.

After the deposition of the older Quaternary gravel there began, in this region, a different type of sedimentation. Most of the older gravel deposits are overlain by a varying thickness of silt, containing much vegetal material. This silt is black when wet but is light to dark gray after the moisture has been removed. No detailed microscopic studies of this material have yet been published, but it appears to be composed of fine subangular to rounded grains of quartz and other rock-forming materials. Some evidence leads to the belief that a considerable part of this material is wind-borne. At the top of such deposits, and locally in layers throughout them, the silt is mingled with much vegetal material, which gives it a black color; and locally beds of peat form a part of the sequence. These deposits of silt containing considerable vegetal material are called "muck" by the miners; but because all the silt is dark-colored when wet the term "muck" is loosely applied to all the dark-colored silts.

These silt deposits, as well as the gravel below them, are usually frozen in whole or in part, in interior Alaska. The silt, however, is much more likely to be solidly frozen than the gravel. It also contains beds and lenses of clear ice, practically free of sediment, which are believed in large part to have formed after the original deposition of this material. These beds of silt in some localities are only a few feet thick, but in other places, as in the Fairbanks district, they may have a thickness of 100 feet or more. The silt beds are not uniform in character throughout, for mining has shown the presence in them of inlaid lenses of grit or even gravel, showing that conditions of alluvial accumulations were by no means uniform, even at any one locality. Such deposits, overlying the older gold-bearing gravel, present one of the great difficulties of placer mining in interior Alaska. The silt itself is practically barren of gold, and in order to reach the underlying placers this overburden must either be removed, or else underground mining methods must be utilized. At some localities, particularly in small-scale operations, a face is opened to bedrock by thawing, and thereafter the silt is allowed to thaw from the heat of the summer sun, aided often by a stream of water directed from a giant. In larger-scale operations the silt is thawed by means of circulating water, supplied by pipes driven into the ground, and after being thawed the overburden is groundsluiced off by hydraulic methods.

These thick deposits of silt contain, in addition to vegetal and vertebrate remains, a considerable fauna of fresh-water mollusks and diatoms. If they occurred only in the low-lying streams, tributary to the Tanana, whose lower courses have been aggraded, they might be considered to be mainly deltaic silt deposits. But they also occur, in other parts of the Yukon-Tanana region, particularly in the Tolovana Basin and in contiguous areas, up to an elevation of at least 1,200 feet above sea level. If this region, in late Pleistocene time, had been inundated by reason of barriers of any kind across the trunk streams, these deposits might well be considered lacustrine in origin. But in that event there should be preserved many terraces and old beach deposits, marking various stages in the formation and disappearance of such fresh-water lakes; and such evidence has not been found. Information is still too meager to furnish an explanation of the origin of these deposits, and the solution of this genetic problem must therefore await a more intensive study of the distribution and character of these deposits.

AGE AND CORRELATION

It is obvious that many types of sediments of varying ages are included among the older deposits of the Quaternary. The geologic age of these deposits must be determined largely upon the basis of contained fossil remains, where such material is available. The relative ages of contiguous deposits—for example, successive terrace deposits—are almost self-apparent. But the relative ages and correlation of widely separated and little-related deposits, like those of the Fairbanks, Rampart, and Hot Springs districts, cannot at present be stated.

The older silt and some of the gravel contain abundant remains of mammals. These weather out of the terrace deposits and are washed down into the present streams and are also uncovered in large numbers in placer mining. In order to obtain good specimens of these mammal remains, it is almost necessary to be on the ground while mining operations are in progress, and as the geologists of the Survey visit the mining camps only for a few days in each year, only fragmentary material has been collected. At the present time the extensive hydraulic operations of the Fairbanks Exploration Co. are uncovering a large supply of such material, but as the result of an arrangement between this company, the American Museum of Natural History, and the University of Alaska this material is now being extensively collected and preserved. On several occasions, however, the Smithsonian Institution has sent men to Alaska for the express purpose of collecting this material, and one of these expeditions, under the direction of C. W. Gilmore,[43] obtained some excellent material, particularly from the Rampart district. Members of the Geological Survey have also obtained more or less of these vertebrate remains, some from the Fairbanks district in earlier days and some from the Rampart district, and this material has been transmitted to the United States National Museum. A list of the vertebrate remains collected by the Geological Survey and a part of those collected by the Smithsonian Institution is given below.

2383. Little Minook Creek, Rampart district. Donors, McLain & Ballou. Collector, Gen. T. E. Wilcox.
  Bison alleni Marsh (skull).

4AH261. Little Minook Creek, Rampart district. Collector, F. L. Hess, 1904.
  Equus sp. (teeth).

—— Little Minook Creek, Rampart district. Collector, D. McLain, 1904.
  Bison occidentalis Lucas.

5514. Tanana River 20 miles above mouth. Collector, Charles Sheldon.
  Bison occidentalis Lucas.

---

[43] Gilmore, C. W., Smithsonian exploration in Alaska in 1907 in search of Pleistocene fossil vertebrates: Smithsonian Misc. Coll., vol. 51, no. 1807, pp. 1–38, 1908.

5AK100. Fairbanks Creek, claim no. 6 above Discovery. Collector, Adolph Knopf, 1905.

Bison alleni or latifrons (foot bone).

5AK101. Upper Cleary Creek. Collector, Adolph Knopf, 1905.

Bison alleni or latifrons (portion of skull).

5726. Little Minook Creek, Rampart district. Donor, J. W. Duncan. Collector, C. W. Gilmore, 1907.

Bison crassicornis Richardson (skull).

5727. Little Minook Junior Creek, Rampart district; Claim 21 above Discovery, from gravel just above bedrock. Donors, Bowen & Coole. Collector, C. W. Gilmore, 1907.

Elephas primigenius Blumenbach (bones).

Bison crassicornis Richardson (rear of skull).

—— Little Minook Creek, Rampart district; claim no. 1 above Discovery. Donor, C. B. Allen. Collector, C. W. Gilmore, 1907.

Elephas primigenius Blumenbach (calcaneum).

—— Little Minook Junior Creek, Rampart district. Collector, C. W. Gilmore, 1907.

Rangifer sp. (fragments of antlers).

7700. Sullivan Creek, near old Tofty, Hot Springs district. Collector, C. P. Snyder, 1912.

Equus niobrarensis alaskae Hay (skull).

7706. Hunter Creek, about 2½ miles above mouth, Rampart district; top of gravel beneath 20 feet of silt. Donor James Nelson. Collector, H. M. Eakin, 1911.

Bison alleni Marsh (skull).

—— East bench of Sullivan Creek, near old Tofty, Hot Springs district; silt 6 feet above basal gravel and 40 feet below surface. Donors, Tilleson & L'Heureux. Collector, J. B. Mertie, Jr., 1931.

Equus niobrarensis alaskae Hay (skull and lower jaw).

21AMt128a. Ruth Creek, tributary of Livengood Creek. Collector, J. B. Mertie, Jr., 1921.

Bison crassicornis (skull).

21AMt128b, c. Goodluck Creek, tributary of Livengood Creek. Collector, J. B. Mertie, Jr., 1921.

Elephas primigenius (tooth and upper end of humerus).

29ASS-11. Valley of Goldstream Creek, near junction of Pedro and Gilmore Creeks. Collector, P. S. Smith, 1929.

Equus lambei Hay (left upper premolar).

Equus of E. lambei Hay (right lower molar).

Bison sp. (left upper milk molar).

Citellus sp. (parts of skulls, three lower jaws, and several limb bones and vertebrae).

These vertebrates were identified largely by C. W. Gilmore and O. P. Hay, of the United States National Museum, who considered them to be of Pleistocene age. They include three or four species of buffalo, two species of horses, and one each of mammoth, caribou, and ground squirrel. Many other remains are also present, and, to judge by the Pleistocene vertebrate fauna collected in other parts of interior Alaska, there should also be included moose, bear, muskox, wolf, and other well-known genera that have persisted to the present day.

Several collections of fresh-water invertebrates and of plants have also been obtained from these older deposits, particularly from the silt. These are listed herewith:

Kindle 2. Rampart, from marl 640 feet above level of Yukon River. Collector, E. M. Kindle, 1906.

Lymnaea caperata Say.
Succinea chrysis West.

—— North bank of Yukon River 12 miles above Tanana; upper 7 or 8 feet of a bank 20 to 25 feet above river level. Collector, C. W. Gilmore, 1907.

Succinea grosvenori Lea.
Euconulus trochiformis Montagu.

29AS8–11. Valley of Goldstream Creek near junction of Pedro and Gilmore Creeks. Collector, P. S. Smith, 1929.

Lymnaea stagnalis (Linné).
Galba palustris (Müller).
Planorbis parvus Say.
Pisidium cf. P. scutellatum Sterki.

32AS100. Goldstream Creek, about 1½ miles upstream from the old Wagner property. Collector, P. S. Smith, 1932.

Mollusks

Lymnaea stagnalis jugularis Say.
Lymnaea (Stagnicola) palustris Müller.
Planorbis (Helisoma) binney Tryon.
Planorbis (Gyraulus) similaris F. C. Baker.

Diatoms

Melosira italica (Ehrenberg) Kützing.
Cyclotella cf. C. meneghiniana Kützing.
Fragilaria construens var. venter (Ehrenberg) Grunow.
Synedra crotonesis Kitton.
Synedra ulna (Nitzsch) Ehrenberg.
Synedra affinis Kützing.
Synedra capitata Ehrenberg.
Tabellaria fenestrata (Lyngbye) Kützing.
Achnanthes lanceolata Brebisson.
Cocconeis placentula Ehrenberg.
Navicula pupula Kützing.
Navicula radiosa Kützing.
Navicula cryptocephala Kützing.
Navicula cuspidata Kützing.
Navicula anglica Ralfs.
Navicula cf. N. hassiaca Krasske.
Navicula exigua (Gregory) Müller.
Pinnularia polyonca (Brebisson) Müller.
Pinnularia appendiculata (Agardh) Cleve.
Pinnularia borealis var. brevicostata Hustedt.
Pinnularia dactylus Ehrenberg.
Pinnularia interrupta W. Smith.
Pinnularia fasciata (Lagerstedt) Hustedt.
Caloneis trinodis (Lewis) Boyer.
Neidium affine var. longiceps (Gregory) Cleve.
Stauroneis anceps Ehrenberg.
Gomphonema subtile Ehrenberg.
Gomphonema constrictum Ehrenberg.
Gomphonema acuminatum Ehrenberg.
Gomphonema acuminatum var. coronata (Ehrenberg) W. Smith.
Gomphonema sphaerophorum Ehrenberg.
Gomphonema gracile Ehrenberg.
Cymbella cistula (Hemprich) Grunow.
Cymbella ventricosa Kützing.
Cymbella parva W. Smith.

Cymbella cuspidata Kützing.
Amphora ovalis Kützing.
Amphipleura pellucida Kützing.
Gyrosigma kützingi (Grunow) Cleve.
Surirella sp.
Epithemia hyndmanni W. Smith.
Epithemia zebra var. procellus (Kützing) Grunow.
Epithemia turgida (Ehrenberg) Kützing.
Rhapolodia ventricosa (Kützing) Müller.
Eunotia arcus Ehrenberg.
Eunotia alpina (Naegeli) Hustedt.
Eunotia sudetica var. bidens Hustedt.
Nitzschia denticula Grunow.
Nitzschia acuta Hantzch.
Hantzschia amphioxys (Ehrenberg) Grunow.
Spicules of fresh-water sponges.

35AS28–29. Valley of Engineer Creek, Fairbanks district. Collector, Stephen Taber, 1935.

Invertebrates.

35AS106. Valley of Engineer Creek, Fairbanks district. Collector, Philip S. Smith, 1935.

Lymnaea stagnalis jugularis Say.
Stagnicola palustris Müller.
Gyraulus parvus Say.
Helisoma trivolvis Say.
Sphaerium occidentale Prime.

35AS22–26. Valley of Goldstream Creek, Fairbanks district. Found in the silt. Collector, Stephen Taber, 1935.

Pieces of white spruce, Picea canadensis.

35AS27. Valley of Engineer Creek, Fairbanks district. Found in the silt. Collector, Stephen Taber, 1935.

Stems of a species of horsetail, Equisetum.
Leaves of the dwarf cassandra, Chamaedaphne calyculata.

35AS104. Ester-Cripple Creek area, Fairbanks district. Linings of ancient rat nests in the silt. Collector, Philip S. Smith, 1935.

Seeds of a species of dandelion (Taraxacum) and the ripened seed cases and seeds of a species of pink (family Caryophyllaceae).

35AS105. Ester-Cripple Creek area, Fairbanks district. Rat droppings in ancient rat nests in the silt. Collector, Philip S. Smith, 1935.

Fragmentary remains of seeds, a small puff-ball, and other vegetal material.

The two collections by Kindle were determined by the late W. H. Dall, of the United States National Museum. The mollusks of collections 29AS8–11 and 32AS100 were determined by W. C. Mansfield, of the United States National Museum, but the diatoms of collection 32AS100 were determined by K. E. Lohman, of the United States Geological Survey. Collection 35AS106 was determined by J. P. E. Morrison, of the United States National Museum. The four collections of plants were determined by Roland W. Brown, of the United States Geological Survey.

Most of these mollusks, diatoms, and plants are referable to species that are still living, and therefore they merely show that the silts from which they were obtained are not probably older than Pleistocene. The stratigraphy of these deposits also shows that the silt was laid down in late Pleistocene and Recent time.

RECENT ALLUVIAL DEPOSITS

As the glaciers north, east, and south of interior Alaska began to disappear, climatic conditions again began to change, and probably also conditions of erosion and sedimentation. The mean annual temperature must have risen, and changes in precipitation may also have occurred. The flood of glacial outwash from the glaciated regions subsequently diminished, and great rivers like the Yukon and the Tanana began to erode and dissipate the aggraded alluvial material in their headwaters. In short, climatic conditions and geomorphic processes like those that are going on at the present time were established.

The Recent alluvial deposits are composed mainly of gravel, sand, and silt. Much of the coarser debris has been eroded from bedrock sources and laid down by the present streams. The silt has been derived in considerable measure from the reworking of the older silt, although a certain proportion has also been deposited by recent streams. Certain solifluxional processes peculiar to sub-Arctic regions have also tended to produce fine sediments of this type. The following sketch will serve merely as an outline of the processes involved.

Stream detritus originates largely by mechanical and chemical weathering of the regional bedrock, but in interior Alaska the relative importance of these methods is modified by local conditions. Chief among these are the low mean annual temperature and the vegetation. The mean annual temperature of the Yukon-Tanana region is about 9° below freezing, which alone is capable of producing a condition of permanent frost in the subsurface. In addition to this, the valley floor and sides and also the ridge tops up to an elevation of 3,000 feet are covered with a mantle of mosses and other vegetation, which act as an insulator and tend to prevent the summer heat from penetrating far into the frozen ground below. And these two conditions combine to produce a curious disposition of the local precipitation, for the frozen condition of the deeper ground prevents deep circulation of water, and the mosses prevent a rapid surface run-off of the rainwater. Therefore, the moisture is conserved in a spongelike mossy mat close to the surface, where it favors the growth of vegetation much denser than might be expected in a region where the annual precipitation is only 11 or 12 inches.

The customary distinction between the water table and the zone of weathering above the water table is in this region hardly valid, for much of the subsurface water, where present, is frozen. Hence the solvent and depositional effects of circulating ground water are almost lacking, and the chemical effects of oxygen and carbon dioxide are sharply restricted, because these reagents are not carried in solution. Chemical weathering, therefore, is much less important as an agent of weathering than in regions farther south.

The surface of the ground in summer, however, is in a state of alternate thawing and freezing that produces marked mechanical weathering, due to the effects of frost heaving and related processes. The bedrock is loosened and fractured by the freezing and thawing of water, and an angular rubble that shows little oxidation is produced. This rubble tends to accumulate on the ridges as residual material. But the same thrusting forces that fracture and comminute the bedrock are also effective as a means of transportation, for the rock debris is thrust upward and laterally away from its place of origin and begins to move slowly down the hill slopes into the valleys below. Such moving sheets of alluvial material often develop characteristic flow lines along the sides of the valleys so that they resemble successive waves on a shallow body of water. (See pl. 13, *A*.)

Although chemical weathering in the headwater regions of the streams is sharply restricted, and mechanical weathering is seasonal, nevertheless the total amount of debris that is moved by the processes above outlined is remarkably great. It is not uncommon to observe sheets of such alluvial material impinging from both sides of a valley upon a headwater stream at a rate faster than the stream can transport the material downstream, so that the stream tends to flow in a narrow channel, sometimes several feet deep and only a foot or two wide; and in places the lateral debris has actually coalesced over the running water.

This residual and semiresidual material is unsorted and includes rock fragments of all sizes, embedded in fine silt. Where the alluvial sheet has moved laterally a considerable distance from its place of origin to a drainage channel, the angular debris becomes rounded to a considerable degree. As soon as this material is exposed to the effects of running water, it begins to move downstream, the silt rather rapidly, especially in times of flood, and the larger rubble more slowly. From this stage onward, however, the erosional processes are essentially similar to those that prevail in more southern latitudes, and the results are essentially the same. The headwater gradients are normally steeper than the gradients of the lower valleys, and at some point or rather some zone in the valley stream action changes from transportation to deposition. As the regional relief is reduced and the headwater gradients are diminished, this zone of deposition moves upstream, thus developing progressively upstream a fluviatile gravel sheet. As the upper part of the gravel sheet is extended upstream, finer sediments cover the lower part, with the final result that the coarser and heavier sediments form the base of the alluvial section. The uniformity of this process is interrupted by floods, which carry coarse material farther downstream than it would ordinarily go and deposit it on top of finer material, thus resulting here and there in alternating beds of fine and coarse material. This general process of stream alluviation is also modified by local conditions. For example, Minook Creek, in the Rampart district, has been rejuvenated in recent time by a local lowering of the baselevel of erosion. This rejuvenation has operated to produce increased gradients in the lower valleys of Minook Creek and its tributaries, and this in turn has operated to erode the older gravel and to replace them with coarse detritus of the type that would ordinarily be found in the headwater parts of these streams.

Another condition that modifies the character of the Recent alluvial deposits is the effect of winter ice. In the larger rivers, like the Yukon, a great thickness of ice accumulates in winter, and when the spring break-up occurs this moving ice becomes a powerful abrasive tool operating upon the underlying gravel. Partly as a result of this movement, and partly as a result of conditions that exist during the formation of this river ice, extensive boulder pavements are developed at places, particularly along the lateral river bars. One of these boulder pavements is shown in plate 14. The boulders in these pavements are faceted, scratched, and grooved in a manner so resembling the effects of glaciation that the two cannot be easily distinguished. In some of the smaller streams the ice increases greatly during the winter, both in thickness and in area, as a result of overflows of water, acting under hydrostatic pressure from upstream. Such bodies of ice do not move downstream in the spring with the normal winter ice but are dissected by the streams and often remain as valley ice, or "aufeis", nearly all summer. Such deposits of aufeis also have the effect of widening valley floors, for in spring, when the water first begins to flow, channels may be cut along the sides of the ice, thus diverting the stream against the valley walls and producing lateral erosion. Many stretches of wide flat valley floor on the tributaries of the Yukon have been produced in this manner, and it is quite possible that the same process, acting on a larger scale during the glacial epoch, may have been a powerful accessory factor in the development of the Yukon Flats.

On the Tanana side of the Yukon-Tanana divide conditions are somewhat different from those existing about Rampart. The headwater portions of streams that head in high country, such as Hutlinana Creek have narrow gravel sheets much like that on upper

Minook Creek, but the lower valleys of all the streams, such as the Tolovana River and Baker and Patterson Creeks, are deeply buried with older alluvium. The Baker Creek Valley, including the lower valleys of Hutlinana and Hutlitakwa Creeks, may be regarded as typical of the conditions of Recent alluviation in the Hot Springs district. This valley is a wide timbered alluvial plain, with swamps and lakes, that slopes very gradually upward from the main drainage channels to the valley walls. Much of the upper part of the old alluvial filling is silt, underlain by a relatively thin deposit of gravel resting on bedrock. This gravel was largely deposited in the ice age and has not been subsequently removed, because aggradation of the Tanana Valley by its tributaries has maintained a relatively high baselevel of erosion. Baker Creek about 15 miles northeast of Hot Springs is deeply incised in this older alluvium but is nevertheless not flowing on bedrock. Its bed is lined with Recent alluvium, carried down from the hills, but the gradient is so low that the coarser debris is dropped farther upstream, and in periods of flood only the finer detritus is transported to the Tanana. In this manner coarse Recent alluvium has been distributed over the finer silty material of the ice age at those localities where the mountain streams debouch into the wide expanse of Baker Creek. This process can be observed particularly well at places like the lower end of Shirley Bar, where mining operations have been carried on in the upper thin veneer of coarser present alluvium that overlies the older silt of the Baker Creek Valley.

Without going into details, the general sequence of events of late Tertiary and Quaternary erosional history from oldest to youngest may be summarized as follows:

1. Deformation and mountain building in mid-Tertiary time, whereby the coal measures and earlier rocks were greatly deformed. Granitic rocks were also intruded at or about this same time. Both the folding and the granitic intrusion probably caused local warping of the surface of the country, which produced marked changes in preexisting drainage channels.
2. Long-continued regional erosion, whereby a maturely dissected land surface was developed.
3. Regional or epeirogenic uplift in the Pliocene epoch, accompanied by local warping of the surface, followed by lowering of the baselevel of erosion in late Pliocene and early Pleistocene time. These events produced the system of terraces so well developed along the Yukon and its tributaries.
4. The coming of the ice age, during which glaciation on a large scale occurred in the Alaska and Brooks Ranges and in the headwaters of the Yukon River. Alpine glaciation also occurred locally in the higher part of the Yukon-Tanana region.
5. Further elevation of the baselevel of erosion, in late Pleistocene time, and the deposition of thick deposits of silt up to an elevation of 1,200 feet or higher. Such deposits are not restricted to the Tanana Basin but are also present in contiguous parts of the Yukon Basin. By the silt alluviation

old drainage channels were largely filled and the earlier bedrock channels were efficiently concealed, so that many streams migrated from their underlying bedrock channels and were therefore superposed upon old valley walls or even cut into preexisting bedrock divides. Numerous examples of this process are known in this region, of which a conspicuous one is the superposition of the Hess-Yukon drainage upon the bedrock divide between Hess Creek and the Yukon Flats.

6. The dissipation of most of the glacial ice, and the aggradation of the Tanana Valley by outwash deposits, thus raising the baselevel of erosion in the Yukon-Tanana region. Silt was deposited in this cycle up to an elevation of 600 feet in the tributaries of the Tanana River. The aggradation of the Tanana Valley, though it accounts for the raising of the baselevel of erosion, does not explain the character of the silt deposits, their wide distribution from the headwaters to the mouths of the tributary streams, and the paucity of other types of detritus.

