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TERTIARY DEPOSITS OF THE EAGLE-CIRCLE DISTRICT ALASKA

BY

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TERTIARY DEPOSITS OF THE EAGLE-CIRCLE DISTRICT, ALASKA

By J. B. Mertie, Jr.

ABSTRACT

A belt of sedimentary rocks of Tertiary age lies south of the Yukon River, between the international boundary and Circle. Conglomerate forms a large part of this series of rocks. All the streams that drain northward to the Yukon, flowing across these Tertiary rocks, contain more or less gold in their valleys, and some of these valleys contain important gold placers, which have been mined for many years. Recently, under the stimulus of a higher price for gold, dredges have been installed in the valleys of Coal and Woodchopper Creeks, and these dredges are now recovering a large quantity of gold.

Miners and geologists have thought for many years that these workable gold placers were derived from gold that was contained in the Tertiary conglomerates. The present investigation proves that these conglomerates are the proximate source of this placer gold, but also suggests that the original sources of the gold were the granitic rocks that form the bedrock farther south. The gold has been found to be so sparsely distributed in the Tertiary rocks that such rocks cannot be regarded as possible sites for lode-gold mining, under present economic conditions. As a result of complex geologic agencies, operating over a long period of time, the gold is also found to be erratically distributed in the Tertiary rocks, thus explaining the presence of placers in a certain few stream valleys and their absence in most of the valleys incised in the Tertiary rocks.

One of the interesting results of the investigation, of possible economic value, is the discovery of a significant amount of platinum, which is alloyed with the placer gold derived from the Tertiary rocks. The presence of platinum had been unsuspected, even by the producers of a large volume of such placer gold. The platinum metals constitute as much as 0.42 percent of the placer gold, but at present no payment is made for small quantities of platinum in placer gold. With a market price of platinum higher than now exists, however, it is possible that it may pay to separate the platinum before the bullion is sent to the Federal mints or assay offices.

INTRODUCTION

The Eagle-Circle district consists of a geographic belt of indefinite width lying along the south side of the Yukon River, between the international boundary and Circle. The general course of the Yukon within this stretch is N. 60° W., and the axis of the belt has approximately the same trend. The location of the district is shown in figure 7. Only the parts of the geologic formations that lie entirely south of the Yukon River are described in this report.

This district forms the northeastern limit of a larger geographic province known as the Yukon-Tanana region. Topographic and geologic mapping have been carried on intermittently in this region by the Geological Survey for more than 40 years, and numerous maps and reports have been published giving the results of this work. A list of

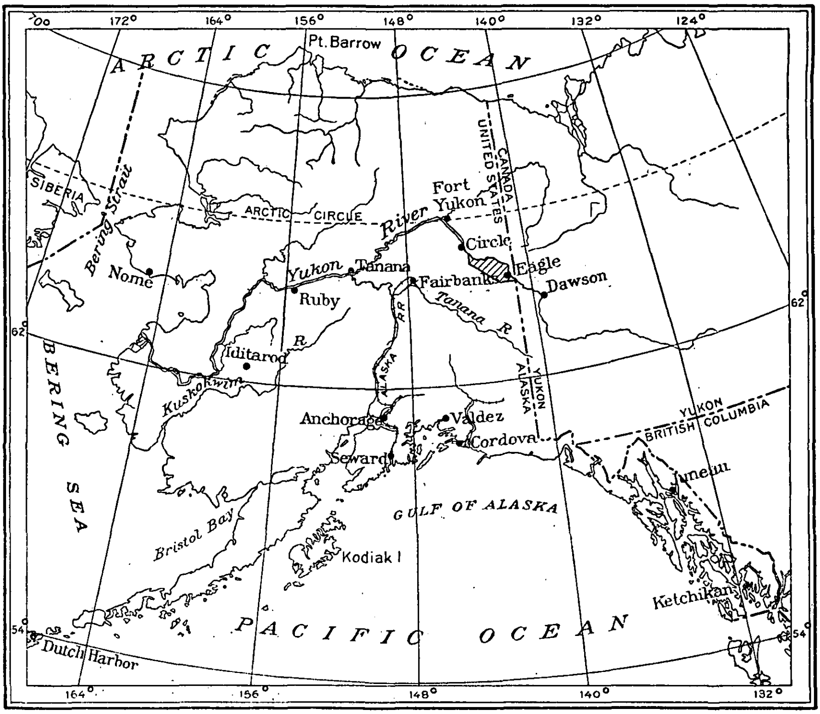


FIGURE 7.—Index map showing the location of the Eagle-Circle district.

these has been given by the writer in an earlier publication.[1] Close to the Yukon River, however, in the 120-mile stretch from the international boundary to Circle, little topographic mapping has been done, and the course of the Yukon itself has not been accurately surveyed. A geologic report on this belt was published earlier by the writer,[2] but the drainage map on which the geologic features were shown is only a generalized sketch map.

The present report aims to supply additional information regarding the Tertiary deposits, which are the source of most of the gold

[1] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 5–8, 1937.

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

placers now being worked in that part of the Eagle-Circle district lying south of the Yukon River. The work was conducted from base camps along the river, but the belt of Tertiary rocks is at places as much as 20 miles from the Yukon, so that it is not easily accessible from the river except in the vicinity of mining camps, where roads or trails have been constructed southward. The most accessible areas were the valley of the Seventymile River, which had been only partly mapped, and the valleys of Fourth of July, Coal, and Woodchopper Creeks, which were entirely unmapped, both as to drainage and topography, so that no suitable base was available upon which to plot geologic information. For this reason a sketch map of the drainage in these areas was made in 1938.

No general geologic mapping was attempted in this area in 1938, though the older geologic reconnaissance map was corrected at a number of localities, and some additional collections of fossils were made. This later work, however, was done mainly in areas where no satisfactory base map existed. For these reasons, a geologic sketch map is presented, the principal purpose of which is to show the distribution of the Tertiary deposits. This map also shows the intrusive rocks, the Quarternary deposits, and the pre-Tertiary sedimentary rocks, the last being grouped as an undifferentiated unit. (See pl. 8.)

GEOGRAPHY

The Eagle-Circle district is part of the great central plateau province of interior Alaska, which extends from the Alaska Range northward to the Brooks Range, a distance of 300 to 400 miles. This province has a diversified topography, but may be characterized generally as a country of rolling hills, among which occur isolated mountains and elongate ridges of greater prominence, though no well-defined mountain ranges are present. In the Yukon-Tanana region the ridge tops range in altitude from 1,500 feet to 5,000 feet, but the general ridge level ranges from 2,500 to 3,000 feet. Within any particular district, if the isolated prominences are disregarded, these crest lines rise to a nearly uniform altitude; and if the tops of all the main ridges of the Yukon-Tanana region were joined the resulting geometric surface would have the general form of a flat dome, highest in the east-central part of the region and sloping gently therefrom in all directions. This reconstructed surface suggests that a well-dissected and maturely eroded ancient land surface, of lower relief than the present topography, existed in mid-Tertiary time.