7. Regional lowering of the baselevel, in the course of which the rejuvenated streams quickly eroded and transported downstream the soft silt deposited during the preceding cycle. As a result of these processes, the thick alluvial deposits in the lower tributaries of the Tanana are characterized by the following generalized section:

(*a*) A coalescing detrital sheet of Recent age that follows the junction of the hills with the present wide valley floor.

(*b*) Silt and fine sand of Pleistocene age underlying the Recent gravel along the borders of the hills and forming the surface of the valley floor farther down in the valleys.

(*c*) Early Pleistocene gravel that underlies the silt and lies upon bedrock. The deep placers of the Chatanika River and Sullivan and Woodchopper Creeks are a part of this older gravel.

IGNEOUS ROCKS

PRINCIPAL GROUPS

Igneous rocks form an important part of the geologic sequence in the Yukon-Tanana region. Several groups of such rocks have been recognized, and some of them have been separately mapped. The oldest igneous rocks of the region are certain amphibolites, hornblende schists, and chlorite schists that are mapped with the Birch Creek schist, although not considered to be an integral part of it. These rocks are the metamorphosed equivalents of basic intrusives, and perhaps extrusives, that originated in early pre-Cambrian time. They are younger than the oldest rocks of the Birch Creek schist, but those of effusive character may be more or less contemporaneous with the youngest rocks of the Birch Creek schist. No detailed petrographic studies of these ancient basic meta-igneous rocks have been made, but their general character is mentioned in connection with the description of the Birch Creek schist (pp. 51–52).

Another group of metamorphic igneous rocks is the Pelly gneiss. This formation, which occurs principally in the eastern part of the Yukon-Tanana region, consists mainly of granite gneiss but includes also darker-colored varieties of monzonitic, dioritic, and even gabbroic origin. Where greatly metamorphosed, these rocks grade into feldspathic quartz-mica schists. The petrographic character of these metamorphic rocks is given in the following pages. The Pelly gneiss has not been separately mapped but could easily be differentiated as a separate unit among the metamorphic rocks by more detailed work. It intrudes the older rocks of the Birch Creek schist and is probably younger than all the crystalline schists but is nevertheless considered to be of pre-Cambrian age.

A third group of pre-Cambrian igneous rocks comprises the younger basic lavas of pre-Cambrian age. These lavas are not known to occur in the Yukon-Tanana region but are well developed a short distance north of the Yukon, along the international boundary. They have been described by the writer in an earlier publication [44] and include amygdaloidal basalts and a variety of associated pyroclastic rocks. In their type locality these rocks are not recrystallized and constitute a part of the nonmetamorphic rocks described elsewhere in this report as the Tindir group. They are believed to be of late pre-Cambrian age and are definitely younger than the crystalline rocks of the Birch Creek schist.

The oldest igneous rocks of Paleozoic age are the basic lavas, tuffs, breccias, and agglomerates of greenstone habit which are typically exposed in the White Mountains. These have been designated the Fossil Creek volcanics. From fossils found in the uppermost tuffaceous beds this formation is assigned to the Middle Ordovician. No detailed study has been made of these lavas and the pyroclastic rocks associated with them, but their general character is outlined in the description of the rocks of the Ordovician system (p. 82).

Another group of basaltic lavas of greenstone habit, with associated pyroclastic rocks, occurs along the Yukon River between Coal and Thanksgiving Creeks and also probably north of Victoria Creek. These rocks are interbedded with massive limestone and with more or less shale, slate, and chert. These lavas and associated rocks have been called by the writer the Woodchopper volcanics. The lava flows are normal basalts, whose general character is set forth in the description of the Woodchopper volcanics (pp. 96–97).

Succeeding the Woodchopper volcanics is a group of basic and ultrabasic rocks, composed mainly of serpentine, that have a wide distribution in the Yukon-Tanana region. The age of these rocks is not definitely known, but inasmuch as they intrude the Middle Devonian sequence and have not been observed in intrusive relations to the Carboniferous rocks, they have been referred tentatively to

---

[44] Mertie, J. B., Jr., The Tatonduk-Nation district: U. S. Geol. Survey Bull. 836, pp. 380–382, 1932.

the Upper Devonian. Their general petrographic character is given in the following pages.

The greatest outpouring of basic lavas that has occurred in the geologic history of the Yukon-Tanana region took place in early Carboniferous time. Good-sized bodies of basic intrusive rocks were also developed at about the same time. The lavas and tuffs, though essentially basic in character, also include some acidic types; and all of them are interbedded with a considerable proportion of sedimentary rocks. This great assemblage of volcanic material with the interbedded sediments is known as the Rampart group and is well developed along the Yukon River, both above and below the Yukon Flats. The igneous members of the Rampart group are separately described in the following pages.

The Mesozoic era was marked by the revival of granitic intrusion in the Yukon-Tanana region. Immense batholiths of granitic rocks, as well as smaller intrusive bodies of the same material, invaded the Paleozoic and pre-Cambrian rocks, sometime in the mid-Mesozoic. The larger intrusive masses are particularly well developed in the eastern part of the region, but smaller intrusive bodies also occur as far west as the Fairbanks district. These granitic rocks are the ultimate source of some of the placer gold in the Fairbanks, Circle, Seventymile, and Fortymile districts. Their petrographic character and probable age are further discussed in a later section of this report.

After these Mesozoic granitic rocks had been injected into the older rocks, there occurred, possibly in early Tertiary time, a great outpouring of lavas of acidic and intermediate composition, comprising mainly rhyolite and dacite. These lavas were poured out chiefly in the eastern and southeastern parts of the Yukon-Tanana region, where they now rest upon the crystalline schists and the Mesozoic granitic rocks. As no Mesozoic sediments are present in this part of the region, and as the age of the Mesozoic granitic rocks is not precisely known, the age of these lavas cannot be accurately determined, although they are thought to be of early Tertiary age. The petrographic character of these lavas is described in a later section of this report.

Sometime in the early Tertiary there occurred another period of injection of granitic rocks. The surface croppings of these rocks are confined to the west end of the Yukon-Tanana region, but there are reasons for the belief that they may also exist in other areas, particularly in the Fairbanks, Seventymile, and Fortymile districts. These granitic rocks are distinctly different from the Mesozoic granitic rocks, not only in their petrographic character but also in regard to their metalliferous associations. They are the ultimate source of most of the placer gold in the Livengood and Hot Springs districts and are also believed to be the source of the cinnabar found in so many of the placer concentrates in these and other mining districts. A detailed description of these rocks is given on pages 219–226.

Late in Tertiary time and extending into the Quaternary, lavas of several diverse types, ranging from acidic to basic, were erupted at the surface. These occur in the eastern part of the Yukon-Tanana region, near the international boundary, and extend still farther east into Yukon Territory. Some of these lavas are very recent, and at one locality on the Dennison Fork of the Fortymile River a volcanic cone is still well preserved. In various parts of this region there are also dikes of basic and intermediate igneous rocks, which are quite unaltered and may be genetically related to these late lavas. Further details of the late Tertiary and Quaternary lavas are given below.

The groups of igneous rocks above outlined include the more abundant types that are now known, but they by no means represent a complete record of the regional volcanism. In the early stages of reconnaissance mapping in this region, when the work was being done by means of linear traverses, without the aid of topographic maps, many collections of igneous rocks were made with the idea of learning something about the great petrographic diversity of such rocks. Hundreds of thin sections of these igneous rocks were cut, and subsequently most of these were examined by the writer. Many curious types of rocks were found in these collections, but the linear nature of the early work makes it impossible, even where the exact localities are known, to utilize these data for cartographic purposes. These sections show, however, that there are numerous specialized varieties of igneous rocks in this region, which the writer cannot specifically allocate in the geologic section. Many of these, perhaps, are the end-products of magmatic differentiation and probably belong in the major groups above outlined. Others may represent periods of volcanism which the writer has not recognized; and finally, it must be remembered that considerable areas in the Yukon-Tanana region have not been visited by any geologist or have been mapped only from a considerable distance. The igneous geology of the Yukon-Tanana region therefore presents a vast field for future investigation and study.

PELLY GNEISS

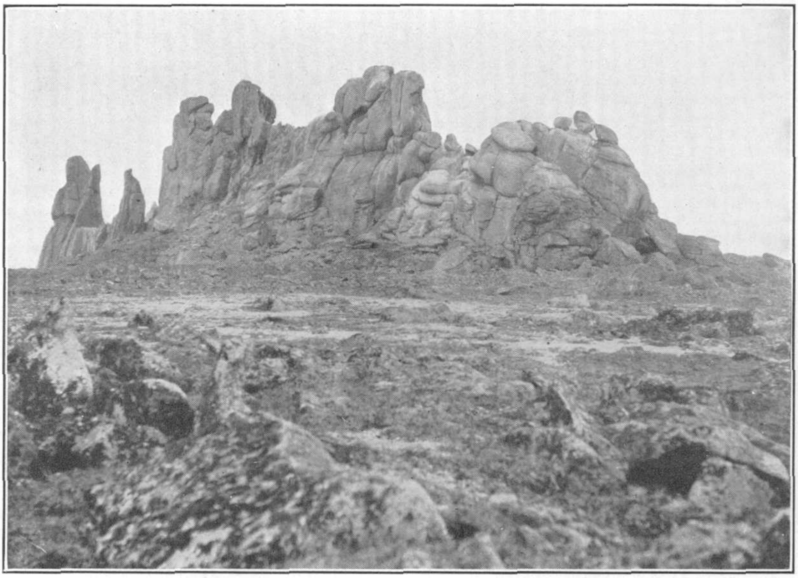
The general occurrence of the Pelly gneiss and its relation to the Birch Creek schist have already been set forth. Its petrographic character is described below.

The Pelly gneiss consists mainly of granitic rocks but locally includes darker varieties of monzonitic, dioritic, and even gabbroic character. The granitic gneisses are typically light-colored rocks, having a secondary structure that ranges from laminated gneissoid to the contorted schistose fabric, and therefore they grade from a rather massive gneiss to a feldspathic quartz-mica schist. At some localities, particularly along ridge tops, these gneisses weather residually into monolithic outcrops. (See pl. 15, *A*.) The more common gneissoid type is characterized by many augen, usually of feldspar, rarely of quartz, which range from 3 inches in diameter downward to microscopic dimensions. (See pl. 15, *B*.) At some places feldspar augen are so thickly crowded together that it is difficult to obtain a specimen of the matrix, and many of these are elongated in the ratio 1 : 1½.

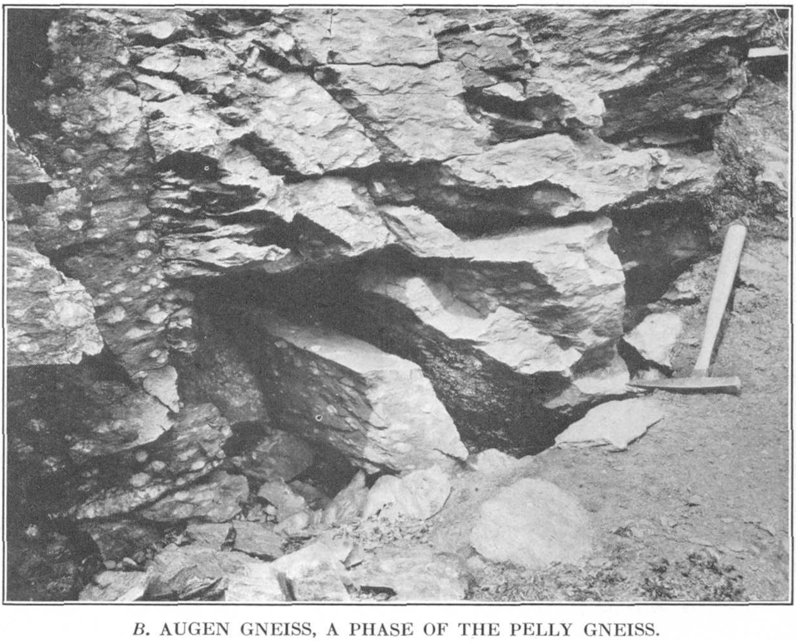
Under the microscope the range of the Pelly gneiss from originally granitic to gabbroic types is even more evident. Rocks that appear to be classifiable as originally granite, quartz monzonite, granodiorite, quartz diorite, and quartz gabbro have been recognized. In the granitic types quartz, orthoclase or microcline, albite, and mica seem to constitute the essential mineral components; the accessory minerals are apatite, zircon, garnet, and magnetite, and the secondary minerals are quartz, sericite, several varieties of chlorite, epidote, calcite, and iron hydroxides. Of the micas, biotite is much more common than muscovite, but as these rocks veer toward feldspathic schist muscovite becomes more common than biotite. In the monzonitic and dioritic types both orthoclase and plagioclase occur in varying amounts, though in a few such rocks potash feldspar is entirely absent; and in these more basic types green hornblende becomes the prominent mafic mineral in place of mica, and titanite and magnetite become more prominent among the accessory minerals. The quartz gabbro types are closely related to the quartz diorites, in that hornblende, and not pyroxene, still constitutes the main dark mineral, although the plagioclase is sufficiently basic to render the designation quartz gabbro applicable.

The constant and locally high percentage of albite among the alkali feldspars of the granitic gneisses is perhaps the most interesting petrographic feature. In some specimens albite and orthoclase are present in a 1 : 1 ratio; in others a much smaller amount of albite occurs; and in some oligoclase rather than albite is present. This sodic feldspar appears to be of three types. One is the result of a replacement of orthoclase and plagioclase by albite and oligoclase, which occurred during the leaching and decomposition of the original feldspars. The second type of albite is believed to be original magmatic material. Such albite is intergrown with quartz and orthoclase

BOULDER PAVEMENT, YUKON RIVER NEAR RAMPART.



A. RESIDUAL WEATHERING OF THE PELLY GNEISS.



B. AUGEN GNEISS, A PHASE OF THE PELLY GNEISS.

in a fabric that seems original, though the crystals may be crushed or elongated by later deformation. Graphic or perthitic intergrowths are rare, and much of this albite is untwinned. The third type is crystalloblastic albite that is really more characteristic of the feldspathic schists.

GREENSTONE INTRUSIVES

DISTRIBUTION

The ultrabasic and basic intrusives occur in two belts that have a pronounced linear distribution. The largest and most persistent of these is a belt that begins at the Tanana River between the mouths of Salcha and Chena Rivers and extends intermittently N. 75° E. to the head of the Salcha. Along the same direction these rocks reappear east of the batholith in the Charley River Valley, at the head of the Seventymile River, and then continue S. 60° E. as intermittent bodies to and probably beyond the international boundary. These rocks form the river bluff just below Eagle. In the other belt these rocks are found both east and west of the Livengood mining camp and as small bodies near Livengood and in the valley of Troublesome Creek. The trend of this belt is also N. 75° E.

Certain basic intrusives of greenstone habit are also found in the Livengood district, cutting the Livengood chert, and similar greenstones cut the undifferentiated Mississippian rocks that lie between Beaver and Victoria Creeks. These and other undifferentiated greenstone intrusives in the region are for convenience included in this cartographic grouping.

PETROGRAPHIC CHARACTER

These intrusive greenstones have been little studied, and in fact few of the field occurrences have been seen by the writer. In the principal belt, however, the writer has seen these rocks where they occur along the ridge north of the Salcha River and northeastward therefrom. This ridge and other ridges and buttes in the higher parts of the region composed of these rocks have a yellowish-brown color and smooth rounded outlines, so that they are strikingly different from the surrounding hills. At close range the rocks north of the Salcha River were found to be a body of serpentine, greatly brecciated along the borders. These fractured zones are filled with secondary minerals, such as calcite, quartz, and chalcedony. Some of this fractured material is ophicalcite. The main mass of serpentine does not show clearly its true origin, but it is probably derived from some ultra-basic intrusive, such as dunite. Farther northeast, however, one of the smaller buttes at the head of the Salcha River was found to be composed of a serpentinous rock, derived from olivine diabase. Other specimens of these rocks, collected by Prindle in 1905, probably at the southwest end of this belt, show clearly their ultrabasic origin, being composed of olivine, altered in part to serpentine, together with tremolite and magnetite. In the same belt the rocks composing Mount Sorenson, at the heads of Flat and Fisher Creeks, were found to be largely serpentine, and some of them were derived from olivine.

Few of these rocks from the northern belt have been examined by the writer. The hills in this part of the region are lower, and these rocks do not have the same conspicuously colored croppings as those in the Salcha-Chena belt. Small bodies of serpentine occur along the south flank of the ridge south of Livengood, and this rock under the microscope appears to be largely serpentine, with some magnetite. The serpentine occurs as anastomosing veinlets and stringers and is evidently secondary after some ultrabasic or basic rock. West of Livengood, however, along the ridge south of the West Fork of the Tolovana River, the observations and thin sections of Overbeck show that a variety of rocks occur, which are grouped under the generic designation of "greenstone." Some of these rocks are altered diabases and diorites, but true serpentine was not observed. Northeast of the Livengood district, in this northern belt, there also occur a variety of greenstones, some of diabasic composition and others which are black glassy-looking rocks, suggestive of ultrabasic lava flows.

In general, therefore, these rocks may be said to be largely of intrusive origin, but they clearly include both ultrabasic and basic types, both of which are partly or wholly altered to serpentine and chloritic products. They are of particular interest because they appear to be a source of chromite and other chromiferous minerals. Thus, in the vicinity of the small bodies of serpentine south of Livengood, a small body of chromite was exposed in the course of prospecting a low-grade gold deposit. The size of this body of chromite was not determined, as the prospecting was being done for gold. The nearby serpentine also contained numerous grains of chromite, scattered throughout the rocks. Moreover, picotite (chrome spinel) was found by the writer in practically all the placer concentrates in the Livengood district. A trace of nickel was found in some of this lode rock by Overbeck, and a small nugget of platinum was found in the clean-up in one of the creeks draining to the southwest from this area. These facts suggest that ores of nickel and platinum may possibly be found in the vicinity of these ultrabasic rocks.

AGE AND CORRELATION

In the Salcha-Chena area no data are available for determining the geologic age of these ultrabasic and basic rocks, as they lie in contact with the crystalline schists. To the northeast, however, this southern belt is interrupted by the Mesozoic granitic rocks, indicating that they are older than these acidic intrusives. Northeast of the Charley River batholith they intrude somewhat metamorphosed rocks which are doubtfully referred to the Devonian. These rocks in the southern belt are therefore probably late Devonian or post-Devonian in age.

In the northern belt the data are somewhat better. The serpentine south of Livengood intrudes rocks from which Middle Devonian fossils have been collected; but it has not been found to the north in the Livengood formation, which is regarded as the basal part of the Mississippian sequence. This localization of the ultrabasic rocks shows that they are younger than the Middle Devonian sequence and suggests strongly that they are older than the Mississippian rocks. These rocks are therefore referred to the Upper Devonian.

The small bodies of basaltic and diabasic greenstone that intrude the Livengood chert and the undifferentiated Mississippian rocks in the northern part of the Fairbanks quadrangle are obviously not of Upper Devonian age, but they are thought not to be younger than Paleozoic and may well be representative of the intrusives associated with the Rampart group.

BEDDED IGNEOUS ROCKS OF THE RAMPART GROUP AND ASSOCIATED INTRUSIVES

The general distribution, lithology, age, and correlation of the Rampart group have been given in the description of the bedded rocks (pp. 122–129). In the following pages the petrographic character of the bedded igneous rocks of the group and the associated intrusives is described.

These igneous rocks, as seen in the belt southwest of Fort Hamlin, consist largely of volcanic flows, tuffs, and breccias, together with a minor but undetermined proportion of intrusive rocks, which, however, are not properly a part of the group. Most of these rocks are characterized by a dark-green color, which, however, is in places modified to lighter hues of green by the presence of considerable amounts of secondary minerals, such as calcite and zeolites. On oxidation at the surface all these rocks change to various hues ranging from yellow brown to brownish red, and here and there even more brilliant tints of red are developed. The brownish range of hills that lies along the northwest side of the Yukon River at and above Rampart is typical of the weathered appearance of these rocks.

In granularity the bedded lavas range from rocks that are too fine-grained to show the individual grains up to fairly coarse rocks of diabasic habit, in which the principal constituent grains are easily visible. The intrusive rocks are still coarser and have the appearance of coarse-grained diabase and gabbro. Some of the lavas were originally vesicular and by subsequent filling of the gas cavities have now become strikingly amygdaloidal. Porphyritic varieties of the lavas are also found. The tuffs likewise vary greatly in granularity, ranging from rocks whose fragmental character is not determinable in hand specimens to coarse flow breccias, though the latter are rather uncommon. The fine-grained nature of many of the tuffs, together with the similar alteration of lavas and tuffs, makes it difficult to distinguish these two types in the field. The tuffs, however, have been particularly susceptible to the influence of later mineral-bearing solutions and are therefore more likely to show extensive silicification than the lavas.

Field observations have shown that the most common types are diabase and basalt of greenstone habit. Tuffaceous rocks are next in abundance. Greatly altered rhyolites, andesites, and intermediate types of lavas and tuffs are also found in small areas, particularly in the basin of Garnet Creek. The intrusive rocks range in composition from basic diorite to gabbro. The following petrographic characters have been determined from about 60 thin sections of the igneous rocks of the Rampart group.

The diabases and basalts are similar in mineral composition and differ mainly in their fabrics. If the diabasic or ophitic fabric is defined as one in which crystals of pyroxene constitute the matrix for bladed laths of feldspar, most of the so-called diabases are not so in fact. This definition may be broadened slightly to indicate that the feldspar crystallized earlier than the pyroxene, so that feldspar laths project into crystals of pyroxene. Under this definition at least half of the lavas of this group should be called diabase. The fabric of the basalts is the so-called intersertal fabric, in which the space between the crystals of pyroxene is filled with laths of feldspar, as well as other minerals. The basalts are also noticeably finer-grained than the diabases. Most of the diabases and basalts are equigranular rather than porphyritic, but in the porphyritic varieties pyroxene is more commonly developed as a phenocryst than feldspar. The basalts also grade into still finer grained rocks in which a proportion of the ground mass was originally glassy.

The essential minerals of the diabases and basalts are plagioclase feldspar, pyroxene, and magnetite (or ilmenite). Apatite is a common accessory constituent and in some rocks is rather plentiful. Olivine is very sparingly developed—in fact, no olivine was found in any of the sections of rocks collected along the Yukon, though it has been observed in some of the greenstones near Livengood.

The tendency is for these lavas to be a little more acidic than normal diabases and basalts, and therefore, instead of olivine, accessory primary quartz appears in numerous specimens, and the plagioclase is more than normally acidic.