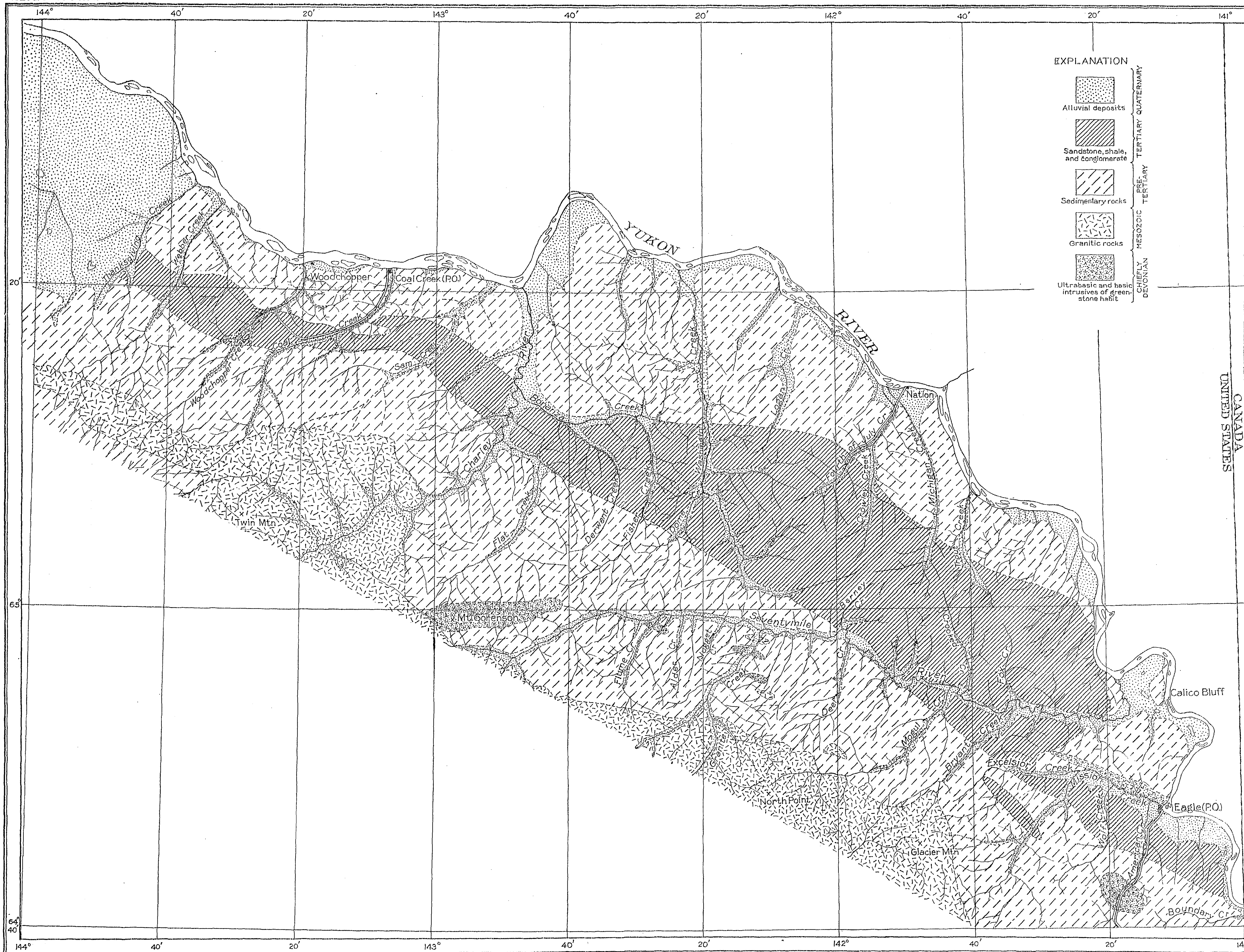
Within the narrow belt lying 20 to 30 miles south of the Yukon, a number of mountains stand out prominently above the general level of the ridges, rising to altitudes of between 5,600 and 6,000 feet. Among these, named from east to west, are Glacier Mountain, North

Point, Mount Sorenson, Twin Mountain, and another peak about 13 miles northwest of Twin Mountain. Glacier Mountain, North Point, and Twin Mountain are near the northern edge of a great granitic batholith, which is one of the striking geologic features of the region. Mount Sorenson is the site of a much older mass of ultrabasic rocks. All five of these mountains lie almost in a line, which trends about N. 60° W., parallel to the general course of the Yukon River and to the general strike of most of the geologic formations. The Yukon River crosses the international boundary at an altitude of 879 feet above sea level, and from that point to Circle has a gradient of about a foot to the mile. Hence the maximum relief of this area is more than 5,000 feet, but the average relief is less than half that much.

Between the international boundary and Circle, as through most of its course from its headwaters to the international boundary, the Yukon River meanders over a narrow valley floor, which is bounded by fairly steep walls that rise 1,000 to 2,500 feet to the summits of those spurs closest to the river. In reality, the Yukon is sharply incised in an old valley of much gentler relief. The general level of the old valley floor, as shown by many terraces, is 700 to 800 feet above the level of the present valley floor, but other lower terraces mark various stages in the sculpture of the present valley. The larger tributaries of the Yukon in this belt, such as the Seventymile and Charley Rivers, likewise flow in terraced valleys. No detailed study of these old base levels has yet been attempted.

Along the south side of the Yukon River, between the international boundary and Circle, the principal tributaries, named in order downstream, are Mission Creek, the Seventymile River, Trout Creek, Michigan Creek, Fourth of July Creek, Logan Creek, Washington Creek, the Charley River, Sam Creek, Coal Creek, Woodchopper Creek, Webber Creek, and Thanksgiving Creek. The two largest tributaries are the Seventymile and Charley Rivers, both of which have air-line lengths from source to mouth of about 50 miles. The others are smaller streams, ranging in length from 10 to 25 miles. Most of these streams head in country southwest of the belt of Tertiary rocks, but a few of them, such as Fourth of July Creek, head within the Tertiary belt. The Seventymile and Charley Rivers and the larger tributaries of the Yukon west of Charley River head in the granitic rocks that constitute the country rock along the south side of this belt.

Eagle and Circle are the principal towns of the Eagle-Circle district, but Circle is a few miles northwest of the area shown on plate 8. Eagle is a picturesque little settlement along the southwest bank of the Yukon River, about 6 miles west of the international boundary. It is an incorporated town and according to the census of 1939 had a population of 73, mainly white people. An Indian settlement, known



Base compiled from earlier surveys by Geological Survey, with revision of drainage of Woodchopper, Coal, and Fourth of July Creeks and other minor creeks from field surveys by J. B. Mertie, Jr., in 1938.

GEOLOGIC MAP OF THE EAGLE-CIRCLE DISTRICT, ALASKA.

Geology by J. B. Mertie, Jr., 1940.

as Eagle Village, is situated about 2 miles east of Eagle. Eagle is the local supply point for miners and trappers who operate in this general vicinity, and a considerable part of the supplies that go southward into the Fortymile mining district pass through Eagle.

Mining camps constitute the other settlements of the Eagle-Circle district. About 10 miles south of Eagle a few men are engaged in placer mining on American Creek and its tributaries, and west-northwest of Eagle a number of small placer-mining outfits are mining and prospecting on Seventymile River and several of its tributaries. Another placer-mining camp is located on Fourth of July Creek, about 35 miles northwest of Eagle. The largest number of people engaged in mining, however, are localized in the vicinity of Coal and Woodchopper Creeks, about 60 miles northwest of Eagle, where two gold dredges are operated during the summer months. Fish camps, wood camps, and trappers' cabins are the only other habitations along the Yukon River within the stretch shown on plate 8.

Fourth-class post offices are located at Eagle and Coal Creek, but the station at Coal Creek is inactive during the winter months. Eagle receives most of its mail during the summer months through a bimonthly service supplied by a mailboat that operates between Dawson, on the Yukon River, and Nenana, on the Tanana River. Some first-class summer mail is also delivered directly from Fairbanks to Eagle by airplane, under an emergency contract. The same general conditions regarding summer mail also apply to Coal Creek. During the winter months regular air-mail service is supplied between Fairbanks and Eagle. An all-year commercial radiophone is owned and operated by the Northern Commercial Co. at Eagle, by means of which communication is maintained with Fairbanks.

The transportation of passengers and supplies into this area is accomplished mainly by the American Yukon Navigation Co., which maintains a fortnightly steamboat service along this part of the Yukon River. The gas boat that carries the mail also carries local passengers and some freight, but many passengers now travel by airplane. The freight rates from Seattle to Eagle range approximately from $70 to $100 a ton for carload lots, and somewhat higher for less than carload lots. Fuel oil for the dredges on Coal and Woodchopper Creeks costs 25 cents a gallon in drums landed at Coal Creek.