The plagioclase feldspar occurs mainly as lath-shaped crystals, and ranges in original composition from basic andesine to acidic labradorite. Where zonal growths occur the range is usually from oligoclase to labradorite. The pyroxene is invariably augite, ranging from pale yellowish green through a light dusty brown to almost colorless. The iron ores occur in equidimensional euhedral to subhedral grains, and the apatite in subhedral laths and needles. The feldspar and pyroxene of these rocks are considerably altered, the feldspar commonly more than the pyroxene. By the leaching of lime the plagioclase in some of these rocks has been albitized, yielding a porous cloudy oligoclase or albite, which gives a more alkalic aspect than the original composition warrants. Sericite and kaolinic products have also been formed in the alteration of the plagioclase. The pyroxene is commonly altered to various chloritic minerals, though in certain rocks the high-temperature alteration to hornblende has occurred. Where the basalts are partly glass, this rock glass has been chloritized, frequently to a nearly isotropic chloritic mineral. The iron ores are also altered to a greater or less extent to hematitic and limonitic materials. Secondary titanite, or leucoxene, is developed from the ilmenite. Secondary calcite is plentiful, and epidote and various zeolites are present in some of the rocks. Pyrite is developed here and there. These data suffice to show that these rocks are normal basic lavas, which have developed a typical greenstone habit.

The tuffaceous rocks of the Rampart group are composed largely of fragments of volcanic material, but the collections so far made indicate that this material includes not only basaltic but also andesitic, dacitic, and rhyolitic debris. In general the tuffs are made up of subangular to rounded grains of feldspar, felsitic and basaltic rocks, calcite, chloritic material, and silica. Some detrital quartz is also present, and by increase in this constituent the tuffs grade into impure sandstone, or graywacke. The calcite in some specimens is evidently an original constituent, and by increase in this mineral, the tuffs also grade into calcareous tuff and tuffaceous limestone of the type from which fossils have been collected. The tuffs also grade into chert, but in such rocks the nature of the silica is doubtful. Some of it is undoubtedly secondary, but another part is almost as certainly of original sedimentary origin. The determination of the original nature of the tuffs is rendered somewhat uncertain by their high degree of alteration. Most of the feldspars are albite, but some of this albite is secondary. Grains of felsitic volcanic material, however, composed essentially of albite and in some specimens mixtures of quartz and albite, show clearly the more acidic character of some of the tuffs.

Rhyolitic lavas and tuffs that constitute a part of the volcanic rocks of the Rampart group in the valley of Garnet Creek, southwest of Rampart, were described by Eakin.[45] These rocks as observed by the writer were found to have a pronounced structure, suggestive of lamination or bedding, striking N. 70° W., which is a variance of 40° from the regional strike of the rocks of the Rampart group. The dip is 70° S. Probably this variance is due merely to local folding. These rocks appear white or buff when viewed from a distance, but along the southwest side of Garnet Creek they exhibit many colors, including green, gray, and red. Some of them resemble banded chert. Others are manifestly fragmental and suggest silicified tuffs and breccias. Here and there are banded zones characterized by opaloid spherulites from very minute size up to half an inch in diameter. Some of the weathered material is porous. The most striking characteristic is the great diversity of color, texture, and lithologic character represented. Under the microscope most of these rocks are clearly fragmental and seem to consist largely of angular pieces and irregular areas of chert, spherulites of quartz and feldspar, calcite, zeolites, and secondary chalcedonic silica. Some of the spherulites show fine-grained graphic intergrowths of quartz and feldspar. In some specimens serpentine is extensively developed. Only one or two thin sections seemed to be true rhyolitic flows, all the others appearing to be fragmental. These rocks are so greatly silicified and otherwise altered that no reliable determination of the feldspar could be made. Some of the feldspar in the spherulites is apparently orthoclase, but some is apparently albite. It is believed, however, that these rocks are really derived from rhyolitic material, possibly a soda rhyolite. Probably a detailed areal investigation would reveal a greater proportion of such lavas. The rocks seen by the writer appear to be largely rhyolitic tuffs and breccias, replaced by silica, zeolites, and calcite. These rocks strongly suggest a correlation with a similar group of fine-grained rhyolitic and dacitic flows and tuffs in the valley of the Sulatna River, in the Ruby district.[46]

Eakin [47] has also described reddish andesites, interbedded with greenstones, as an integral part of the Rampart group. Such rocks were observed at the head of Squaw Creek, northwest of Rampart.

---

[45] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 18–19, 1913.

[46] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 60–62, 1924.

[47] Eakin, H. M., op. cit., p. 19.

No thin sections of these are available, but in view of the andesitic character of some of the tuffs between Rampart and Fort Hamlin, such rocks may have formed an appreciable part of the volcanic sequence.

Coarse-grained intrusive rocks form only a minor proportion of the igneous rocks but are present at several places along the Yukon above Rampart and also in the valley of Hess Creek and its tributaries. The general character of these rocks as here described is based on an examination of about a dozen of the sections. In general, they consist of gabbro and pyroxene diorite, locally containing also a considerable proportion of quartz. These are hypidiomorphic granular massive dark-green rocks made up essentially of plagioclase feldspar, augite, rarely hornblende, and iron ores, with accessory quartz, apatite, biotite, and rarely zircon. They grade, by a change in fabric, into coarse-grained diabasic rocks. The plagioclase ranges in composition from labradorite to andesine, and therein these rocks differ markedly from the pyroxene-bearing monzonitic rocks elsewhere exposed in the Rampart and Hot Springs districts, which have more alkalic feldspars. The feldspar and pyroxene are altered in the same manner and to much the same degree as in the basic lavas, and these rocks are therefore also classified as greenstones. They suggest strongly the basic intrusive rocks associated with the Strelna formation in the Kotsina and Kuskulana Valleys of southern Alaska.[48]

In the description of the general stratigraphy of the Rampart group it was stated that the Circle volcanics, which are exposed along the Yukon River upstream from Circle, are now correlated in general with the Rampart group. These Circle volcanics appear to contain a smaller proportion of interbedded fragmental rocks than the Rampart group in its type locality, but the igneous members of the group are essentially the same and will not be separately described.

Another group of greenstones that are correlated with the Rampart group are found in the southeastern part of the Yukon-Tanana region, north of the Tanana River. These rocks were originally differentiated by Brooks[49] and have not subsequently been visited by any other geologist. Ten thin sections, however, have been examined by the writer, and the information derived from these sections constitutes the basis for the following description.

Four types of rocks are represented—gabbro, diabase, basalt, and ultrabasic rocks—all much altered, with the development of a greenstone habit. The gabbro is a coarse-grained hypidiomorphic granu-

[48] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 67–69, 1923.

[49] Brooks, A. H., A reconnaissance in the White and Tanana River Basins, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, p. 470, 1900.

lar rock composed essentially of kaolinized plagioclase feldspar, pyroxene largely altered to chloritic products, and iron hydroxides. In one or two specimens the original rock-forming minerals have been completely replaced by secondary minerals, such as quartz, chlorite, calcite, and epidote. The diabasic and basaltic greenstones differ from the gabbroic greenstone mainly in their finer granularity and different fabric and on the whole are less altered than the gabbroic rocks. Chlorite, calcite, and quartz are the main secondary minerals. Three specimens of ultrabasic greenstones consist essentially of olivine, with a considerable percentage of magnetite or ilmenite in elongated patches along lines of cleavage. Actinolite is an abundant constituent of one of these specimens. Brooks also mentioned the presence in this assemblage of dioritic greenstone (metadiorite) and tuffaceous greenstone.

These rocks are closely associated with the Mississippian rocks of this area known locally as the Wellesley formation, and for this reason the writer believes that they are probably a part of the Rampart group. Their petrographic character, however, suggests that they may possibly belong with the basic and ultrabasic rocks of Upper Devonian age. Ultrabasic rocks, however, may be expected as differentiates of a basic magma, and the occurrence of such types among the basic lavas and flows hardly justifies their classification as Upper Devonian.

MESOZOIC GRANITIC ROCKS

DISTRIBUTION

Granitic rocks are widely distributed in the Yukon-Tanana region, but the larger intrusive bodies are confined to the eastern part of the region. The largest surface exposure of these rocks is an irregular-shaped body which lies largely in the basin of the Charley River. This mass extends about 80 miles from east to west and about 50 miles from north to south and comprises an area of nearly 1,500 square miles. Another irregular-shaped area of granitic rocks, having an area of 1,000 square miles or more, lies south of the Charley River batholith. Another large body centers around Mount Fairplay, south of the Mosquito Fork of the Fortymile River, and a fourth lies along the north side of the Tanana River downstream from Tanana Crossing. In addition to these, about 80 smaller bodies of granitic rocks are shown on the accompanying geologic map. In the absence of critical evidence to the contrary, all these rocks that are found east of the Tolovana Valley are mapped as Mesozoic, but it is possible that some of the smaller bodies, especially those in the vicinity of Fairbanks, may later prove to be of Tertiary age. All the granitic rocks west of the Tolovana Valley are believed to be of Tertiary age and are so mapped.

Though irregular in outline, these granite bodies show a tendency toward an elongation parallel to the original structure of the country rock. In the east half of the region the regional strike of the rocks is about N. 60° W., and the Charley River batholith has extensions at both its eastern and western ends that trend in this direction. Similarly, in the area east of the White Mountains the smaller granitic bodies are elongated in a direction about N. 60° E., parallel to the regional strike in this north-central part of the region.

On the higher ridges and domes the granitic rocks, from pre-Cambrian to Tertiary, weather out largely by frost action, producing isolated and at some localities fantastic monolithic forms. The rocks separate along cracks and joint planes, and these more or less regular blocks are further modified by exfoliation into boulders.

PETROGRAPHIC CHARACTER

The granitic rocks consist principally of granite and quartz diorite but include also some quartz monzonite, as well as acidic and basic differentiates of the granitic magma. Most of the granitic rocks are coarse-grained, hypidiomorphic granular rocks, but porphyritic varieties are also found, especially as dikes and along the borders of the larger intrusive masses. The common mineral constituents are quartz, potash and soda-lime feldspars in varying proportions, biotite, and hornblende, with several accessory minerals. Detailed work will be necessary in this district to map separately the different petrographic types.

The most common of the Mesozoic granitic rocks is biotite granite. In the larger masses this is a dark-gray hypidiomorphic granular rock, but some of it has a slight greenish hue due to chloritization of the biotite. In some of the smaller intrusive bodies the biotite granite is distinctly porphyritic, with phenocrysts of feldspar an inch or more in length. The mineral constituents are quartz, orthoclase (less commonly microcline), plagioclase, and biotite, with apatite and zircon as the common accessory minerals. Locally garnet is also present. The orthoclase in some of these rocks is graphically intergrown with the quartz. Plagioclase constitutes from 5 to 30 percent of the feldspars. The average composition of the plagioclase feldspar is about that of basic oligoclase, though some of the rocks have zonally grown plagioclase, ranging in composition from acidic oligoclase on the edges of the crystals to acidic labradorite in the centers. Titanite and magnetite also occur as accessory minerals but chiefly where hornblende is also present and the granite tends to be somewhat more basic. These rocks are not usually altered to any considerable extent, but where subsequent alteration has occurred the biotite is usually altered to chlorite, less commonly to epidote or muscovite, and the plagioclase is more or less sericitized. Other secondary products are calcite, pyrite, and hematite.

Any of the large masses of granite or quartz diorite in this region are likely to have a biotite granite facies, and this type is therefore widely distributed. A specialized type of highly potassic biotite granite was also found among the granitic rocks in the 4,000-foot dome southeast of the forks of the Ladue River. This consisted of orthoclase, microcline, little or no plagioclase, chloritized biotite, and some epidote. Similar rocks were found along the north side of the Tanana River, below the mouth of the Tok River.

By a gradual decrease in the amount of biotite and a corresponding increase in the amount of muscovite, there are also developed the biotite-muscovite and muscovite granites. These are lighter-colored rocks than the biotite granite, and some of them, owing to subsequent leaching of the biotite, appear in hand specimens to be muscovite granite, and their true character can be discerned only under the microscope. The feldspar of these rocks is usually orthoclase, and the plagioclase is oligoclase. The accessory constituents commonly include apatite, zircon, and garnet. Compared with the biotite and hornblende granites, the biotite-muscovite and muscovite granites are relatively scarce, though good-sized bodies of these rocks are present locally, as, for example, in the divide at the head of Coal Creek. In general, however, these two types of granite occur as dikes cutting the other granitic rocks.

By a decrease in the amount of biotite and an increase in the amount of hornblende, the biotite granite grades into hornblende granite. Many of the granitic rocks contain both biotite and hornblende, but relatively few true hornblende granites have been observed. The biotite-hornblende granites are darker in color than the biotite granite, owing mainly to the larger proportion of mafic minerals, and as a rule it is not practicable in the field to distinguish them from the quartz diorites. This distinction is based on the character and proportion of the feldspars and is best made under the microscope. As a rule, the biotite-hornblende granites do not differ materially in granularity from the biotite granites, although those in which hornblende is the chief mafic mineral may be a little coarser. The feldspar of the biotite-hornblende granite includes both orthoclase and plagioclase, the latter with an average composition about that of basic oligoclase. Where hornblende is an important part of the rock, titanite is one of the more abundant accessory minerals. The other accessory minerals are apatite, magnetite, and zircon, and the more common secondary minerals are epidote, calcite, and sericite. Locally the granitic rocks show evidence of metamorphism, and one specimen from a point 2½ miles west of the junction of Manila Creek with the Middle Fork of the Fortymile River shows undulatory extinction in the quartz crystals, and myrmekite, or secondary quartz and feldspar, with the original feldspars. Another specimen, collected from the north side of Slate Creek where it joins the Fortymile River, is a basic differentiate, consisting largely of hornblende and biotite, with subordinate quartz, orthoclase, and albite that show strain phenomena. In this rock the hornblende is zonally grown, being brown in the center and grading outward to green.

Biotite-hornblende granite is the second most plentiful of the granites. Hornblende granite has been observed at Veta Mountain, on the spur between Ole and Independence Creeks, and on the spur between Pittsburg and Portage Creeks, in the Circle quadrangle; in the granitic mass west and northwest of Wolf Creek, in the Dennison Fork district, and at other localities, but is relatively uncommon. No true pyroxene granites have been found among the Mesozoic granitic rocks, but a few have been observed in which the mafic minerals include diopside, as well as hornblende and biotite.

Many special varieties of granites occur in this region, but it is beyond the scope of this report to describe them in detail. Chief among such rocks are the tourmaline granites. Tourmaline is found at many places as one of the mafic minerals, but only at a few localities is tourmaline the sole or chief dark mineral. One such specimen, which was found by Prindle as float in Liberty Creek, consisted of quartz, orthoclase, oligoclase, tourmaline, apatite, and zircon and is believed to be of pegmatitic origin. Another tourmaline granite forms a small intrusive body cutting the massive Silurian limestone of the White Mountains. The neighboring limestone is altered to a white, finely crystalline marble. Another occurrence of tourmaline granite is at the head of Hope Creek, where the tourmaline occurs as irregular grains and masses, replacing some of the feldspar. At this locality fluorite is also abundant, occurring mainly with quartz and pyrite in veins, which cut the adjoining schist, but also as small grains in the tourmaline granite.

Highly silicic dike rocks are also of common occurrence. These include quartz porphyry, alaskite, aplite, and pegmatite. The alaskite and aplite are characterized by the absence or scarcity of dark-colored minerals. Alaskite is composed entirely of quartz, perthitic alkali feldspar, a little oligoclase or albite, and a little muscovite, arranged in a hypidiomorphic granular fabric. The aplites have about the same composition but have a sugary, panidiomorphic granular habit. As these rocks become porphyritic, and the minerals of the groundmass decrease in size, they grade into granite porphyries. Dikes and sills of granite porphyry are well developed in the schists at the heads of Faith and Bachelor Creeks. Another interesting granitic differentiate occurs among the granitic rocks at the west side of Mount Fairplay. This is composed essentially of quartz and muscovite, with accessory tourmaline, hematite, and zircon but no feldspar whatever. Syenite has been noted by Prindle [50] in a small area on Bear Creek east of Cache Mountain. This is a porphyritic rock with a trachytic fabric, composed chiefly of tabular orthoclase and pyroxene, with a little biotite. Such rocks must be exceedingly rare, for a high percentage of quartz is an almost universal feature of the granitic rocks of this region.

Second among the granitic rocks in abundance is the family of diorites, and among these quartz diorite is the most common. These rocks closely resemble the biotite-hornblende granites but differ in containing relatively little alkali feldspar. Several varieties of quartz diorites have been recognized, the differences depending upon the dominance of particular types of mafic minerals. The primary minerals that have been observed in these rocks are quartz, plagioclase, orthoclase, biotite, hornblende, apatite, augite, titanite, magnetite, ilmenite, and zircon, and the secondary minerals are sericite, epidote, zoisite, chlorite, calcite, pyrite, and quartz. Quartz and feldspar are the most plentiful constituents, and in some of these rocks these two minerals have developed as phenocrysts, giving rise to a porphyritic fabric. The plagioclase feldspar is characterized in general by zonal growths, ranging in composition from oligoclase to labradorite, with an average composition of andesine. Orthoclase constitutes 15 percent or less of the feldspar. The chlorite and sericite are derived largely from biotite, and the epidotes from hornblende. Augite is an accessory mineral.

Quartz diorite is found at many localities, among which may be mentioned Pedro Dome, the Goodpaster River, the ridge at the head of Miller Creek in the Circle district, the ridge at the head of Coal Creek, the ridge east of Granite Creek, and the head of Shaw Creek. More extensive occurrences are found at Twin Mountain and West Point. Diorite without quartz is of rare occurrence and is not known to form any large bodies of intrusive rock, though some smaller bodies and dikes of both hornblende diorite and augite diorite have been observed, the latter in particular occurring among the granitic rocks west of Wolf Creek. Such rocks must be regarded in general as differentiates of the granodioritic magma, rather than characteristic types.

---

[50] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 53, 1913.

Inasmuch as both granite and quartz diorite are characteristic types among the Mesozoic granitic rocks, it might be expected that intermediate types, such as quartz monzonite and granodiorite, might also be common. Such, however, is not the case. Among the several hundred thin sections of the Mesozoic granitic rocks studied, only a very few have been identified as quartz monzonite. One such rock occurs on the ridge between Mosquito Fork of the Fortymile River and Buckskin Creek, and one was found in the Fortymile quadrangle, but several others were recognized among the granitic rocks collected by Brooks along the north side of the Tanana River below the Tok River. Those of the Fortymile country consist of quartz, orthoclase, and plagioclase in about equal amounts, hornblende, biotite, titanite, apatite, and magnetite. Those along the Tanana had about the same mineral composition, but one of the specimens also contained augite. The plagioclase feldspar ranges in composition from oligoclase to andesine. Granodiorite also has been observed only at a few localities. This marked scarcity of gradational types between the granite and quartz diorite is a characteristic and noteworthy feature of the Mesozoic granitic rocks and suggests two stages in the intrusion of these rocks. This condition also is in marked contrast to that which prevails in the Tertiary granitic rocks, which are dominantly of monzonitic character.

Gabbroic differentiates of the granitodioritic magma have been found only at a few localities. One specimen of this type was found at the east side of the granitic area west of Kechumstuk Mountain. This is a true gabbro, consisting of plagioclase, augite, a little biotite, apatite, and magnetite. The plagioclase is zonally grown, with rims of andesine and centers of bytownite and an average composition of about acidic labradorite. Another specimen collected by Brooks along the Tanana below the Tok River is an olivine gabbro. A third specimen from the junction of Shaw Creek with the North Fork of Birch Creek contained quartz and is really a quartz gabbro. Still other basic and even ultrabasic differentiates have been found, and others will doubtless be discovered when more detailed work is done.

AGE AND CORRELATION

The granitic and dioritic rocks of this region occur mainly in areas of Paleozoic and pre-Cambrian rocks, and although it is clear that they are post-Paleozoic, a more precise determination of their age is difficult to make. In the Charley River country a conglomerate was found by Prindle and the writer, in which the pebbles and cobbles consisted largely of granitic material. The age of this conglomerate was given by Prindle [51] as Upper Cretaceous (?), but the

[51] Prindle, L. M., A geologic reconnaissance in the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, p. 32. 1913.

writer regards it as more probably early Tertiary. Along the Yukon River the Lower Cretaceous rocks contain much conglomerate, but no granitic pebbles were observed in these rocks, although the granitic rocks are found at no great distance to the north. This does not prove, however, that the granitic rocks are younger than Lower Cretaceous, for they might have been formed prior to the deposition of the Lower Cretaceous rocks, without having been exposed at the surface by erosion at that time. Jurassic rocks have not been found in the Yukon-Tanana region, and the relations of the intrusives to rocks of that age cannot be determined. On the stratigraphic evidence alone it can only be said that these granitic and dioritic rocks are post-Paleozoic and pre-Tertiary, and therefore they have been mapped as Mesozoic.

The mere fact, however, that Jurassic rocks have not been found in the Yukon-Tanana region, suggests that the Jurassic in this region was probably a period of extensive uplift and possibly of mountain building; and it is probable that these great masses of granitic rocks were intruded more or less contemporaneously with such orogenic movements. In the Talkeetna Mountains of Southern Alaska the granitodioritic rocks have been shown by Paige and Knopf [52] to be of Jurassic age, for they intrude Lower or Middle Jurassic rocks, and their pebbles are found in Upper Jurassic rocks. In southeastern Alaska the Coast Range batholith is generally regarded as ranging from Jurassic to Lower Cretaceous in age; and in northern Alaska the granitic rocks have been shown by Smith and the writer [53] to have been in existence before the Upper Cretaceous rocks were formed. These comparative data cannot be utilized to prove the age of the granitic rocks of the Yukon-Tanana region, but they show that granitic rocks were intruded in many parts of Alaska some time in the late Jurassic or early Cretaceous and thereby suggest that the granitic rocks of the Yukon-Tanana region may have been formed at or about the same time.

EARLY TERTIARY VOLCANIC ROCKS

DISTRIBUTION

The early Tertiary volcanic rocks are found mainly in the southeastern part of the Yukon-Tanana region, in a large area lying between the Tanana River and the head of Dennison Fork of the Fortymile River. These rocks have also been observed in some smaller areas at the head of the Charley River and in the vicinity of Manila Creek, in the valley of the Middle Fork of the Fortymile.

---

[52] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 20, 1907.

[53] Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 264–265, 1930.

As the central and southeastern part of the Yukon-Tanana region has not been fully explored, other small areas now unrecognized may be later discovered.

PETROGRAPHIC CHARACTER

The early Tertiary volcanic rocks consist mainly of rhyolite, dacite, and andesite, but they may also include basaltic lavas, though these for the most part are of later origin. The rhyolitic rocks, which are the most numerous, are light-colored and commonly porphyritic, with phenocrysts of quartz and feldspar. The ground mass of both the porphyritic and nonporphyritic varieties is usually fine-grained, though the identity of the principal dark-colored minerals can often be recognized. Under the microscope, however, most of the rhyolitic rocks are seen to be holocrystalline, relatively few of these rocks having any considerable proportion of glass in the ground mass. The most common type of rhyolite and rhyolite porphyry consists of quartz, orthoclase, acidic plagioclase, and biotite, with the accessory minerals apatite, titanite, zircon, magnetite, ilmenite, and locally garnet.

Where these rocks are porphyritic the phenocrysts are usually quartz and feldspar, either orthoclase or plagioclase and in some specimens both. Magmatic corrosion of the phenocrysts is noticeable in some of these rocks. The groundmass is usually a finely granular matte of quartz and orthoclase, with a minor proportion of plagioclase. Graphic intergrowths of quartz and orthoclase are not uncommon, and spherulitic orthoclase is present here and there. The plagioclase, in both phenocrysts and groundmass, has the average composition of basic oligoclase, but the phenocrysts of plagioclase are as a rule zonally grown and show a considerable range in composition from rims to centers. Much of the biotite is more or less altered to chloritic minerals and epidote. Muscovite occurs also as one of the primary minerals but is less abundant than biotite. Hornblende is rare. The common secondary minerals are chlorite, sericite, epidote, and calcite.

A more specialized type of rhyolite was observed at several localities. This is a sodic rhyolite, some of it porphyritic and some nonporphyritic, consisting mainly of quartz, albite, and biotite or locally hornblende. In much of the porphyritic rock the phenocrysts are corroded orthoclase. The groundmass is a fine intergrowth of quartz and albite.

The dacitic rocks, like the rhyolitic rocks, include both porphyritic and nonporphyritic varieties. They much resemble the rhyolitic rocks but on the whole are darker and seem to be more altered. Tuffaceous varieties were also seen. The rock constituents are chiefly quartz, plagioclase, biotite, and hornblende. Orthoclase is relatively scarce. The plagioclase, about andesine, is usually much sericitized, and the mafic minerals biotite and hornblende are nearly everywhere altered to chlorite, epidote, and other secondary products. Apatite, titanite, and iron oxides are the principal accessory minerals.

Andesites are scarce and relatively of small extent. They resemble the dacites in general character and mode of occurrence but contain little or no quartz.

AGE AND CORRELATION

These rhyolitic and dacitic rocks were first recognized by Prindle and the writer [54] at the headwaters of the Charley River. In that district these rocks were observed to lie upon the surface of Mesozoic granitic rocks, forming mesalike cappings on some of the hills. Dikes cutting the granitic basement were also observed, which appeared to be connected with the overlying lavas. These dikes had a regional strike ranging from north to northeast and were therefore nearly at right angles to the major structural trend of the schist and to the direction of elongation of the granitic bodies. The larger of these dikes were interpreted as occupying the fissures through which the lava welled upward to the surface, and the flows themselves were therefore classified as fissure flows.

Subsequent work by the writer in the Dennison Fork district [55] revealed the fact that these lavas occur there in much the same manner, though on a larger scale. One difference, however, was noted. The porphyries of the Dennison Fork district do not consistently overlie the Mesozoic granitic rocks but instead appear to be irregularly intermingled with them. This mode of distribution is interpreted as due in part to the outpouring of the lavas from several centers at different elevations and in part, perhaps, to subsequent folding or tilting of the rocks in this area. The petrographic similarities are so great, however, that there is little doubt that the rhyolitic and dacitic rocks of the Dennison Fork district are correlative with those at the head of the Charley River.

The geologic age of these flows is uncertain, because stratigraphically the lavas are largely associated with the Mesozoic granitic rocks, the precise age of which has not been determined. If the Mesozoic granitic rocks are of late Jurassic or early Cretaceous age, the rhyolitic and dacitic lavas might possibly be late Cretaceous, but the Cretaceous period in general does not seem to have been characterized in this region by much volcanic activity. These lavas are

---

[54] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pp. 43–48, 1913 (description of igneous rocks by J. B. Mertie, Jr.).

[55] Mertie, J. B., Jr., A geologic reconnaissance of the Dennison Fork district, Alaska: U. S. Geol. Survey Bull. 827, pp. 37–39, 1931 [1932].

therefore assigned to the early Tertiary. No data whatever are available as to their age relations to the Tertiary granitic rock, for these two groups occur in widely separated and different areas. They show no close petrographic similarity, however, and the lavas are therefore not considered to be the surficial equivalents of the Tertiary granitic rocks but rather as representing a distinct epoch of volcanism, probably earlier than the intrusion of the mid-Tertiary granitic rocks.

It is reasonable to believe that such rhyolitic rocks should have had deep-seated granitic equivalents, and this in turn suggests the possible occurrence of granitic rocks that are younger than the Mesozoic granitic rocks, and older than the mid-Tertiary granitic rocks that occur in the western part of this region. A comparative study of all the granitic rocks of the Yukon-Tanana region, by means of their radioactive properties, by both chemical and spectroscopic methods, appears to offer the greatest promise of a precise determination of the ages of these rocks.

TERTIARY GRANITIC ROCKS

DISTRIBUTION

Granular intrusives that are classified generally as granitic rocks occur at several localities in the western part of the Yukon-Tanana region. One of the largest of these is a body about 10 miles long and nearly 3 miles in greatest width that lies northwest of Hot Springs, along the southeast flank of Hot Springs Dome. A still larger body of such rocks lies in the Tolovana Basin, east of Idaho Creek. It has not been visited by the writer but is assigned to the Tertiary largely on the basis of the occurrence of hot springs along its east flank. Another good-sized body of granitic intrusives forms the core of Roughtop (Moose) Mountain, at the head of Boulder Creek. These rocks crop out in the Ramparts of the Yukon and form the cores of Elephant, Wolverine, and Sawtooth Mountains, in the Rampart district. A number of smaller bodies are also mapped, and at least two of them are known to have produced mineralization in the adjoining country rock, from which gold placers have been derived. One of these is the small granitic mass that constitutes Amy Dome, south of Livengood Creek; and the other is the small body of granitic rocks at the heads of Glen, Rhode Island, and Omega Creeks, in the Hot Springs district. The presence of these rocks in some of the highest mountains in this region is apparently due to their superior resistance to erosion, as compared with the surrounding Mesozoic and Paleozoic sedimentary rocks.

In addition to these larger intrusive masses, numerous dikes, sills. and small intrusive bodies are present, particularly along the peripheries of the larger masses. On account of the large number and small size of these dikes, it has not been found practicable to show them on the accompanying geologic map.

PETROGRAPHIC CHARACTER

These rocks are light to dark gray, and in the larger intrusive bodies range from medium to very coarse grain. The average size of the grains is perhaps 3 millimeters; but at Roughtop and Sawtooth Mountains crystals of feldspar 5 centimeters or larger were observed. As a rule these rocks are not porphyritic, except along the margins of the intrusive bodies and in finer-grained dikes emanating therefrom. In most hand specimens feldspar, pyroxene, and biotite can readily be distinguished, but the finer-grained dike rocks are aphanitic and also tend to be differentiated into acidic and basic fractions.

The larger masses of granitic rocks may be classified in three general types—monzonite, quartz monzonite, and granite. The granite has been recognized only in the intrusive body southeast of Hot Springs Dome and in the Livengood district and is quite distinct petrographically from the others. The quartz monzonite and monzonite grade into each other by a variation in their content of quartz and are certainly consanguineous.

The rocks of Elephant Mountain are characterized by great uniformity in texture. From one end of the mountain to the other, a distance of about 5 miles, little variation appears to exist in these rocks. Under the microscope orthoclase is seen to constitute about half of the feldspar, and some of it is graphically intergrown with quartz. It is also mixed with albite in perthitic intergrowths so fine-grained as to be almost submicroscopic and therefore in some thin sections appears to have an index of refraction a little higher than that of normal albite. The plagioclase feldspar has about the composition of andesine. Quartz is present in small amounts as an interstitial mineral. Augite is the principal mafic mineral and in some of these rocks is pink and probably titaniferous. It is rather common for the augite to occur in good-sized crystals and to include numerous smaller crystals of biotite and apatite, having the same crystallographic orientation, thus producing locally a poikilitic texture. Augite has also suffered a high-temperature alteration to green hornblende, and where hornblende is present much of it seems to have been thus produced. Biotite is the second most plentiful mafic mineral and occurs in good-sized blades, except where included in augite. The accessory minerals are apatite, magnetite or ilmenite, zircon, and titanite, the last in part secondary after ilmenite.

The rocks from Roughtop Mountain appear to be essentially the same as those from Elephant Mountain but differ in certain textural respects. Many of them are exceptionally coarse-grained, and a great range in fabric is visible. Also these rocks appear to have suffered more differentiation, for aplitic and basic segregates are rather common along the borders and are observable even within the main intrusive body. This type rock under the microscope is seen to be about the same as that from Elephant Mountain. Among the differentiated varieties may be mentioned a porphyritic quartz monzonite porphyry, consisting of a granophyric groundmass of orthoclase and quartz, with plagioclase as phenocrysts. Titaniferous augite, biotite, and olivine also occur, both as phenocrysts and in the groundmass. The accessory minerals are apatite and magnetite. Another differentiate is a fine-grained gabbroic rock consisting essentially of coarse crystals of augite in a matrix of fine crystals of basic plagioclase. Biotite and magnetite are also present in considerable amount, and apatite is accessory. Granitic and alaskitic types are also present. The former differs from the monzonite in having a large proportion of orthoclase and considerable quartz. The plagioclase is present in smaller amount and is commonly oligoclase. Augite is absent and is replaced by biotite and hornblende. The alaskite consists of orthoclase, quartz, and a little plagioclase and muscovite. The rocks from the Sawtooth Mountains also show a considerable range in texture and are probably more closely related genetically to those at Roughtop Mountain.

The rocks from Wolverine Mountain and from the two smaller intrusive bodies to the northwest and southeast, like those from Elephant Mountain, are rather uniform in composition and texture but differ in being lighter in color and in having quartz as one of the principal constituents of their modes. These rocks are quartz monzonites. They consist of quartz, orthoclase, plagioclase, augite, biotite, green hornblende, and accessory apatite, zircon, and titanite. The plagioclase has about the composition of oligoclase and is commonly more or less sericitized. Minute, almost submicroscopic perthitic intergrowths of orthoclase and albite are also present. Some of the hornblende is secondary, replacing augite.

The granite from Hot Springs Dome, exemplified by sample 6 in the table on page 222, differs from the others so far described. It consists of orthoclase, quartz, plagioclase, and biotite, with accessory apatite, zircon, and iron oxides. Pyroxene and hornblende are absent. The orthoclase forms three-quarters or more of the feldspar, and the remainder is oligoclase. Graphic intergrowths of orthoclase and quartz also occur. This rock should be classified as a biotite granite.

The granitic rocks from the vicinity of Livengood, particularly from Amy Dome, have been classified earlier by the writer[56] as dioritic, this determination being based largely on the character of the mafic minerals. In reality, the feldspars in the specimens examined are so completely kaolinized that they are entirely indeterminate, and these rocks might equally well be called monzonites. Along the north side of Amy Dome, in the upper valley of Amy Creek, albite granite is also exposed, and soda rhyolite cuts the country rock on the same ridge at the heads of Ruth, Lillian, and Olive Creeks. These two types of rock are closely associated with the Tertiary ores of this area and indicate the Tertiary age of the neighboring granitic rocks.

In order to obtain chemical as well as petrographic data on the Tertiary granitic rocks, five samples from the Rampart and Hot Springs districts and one from the Sawtooth Mountains were analyzed in the laboratory of the United States Geological Survey. The analyses are given below.

1. Composite sample of specimens 31AMt103, 104, and 114. Roughtop (Moose) Mountain, 14 miles N. 20° W. from Hot Springs.
2. Composite sample of specimens 31AMt141, 143, and 145. Elephant Mountain, 26 miles N. 41° E. from Hot Springs.
3. Specimen 31AMt153. Wolverine Mountain, 15 miles S. 35° E. from Rampart.
4. Specimen 31AMt180. Mountain 17 miles S. 41° E. from Rampart.
5. Specimen 31AMt654. Sawtooth Mountains, 21 miles S. 68° E. from Rampart.
6. Composite sample of specimens 31AMt682, 699, 701, and 702. Hot Springs Dome, 3 miles northwest of Hot Springs.

Chemical analyses of Tertiary granitic rocks from Yukon-Tanana region

	1	2	3	4	5	6		1	2	3	4	5	6
SiO_2	54.20	56.89	67.44	64.52	53.11	73.92	K_2O	5.31	6.32	5.97	5.98	6.38	5.18
Al_2O_3	18.43	14.59	15.45	14.90	16.45	13.46	H_2O-	.05	.14	.06	.09	.20	.20
Fe_2O_3	.55	.45	.65	.42	.76	.94	H_2O+	.28	.74	.51	.76	1.15	.36
FeO	6.38	6.13	2.68	3.72	8.29	1.26	TiO_2	.81	1.00	.41	.45	1.40	.35
MgO	3.08	4.23	.88	1.85	3.28	.53	CO_2	.23	.55	.32	.71	.95	.15
CaO	7.20	6.10	2.38	3.52	5.65	1.11	P_2O_5	.60	.40	.16	.20	.55	.10
Na_2O	2.64	2.10	3.26	2.62	2.02	2.42	MnO	.12	.11	.03	.09	.08	.04

Sample 1 analyzed by Charles Milton; samples 2-6 by J. G. Fairchild.

Norms

	1	2	3	4	5	6
Quartz	----------	1.38	17.88	14.94	----------	36.78
Orthoclase	31.14	37.25	35.58	35.58	37.81	30.58
Albite	22.53	17.82	27.77	22.01	17.29	20.44
Anorthite	22.80	11.68	9.45	11.12	16.68	4.73
Corundum	----------	----------	----------	----------	----------	2.14
Diopside	7.88	13.05	1.18	4.64	6.53	----------
Hypersthene	3.94	13.67	5.43	8.09	6.79	2.36
Olivine	7.40	----------	----------	----------	7.84	----------
Magnetite	.70	.70	.93	.70	1.16	1.39
Ilmenite	1.52	1.82	.76	.91	2.58	.61
Apatite	1.34	1.01	.34	.34	1.34	.34

Quantitative classification: 1, II.5.3.2″ (auruncose); 2, II.5.″3.2 (auruncose); 3, I″.4.2.2(3) (dellenose); 4, (I)II.4″.2.2 (unnamed); 5, II.5.(2)3.2 (auruncose); 6, I.3(4).(1)2.2(3) (mihalose).

[56] Mertie, J. B., Jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 247-248, 1918.

On examining the analyses of these granitic rocks from the Rampart and Hot Springs districts, one is impressed by the fact that all belong in subrang 2, of the quantitative classification.[57] This subrang is based upon a ratio of $K_2O \div Na_2O$ that ranges from 7 to 1.67, with a central zone that is defined as ranging from 4.3 to 2.2. The average ratio of $K_2O \div Na_2O$ for these six analyses is 2.3, which lies within this central zone. This ratio is fairly uniform, and in rocks that differ so considerably in other respects as these do, this relationship suggests a definite petrographic consanguinity. With regard to their rangs, based upon the ratio $(K_2O + Na_2O) \div CaO$, a somewhat different condition exists. These ratios range from 1.1 to 6.8, with an average of 2.85, corresponding to a central position in rang 2; but in the individual ratios the rocks fall into three rather distinct types, as three lie in rang 3, two are centrally located in rang 2, and one is transitional between rangs 2 and 1. The rocks of rang 3 are represented by samples 1, 2, and 5, from Roughtop, Elephant, and Sawtooth Mountains, respectively; the two which are centrally located in rang 2 are represented by samples 3 and 4, from Wolverine Mountain and from the mountain close to Wolverine Mountain, respectively; and the one which is transitional between rangs 2 and 1 is from Hot Springs Dome.

The norms of these rocks, based upon the classes and orders of the quantitative classification, likewise show a natural cleavage into the same three types. In samples 1 and 5 quartz is absent, and in sample 2 only 1.38 percent is present. Moreover, the orthoclase and plagioclase in these three samples occur in approximately equal amounts, and these features confirm definitely the assignment of these rocks to the family of monzonites. The femic minerals of the norms differ from the mafic minerals of the modes, as might be expected. Some of the K_2O has been used in the formation of biotite; and Al_2O_3 has also been separated from the feldspars to form biotite and aluminous pyroxene, instead of diopside and hypersthene. Olivine is present in two of the norms but is absent in the modes, except in the porphyritic differentiate above described. The MgO and FeO of the normative olivine are evidently included in the mica and pyroxene.

The norms of the samples from Wolverine Mountain and from the mountain east of it also agree, so far as the salic minerals are concerned, with the modes. Orthoclase and plagioclase are present in approximately equal proportions, but these samples differ from the three preceding samples in that quartz forms from 15 to 18 percent of the rock, being thus one of the major constituents. The same

[57] Cross, Whitman, Iddings, J. P., Pirsson, L. V., and Washington, H. S., Quantitative classification of igneous rocks, p. 137, Univ. Chicago Press, 1903.

distribution of the basic oxides has occurred to form aluminous pyroxene and biotite, instead of diopside, hypersthene, and olivine. The salic minerals of the norm confirm the designation "quartz monzonites" for these rocks.

Salic minerals constitute more than 92 percent of the norm in the sample from Hot Springs Dome. Orthoclase constitutes about 56 percent of the normative feldspar, which in the absence of other evidence would warrant the classification of this rock as a quartz monzonite; but the paucity of femic minerals and the modal characteristics previously described render it necessary to classify this rock as a granite.

The three samples from Roughtop, Elephant, and Sawtooth Mountains are referred in the quantitative classification to the subrang auruncose (II.5.3.2), a relatively rare type of igneous rock. Among the 8,602 rocks whose analyses are tabulated by Washington, only 6 have been referred to this subrang,[58] and most of these are intermediate or transitional forms. No true type is given by Washington, but a sample from Campbell Pond, Lincoln County, Maine, comes closest to the mean. Sample 1, from Roughtop Mountain, coincides very closely with this type, but samples 2 and 5, from Elephant and Sawtooth Mountains, respectively, are likewise close to the average type. These three rocks veer toward alkaline types, and this fact is attested by the inclusion by Washington of leucite-bearing rocks in divisions II.5.3.2 and II.5.2.2. In other words, the monzonitic rocks of this area are as alkalic as rocks elsewhere that carry feldspathoids, but the percentage of silica is just high enough to prevent that mineral expression.

The sample from Wolverine Mountain is assigned in the quantitative classification to the subrang dellenose, but the class is distal, veering toward a less salic type exemplified by II.4.2.2. Sample 4 belongs in this less salic division but is transitional toward dellenose and also in order toward a less quartzose type. Type II.4.2.2 represents an unnamed division in the quantitative classification, to which only 3 of 8,602 rocks have been assigned by Washington. None of these three are typical of this division, all being distal or transitional in class, order, rang, or subrang. They are described petrographically as granite, quartz syenite, and syenite.

The composite sample from Hot Springs Dome belongs in a division of the quantitative system classified as mihalose, of which the type sample comes from Nagy Mihaly, Hungary. This also is a relatively rare group of igneous rocks, containing only 8 of the

[58] Washington, H. S., Chemical analyses of igneous rocks: U. S. Geol. Survey Prof. Paper 99, pp. 467-469, 1917.

8,602 classified by Washington. The sample from Hot Springs Dome, however, is transitional in order, rang, and subrang in the direction of a type less rich in quartz and orthoclase. All the rocks classified by Washington as mihalose are either granites or rhyolites, and this agrees completely with the petrographic characters observed in the biotite granite under discussion.

AGE AND CORRELATION

All the rocks whose analyses are given above, with the exception of the monzonite from the Sawtooth Mountains, intrude Cretaceous sedimentary rocks. Most of these intruded sediments are of Lower Cretaceous age, but some of them around Wolverine and Elephant Mountains, on the basis of their fossils, are classified as Upper Cretaceous. Some conglomerate beds are present in the early Tertiary rocks near Rampart, but no granitic rocks have been recorded from the contained pebbles.

These stratigraphic data are insufficient to determine precisely the geologic age of these granitic rocks, but they suggest strongly that they were intruded in Tertiary time. The absence of granitic pebbles suggests either that these granitic rocks had not been exposed to erosion when the coal-bearing rocks were laid down, or that they are even younger than the coal-bearing rocks. One other condition that might be considered to have a bearing on the age of these intrusives is the presence of hot springs along the southeast flanks of both Elephant Mountain and Hot Springs Dome. A deduction that might be drawn from the presence of these hot springs is that these granitic rocks are relatively young, and this implication would favor their assignment to an epoch later than the coal-bearing rocks. Such an assignment would relate them genetically to the diastrophic movements that are considered to have taken place in mid-Tertiary time.

Both Mesozoic and Tertiary granitic rocks are widely distributed in interior Alaska. Most of the granitic rocks of the Yukon-Tanana region, including the great batholiths of the Fortymile and Circle quadrangles and the granitic intrusives around Fairbanks, are considered to be of Mesozoic age. These rocks are essentially biotite granite and quartz diorite and are characterized by a marked paucity of monzonitic types. Most of the granitic rocks of the Kuskokwim and lower Yukon Valleys, on the other hand, are of Tertiary age, and at one place, at least, they have been found by the writer to intrude early Tertiary rocks.[59] It is therefore believed that at least some of these Tertiary granitic rocks are as young as Oligocene or Miocene. In the Ruby, Innoko, and Iditarod districts, where the

[59] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, p. 71, 1924.

data on stratigraphic age are best, these Tertiary intrusives are monzonites and quartz monzonites, made up of orthoclase, plagioclase, quartz, augite, biotite, and hornblende, with small amounts of magnetite, apatite, and zircon. It is also characteristic of many of the Tertiary granitic intrusives of southwestern Alaska that the auriferous gold placers which they have produced carry cinnabar.