Other features of the country, such as climate and plant and animal life, have been adequately described in earlier publications. It suffices here to state that the Eagle-Circle district is a part of the great interior province of Alaska, which is a subarctic region that is fairly well wooded up to an altitude of 2,500 feet. Throughout most of the district the ground is permanently frozen to considerable depth, ex-

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cept close to streams. The precipitation is light, averaging about 11 inches, and falls mainly in the months of July, August, and September.

GENERAL GEOLOGY

A number of geologic formations or groups of formations, ranging in age from early Paleozoic to Lower Cretaceous, have been differentiated and mapped in this area in earlier years, and this information has been published in several reports by the writer.[3] The present report, however, is concerned mainly with the sedimentary rocks of Tertiary age, and for this reason all the older sedimentary and bedded rocks have been grouped together on plate 8 as a single cartographic unit. The other groups that are mapped consist of two kinds of igneous intrusives and the Quaternary deposits. A short summary of the general character of these pre-Tertiary bedded formations will therefore suffice.

The oldest rocks are a group of recrystallized sedimentary rocks, known as the Birch Creek schist, with which are associated a variety of meta-igneous rocks. These ancient rocks, of pre-Cambrian age, are widely distributed in the region to the south and west, but also crop out as narrow bands within the area mapped as pre-Tertiary. The early Paleozoic rocks consist of many types of rocks, including sandstone, quartzite, slates of several colors, and limestones in varying degrees of recrystallization. These rocks are overlain by two groups of Devonian rocks, one of which, called the Woodchopper volcanics, consists of basaltic lava flows and intercalated beds of marine limestone. The type locality for the Woodchopper volcanics is along both sides of the Yukon River, upstream and downstream from the mouth of Woodchopper Creek. The other group of Devonian rocks consists of limestone. In the earlier reports both these groups have been separately mapped.

A thick and diversified sequence of Carboniferous rocks exists in this region, and in the general report on the Yukon-Tanana region the writer[4] divided these rocks into seven cartographic units; but these units are not mutually exclusive, as the complete Carboniferous sequence has not yet been definitely established. The oldest group of the Carboniferous rocks is composed principally of chert, with which is associated chert sandstone, chert conglomerate, and a minor proportion of rocks of other types. In their type locality in the Tolovana district, of the Yukon-Tanana region, this group has been

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[3] Mertie, J. B., Jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, 1930; The Tatonduk-Nation district, Alaska: U. S. Geol. Survey Bull. 836, pp. 347–443, 1933; The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, 1937.

[4] Mertie, J. B., Jr., op. cit. (Bull. 872), pp. 104–153.

called the Livengood chert. The chert is believed to be primary. The chert sandstone and chert conglomerate are distinguished by the fact that the grains and pebbles of these rocks are largely chert, with more or less quartz, and also by the fact that the binding matrix is principally chert. In the type locality chert conglomerate occurs at or near the base of this group of rocks, but intraformational horizons of chert conglomerate have also been recognized. The origin of these rocks has been discussed in earlier reports. A belt of such rocks, composed mainly of chert conglomerate and chert sandstone, crosses Coal and Woodchopper Creeks, and an isolated outcrop of chert forms the bedrock on a high hill west of the mouth of Coal Creek, close to the Yukon River. On the north side of the Yukon, north of Coal and Woodchopper Creeks, chert and chert conglomerate are known to have a wide distribution.

A group of Mississippian lava flows and interbedded sedimentary rocks with associated basic intrusives constitute another part of the Carboniferous sequence. This group of rocks, known as the Rampart group, is considered probably to overlie the chert formation. The type locality of the Rampart group is in the vicinity of Rampart, about 100 miles west of Coal and Woodchopper Creeks, but rocks considered to be of the same age also crop out along the Yukon River south of Circle, where they were formerly described by the writer as the Circle volcanics. These rocks continue eastward into the country north of the Yukon.

A well-known group of upper Mississippian rocks, known as the Calico Bluff formation, occurs at several localities along and close to the Yukon River, between Eagle and the mouth of Tatonduk River. The type locality is at Calico Bluff, about 4 miles upstream from the mouth of the Seventymile River. The Calico Bluff formation constitutes a mappable unit, whose age is well substantiated by large collections of fossils. The top of the Calico Bluff formation, however, cannot be seen at Calico Bluff, and the formation is underlain by cherty rocks whose basal horizons likewise are not visible. Hence there exist two other groups of Mississippian rocks, one above and the other below the Calico Bluff formation, which in the earlier geologic reports were designated as "undifferentiated Mississippian."

The sixth unit of the Carboniferous sequence is a group of terrigenous rocks, known as the Nation River formation. The type locality is along both sides of the Yukon River, in the vicinity of the mouth of Nation River. The age of this formation is not established upon a fossiliferous basis, but its rocks underlie conformably another formation, to which a position low in the Permian has been assigned. It has therefore been classified tentatively as Pennsylvanian. The principal bearing of the Nation River formation upon the matters discussed in this paper is that it contains horizons, in part intraformational, of conglomerate which can be distinguished only with difficulty from similar conglomeratic rocks among the Tertiary sequence.

The seventh and youngest formation of the Carboniferous is known as the Tahkandit limestone. It occurs principally on the north and south sides of the Yukon River, in the vicinity of the mouth of the Nation River, but it is also exposed at other places close to the river, between the Nation and the Tatonduk Rivers. Some faulted fragments of this limestone also occur near and in the valley of Coal Creek. Like the Calico Bluff formation, the age of the Tahkandit limestone is well established upon paleontological grounds, and it is assigned a position in the lower part of the Permian.

The Mesozoic sequence in this area is represented by three formations, only two of which have heretofore been mapped. The oldest of these are Upper Triassic rocks, consisting of thin beds of black shale interstratified with dark-colored limestone. These rocks crop out inconspicuously along the south side of the Yukon River, opposite the mouth of Nation River and in the valley of Trout Creek.

The second Mesozoic formation is a limestone, which crops out on Woodchopper Creek, about 2¼ miles from its mouth, and in the valley of a small stream about 2 miles west of Woodchopper Creek. On stratigraphic grounds this limestone had previously been mapped as Paleozoic, but fossils collected from it in 1938 established its Mesozoic age. This fossil record is presented herewith:

38AMt91 (18068). West side of Woodchopper Creek, about 2¼ miles from mouth of creek:

- Lingulid brachiopod.
- Terebratulid brachiopod.
- Rhynchonellid brachiopod.
- Gervillia sp.
- Inoceramus sp. or Pinna sp., fragments of a thick prismatic shell.
- Oxytoma sp., surface not seen.
- Ostrea sp., small simple species.
- Entolium sp.
- Camptonectes sp.
- Lima sp., broad form with fine sculpture.
- Lima sp., slender form with medium sculpture.
- Lima (?) sp., broad form with coarser sculpture.
- Cardium (?) sp.
- Anixomyon (?) sp.

38AMt94 (18069). Valley of small stream, tributary to Yukon River, about 2 miles west of Woodchopper Creek:

- Oxytoma sp.

These invertebrates were examined by Edwin Kirk and J. B. Reeside, Jr., of the Geological Survey, and by G. A. Cooper, of the

United States National Museum. The first three brachiopods of collection 38AMt91, according to Mr. Cooper, lack diagnostic features but can scarcely be Paleozoic. Dr. Reeside's statement with regard to this collection is as follows:

None of the better preserved material is familiar, and a hasty comparison with previous collections does not give any clue to exact age. Cooper, Kirk, and I are agreed that the material is not Paleozoic. This assemblage appears to me to fall into either the Jurassic or the Cretaceous.

Collection 38AMt94 was determined by Dr. Reeside to be of Mesozoic age.