There can be little doubt that the granitic rocks of the Rampart and Hot Springs districts should be classified as Tertiary. Petrographically they are the counterparts of the acidic intrusives of southwestern Alaska, and all the available data above presented indicate that they are relatively young. Cinnabar is not everywhere present in the gold placers of the Rampart and Hot Springs districts, as in southwestern Alaska, but it is found in some of the concentrates from the Eureka area and also in the Livengood district, and its absence elsewhere may be due to the conditions of placer accumulation that destroyed this soft mineral. At any rate, the petrographic, stratigraphic, and correlative data are so mutually concordant and convincing that the writer is led without hesitation to assign all the granitic rocks of the Rampart and Hot Springs districts to the Tertiary. It is furthermore probable that they are younger than the early Tertiary coal-bearing rocks, so that their age may be mid-Tertiary, but this is a hypothesis that cannot be proved at the present time. The granitic intrusives in the Sawtooth Mountains and the plug forming Amy Dome, in the Livengood district, are also correlated, on petrographic grounds, with the granitic rocks of the Rampart and Hot Springs districts.

LATE TERTIARY AND QUATERNARY VOLCANIC ROCKS

DISTRIBUTION

Most of the lavas of late Tertiary and Quaternary age are found in the Dennison Fork district, in the southeastern part of the Yukon-Tanana region. The principal area is a narrow belt between the main forks of the Ladue River that extends eastward across the international boundary into Yukon Territory. The continuation of this belt has been mapped and described by Cockfield.[60]

These rocks, which comprise both lavas and tuffs, strike a little north of west and crop out in a belt about 2 miles wide over a distance of 14 miles in Alaska and 4 miles in Yukon Territory. At one point about 10 miles west of the international boundary, along the south side of this belt, the lavas can be plainly seen in bedded sequence, dipping about 30° N. Here 25 beds of lava and tuff were counted, and after making due allowance for covered zones on the

[60] Cockfield, W. E., Sixtymile and Ladue River areas, Yukon: Canada Geol. Survey Mem. 123, pp. 31–33, 1921.

hill slope, the writer believes that at least 40 beds are present at this locality, with a total thickness of about 600 feet. This is by no means a measure of the total thickness of the formation. If the same dip continues northward to the limit of these rocks, the total thickness may well be several times as great, but of this there is no direct evidence, as the exposures on the north slopes are not good. It seems probable, however, even if the structure is reversed, that this formation may embrace 2,000 feet of lava and tuff.

Two other small areas of basic rocks occur north of the East Fork of Dennison Fork. The more northerly of these comprises two small hogbacks of basaltic rock. The southern area is a little volcanic cone, with a well-developed crater, which likewise must be relatively young, as it is but little dissected.

Lava flows are known at other places in the Yukon-Tanana region. Thus in the Fairbanks district Prindle[61] found a basaltic lava flow, about 250 feet thick, which forms the end of the Fourth of July Hill, facing Fish Creek. This flow is about horizontal, lying directly upon the Birch Creek schist. The present occurrence is probably only an uneroded remnant of a considerably larger flow. A similar flow was found about a mile above the mouth of Alder Creek, also in the Fairbanks district.

In addition to lava flows, volcanic ash occurs in the eastern part of the Yukon-Tanana region. This material is visible along the banks of the Yukon River from Lake Lebarge, in Yukon Territory, downstream to a point below Eagle and has also been noted by Brooks along the upper Tanana. The source of the ash, according to Capps,[62] is an ancient volcano somewhere in the headwater region of the White River. According to Knopf,[63] this ash is an andesitic pumice.

PETROGRAPHIC CHARACTER

The main belt of volcanic rocks above described consists of lavas of several kinds and subaerial tuffs and flow breccias. Rhyolite, dacite, and basalt were observed in such close relations with one another as to suggest their nearly contemporaneous origin. All these rocks are porphyritic, and some of them are partly glassy, but aside from that they have no particular petrographic characteristics that merit special description. Banded tuffs are prominent, as they weather to various shades of brown and red. At the volcanic crater above described the main lava is a normal basalt, but ultrabasic inclusions of lherzolite and websterite are also found in these lavas.

---

[61] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 74, 1913.

[62] Capps, S. R., An ancient volcanic eruption in the upper Yukon Basin: U. S. Geol. Survey Prof. Paper 95, pp. 59–64, 1915.

[63] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pp. 43–44, 1909.

The basalt from Fourth of July Hill, in the Fairbanks district, is described as a brownish-black rock, which weathers into spherical masses that have a superficial resemblance to boulders. It is composed of laths of plagioclase feldspar, pinkish augite, olivine, more or less altered brownish glass, and a considerable quantity of iron ores.

AGE AND CORRELATION

These lavas are undoubtedly of several ages. The lavas and tuffs that lie between the forks of the Ladue River are believed to be post-Eocene and have been considered by Cockfield [64] to be post-Miocene. As these rocks do not lie in contact with late Tertiary deposits on the Alaska side of the international boundary, their age cannot be definitely ascertained, but the writer is in entire accord with Cockfield's suggestion that they originated late in the Tertiary period. The volcanic cone to the north, however, is so well preserved that it may be of Recent age. The volcanic ash in the eastern part of the Yukon-Tanana region is certainly of Recent age, and Capps estimated that the eruption which produced the ash took place about 1,400 years ago. In general, therefore, it appears that volcanism has continued in the Yukon-Tanana region into Recent time.

GEOLOGIC HISTORY

The records preserved in the rocks show that the Yukon-Tanana region has had a long and intricate geologic history. These records, so far as they are now known, have been presented in the preceding part of this report, and it remains now to correlate and summarize these data in order to give a sequential history of the whole region. It has been shown that many major geologic problems in this country still remain unsolved, and it is therefore obvious that no complete history of geologic events can be presented. Nevertheless, enough information is now available to sketch at least the main cycles of sedimentation, erosion, mountain building, and volcanism. In so doing, however, even the geologic records of the Yukon-Tanana region are inadequate, and the writer is obliged to some extent to draw upon geologic data and experience acquired in neighboring areas.

The oldest rocks now known in the Yukon Valley are the quartzite and schist of the Birch Creek schists, which are of sedimentary origin. These sediments, except for their high degree of induration and metamorphism, are not essentially different from others that are being formed at the present day, and it is therefore concluded that the ordinary processes of erosion and sedimentation functioned then

[64] Cockfield, W. E., op. cit., p. 34.

in much the same manner as at present. Such traces of original fabric as are preserved in these rocks indicate that the basal arenaceous sediments, now represented by quartzite and quartzite schist, originated as well-sorted littoral deposits. Somewhat later, however, the sediments appear to have become dominantly argillaceous, and even to a degree calcareous, the resulting deposits being now represented by graphitic, sericitic, and chloritic schists, calcareous schist, and crystalline limestone. As no fossils have been found in these rocks, it cannot be stated with assurance whether they were of marine or nonmarine origin. Though greatly metamorphosed in general, some of these rocks are sufficiently well preserved to retain at least fragments of fossils, if organisms with hard parts had existed at the time the sediments were laid down. The natural inference from the total absence of such remains is either that marine invertebrates with hard parts had not been evolved at this early date, or else that these sediments are of fresh-water origin. The source, or land mass, from which these deposits originated is also unknown, but as they were formed hundreds of millions of years ago it is hardly surprising that their origin and mode of formation are obscure.

Toward the end of this era of early sedimentation, there occurred the earliest volcanism of which any record exists in this region. Lava of basaltic character and perhaps other types were extruded at the surface, and other volcanic material was injected into the sediments; and in the course of time these volcanic rocks have been metamorphosed to form some of the green schists, as well as the amphibolite and hornblende schist, which now characterize these ancient rocks. This period of sedimentation and volcanism was terminated by the intrusion of granitic rocks, which invaded the earlier sediments.

All the sedimentary rocks that form the Birch Creek schist and all the igneous rocks associated with this group are now intensely metamorphosed. Moreover, they are much more metamorphosed than the later pre-Cambrian rocks, and it therefore follows that one of the major periods of diastrophism in this region must have occurred after these rocks had been formed. It does not follow, however, that this was the earliest period of diastrophism in the region, for in a geologic sequence of events as long as that represented by the Birch Creek schist there may have been several such periods of regional deformation. Nevertheless, this early diastrophism, accompanied by the intrustion of granitic rocks, is the earliest manifestation of this type of deformation of which there is any record and is considered one of the significant features of the geologic history.

After or perhaps during the injection of these ancient granitic rocks, the region must have been elevated, the water in which the earliest sediments had been accumulating was drained off, and the region became a positive element, perhaps of continental proportions. Drainage channels were developed, and the process of terrestrial erosion was begun. How long this condition prevailed cannot be learned, but at some later time, perhaps millions of years later, the region was warped downward in such a manner that large bodies of water again formed on its surface, and sedimentation was renewed on a major scale, forming the later pre-Cambrian sediments. Farther south, in British Columbia, sedimentation of the same type resulted in the formation of the Belt series. The evidence from this region and from other parts of North America indicates that this sedimentation took place in several bodies of water, which not only were not connected with one another but also had no tidal connections with the ocean. The resulting sediments were therefore nonmarine. It is only by this postulate that the absence of marine organisms in these sediments has been satisfactorily explained, for many of them are little altered, and invertebrate forms, if they had existed in these waters, would certainly have been preserved. Moreover, highly developed organisms with skeletons composed of hard parts suitable for preservation are known to have had a wide distribution in the succeeding geologic epoch, and the ancestral forms of these invertebrates must certainly have existed in the open ocean at the time when the later pre-Cambrian sediments were being formed.

The diversity and great thickness of the sediments that now constitute the Tindir group and the other of the later pre-Cambrian rocks have already been described. The history of this period of sedimentation is one of the least understood chapters of the regional history. It is inconceivable that such a volume of sediments could accumulate upon a continental platform without the gradual sinking of the floor of the basin of sedimentation, for otherwise it would be necessary that the bodies of fresh water should have been 3 or 4 miles deep. Whether this sinking of the floors of such basins in this region was a continuous or an intermittent process is not definitely known. Probably it was intermittent, and the process may possibly have been reversed for long periods, resulting in the elevation and erosion of sediments already laid down.

This long period of sedimentation was interrupted or accompanied by several periods of volcanism, during which basic lavas were poured out, many of them as subaqueous flows. During one of these volcanic periods, represented by unit D of the Tindir group, at least 1,000 feet of lavas accumulated, mostly below the surface of the water. The record also shows the eruption of earlier flows of the same type during this same epoch of sedimentation and also of later flows of volcanic debris that may have accumulated as terrigenous deposits. The latest stages of this epoch were apparently devoid of volcanic activity.

This period of continental sedimentation appears to have been terminated by a gradual sinking of the continental areas, with the consequent invasion of the waters of the ocean. The stratigraphy and structure of the later pre-Cambrian and the superjacent Cambrian rocks suggest that this sinking was not accompanied by deformation of the rocks but instead was epeirogenic in character. The marine sedimentation which then began marks the beginning of Cambrian time. The present restriction of Cambrian rocks to areas where the later pre-Cambrian rocks are typically developed shows that in the early stages of this marine inundation the oceanic waters were localized in the old pre-Cambrian basins of sedimentation, but as the continent continued to sink the ocean spread out over large areas and reached its maximum extent in Upper Ordovician time. So far as can be learned at present, this invasion of the ocean during Cambrian and Ordovician time was a continuous process, and although the strand line may have oscillated seaward and landward in a minor degree, the oceanic waters do not appear ever to have retreated entirely during these two periods.

Much of the sediment laid down in interior Alaska during Cambrian and Ordovician time was of a calcareous type, resulting in the formation of great bodies of limestone, separated by minor deposits of argillaceous material and siliceous material. These limestones and associated rocks contain a considerable fauna, which represents some of the oldest marine organisms of which there is any record upon the earth. These organisms, however, were highly developed at the time when the oceanic waters first invaded the continent, and many millions of years must have elapsed while these invertebrates were evolving from simpler unicellular forms in their oceanic birthplace. As oceans existed prior to Cambrian time, it is probable that the ancient strand lines, along which the more primitive types of fossils lived, are now buried by the present oceans.

The Cambrian and early Ordovician sedimentation in this area was a quiet, orderly process, uninterrupted by orogenic disturbances or by volcanic activity. Toward the later part of Middle Ordovician time, however, volcanism was again renewed, as shown by the lava flows in the White Mountains. These lavas, like those of the Tindir group, were basaltic in character and subaqueous in origin, though they were also submarine. The Upper Ordovician record is absent in the White Mountains, but the record from southwestern Alaska shows that these lava flows continued and increased in volume during Upper Ordovician time and in their later stages were probably more or less contemporaneous with a regional uplift of the region and a draining off of the oceanic waters.

The Yukon-Tanana region evidently remained above the sea during early Silurian time, for no rocks of this age are known in interior Alaska. During this interval erosion of the country by stream action must have occurred, but it is probable that the land stood at no great elevation above the sea, and that erosion was not a very active process. In middle Silurian (Niagaran) time the region was again depressed and was widely invaded by the ocean. The extent of this marine inundation is indicated by the great thickness and wide distribution of middle Silurian limestone, not only in the Yukon-Tanana region but more particularly in northern and southwestern Alaska. Notwithstanding the lapse of time and the depositional hiatus represented by the early Silurian, the middle Silurian limestone of the White Mountains lies without any observable structural unconformity upon the underlying Ordovician volcanic rocks. It therefore seems probable that this uplift of this region in late Ordovician time and its subsequent submergence in the middle Silurian affected the region as a whole, without the accompaniment of mountain-building processes.

Marine sedimentation continued in this region throughout the middle Silurian and for an undetermined period in the late Silurian. Late in Silurian time, however, the region was again uplifted above the sea and exposed to terrestrial erosion; and the absence of Lower Devonian rocks indicates that this region remained land throughout Lower Devonian time. Early in the Middle Devonian the region was invaded by the ocean, and marine sedimentation was again begun. This uplift and depression, unlike the one which occurred at the end of Ordovician time, was accompanied by folding of the pre-Devonian rocks; and at every place in interior and northern Alaska where Devonian and Silurian rocks adjoin each other this deformation is made evident by differences in the structure and in the degree of metamorphism between the rocks of these two periods. The first recognizable orogenic disturbance of this type, which occurred in pre-Cambrian time, was accompanied by the intrusion of granitic rocks, but so far as now known, the injection of granitic rocks did not accompany the Lower Devonian diastrophism in the Yukon-Tanana region, though the writer[65] has presented evidence to show that such granitic intrusion did in fact occur in northern Alaska.

The marine sedimentation, which was renewed in Middle Devonian time, probably continued in this region without major interruptions, though possibly with minor ones, to the end of Devonian time. The earliest of the sediments thus laid down was dominantly lime-

[65] Mertie, J. B., Jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, p. 244, 1925.

stone, which occurs in the Yukon-Porcupine region. This was followed by the deposition of thin beds of sandstone, shale, and limestone, and finally by the limestone and associated volcanic rocks that occur along the Yukon at Woodchopper Creek and also north of Victoria Creek. It will thus be seen that the early Middle Devonian sedimentation was free of volcanic activity, but in the later part of Middle Devonian time basic lava flows were again extruded, largely below the surface of the sea, and were interbedded with the marine sediments. This surficial volcanic activity may have continued into Upper Devonian time, but there is no direct evidence of it. In fact, no sediments that are definitely of Upper Devonian age have been recognized in the Yukon-Tanana region, though rocks of this age have a wide distribution in northern Alaska. Certain basic and ultrabasic intrusive rocks, however, are believed to have been intruded, and perhaps in part extruded, in the Yukon-Tanana region during the Upper Devonian epoch.

The stratigraphic relations that exist between the Devonian and the oldest Carboniferous rocks in the Yukon-Tanana region are not definitely known. No structural unconformity has been recognized, but the apparent absence of the typical Upper Devonian of northern Alaska, characterized by *Spirifer disjunctus*, suggests either that the Yukon-Tanana region was not submerged during Upper Devonian time, or else that the Upper Devonian rocks, after their formation, were uplifted and eroded prior to the beginning of Carboniferous sedimentation. In either case, a stratigraphic discontinuity appears to exist between the rocks of these two periods.

The earliest known event in the Carboniferous history of the Yukon-Tanana region was the beginning of a peculiar type of marine sedimentation, which resulted in the deposition of the cherts and associated rocks of the Livengood formation. In the preceding pages certain suggestions have been made to explain the origin of these unique siliceous deposits, and it suffices here to state that certain conditions existed in this early Carboniferous sea that have not been duplicated on the same scale, before or since that time. In the later stages of the formation of these cherty deposits submarine volcanic activity was again initiated, and, increasing in intensity, it finally resulted in the greatest outpouring of lavas that is known in the entire geologic history of this region. This period of volcanism began with intermittent lava flows, which were interbedded with cherty beds, then culminated in a vast assemblage of lavas, and finally ended with intermittent eruptions, as it had begun. The volcanic material and associated sediments of this epoch are designated the Rampart group. Ample evidence is available to show that this great volcanic eruption, which occurred in part below the surface of the sea, was not merely a local feature but also occurred on as great or even greater scale in southern Alaska.

After this epoch of volcanism marine sedimentation continued in the Yukon-Tanana region throughout the remainder of Mississippian time. A considerable thickness of alternating limestones and shales were deposited in thin beds, which make up the Calico Bluff formation. These are highly fossiliferous rocks and therefore constitute an important geologic horizon marker. At the type locality, at Calico Bluff, the uppermost beds of this formation are not exposed, nor in fact have they been definitely recognized elsewhere. The late history of this upper Mississippian sedimentation is therefore incomplete, but it is believed that Pennsylvanian time, not only in this region, but throughout Alaska, was marked by a regional uplift, whereby the ocean retreated beyond the limits of the present strand line. This belief is based on the lack of recognition of marine Pennsylvanian sediments in Alaska. In the upper Yukon Valley terrigenous sediments, which represent this missing marine interval, are still preserved and constitute the Nation River formation. This formation has not yet been found in contact with the Calico Bluff formation at any locality where no possibility of faulting exists, and upon this observed fact depends the classification of this early Pennsylvanian uplift. The general stratigraphic relations, however, do not suggest that the rocks of the Calico Bluff formation were folded before the rocks of the Nation River formation were laid down, and this uplift is therefore tentatively classified as epeirogenic.

At the end of this period of regional uplift the country was again depressed and invaded by the sea, with the formation of marine Permian limestones, which rest without angular discordance upon the uppermost beds of the Nation River formation. These limestones are known collectively as the Tahkandit limestone. This was a regional subsidence without any marked orogenic disturbances, for the structure of the Pennsylvanian and Permian rocks is identical. The Tahkandit limestone, in turn, is overlain without any angular discordance by Upper Triassic rocks. As the Lower and Middle Triassic rocks are missing, another epeirogenic uplift and submergence of the region must have occurred. These upward and downward movements of this region, in late Paleozoic and early Mesozoic time, were undoubtedly accompanied by erosion, when the region was above sea level, but so far as known they took place without any marked orogenic or volcanic disturbances.

After the deposition of the Upper Triassic beds the Yukon-Tanana region was again uplifted above the sea and remained a land surface throughout Jurassic time. The geologic history of this period is obscure, but it is probable that this uplift was more or less concomitant with the injection of the great masses of granitic rocks that now occupy considerable areas in the central and southeastern parts of this region. These granitic intrusions were accompanied by orogenic movements of the first magnitude, as a result of which the earlier rocks of the region were regionally metamorphosed and also extensively altered along the borders of the granite bodies. Broad highland areas were probably also formed at the same time; and finally, as a result of the granitic intrusions, came the earliest period of gold mineralization of which there is a definite record in interior Alaska. During this period of mineralization were formed many of the gold-quartz veins of interior Alaska, from which some of the richest of the placers have been derived. The Circle, Fortymile, and probably the Fairbanks districts illustrate this period and type of mineralization.

By a subsequent sinking of the land marine sedimentation was once more begun in this region in Lower Cretaceous time, resulting in the formation of the various sediments of that age along the upper Yukon and in the Rampart district. These two areas probably represent the remainder of a much greater area of such sediments, which have subsequently been removed by erosion, but it is probable that the highland areas, such as the country at the head of the Charley and Goodpaster Rivers, were not submerged at this time.

The geologic events that occurred during the period between the end of the Lower Cretaceous and the beginning of the Tertiary are not definitely known, for few Upper Cretaceous rocks occur in the Yukon-Tanana region, and their relation to the Lower Cretaceous and Eocene rocks are obscure. Apparently the region was elevated above sea level at the end of Lower Cretaceous time and was eroded for a long period. This elevation was probably accompanied by orogenic movements and may also have been characterized by intrusive igneous activity, though such diastrophism and volcanism have not been proved in the Yukon-Tanana region. In any event, the interval between the retreat of the Lower Cretaceous sea and the renewal of marine Upper Cretaceous sedimentation is considered to be one of the major periods of uplift and erosion in this region.

Marine sedimentation was again renewed in certain areas in the Yukon-Tanana region in Upper Cretaceous time, but most of this sedimentation took place farther to the southwest, in what are now the lower valleys of the Yukon and Kuskokwim Rivers. Apparently a great lowland area then existed in southwestern Alaska, and the sea first inundated that part of Alaska and swept progressively eastward. Few Upper Cretaceous rocks, however, are now known in the Yukon-Tanana region, and those which have been found, to judge from the mixture of marine invertebrates and land plants which they contain, must have been of near-shore origin. It is therefore probable that most of the Yukon-Tanana region during Upper Cretaceous time was a land area that was being actively eroded and was a source of supply for the material deposited farther to the southwest.

The late Cretaceous and early Tertiary history of this region is obscure. It may be that the region was uplifted and eroded after the Upper Cretaceous rocks were deposited and before the Tertiary sedimentation began. But to judge by the close association of the Upper Cretaceous and Tertiary rocks along the Yukon River below Eagle and by the difficulty experienced in distinguishing the floras of these rocks, it seems probable to the writer that no marked stratigraphic hiatus separates the Upper Cretaceous sediments from those of the basal Tertiary, but that a slight elevation of the land caused local conditions of sedimentation to change from a near-shore marine type to a fresh-water type, characteristic of the lower courses of open valleys close to the sea. Terrigenous deposits of Eocene age then gradually accumulated in such wide valleys, under conditions favorable for the formation of peaty deposits, from which the Eocene coals were subsequently derived. The great thickness of these Eocene deposits, however, points to a gradual subsidence of the region in the later stages of their formation.

Later in the Tertiary period, after these terrigenous deposits were formed, the region was again uplifted, folded, and intruded by granitic rocks. These intrusions gave rise to a second period of gold mineralization in this region and furnished the source of later gold-quartz veins, the deposits of cinnabar, and most of the tin deposits of the region, particularly those in the vicinity of Hot Springs. It is also probable that new highland areas were formed during this Tertiary period of orogenic disturbance, and that the streams were rejuvenated, initiating renewed and long-continued erosion.

After the Tertiary granitic rocks were intruded, the old and also the newly uplifted highland areas were progressively eroded for a long period of time and were gradually reduced to a maturely dissected land surface. This period of erosion continued without interruption until late Pliocene time, when the country was again regionally uplifted. In the accelerated erosion that followed, the streams were incised in their old valleys, and the high terraces described elsewhere in this report were formed. Considerable warping of the surface also took place about this time, or a little later, thus creating anomalies in the drainage systems, some of which have persisted to the present day.