The third group of Mesozoic rocks, called the Kandik formation, is of Lower Cretaceous age. This formation constitutes a prominent part of the geologic sequence of this area, cropping out on both sides of the Yukon River from the mouth of Coal Creek upstream for nearly 40 miles. A narrow belt of these rocks also extends westward from Coal Creek for 10 miles or more and in the valley of Woodchopper Creek crops out directly north of the Mesozoic limestone above described. These Lower Cretaceous rocks, however, consist of quartzite and slate, and some of the slate contains the type fossil *Aucella crassicolis* Keyserling, as well as other fossils. These rocks are believed to be younger than the Mesozoic limestone; therefore the limestone is more probably Jurassic than Cretaceous.

The only hard-rock formations younger than the Lower Cretaceous rocks are the Tertiary rocks, which are subsequently described in some detail. It suffices here to state that they crop out in a belt that trends parallel to the general course of the Yukon, from the international boundary west-northwest to Thanksgiving Creek, a distance of about 90 miles. A part of this Tertiary sequence, however, has been assigned on paleontologic evidence to the Upper Cretaceous epoch, but this evidence is so inconclusive that the entire sequence has been included in this report as Tertiary.

Unconsolidated fluviatile deposits of Quaternary age are found in the valleys of all the streams tributary to the Yukon but have their greatest development in the main Yukon Valley. Such deposits are known to be of both Pleistocene and Recent age, but no attempt has been made in this area to map them separately as older and younger groups. It is also possible that on the tops of the high terraces overlooking the Yukon some Pliocene gravels may still be preserved, but they have not been definitely recognized as such.

The igneous rocks of this area are mapped as two units. The older group consists in part of ultrabasic intrusives of peridotitic character and in part of basaltic and diabasic intrusives and extrusives of greenstone habit. The ultrabasic intrusives occur typically at Mount Sorenson. The basic intrusives and extrusives occur in the valleys of

Mission and American Creeks and at other localities. The age of these basic and ultrabasic rocks is not definitely known, but in general they are of post-Middle Devonian age and also antedate the intrusion of the Mesozoic granitic rocks. Probably most of these basic and ultrabasic igneous rocks, but particularly the ultrabasic varieties, are of late Devonian age.

The granitic rocks crop out mainly as a great batholith, the northern side of which, though irregular in outline, parallels roughly the trend of the Tertiary rocks. Glacier Mountain forms the eastern limit of the batholith, whence it extends about 80 miles to the west. In the valley of Charley River the batholith has a width, from north to south, of about 48 miles, but in the vicinity of Glacier Mountain it has a width of only 10 miles. Its total area is about 1,900 square miles. Only the northern edge of the batholith is shown on the accompanying map. The petrographic character of the granitic rocks that constitute this batholith has been given in some detail in an earlier report.[5] In general, this intrusive mass and its satellitic outliers consist of granite and quartz diorite, with relatively few rocks of intermediate type, such as quartz monzonite. The commonest type is biotite granite, but biotite and hornblende occur together in many of the granites and quartz diorites.

Many silicic dike rocks, including alaskite and aplite, as well as pegmatite, and also some basic differentiates, are associated with the principal intrusives. The geologic age of these granitic rocks cannot be definitely determined upon the basis of stratigraphic evidence, but all available information leads to the belief that they are of Mesozoic age. Pebbles of these granitic rocks are found at some localities in the conglomeratic horizons of the Tertiary rocks. They may have originnated within either the Jurassic or the Cretaceous periods.

TERTIARY ROCKS

The Tertiary rocks have many features of geologic significance, but one particular feature, which renders them of economic importance, is the fact that certain of them contain detrital gold. This gold was derived originally from quartz veins or other types of lodes, which were probably associated either with the Mesozoic granitic rocks now exposed to the south or with similar granitic rocks of the same age that lie near to, but north of, the main batholith. The auriferous horizons in the Tertiary rocks are not likely to be of interest as sites for lode mining, but they are of much significance as the proximate sources of certain gold placers that are now being worked in this area.

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[5] Mertie, J. B. Jr. The Yukon-Tanana region, Alaska. U. S. Geol. Survey Bull. 872, pp. 210–216, 1937.