In the Pleistocene epoch the glaciation of Alaska began, but the Yukon-Tanana region, though girdled by ice on the north, east, and south, was not glaciated, except for some small glaciers of the Alpine type that existed in the highland areas. The geomorphic history of Pleistocene and Recent time is a complex problem, the solution of which has hardly yet begun. While glacial ice was accumulating in the areas somewhat removed from the Yukon-Tanana region, the baselevel of erosion for this region was in some manner elevated, and extensive silting took place in two or more stages. By a subsequent lowering of the baselevel, in Recent time, most of these silts were removed by renewed erosive action of the streams, but in so doing the streams suffered many and extensive changes in their courses, if not in their directions. These changes in the drainage courses, which were induced not only by Pleistocene silting but also by differential warping of the surface of the region, have led to many anomalous features in the present streams, the full interpretation of which has not been worked out.

ECONOMIC GEOLOGY

Studies of the mineral resources of Alaska have been carried on by the United States Geological Survey in Alaska for 35 years, with the primary object of fostering the mining industry in the Territory. The investigations have been planned with a twofold purpose—first, to gain a better understanding of the sources, character, and extent of the known mineral deposits, in order that their future development might be facilitated; second, to apply the information thus gained to the discovery of new mineral deposits. In the practical carrying out of these objectives, the science of geology has been freely applied to the discovery and development of mineral deposits. This has required not only that the individual properties should be examined but also that regional geologic history should be deciphered, in order that the geologic facts may be available for general application to mineral economics. After such facts have been ascertained, it remains for the geologist to translate these data into working principles that will be of use to the mining operator and to the prospector. This is the object of the present chapter.

Federal geologists have visited all the mining camps in the Yukon-Tanana region; and some of the mining districts, such as the Fairbanks district, have been studied with considerable care. The results of these examinations have been published in a considerable number of Geological Survey bulletins, and it is not the purpose of the writer to reproduce these detailed descriptions and the localized deductions resulting from them. Such work, however, has resulted in some rather important conclusions, which are of general significance and of widespread application throughout this region; and it is the specific purpose of the following pages to present in condensed form such generalized deductions regarding the distribution and occurrence of mineral deposits in the Yukon-Tanana region. It is also the purpose of the writer to state these conclusions, so far as possible, simply and in nontechnical language, so that they will be understood by mining men and prospectors, who are not always conversant with the specialized geologic nomenclature.

CLASSES OF MINERAL DEPOSITS

Both metalliferous and nonmetalliferous mineral deposits occur in the Yukon-Tanana region, but so far only the metalliferous deposits have proved to be of economic significance. These consist mainly of gold and silver, but tin, tungsten, and antimony have also been produced on a commercial scale; and deposits of lead, zinc, copper, chromium, iron, cobalt, nickel, platinum, molybdenum, and bismuth are known to be present, though some of these ores have not been found in their bedrock sources, and many of them are only scantily represented. At the present time gold (with alloyed silver) is the principal metallic product of the region, but small amounts of tin are also being recovered.

The nonmetalliferous deposits consist of coal, oil shale, and mineral waters, as well as deposits of sand, gravel, clay, building stone, lime, marble, and other products. Most of these deposits cannot be exploited under present economic conditions, except in a small way for local use. In the early days of the exploration and settlement of this region, attempts were made to utilize the coals along and contiguous to the Yukon River for local needs, but the abundance of cheap wood and the small demand for coal made it impossible to produce coal on a commercial scale. Locally, however, as in the vicinity of Chicken, in the Fortymile district, coal is occasionally mined, when needed for blacksmithing or similar work.

METALLIFEROUS DEPOSITS

At the present time placer deposits are of greater economic significance in this region than lode deposits, but mineralization of some kind must have occurred before a placer can be formed, and it is therefore logical to consider first the lodes. Little intensive prospecting for metalliferous lodes has as yet been done in this region. This is easily understood when it is remembered that the Yukon-Tanana region contains many commercial gold placers, which at the outset could be worked with a minimum of equipment and which, under the higher costs of living and transportation that prevail in this country, yielded a greater margin of profit. The placers, therefore, in the early mining history of a country, receive the major attention of those engaged in prospecting and mining; and even in the later stages of mining development the large-scale low-grade placer-mining operations that then develop give employment to many persons. However, if a mining industry is to thrive in fullest measure, the bedrock sources of the minerals found in the placers should be located. The Fairbanks district has already entered upon the development of metalliferous lodes, and a gold lode mining industry is gradually being established. In most of the other mining districts of the Yukon-Tanana region the bedrock sources of the gold and other minerals that are found in the placers have not yet been located.

The placer-mining operations, however, have shown the character of most of the minerals that exist in this region, for such minerals accumulate in the concentrates recovered with the placer gold and have been identified by laboratory examination and studies. The geologic formations which occur in the basins of valleys containing gold placers and from which those placers are derived furnish a further clue to the sources of these minerals; and from these and other related facts the general mode of occurrence of such minerals may be predicted.

Most metallic deposits have been derived directly or indirectly from igneous rocks, though in some deposits the connection is remote. In the Yukon-Tanana region, however, the connection between mineralization and igneous activity is everywhere apparent, and many of the lodes must be closely associated with igneous rocks. This fact gives an initial clue for the prospector. However, many kinds of igneous rocks exist in this region, as shown in the preceding description of such rocks. Silicic, basic, and intermediate types are present, both as intrusive bodies and as lava flows. Moreover, igneous rocks of the same general character have been intruded and extruded at different epochs, so that two rocks of the same general character may have produced mineralization of different kinds. At first sight this complex history of volcanism may seem a stumbling block to one not versed in geology, such as a practical miner who is endeavoring to utilize geologic facts in his search for minerals. Fortunately only certain types of igneous rocks, which are readily recognized, have an important bearing upon the origin of lodes that are likely to be of commercial value. Moreover, on the accompanying geologic map the distribution of the more conspicuous of these igneous rocks is shown, and although there are doubtless other bodies that have not been located in the course of the reconnaissance surveys, the prospector can thus find type localities and obtain specimens of such rocks, from which to extend the information gained to less well-known areas.

With the exception of the platinum metals and the ores of chromium, iron, and nickel, most of the minerals of the Yukon-Tanana region are associated with granitodioritic intrusive rocks, and practically all the minerals that are likely to have any future economic significance are related genetically to such intrusives. This group of granitodioritic rocks includes granite, quartz monzonite, monzonite, quartz diorite, and diorite, together with specialized variants of these rocks and related dike rocks. All these rocks resemble one another to a greater or less degree, and in fact their true petrographic character is often not determinable except with the aid of a microscope. Most prospectors and mining operators recognize these granitodioritic or granitic rocks at sight. They commonly consist of quartz and feldspar in varying amounts, together with mica, hornblende, or pyroxene, or mixtures of these. The quartz and feldspar are light-colored minerals, the others are dark-colored, and the resulting color of the rock therefore ranges from a white or very light gray to dark gray, depending upon the mineral constituents. The grain of these rocks is usually sufficiently coarse to make the component minerals discernible with the naked eye, though a low-powered lens is often helpful.

MINERALIZATION CONNECTED WITH GRANITIC INTRUSIVES

Granitic rocks have been intruded in at least three different geologic epochs in the Yukon-Tanana region. The oldest of these are represented by the Pelly gneiss, which is especially well developed in the eastern part of this region, though also known as far west as the Fairbanks district. It is possible that this ancient granitic intrusion was the source of some of the old quartz veins in this region, most of which have subsequently been greatly metamorphosed and recrystallized. Most of these older quartz veins, however, appear to contain little gold or other metalliferous minerals, and if gold quartz veins of commercial value were originally formed during this early period of granitic intrusion, it seems probable that most of them have subsequently been eroded away and that their metallic contents have been dissipated. Nevertheless, valuable mineral deposits are known elsewhere in association with similar ancient granitic intrusives, and it should not be assumed that the Pelly gneiss is of no importance as a source of mineral deposits. In other words, areas contiguous to the ancient gneisses are by no means a poor place for prospecting, and it is possible that the occurrence of so many of the larger mining camps, such as the Fortymile, Fairbanks, Koyukuk, and Nome camps, in areas of ancient crystalline rocks may be attributable in some measure to the mineralizing influence of these ancient granitic intrusives.

The second period of granitic intrusion occurred sometime in the Mesozoic era, probably in late Jurassic or early Cretaceous time. The granitic rocks of this period form the Charley River batholith and also constitute most of the other granitic areas in the central and eastern part of the Yukon-Tanana region shown on the geologic map. These granitic rocks gave rise to the first major period of mineralization in this region of which there is any definite record, although, as above stated, the Pelly gneiss may have been the source of still earlier mineral deposits.

A third period of granitic intrusion occurred in Tertiary time, probably in post-Eocene time. The granitic rocks of this period are found mainly in the western part of the Yukon-Tanana region, though some evidence is available to show that they also occur in other parts of the region, below but not far below the present surface. As set forth in an earlier part of this report, these Tertiary granitic rocks, though they look like the Mesozoic granitic rocks, have certain specialized petrographic characters that warrant their reference to the family of monzonitic rocks. These quartz monzonites and monzonites gave rise to the second major period of mineralization in the Yukon-Tanana region.

Two major periods of mineralization are thus recognized in the Yukon-Tanana region, but it should not be understood from this that in both of these periods the granitic intrusion and mineralization were consummated quickly or simply. The introduction and emplacement of large masses of igneous rock, like the batholith in the basin of the Charley River are likely to have occupied a long interval of time and in all probability took place in a number of different stages. Similarly the mineralization that accompanied the intrusion of the granitic rocks, both of Mesozoic and of Tertiary age, is likely to have occurred in several stages, and ample evidence of this is available in some of the mining districts.

FIRST PERIOD OF MINERALIZATION

The most widespread and most important mineralization that has occurred in the Yukon-Tanana region is the first or Mesozoic type. This mineralization probably produced the lodes in the Fairbanks district and also indirectly most of the gold in the placers of the Circle, Seventymile, Fortymile, and Tenderfoot districts and in the scattered placers elsewhere in the central and eastern part of the Yukon-Tanana region. Some of the placer gold in the Rampart district may also have originated at this time.

In the Fairbanks district the extensive mining of lode deposits has made it possible to learn more regarding the character of this first period of metallization than elsewhere in the region, where little lode development has been attempted. Lode deposits in this district occur at two separate localities, one in the east-central part of the district and one in the western part. In the east-central area the lodes occur mainly as fissure veins, which strike in general N. 60° W., cutting the foliation of the Birch Creek schist. The gold is confined largely to these veins, which in turn are believed to be derived from granitic and dioritic rocks that crop out nearby. In the western area granular intrusives do not crop out in large bodies, but porphyritic derivatives of such rocks indicate the presence of granitic stocks at no great distance below the surface. Here the gold occurs both in fissure veins and in more diffuse mineralized zones, and the strike of the ore bodies is less uniform. The paragenesis of all these veins and other lodes has not been studied in great detail, but it is evident from the work already done that at least three stages in this first period of mineralization may be recognized. In the first stage some gold was deposited, accompanied by vein quartz and considerable pyrite. In the second stage quartz veins and other lodes with a higher content of gold but containing also a considerable diversity of sulphides were formed, and some of the older veins were reopened and enriched. In the third stage another generation of quartz veins and disseminated deposits were formed, which consisted of quartz, scheelite, and perhaps tin ores but contained little gold. Still another type of mineralization, characterized by the formation of high-temperature minerals, such as tourmaline and cassiterite, has also taken place in the Fairbanks district, but data are lacking for correlating this stage of mineralization with the three stages of quartz-vein formation.

In addition to pyrite and its alteration products limonite and hematite, the following ore minerals, as shown in a list compiled by Hill,[66] are known to be present in the lodes of the Fairbanks district: Argentite, arsenopyrite and its alteration products löllingite and scorodite, native bismuth, bismuthinite, boulangerite, chalcocite, chalcopyrite, covellite, galena, jamesonite, manganese oxide, sphalerite, stibnite and its alteration products ceroantite and stibiconite, and tetrahedrite. Of these, arsenopyrite and its alteration products, galena, jamesonite, sphalerite, stibnite and its alteration products, occur rather plentifully at places, but the remainder are relatively rare. During the era of high prices for certain mineral products in 1916–17 the ores of stibnite (antimony) and scheelite (tungsten) were mined commercially. In addition to the minerals above listed, cassiterite and wolframite have also been found in the placer concentrates.

---

[66] Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849–B, pp. 71–73, 1933.

It is apparent from this list of ore minerals that the Fairbanks district has been intensively mineralized. The paragenesis of all these minerals is not known, but except pyrite and the tungsten minerals, most of them are believed to have been introduced in the second stage of mineralization. Stibnite is one of the commonest of the sulphides. It occurs in the lodes both with and without quartz and does not itself carry much gold, but where it occurs in the older veins, enriching them, high-grade gold ores have been formed. The same is true of arsenopyrite. Prindle states that at one locality stibnite was found in so close association with a sericitized dike of granite porphyry that a genetic relationship was apparent, but as a general rule the gold lodes of the Fairbanks district are indirectly related to the granitic bodies, through the medium of quartz veins, and are not formed in or directly along the peripheries of the granitic rocks. These quartz veins are fairly regular in direction, and most of them have well-defined walls; and as no high-temperature minerals have been recognized in the gold quartz veins, it is inferred that they originated at moderate depth—deep enough to insure a fair degree of regularity to the fissures but not deep enough to show the effects of high-temperature mineralization.

The tin and tungsten minerals of the Fairbanks district include cassiterite, scheelite, and wolframite. Scheelite has been found in the lodes, but cassiterite and wolframite have been recognized only among the heavy minerals of the placer concentrates. Scheelite occurs at the head of Gilmore Creek in mineralized zones or ore shoots in silicated limestones but is not considered to have originated as a contact-metamorphic deposit, because the alteration of the country rock in which it occurs is believed to have preceded the formation of these ores. Scheelite is also found both in quartz veins and as disseminated deposits at the heads of First Chance and Steele Creeks and in quartz veins on Fairbanks Creek. It is probable that all the scheelite ores were deposited contemporaneously with the last stage of vein-quartz formation in this district. The source and manner of formation of the cassiterite and wolframite, however, are not known.

The Circle district is another example of the first or Mesozoic stage of mineralization. Gold is the principal mineral of economic importance here, but no lodes of commercial worth have been located, and only the placers have been developed. In addition to gold, however, the concentrates recovered with the gold on Deadwood Creek show also the presence of wolframite, cassiterite, magnetite, ilmenite, arsenopyrite, pyrite, galena, limonite, garnet, tourmaline, and quartz.[67] Some of these minerals, such as the magnetite, garnet, and

[67] Johnson, B. L., Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district: U. S. Geol. Survey Bull. 442, pp. 246–250, 1910.

tourmaline, are high-temperature minerals, but granitic rocks also occur on Deadwood Creek, and these minerals probably originated in the granite rather than in the gold-quartz veins. Except for the absence of cassiterite and wolframite, about the same group of heavy minerals are found in the other stream concentrates of the Circle district. The source of all these ore minerals lies probably in quartz veins derived from small bodies of granitic rocks, most of which have not yet been uncovered by erosion, though some are exposed on Deadwood and Mammoth Creeks, but the mode of occurrence of these minerals is unknown.

The Fortymile district is also considered to be an example of Mesozoic mineralization, though the presence of cinnabar at certain localities suggests that it was also affected by the Tertiary mineralization. The concentrates recovered with the gold in the creeks of this district are largely rock-forming minerals, such as magnetite, ilmenite, garnet, hematite, and zircon, but on Wade Creek the concentrates include a large amount of barite, as well as smaller amounts of cinnabar, pyrite, and cassiterite. Barite in smaller quantities is also found on other creeks in this district, and cinnabar in small amounts was recognized on Franklin Gulch. Similarly just east of the international boundary, the concentrates of the placer creeks at the head of the Sixtymile River have been found by Cockfield[68] to consist of hematite, magnetite, zircon, garnet, and titanite, together with galena, pyrite, and a little cinnabar. Tungsten minerals were specifically tested for and were found to be absent.

Most of the mining in the Fortymile district has been placer mining, but at least one lode has been prospected and sampled. This is at the head of Lilliwig Creek, a small tributary of Ingle Creek from the west. The lode material is sericitized quartz diorite, cut by numerous veinlets of calcite and quartz, containing gold, pyrite, and a little chalcopyrite. Not only is this lode localized in a small body of quartz diorite, but the creek downstream from this intrusive rock contains workable gold placers, whereas upstream from the intrusive rock the stream gravel is barren of gold. This lode deposit shows the relationship that exists between the granitic intrusions and the mineralization at this locality, and similar relationships are believed to exist elsewhere in the Fortymile district, for the placers appear to be distributed close to a number of small bodies of similar intrusives. Doubtless many other lode deposits have been seen by prospectors in this region, but they have not been

[68] Cockfield, W. E., Sixtymile and Ladue Rivers area, Yukon Territory: Canada Geol. Survey Mem. 123, p. 52, 1921.

intensively prospected and are not known to the writer. A copper lode, however, has been found in the upper valley of Kechumstuk Creek, of which the principal ore mineral is bornite; and some miles northwest of this an antimony lode is also reported. Also at the "kink" of the Fortymile River, where placer mining was once done, the placer concentrates contained cassiterite.

Most of the mineralization in the Fortymile district is considered by the writer to have been due to the effects produced by the intrusion of granitic rocks during the Mesozoic era. The occurrence of cinnabar in the Fortymile and Sixtymile districts, however, suggests that Tertiary mineralization has also been operative in this part of the region. It is of interest in this connection to know that Cockfield,[69] though admitting the Tertiary significance of the cinnabar in the Sixtymile district, is inclined to ascribe most of that mineralization to the influence of the Pelly gneiss, thus placing the geologic date of the mineralization back in the pre-Cambrian. This is an interesting hypothesis, and if it can be shown that the gold of the Sixtymile district originated in pre-Cambrian quartz veins rather than in Mesozoic quartz veins, this fact may render the Pelly gneiss of much greater potential importance as a source of gold mineralization in other parts of the Yukon-Tanana region.

Little prospecting for lodes has been done in the Seventymile district, and little or no study has been made of the heavy minerals that are recovered with the concentrates. So far as known, however, conditions here are similar to those in the Fortymile district and most of the mineralization originated as a result of the Mesozoic granitic intrusions, though on Canyon Creek, in the Seventymile Valley, good-sized pebbles of cinnabar have been found.

One other type of deposit that is attributable to the effects of the Mesozoic mineralization should be mentioned. At the head of the Healy River, on the south slopes of Mount Harper, a deposit of molybdenite has been found. This deposit is a fissure vein of white quartz in which small bunches of molybdenite are scattered. This locality is within a large area of Mesozoic granitic rocks and is probably a late phase of the intrusive action.

These scattered examples of mineralization in the central and eastern parts of the Yukon-Tanana region by no means represent all the mineral deposits that have been found in this country, but they probably give a general idea of the types of ores that may be expected to be found by prospecting. The available evidence to date suggests that most of the gold deposits were formed at a moderate yet considerable depth below the surface and that they are localized in quartz veins, usually at some distance from the granitic contacts.

[69] Cockfield, W. E., op. cit., p. 49.

Experience has also shown that the smaller bodies of granitic rocks are more likely to be the source of workable lodes than the large intrusive masses, such as the batholith in the basin of the Charley River. The explanation of this fact lies in the probable concentration of metallization, except the contact-metamorphic metallization, at the higher points or apexes of the invading granitic rocks. As such bodies of granitic rocks are subsequently bared by erosion, these mineralized zones are first exposed and make the smaller croppings of granitic rocks. Subsequently, these smaller outcrops, together with the mineralized zones that may have formed about them, are eroded away, and the larger granitic masses are exposed, which are lean or barren of mineral deposits.

SECOND PERIOD OF MINERALIZATION

The second period of mineralization was connected genetically with the intrusion of the monzonitic rocks that are prevalent in the western part of the Yukon-Tanana region. Mineralization of this same period and type was still more widely distributed to the southwest, in the lower valleys of the Yukon and Kuskokwim Rivers. It is possible, of course, that metalliferous deposits formed during this period may be present almost anywhere in Alaska, for the metal-bearing solutions in their upward or outward passage from the underlying intrusive masses must have penetrated sedimentary rocks of all ages. Nevertheless, it is remarkable that these later deposits appear to be scarce in regions of dominantly pre-Mesozoic rocks. Thus in the Yukon-Tanana region evidence of Tertiary mineralization has been recognized with assurance only in the Hot Springs, Rampart, and Tolovana districts, which are situated either among or near to the Mesozoic sedimentary rocks. It is likely that this restricted distribution is in some way related to the orogenic history of Alaska, but the exact connection is not understood.

Little intensive prospecting for lode deposits has yet been done in the areas affected by this late period of mineralization, but the ore minerals found in the placer concentrates, together with the few known lodes, give some idea of the metallization that has been produced. The principal ore minerals include gold (with alloyed silver), cassiterite, pyrite, barite, cinnabar, galena, stibnite, picotite, native copper, native silver, chalcopyrite, and cobalt and nickel ores. The occurrence and paragenesis of these minerals so far as they are now known have been described by the writer in a recent report,[70] and it is unnecessary in the present report to repeat the details. In

[70] Mertie, J. B., Jr., Mineral deposits of the Rampart and Hot Springs districts: U. S. Geol. Survey Bull. 844–D, pp. 217–223, 1934.

general, however, the mineralization of the Rampart and Hot Springs districts has probably occurred in three stages, as follows:

1. An early stage, characterized by the deposition of gold, silver, and copper ores, which was effective in the valley of Minook Creek and its tributaries.

2. A second stage, characterized by the deposition of gold and cinnabar, though at some localities the cinnabar deposits are lacking. This stage is represented in the Eureka and Tolovana districts.

3. A third stage, characterized by the deposition of gold, cassiterite, and other ores. This stage probably had a complex history and resulted in the formation of a variety of lodes, some with and some without cassiterite. The type locality is in the Hot Springs district.

The Tertiary age of the earliest of these three stages of mineralization is somewhat in doubt. No lodes representative of this stage have been found, but the gold placers found in the tributaries of Minook Creek are so distributed as to suggest that the gold and associated ores have been derived from an underlying body of granitic rocks, by which the Carboniferous country rock has been contact-metamorphosed and mineralized. The local geologic relations are such as to suggest further that the granitic rocks which produced these effects may possibly have been of Mesozoic age, but this hypothesis cannot be proved. In any event, this earliest stage of mineralization in the Rampart district produced gold of high grade and, to judge by the concentrates recovered with the gold, also produced barite-galena lodes, which probably were silver-bearing. This galena has not been analyzed, but its argentiferous character is suggested by the presence of nuggets of native silver on Slate Creek. This stage of mineralization also produced copper lodes, as indicated by the common occurrence of native copper in the concentrates from Hunter and Little Minook Creeks. Later Tertiary mineralization, however, is indicated by the presence of traces of cinnabar in the concentrates from Hunter Creek.

In the Tolovana district the common minerals collected in the gold placer concentrates, in addition to rock-forming minerals, are pyrite, arsenopyrite, picotite, and barite, but in the streams that drain southwestward from Amy Dome cinnabar, scheelite, and stibnite have also been identified in the placer concentrates. Moreover, at one locality at the head of Lillian Creek the writer was able to pan cinnabar out of decomposed granitic material. On the spur west of Ruth Creek a low-grade stringer lode has also been prospected, which, in addition to gold contains pyrite and arsenopyrite. Most of these ore minerals, with the possible exception of the picotite, have probably been derived from quartz veins and lode deposits of more diffuse types, which originated close to the granitic rocks that are exposed on the ridge south of Livengood Creek.

Cinnabar is a characteristic product of the Tertiary mineralization, not only in the Yukon-Tanana region but also in southwestern Alaska. On the other hand, cinnabar is not found in all the placers that have been derived from Tertiary lodes. This is well illustrated in the Tolovana district, where cinnabar has not been recognized in the bench placers of Livengood Creek, though it is found in a number of streams draining the west end of the ridge south of Livengood Creek. The mere absence of cinnabar, therefore, cannot be regarded as evidence of pre-Tertiary mineralization. It is also characteristic of the cinnabar-bearing gold lodes that they occur in intimate association with the granitic rocks and are commonly found in small veins and veinlets within or along the peripheries of these intrusives. The Tertiary monzonitic rocks have apparently been intruded closer to the surface of the region, as it existed at the time of their formation. The cinnabar-gold deposits, which were formed near the apexes of these intrusives, likewise were formed closer to the surface than the original gold quartz veins of the Fairbanks district. This condition is reflected in the less regular character of the quartz veins, in both the Tolovana and Eureka districts.

A good illustration of the final stage of Tertiary mineralization is found in the Hot Springs district. A variety of mineral deposits originated during this stage of mineralization, but little is known of the bedrock source of these ores, and, therefore, little can be stated regarding their paragenesis. The most conspicuous feature of this district is a mineralized belt, known as the tin belt, which lies mainly in the valleys of Woodchopper, Sullivan, and Cache Creeks but also extends northeastward into the headwater region of Baker Creek. Within this belt high-grade gold-cassiterite placers have been mined for many years. A more detailed description of these deposits has been given by the writer in a recent report.[71] In addition to gold, cassiterite, and the rock-forming minerals, the concentrates from these placers include also pyrite, picotite, monazite, aeschynite (?), and native copper. Cassiterite is very plentiful, amounting in some of these placers to 0.2 pound to the square foot of bedrock; and it is saved and shipped as a byproduct of the gold placer-mining operations. The bedrock source of this cassiterite has not been located, but a cut and polished section of some of the low-grade ore found in the gravel shows that the cassiterite is intimately intermixed with vein quartz and country rock. Apparently, the vein quartz was extensively fractured after its introduction into the country rock, and the cassiterite was then introduced into the cracks and crevices thus made. There is no evidence of replacement and

[71] Mertie, J. B., Jr., Mineral deposits of the Rampart and Hot Springs districts: U. S. Geol. Survey Bull. 844–D, pp. 205–213, 1934.

little evidence to suggest a pneumatolytic origin, for although the concentrates contain tourmaline, the other minerals that contain volatile constituents, such as topaz, fluorite, and axinite, are rather scarce.

South of the tin belt late Tertiary mineralization of another type has taken place near the top of Hot Springs Dome. Here the ores are found in bedrock, but so little prospecting has been done that the paragenetic relations are not clear. The ores occur in shear zones that trend east, more or less parallel to the elongation of a body of Tertiary biotite granite that lies a short distance to the south. The surface ores are galena and limonite, the former in pockets in the latter. Little quartz is present, but along with the limonite are some siderite, hematite, and manganese ore. Though galena is the chief sulphide, small quantities of chalcopyrite, pyrrhotite, and pyrite are also present, with here and there a little malachite or azurite. In one open cut erythrite or cobalt bloom was observed, both on quartz stringers and without quartz in crevices. Nickel minerals are also reported to occur in a nearby pyrrhotized basalt dike. These shear-zone deposits carry $1 to $2 a ton in gold and from 5 to 8 ounces in silver and are therefore low-grade deposits. All the ores are more or less oxidized, and nothing whatever is known of their condition and content in depth. The genetic relations that exist between these deposits and the gold-tin ores are likewise unknown, but both types of deposits are believed to have originated in the final stage of Tertiary mineralization.

Experience in other parts of the Yukon-Tanana region suggests that tin and tungsten lodes are likely to have been formed more or less simultaneously, though tungsten minerals are not everywhere found with cassiterite. Tin and tungsten minerals are definitely known, however, to have originated both during Mesozoic and Tertiary stages of mineralization, and these minerals are therefore no index of the age of mineralization. In the Hot Springs district the stream tin is of Tertiary age. In the Tolovana district some scheelite has been found in the streams draining the ridge west of Amy Dome, and this scheelite is considered to be of Tertiary age merely because the other mineralization of this district appears to be of Tertiary age. Similarly, in the gold placers of Quail and Troublesome Creeks, the association of cinnabar, cassiterite, and scheelite suggests a Tertiary age for the tin and tungsten minerals of that area. Ores of tin and tungsten may therefore be found in association with both Mesozoic and Tertiary granitic rocks.

Of all the minerals thus far enumerated as representative of Mesozoic and Tertiary mineralization in this region, only cinnabar can be said to be distinctly limited in a geologic sense. So far as now known, cinnabar has been found in Alaska only in lodes of Tertiary age and in placers derived from such lodes. This mineral therefore appears to constitute an important time marker in the sequence of mineral deposits. Molybdenite, to be sure, has been observed only in association with the Mesozoic ore deposits, but the single occurrence of this ore in the Yukon-Tanana region does not warrant any general deductions.

In searching for mineral deposits, therefore, the location of bodies of granitic rocks is of great importance, but small outcrops of intrusive bodies of this type are more likely to be the source of mineralization than larger outcrops. The presence of quartz veins, however, is equally important, for although such veins are usually derived from nearby or underlying bodies of granitic rocks, those rocks may be concealed by overburden or may not have been bared to the surface by erosion. Mesozoic and Tertiary granitic rocks are equally significant as sources of ore minerals, but past experience has shown that lodes are more likely to be found in close association with Tertiary granitic rocks than with Mesozoic granitic rocks, for the latter in general exhibit a more distal type of mineralization, exemplified by quartz veins that may be some distance from the intrusive bodies. On the other hand, the Mesozoic mineralization is more likely to have resulted in the formation of ore bodies that are confined within district fissure veins, where they can be more easily and profitably worked.

MINERALIZATION CONNECTED WITH BASIC IGNEOUS ROCKS

The metallic lodes connected genetically with basic igneous rocks in the Yukon-Tanana region have not so far proved to be of economic significance. Chromium, nickel, and platinum ores belong in this category, but the known occurrences of these elements are few.

The only known occurrence of chromite in place is on the spur west of Ruth Creek, south of the settlement of Livengood. Here in the course of prospecting a gold lode a small body of chromite was exposed, but the size of this body was not ascertained. Small intrusive bodies of Devonian serpentine, however, occur nearby, and the writer believes that the chromite is related genetically to the serpentine. Picotite (chrome spinel), however, is common in all the productive placer creeks of the Tolovana and Eureka districts, in the placer creeks draining Wolverine and Sawtooth Mountains, and in the tin belt of the Hot Springs district. This mineral surely originated in basic rocks, but that it originated only in the Devonian basic rocks cannot be asserted. Its widespread distribution suggests an additional source in basic differentiates of the Tertiary monzonitic rocks.

Nickel is of no economic importance in this region but has been reported to have been found in small amounts in the Tolovana district and in the mineralized belt near the summit of Hot Springs Dome.

Platinum has been recorded at only one locality in the Yukon-Tanana region. Overbeck[72] states that a small nugget of this metal was given to him which was reported to have come from a clean-up on one of the producing placer creeks of the Tolovana district. The exact locality is not stated, but the nugget is believed by the writer to have come from one of the creeks that drains the west end of the ridge south of Livengood. Platinum metals are known to be derived mainly from ultrabasic rocks, such as serpentine and pyroxenite, and the widespread occurrence of Devonian rocks of this type in the Yukon-Tanana region warrants a more careful lookout for platinum, palladium, osmium, iridium, and the other metals of this group in prospecting for gold placers.

PLACER DEPOSITS

OCCURRENCE AND TYPES

Most of the metals and metallic ores that occur in the lodes are found in the placers of the Yukon-Tanana region, but only gold has been found in placer deposits of commercial value. Cassiterite, the oxide of tin, is also recovered as a byproduct of the gold-placer mining in the Hot Springs district, but these placers could not be worked commercially for their content of tin alone. Small amounts of cassiterite and wolframite were also saved and shipped from the gold placers of the Circle district during the era of high prices for tin and tungsten in 1917, but these gold placers contain relatively small amounts of these minerals. Gold placers may therefore be said to be the only placers in this region, at present known, that can be worked on a commercial scale.

The principal gold placers that have been worked in the Yukon-Tanana region are in the Fairbanks, Rampart, Hot Springs, Tolovana, Circle, Eagle, and Fortymile districts. Many other gold placers, of course, have been prospected and worked, such as those in the Tenderfoot district and the placers of the Fourth of July Creek, along the upper Yukon, but the bulk of the gold production has come from the seven districts above named. The sequential history of the discovery of these districts has already been given in several earlier reports. Many of these gold placers were phenomenally rich, and in the early days of mining considerable fortunes

[72] Overbeck, R. M., Placer mining in the Tolovana district: U. S. Geol. Survey Bull. 712, p. 184, 1920.

were acquired by many operators, working on a small scale. The bonanza deposits, however, were soon worked out, and as time passed manual methods of mining gave way to cheaper and more effective methods, involving the use of hydraulic operations for surficial deposits and steam-hoisting plants for underground deposits. At the present time all the seven principal mining districts are still producing placer gold, but in most of them highest-grade placers are now worked out, and most of the gold is being recovered by large-scale mining operations. An example of this is in the Fairbanks district, where mining of the low-grade deposits is now in progress on a gigantic scale by the use of hydraulic methods and dredging. The other districts may eventually be worked in this same way, and upon the adoption of such methods depends the future of the placer-mining industry in these older camps. Such development in the Fairbanks district, however, has been made possible by the building of the Alaska Railroad, which by reducing the cost of transportation has lowered the cost of all commodities and thereby decreased materially the cost of mining operations. The similar development of the outlying camps will probably have to await the construction of highways that will connect them with the Alaska Railroad.

All the placer-mining districts have been repeatedly visited and studied by Federal geologists in the course of the last 35 or 40 years, beginning with the work of J. E. Spurr in 1896. A bibliography listing all these reports has been given in the introductory part of this report, and the reader is referred to this rather voluminous literature for detailed descriptions of the placer deposits. To attempt even to summarize these detailed descriptions would take far more space than can be allotted in a general report. Instead, the writer will present only a genetic classification of these placers, citing certain localities as illustrative examples.

The process of concentration of gold in the streams of the Yukon-Tanana region involves a tremendously complex geomorphic history, which is only beginning to be understood. From one point of view this process is simpler here than in southern Alaska, because the region is essentially unglaciated, and the valleys have not been affected by glacial ice. Yet indirectly the glaciation in nearby areas, particularly in the Alaska Range, produced profound geomorphic and climatic changes, which are reflected in the character of the sediments deposited during that epoch. The process of placer formation, however, is definitely simplified by the absence of marine or fresh-water beach deposits, so that in general only fluviatile and closely related placers have been formed.

The placer deposits of this region may in general be classified as follows:

Residual and hillside placers.
Stream placers:
- Ancient stream placers:
  - Bench placers.
  - Buried placers.
- Recent stream placers.

RESIDUAL AND HILLSIDE PLACERS

Residual placers are formed by rock weathering and decay in place. By frost heaving and other processes, the volume of such debris overlying the bedrock may have been materially diminished, but fundamentally the gold of residual placers was not transported to any material degree by running water but was concentrated mainly by gravitative sinking through disintegrated rubble that accumulated upon an upland bedrock surface. Residual deposits of rock debris are not uncommon in this region, but no example of a strictly residual gold placer can be given, as most of the gold placers that approximate this type have been formed on sloping surfaces, where hillside creep has also been an important factor. The gold placers of Shirley Bar, in the Eureka district, are almost residual placers, for the gold accumulated upon the very gently sloping valley wall of the North Fork of Baker Creek. Such placers can be of commercial value only where the underlying bedrock has been extensively and highly mineralized, and Shirley Bar is no exception to this rule, for the really valuable placers at that locality were those in which the gold of the residual material had been reconcentrated by small streams that drained the bedrock surface.

Hillside or eluvial placers are residual placers that have been formed on sloping bedrock surfaces, usually on gently sloping valley walls, and have been transported down such slopes for some distance by soil creep, frost heaving, and the action of tiny rivulets within the disintegrated rock debris. Such deposits are common in the Yukon-Tanana region, though few of them constitute rich placers. In the formation of such deposits the gold gradually sinks to the bottom of the moving debris, where it is retarded by irregularities and crevices in the surface of the bedrock, while the overburden continues to move downward toward the valley floor. The net result is an accumulation and concentration of gold upon the bedrock surface. Such deposits may be of considerable areal extent and are characterized by the presence of unsorted angular or subangular rock fragments, commonly embedded in clay. They are also characterized by a deeply weathered and locally iron-stained bedrock surface. One of the best examples of a commercial hillside deposit is the gold placer of McCaskey Bar, in the Eureka district.

STREAM PLACERS

The formation of stream placers is a complex process, involving many factors. One of the most influential of these factors is the climate that existed when the placer was formed, for upon the temperature, the humidity, and the character, amount, and seasonal distribution of precipitation depend in considerable measure the character and speed of erosion, and the consequent movement of rock debris. Preexisting climatic conditions are also involved, for upon them depend the conditions of a stream valley and its alluvial deposits at the time when placers began to form. The nature of the bedrock and the relation of a stream to structural conditions that exist in the bedrock are further matters for consideration. Again, both the regional and the local deformation of the earth's surface by tectonic movements, before, during, and even after the formation of a placer deposit, constitute additional factors, which have greatly increased the complexity of the geomorphic history in many mining districts in the Yukon-Tanana region. In addition to these more generalized factors, which apply to areas of considerable size, there are other factors that may apply locally, so that the geomorphic history of many stream valleys can be deciphered only by detailed local studies. Obviously, therefore, the genesis of the stream placers in the Yukon-Tanana region cannot be stated in detail, and insufficient work has yet been done even to warrant the attempt. Certain general principles are recognized, however, which apply to the formation of most stream placers.

Stream placers are the common type in the Yukon-Tanana region. Such placers are formed by the action of running water, and their origin is closely connected with the history of the alluvial deposits in which they occur. Most streams with a normal geomorphic history have relatively high headwater gradients, which gradually decrease downstream. A great deal of the active erosion in a stream valley occurs in its headwaters, and in the clear-water streams of the Yukon-Tanana region the transportation of rock debris takes place mainly during periods of high water. At such times the headwater detritus is moved downstream to a certain zone, where the current of the stream slackens, and the coarser material begins to be deposited. The finer rock debris is moved farther than the coarser debris, and sand and silt may be transported far downstream before they are dropped. Alluvial material is therefore present in all sections of a stream valley, from its headwaters to its mouth, but most of these deposits may be regarded as transient material, which is awaiting further downstream transportation on the next flood. There is, however, a certain critical point or zone, in a normal stream, above which all the material in the stream bed is of transient character, for all such material, from the surface to bedrock, is subject to further transportation downstream in periods of high water. Below this critical zone, on the other hand, there is a body of alluvium at and near bedrock which will not be further disturbed by high water and which will not again be moved until the overlying deposits are removed by some geomorphic change, such as a lowering of the local baselevel of erosion. The thickness of this substratum of permanent alluvium increases in general downstream. Gold, because of its heaviness, tends to remain with the coarser rock debris; and when rock debris is in process of movement downstream, the gold tends to accumulate at the upper end of this critical zone. The site of deposition of the gold, however, is somewhat variable, depending upon diurnal or seasonal variations in the volume of water and upon the amount of other material transported; but there is a rather definite zone, beyond which little gold will be moved downstream.

Streams, however, seldom remain indefinitely in a single channel but instead will migrate laterally in their valleys. In this process channels are cut in older alluvial deposits, and debris of various types and ages may be intricately intermixed. Gold placers that have remained for a long time untouched by running water are again reworked, and many of the anomalous features found in placer pay streaks may be attributed to such reworking of older deposits by lateral stream migration. Yet in general even this phase of erosive activity is confined to transient deposits and does not affect the permanent alluvial substratum downstream from the critical zone. Therefore, in general the deposition of gold is still restricted to the upper end of the critical zone.

As a stream continues in its cycle of erosion, its upper valley is usually extended progressively backward into the divide at its head; or if this process is opposed by another stream on the opposite side of the divide, the elevation of the land between the two streams will be progressively lowered. In either event, the original headwater gradient will be gradually lowered, and as this occurs the critical zone that marks the upstream limit of the permanent alluvial substratum will gradually migrate upstream. As this process continues, old deposits of gold will gradually be covered by the substratum of permanent alluvial material, the upper limit of which is moving upstream with the critical zone; and as the site of gold deposition is also dependent upon the location of the critical zone, gold will be deposited progressively farther upstream. In this manner, pay streaks are gradually evolved, and a continuous pay streak should therefore be regarded as a series of overlapping gold placers, the oldest of which lie farthest downstream.

ANCIENT STREAM PLACERS

If the process of stream alluviation were continued to its final stages, all the hills would be eroded away and all the resultant rock debris which the streams could not transport to the sea would be deposited as an alluvial cover upon the broad valley floors of the region. Usually, however, tectonic disturbances or other causes will change the baselevel of a stream long before the cycle is completed. If the baselevel is lowered, the streams will be rejuvenated and will begin to cut into and dissipate their older alluvial deposits. If this rejuvenation is one of considerable magnitude, the streams will become entrenched in their older deposits, and the older deposits will be left as gravel terraces or benches along the sides of a new valley. Such high gravel deposits, if they originally contained considerable gold, will constitute typical bench placers. If the entrenchment continues to the old bedrock surface and the stream erodes further in that surface, gravel-covered bedrock terraces will be found along the valley walls, and as the tributary streams denude the original gravel, the placer may be in part or wholly destroyed, leaving only a bedrock terrace. When, on the other hand, the baselevel of a stream is elevated, new alluvial deposits will form upon the older ones, and an original pay streak may become deeply buried under a great thickness of alluvium. In the later stages of such a period of alluviation various factors may cause the stream to wander laterally far from its original course; and if the baselevel is again lowered and the stream incises itself in its alluvial valley floor, its new course may be quite different from its original course. Under such conditions the stream may destroy parts of an original pay streak and leave untouched other parts, which lie on either side of its new course. Such old buried placers, in a wide valley, may lie at a considerable horizontal distance from the present stream course. They are buried placers rather than bench placers, although in ordinary mining parlance all placers that lie at a considerable horizontal distance from the present stream courses are loosely designated "bench" deposits. If, however, during the subsequent cycle of lowering of the baselevel, the present stream incises itself deeply in the alluvial deposit that constitutes the buried placer, the latter will become essentially a bench placer, though its geomorphic history will have been quite different from that of a typical bench placer. Indeed, the process may continue still further, so that the present stream not only may excavate a new channel in an old buried placer, but may eventually incise itself in bedrock, thus producing gravel-covered bedrock terraces. This stage has actually been reached by some of the streams tributary to the Tanana River.

Considering the variation in the baselevel of a stream, it can be readily seen that the datum plane may remain constant for a long time, or it may be elevated or depressed at varying rates. The resulting variation in the character of sedimentation may be of almost infinite diversity. In addition to variations in the baselevel originating outside of the valley of a particular stream, many streams in the Yukon-Tanana region are believed to have been subjected to the effects of local warping, either within their own drainage basins or in the hills that form their divides. Downwarping in a stream valley would result in the local accumulation of a great thickness of alluvium, with bedrock surface in one part of the valley that sloped in a direction opposite to the flow of the stream. Upwarping might result in the formation of a rock-cut canyon, with a bedrock surface above the canyon that also sloped opposite to the direction of flow of the stream and was covered by alluvium, which increased in depth upstream. Downwarping in the divide at the head of a stream would result in a diminution of the volume of rock debris entering the stream, or it might conceivably result in stream piracy. And upwarping in the divide at the head of a stream would result in a great increase in the volume of rock debris thrown into the stream. But many of these geomorphic effects can also be produced in other ways than by upwarping or downwarping, particularly in streams whose base level has been elevated, so that they have been superposed upon original valley walls or upon bedrock divides. It will readily be seen what diverse geomorphic results may be produced when these many variations in the regional baselevel act concurrently with local warping. This picture of a complex geomorphic history is by no means overdrawn, for all these and other unknown variable factors have actually been effective during the late geologic history of the Yukon-Tanana region.

Bench placers, or elevated placers that originated essentially as the result of a lowering in the baselevel of a stream, are well known in the Yukon-Tanana region. At some localities the bedrock surface under both the bench gravel and the present stream gravel has essentially the same elevation, so that only gravel benches have been developed. More commonly, however, both the bench gravel and the bedrock below it have a higher elevation than the bedrock below the present stream, and this condition is usually observable in the configuration of the valley walls. The successive terraces in the valley of Minook Creek and some of its tributaries, previously described, are excellent examples of gravel-covered bedrock terraces, and the lowest of these in the valley of Hunter Creek is a bench placer. A still better illustration in the same district is Idaho Bar, which is an ancient bench placer, of late Tertiary age, which lies 600 to 800 feet above the present level of Little Minook and Hunter Creeks. Another good example is the bench placer that forms a continuous pay streak along the north side of Livengood Creek. Here it is probable that the bench is a result of elevation of the baselevel, followed by a lowering of the baselevel, the second process being of greater magnitude than the first. Additional examples of bench placers are found at many places in the Fortymile district, where a succession of stream terraces have been formed not unlike those in the Rampart district. Good illustration of bench placers in the Fortymile district are the pay streak that lies along the north side of Dome Creek and the bench placers on Myers Fork of Chicken Creek, where mining operations are now in progress.

Pleistocene and Recent climatic conditions in this region were such that most of the alluvial deposits are permanently frozen, but where such gravel lies close to or below the level of present streams, it is likely to be partly thawed in irregular patches by the action of natural cold-water thawing. The bedrock surfaces of bench placers, however, lie well above the level of the present streams and are therefore not so likely to be subjected to cold-water thawing by running water. The bench deposits are therefore as a rule solidly frozen and are more economical to work by underground mining methods, as no pumping and little timbering are required. The bench placers of Livengood Creek exemplify this condition, for this pay streak is solidly frozen and dry from one end to the other, and in underground mining it was not uncommon to clean 30,000 or 40,000 square feet of bedrock from a single shaft, with little or no timbering. Many bench placers are well adapted to hydraulic mining methods, but irrespective of the mining methods used, if they are not too far from the present creek, they have the added advantage of yielding an adequate grade for sluicing and ample room for placer tailings.

Buried placers, or placer deposits that have been formed essentially as the result of an elevation of the local baselevel, are also well known and constitute in fact some of the most valuable placers in the Yukon-Tanana region. In such placers the bedrock below the gravel is usually little higher and often lower than the surface of bedrock under the present streams, and as the surface of the valley rises gradually away from the streams, it is characteristic of such deposits to be deeply buried under a thick overburden. Such deposits are therefore worked, at least in the earlier stages of mining, by underground methods. It is also characteristic of buried placers that they are commonly more or less thawed, and in underground mining this necessitates considerable timbering and often pumping. Buried placers of this type are more expensive to mine by underground methods than true bench placers, but it so happens that the tenor of many of the buried placers in the Yukon-Tanana region has been so high that the greater cost of mining has been more than offset by the increased returns. Buried deposits, however, are advantageously worked by dredging.

Most of the gold placers of the Fairbanks and Hot Springs districts exemplify this class of buried placers. In the Fairbanks district the gold placers were laid down in ancient streams whose courses in general were different from those of the present streams. After the placers were formed the baselevel in this district was elevated, and the stream valleys were progressively alluviated with later deposits of gravel and silt, up to an undetermined elevation. During this alluviation the streams became sluggish and migrated laterally from their old channels. Subsequently, the local baselevel was lowered, and the streams began to excavate the alluvial filling in the valleys, but in so doing, owing to their prior lateral migration, they incised new gorges which had no necessary relation to the underlying surface of bedrock. They, therefore, dissected the alluvial deposits and the underlying placers in a most irregular fashion and in places were in fact superposed upon the lower slopes of old valley walls. As a result of this process, the present valleys may have buried placers first on one side of the stream and then on the other. Thus, on Cleary Creek the pay streak in the upper valley above Wolf Creek lies along the west side of the present stream, but below Wolf Creek the pay streak continues along the east side to the town of Chatanika, where it again crosses to the west side. The same condition is observable in the pay streak that occupies the valleys of Pedro and Goldstream Creeks.

The lowering of the local baselevel, however, was not of uniform magnitude on all the streams in the Fairbanks district, and the process may have been further complicated by local warping. The net result has been that the present streams have lowered their bedrock channels in varying degrees, so that although most of them flow at nearly the same level or slightly higher than the old bedrock surface below the placers, others have incised their channels to a level appreciably lower than the old bedrock surface. Thus on Goldstream Creek some of the bedrock surface below the productive placers is higher than the surface of bedrock under the present creek, yet fundamentally the Goldstream pay streak is a buried placer and not a bench placer. The deep placer in the valley of Patterson Creek, in the Hot Springs district, is another excellent example of a buried placer, but here the elevation of the baselevel, which resulted in the alluviation of the valley of Patterson Creek, may have been further complicated by local warping.

Most of the richer placers of the Yukon-Tanana region are ancient placers, of either the buried or bench type, which originated mainly in early Pleistocene time. It is possible that the climatic and erosional conditions before and in the early stages of Alaskan glaciation were somewhat different from those which existed during or after the ice age. The climate was probably milder, and rock weathering took place more in the manner now observed in temperate climates. A ground-water table was probably present in the late Tertiary, and residual decomposition and accumulation of rock debris were important factors in weathering. Such conditions favored the production of a greater volume of rock debris, which incidentally included gold in mineralized areas, so that even with the same volume of water the downstream transportation of gravel was a more constant process than at present, with the result that more gold was concentrated in the valleys. The great width and depth of many valleys in this region seem entirely out of proportion to the size of the streams that now occupy them. These oversized valleys indicate a long and uninterrupted erosional cycle prior to the ice age, but it is also possible that this erosional cycle was accompanied by a greater precipitation than now occurs in this region. It is also a fact worthy of emphasis that nearly all the richer ancient gold placers of Alaska are found in districts of low elevation. Also, the ancient placers occur mainly in areas of moderate relief, where the stream gradients are low now and were also relatively low at the time of the formation of the placers.

RECENT STREAM PLACERS

The recent stream placers in this region require little explanation. They lie in the gravel deposits that form the present valley floors and have been concentrated in part by direct erosion of mineralized bedrock and in part from the destruction of ancient placers. Where bench gravel carrying gold has been eroded by the present streams, the resulting stream gravel has the greatest chance of containing commercial placers, for even though the original gold tenor of the bench gravel may have been low, the elevated position of these deposits makes them particularly susceptible to stream erosion, so that a great volume of gravel may be reworked and the gold concentrated from it. Where ancient buried placers have been eroded by the present streams, the resulting stream placers are less likely to be of economic significance, for as a rule only parts of the older placers have been eroded in any one valley. It may happen at some localities that all the gold in the recent placers is derived directly from mineralized bedrock, though this condition is seldom realized. In this event, if the intensity of mineralization was of the same order of magnitude as in the bedrock that supplied the gold of the ancient placers, the chances for a workable placer are less favorable, for the amount of erosion in the present stream valleys since the ice age has not been so great as in the ancient preglacial streams. Irrespective of their origin, the recent stream placers of the Yukon-Tanana region are relatively unimportant, compared with the ancient placers, though some of them constitute workable placers of medium grade. The gold placers that are now being worked in the upper valley of Walker Fork of the Fortymile River constitute a good example of a recent placer deposit that can be profitably exploited. The gold placers of Nome Creek, in the Fairbanks district, constitute another example of such workable deposits of Recent age; and the gold placers of American Creek, in the Hot Springs district, may be cited as a third example.

In addition to the lower gold tenor, the recent stream placers are usually in considerable measure unfrozen. If the recent gold placers are deeply buried, so that they must be worked by underground methods, this unfrozen condition is an economic disadvantage, and the content of gold must be correspondingly high to warrant their exploitation. If the recent placers are of shallow depth, however, their unfrozen condition is a decided advantage, as they can be advantageously worked by open-cut methods, such as hydraulic mining and dredging.

NONMETALLIFEROUS DEPOSITS

Coal is the only one of the nonmetalliferous deposits of this region that has been explored with an idea of its commercial production. In earlier years the coal beds of this region, particularly along and near the Yukon River, were opened up, and coal was actually mined at several localities. The present small population along the Yukon, however, together with the lack of industrial use for coal, and the abundance of wood for local needs, has rendered the exploitation of coal profitless, and at the present time little or no coal is being mined. The coal beds that occur along or near the Yukon were examined and studied years ago by Collier,[73] and additional information has been published by other workers—for example, certain data given by the writer[74] regarding the coals near Chicken. In the present report it suffices to review briefly these occurrences of coal.

---

[73] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 20–44, 1903.

[74] Mertie, J. B., Jr., Mining in the Fortymile district: U. S. Geol. Survey Bull. 813, pp. 141–142, 1930.

Most of the coal beds occur in the Tertiary rocks, and, as shown on plate 1, these rocks crop out principally along the Yukon between the international boundary and Circle and farther downstream between Hess Creek and Tanana. In the upper river or Eagle district coal beds have been found at several localities in the basin of Mission Creek, particularly on American Creek; on the Seventymile River; on Washington Creek; on some of the tributaries of the Charley River; and on Coal Creek. All these coal croppings occur at distances of 5 to 20 miles south of the Yukon. These beds of coal are in the lower part of the Tertiary sequence and range in thickness from a few inches to 6 feet. Three analyses given by Collier [75] show that the coals had an average content of fixed carbon of about 40 percent and of volatile matter about 42 percent. Most of this coal is black and glossy, with a conchoidal fracture, but some of it shows a certain amount of woody structure. All of it is classified as lignite.

In the lower river or Rampart district the coal beds early attracted attention. Directly opposite the mouth of Hess Creek coal croppings are visible along the Yukon, and in 1895 or 1896 a prospector named O. C. Miller drove a tunnel to explore these coal-bearing rocks. This was then called the Miller mine but subsequently came to be known as the Pioneer mine and still later as the Drew mine. The coal seams here, in contrast to those in the Eagle district, occur in the upper fifth of the Tertiary sequence, which is composed mainly of fine-grained sandstone, black shale, and beds of coal; and unless the sequence is repeated by faulting at least seven coal seams are present, ranging in thickness from 1 to 7 feet. Analyses of three of these seams of coal and of two other coal beds near Minook Creek were given by Collier,[76] and another analysis of the coal from the Drew mine had earlier been published by Spurr.[77] From these six analyses it is found that these coals in the Rampart district have an average content of fixed carbon of about 37 percent and of volatile matter about 41 percent. This coal is similar in general character to that found in the Eagle district and is classified as a black lignite. About 1,200 tons of coal was mined at the Drew mine, of which the greater part was used on the river steamboats, but it appears not to have proved satisfactory for that service.

Similar beds of Tertiary coal occur in the Fortymile district, and at Chicken one bed of coal has been mined and utilized for blacksmithing and similar work. A 35-foot shaft near Chicken disclosed 22 feet of coal, in a vertical position, but neither the top nor the

[75] Collier, A. J., op. cit., pp. 27–33.
[76] Idem, pp. 39–43.
[77] Spurr, J. E., Coal in the neighborhood of the gold belt: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 381–382, 1897.

bottom of the seam was seen. A run-of-mine sample of this coal showed it to contain about 36 percent of fixed carbon and 31 percent of volatile matter, but a picked sample of higher-grade coal was found to contain about 48 percent of fixed carbon and 35 percent of volatile matter. The run-of-mine sample is evidently a lignite, but the picked sample is really a subbituminous coal of average grade, comparable with some of the subbituminous coals of the Rocky Mountain States.

Another occurrence of coal in this region is found along the Yukon River at the mouth of the Nation River. This coal differs both in age and in character from the Tertiary coals above described. It occurs in the rocks of the Nation River formation, of Pennsylvanian (?) age, but the coal-bearing rocks at this locality lie along a fault zone, so that their position in the Nation River sequence cannot be ascertained. In general the rocks are vertical, and the coal occurs in pockets and kidneys as large as 8 feet thick and 13 feet long. An analysis of this coal, given by Collier,[78] shows about 56 percent of fixed carbon and about 40 percent of volatile matter. This is a bituminous coking coal. About 2,000 tons of this Nation River coal was mined in 1897 and was used on the Yukon River steamboats, but the difficulties of mining and the cheapness of wood rendered its further exploitation unprofitable.

Another potential nonmetalliferous resource along the Yukon River is oil shale. This material occurs in the Upper Triassic rocks opposite the mouth of the Nation River and on Trout Creek, farther up the Yukon. A sample of the material from Trout Creek was distilled in the chemical laboratory of the United States Geological Survey by E. T. Erickson and was found to yield 28 gallons of shale oil to the ton. The complete report on this material is as follows:

> The sample as received appeared to have been exposed to weathering, which is likely to influence the character as well as the yield of the oil. For further chemical test the shale deposit should be resampled at a position unaffected by weathering.
>
> A distillation test was made according to the oil-shale distillation method used by the Bureau of Mines for determining the yield of crude shale oil. The total time required for the distillation was 1½ hours; rate of oil distillation, 0.5 cubic centimeter a minute.
>
> Upon comparison with other crude oils that were obtained from typical oil shales by the Bureau of Mines distillation apparatus, using a similar distillation rate, the crude oil obtained from the sample of shale from Trout Creek may be described as high in gravity and low in setting point. In these respects it is more nearly like the crude oil obtained from the Kentucky oil shale.

---

[78] Collier, A. J., op. cit., pp. 35–36.

Results of distillation of samples of oil shale

	Trout Creek, Alaska	No. 2, DeBeque, Colo.	No. 18, Colorado	No. 11, Elko, Nev.	No. 12, Australia	No. 7, Kentucky	Scotland
Crude oil.........gallons per ton..	28	35.73	63.32	59.19	120.56	15.01	....
Specific gravity....................	0.934	0.913	0.894	0.867	0.877	0.948	0.864
Setting point...............° C..	0	22	19	35	23	0	22

The chemical composition of oil shales has not yet been sufficiently investigated to compare them with typical petroleums, such as paraffin-base petroleum, which is low in specific gravity and high in content of paraffin series hydrocarbons; or a naphthene-base petroleum, which is largely composed of naphthene series and other cyclic hydrocarbons; or a mixed-base petroleum, which is intermediate in gravity and composition between paraffin-base and naphthene-base petroleums. The high gravity of the crude oil obtained from the shale of Trout Creek favors its commercial use for the production of lubricating oils. The low setting point indicates the absence of commercial quantities of paraffin.

This oil shale from Trout Creek was also examined microscopically by Miss Taisia Stadnichenko, of the United States Geological Survey, and the source of the shale oil was found to be myriads of spores in the rock. These deposits of oil shale are not of commercial significance at present but may sometime be utilized.

The mineral waters from several hot springs in the Yukon-Tanana region constitute a resource of considerable potential value for the future, for these hot waters have an unquestioned medicinal value; and where such springs are located at sites favorable for outdoor sports they may be developed into popular watering places. Some of the better-known springs are already being developed in this way. The composition of most of the hot and cold mineral springs of the Yukon-Tanana region is given in a report by Waring.[79]

PROSPECTING IN THE YUKON-TANANA REGION

Under present conditions of high cost of transportation and commodities of all kinds, most prospectors in Alaska who make their living by mining on a small scale will continue to search for gold placers and for high-grade lode deposits of gold and other metalliferous ores. Another type of prospecting, however, is now being developed in Alaska, which will doubtless in time to come be of major importance. This is the organized large-scale prospecting, by groups of qualified men, who will examine the country more systematically and more intensively, with the idea of discovering all kinds of mineral deposits, large and small, that may be commercially developed, either at the present or at some later time when changing

[79] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, 1917.

economic conditions warrant their development. Such large-scale prospecting will require much capital and will necessarily be financed either by large mining companies or by the Federal Government.

Regardless of the magnitude of such activities, prospecting should be done in and around bodies of granitic rocks, more particularly near the smaller bodies as now exposed. Valuable ore deposits have seldom been found in interior Alaska in association with granitic masses larger than 3 or 4 miles in diameter, and most of those known are associated with smaller intrusive masses or with dikes and sills. About 80 such bodies of granitic rocks are shown on the accompanying geologic map, but many others, particularly smaller masses, are also present, which either have not been seen in reconnaissance mapping or are too small to be shown on a map of this scale. As a rule, however, granitic rocks are fairly resistant to erosion and are therefore likely to stand out conspicuously among other rocks of the region. But exceptions to this rule are known, as, for example, in the Takotna district of southwestern Alaska, where a body of Tertiary quartz monzonite lies in the valley of Candle Creek and the surrounding ridges and spurs are composed mainly of basaltic rocks. The rich placers of Candle Creek, derived from this body of quartz monzonite, should serve as a warning against placing too great dependence upon topographic form.

Granitic dikes and sills are also important to find, for they may also be the source of valuable ores, or they may indicate the presence of nearby granitic rocks that may be a source of valuable lodes. Quartz veins must be carefully examined, when found, for after all most of the lodes are found in association with vein quartz. Quartz veins, moreover, may be found in areas where underlying masses of granitic rocks have not been bared by erosion, and in such places the relation of valuable lodes or placers to granitic rocks may be neither evident nor demonstrable. After bodies of granitic rocks, or granitic dikes and sills, or quartz veins are located, however, it still remains to determine whether such intrusives or veins have given rise to any metalliferous deposits. Not all intrusive bodies nor even all small intrusive bodies of granitic rocks have effected metallization, but, on the other hand, no valuable ore deposits have been found in interior Alaska that were not connected in some way with such rocks. They afford, therefore, the most favorable sites for prospecting, but they are by no means certain to yield ores.

All that has been said of lode prospecting applies equally well to placer prospecting, for the lode antedates the placer. It is a great waste of time and effort to prospect blindly from year to year, as some prospectors do, without having any good reason for believing beforehand that a gold placer may exist where they undertake to prospect. Some rich placers have been found in this way, but it is equally true that an understanding of geologic conditions has often resulted in discoveries that otherwise might not have been made for a long time. The discovery of the high-bench ancient beach placers at Nome is a case in point, for it was predicted by Federal geologists,[80] and other examples might also be cited in interior Alaska, where men who have been guided by geologic knowledge have been able to precede the uninitiated in making important discoveries.

In searching for placers the prospector should utilize to the greatest possible degree the accompanying geologic map (pl. 1), as the more conspicuous bodies of granitic rocks are there shown. But he should also keep in mind that unmapped bodies of granitic rocks, which either have not been seen or are too small to be shown on a map, are also present in the region. The next step is to discover whether such granitic rocks have produced metallization, either along their peripheries or in the adjoining country rock. After such metallization has been observed, the prospector should examine the streams draining from such areas. One difference, however, must be cited, between prospecting for placers and prospecting for lodes. In placer prospecting it is not necessary to find first a high degree of metallization nor to discover a rich lode, for mineralized rock of low grade may by long-continued erosion and stream concentration yield a rich placer. The placers of the Klondike region are an example of this condition. In fact, if the prospector finds a small area of granitic rocks or an area cut by many quartz veins or granitic dikes, he would do well to prospect the streams draining such an area, even if evidence of metallization has not been discovered in the bedrock. If a commercial gold placer is present in the vicinity, some inkling of the fact is rather likely to be obtained by panning on the bars and riffles of some of the streams nearby.

Another point that deserves stress is the desirability of searching in particular for bench deposits. The conditions that make for the development of continuous commercial pay streaks are long-continued and deep residual weathering, moderate stream gradients, and a nice adjustment between the factors that regulate the erosion and transportation of rock debris. It is believed that favorable conditions of this sort prevailed more generally in interior Alaska during the geomorphic cycle preceding the present one than they do now. For this reason where "bench" and stream placers both

[80] Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region (U. S. Geol. Survey special publication), pp. 22–23, 1900. Brooks, A. H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900 (U. S. Geol. Survey special publication), pp. 80–91, 1901.

occur the former are likely to be the richer, but the prospector who is searching for placers that may be worked on a large scale will not necessarily be deterred by this consideration.

Some consideration should be given to the topographic type of country in which workable placers are most likely to be developed. One of the conditions that is regarded as favorable for the accumulation of commercial placers is a moderate stream gradient, and such gradients are prevalent in the lower parts of the region. To be sure, moderate gradients may be found in the lower courses of larger streams, even in a district of high relief, but the chances for the formation of a workable placer are less in a wide valley drained by a large stream than in the smaller tributary valleys. It does not necessarily follow that workable placers will not be found in the higher country, for a sufficiently rich mineralization may give rise to rich placers under conditions that in general are considered adverse. The chances of discovering high-tenor placers, however, are much better in the regions of low relief if the conditions for bedrock metallization appear to be equally favorable.

The question is often asked by prospectors and mining men whether deposits that would justify new mining camps are likely to be discovered in Alaska, particularly in the Yukon-Tanana region. This question is raised more in regard to new gold placer fields than in regard to lode deposits, for placer gold offers the best opportunity for quick and rich returns. A great deal of placer prospecting has been done in the Yukon-Tanana region in the last 40 years, but when the amount of such work is considered in relation to the great area of the region, it ceases to be so significant. It is probably true that no new placer-mining areas as large as the Fairbanks district are likely to be discovered in this region, because even the amount of prospecting so far done has probably sufficed to locate these major areas of mineralization. But the writer is firmly convinced that smaller mining areas, where the gold placers are localized mainly in one valley, are likely to be discovered from time to time as prospecting continues. The Tolovana placer camp, for example, lies but a short distance north of Fairbanks and is directly in the line of summer ridge travel between Fairbanks and Rampart, yet these valuable placers of Livengood Creek remained undiscovered for more than 10 years after the discovery of gold in the Fairbanks district, and even then they were finally discovered during an unwarranted stampede into this area, to stake creek placers that never amounted to much. Once the gold hunters were on the ground bench claims were staked in first, second, and third tiers, the latest comers staking farthest from the creek. Then some

54984—37——18

holes were sunk to bedrock on the bench claims, and the real pay streak was discovered.

The lesson to be learned from the Livengood stampede is that the major importance of ancient placers has not yet been properly realized. Panning and shallow prospecting in the present stream gravel are of course the first step in prospecting for gold placers, but as soon as colors are found in a creek, attention should at once be directed to the lower valley floors on both sides of the creek, whether well-defined benches are present or not, for ancient placers may be present which will be of higher value than any modern stream placers that may be located.

New placers will not be found, however, without intensive prospecting, and at the present time little prospecting is being done, as compared with such activity 20 or 30 years ago. This is due in some measure to the smaller white population now living in this region, and also to the lack of funds for financing prospecting. Years ago, when the larger camps were booming, men had ample opportunity, in a few months' work, to accumulate sufficient funds to finance their prospecting operations, perhaps for a year. Also, with prosperity everywhere, it was not difficult to obtain a grubstake from some merchant for a year's prospecting trip, if the prospector was a man of known integrity, and his project looked like a favorable one. These conditions are now changed, and at the present time it is difficult for a prospector either to earn or to borrow the funds necessary to finance a worth-while project. Still another obstacle exists, however, to a renewal of prospecting. The men who came to Alaska in the days of the early gold rushes and actually prospected were accustomed to a much less luxurious standard of living than now prevails in the United States and accordingly were less appalled by the prospects of hardship than a similar class of men of the present day would be; and though at the start many of this earlier generation knew little or nothing of prospecting and mining, they persisted in the face of discouragement and hardship and eventually succeeded in their new work. Many of these proved prospectors are now dead; most of the survivors are too old for this kind of work; and many of the newer arrivals in Alaska are unwilling to make the effort and sacrifices that are necessary to take the places of their predecessors.

INDEX

U

V

W

Y

The use of the subjoined mailing label to return this report will be official business, and no postage stamps will be required

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFFICIAL BUSINESS

This label can be used only for returning official publications. The address must not be changed.

PENALTY FOR PRIVATE USE TO AVOID PAYMENT OF POSTAGE, $300

U. S. GEOLOGICAL SURVEY,

WASHINGTON, D. C.