DISTRIBUTION

It has already been stated that the Tertiary rocks in this district crop out south of the Yukon River in a belt about 90 miles long. The strike of this belt is N. 60° W., which is roughly parallel to the general course of the Yukon River in this part of Alaska. The width of this Tertiary belt is least at its western end, where it decreases to 2 miles or less, and it is greatest in the eastern part of the valley of Seventymile River, where it is as much as 13 miles. At their western limit these rocks pass below unconsolidated alluvial deposits, which mantle much of the country west of Thanksgiving Creek. Farther west, but southeast of the Yukon Flats, the Tertiary rocks have been found at only one locality, a small area in the valley of the North Fork of Preacher Creek. There the Tertiary rocks are dominantly conglomeratic. Still farther west, in the country around Rampart and Tanana, other Tertiary rocks are also known, but they are mainly sandstone and shale containing beds of coal, and nowhere in this vicinity have they been found to be auriferous. East of the international boundary the Tertiary rocks cross to the north side of the Yukon River and crop out southeastward for an undetermined distance within this unmapped region. It has been reported to the writer that similar rocks occur in Yukon Territory, north of the Klondike mining district.

Within the Eagle-Circle district, most of the Tertiary rocks occur in a wooded belt of low relief. This belt consists naturally of lower hills, because it lies fairly close to the Yukon River, but in addition to this the Tertiary rocks are less indurated than the Paleozoic rocks that bound them and have therefore undergone more erosion. Hence there is a distinct topographic expression to the Tertiary belt, and at most places it appears clearly as a lower stretch of country, lying between higher hills on the north and south. In the absence of good cutcrops, this is a valuable diagnostic feature in outlining the areal limits of these rocks.

Outcrops of the Tertiary rocks are uncommon, partly because much of the area occupied by these rocks is covered by timber and other vegetation but more particularly because these little-indurated rocks revert easily under atmospheric conditions to their original detrital materials. On the spurs and ridges almost no outcrops of Tertiary rocks occur, though the detritus derived from them is visible at many places, particularly above the timber line. Practically all the exposures are found in the valleys; yet in only a few valleys do such exposures occur. Certain conglomeratic beds of the Tertiary sequence, for example, are well exposed in the eastern part of the valley of Seventymile River, where the river follows the strike of the formation. Intermittent exposures are also visible on some of the tributaries of the Seventymile River, particularly on Bryant Creek; and along the south bank of the Yukon River, about 2 miles downstream from the mouth of the Seventymile, these rocks are intermittently exposed for a distance of 3½ miles.

GENERAL FEATURES

The rocks of the Tertiary system consist dominantly of sandstone, conglomerate, and shale, with some beds of lignitic coal. No complete section is exposed anywhere, and no series of partial sections is known that can be fitted together to give a composite section. Hence the description of these rocks, based upon partial sections at only a few localities, may fail to give a complete picture of the lithology and structure.

The Tertiary rocks vary markedly in their degree of induration. At some localities—for example, along the Seventymile River—the conglomerate and sandstone are massive, well-indurated, cliff-making rocks. At other localities, such rocks are so little consolidated that they may readily be disintegrated with a pick and panned in the same way as stream gravels. At still other localities, especially on the spurs and ridges, no coherent rocks can be found, but instead only loose rubble is present. These differences in the degree of induration are undoubtedly due to two causes, the exact importance of which at individual croppings may not be evident. First, there is every reason to believe that the degree of compression that these rocks have undergone is not uniform. Some of them must have been more deeply buried than others and must therefore have been more compressed and plastically deformed than the beds which lay above them. Moreover, the degree of metamorphism may have been different at points many miles apart. The second cause for differences in degree of induration is the varying degrees in which these rocks have been affected by surficial alteration. At some localities it is apparent that deep residual decomposition has occurred, and this process, though apparent in some stream valleys, is most marked on the tops of the spurs and ridges. The net result of these conditions is that all types of Tertiary rocks can be found, from hard, well-indurated sandstone and conglomerate to soft, incoherent rocks, and finally reverted rubble.

The materials composing the Tertiary conglomeratic rocks and sandstones tend to be fairly uniform in lithologic character, but at some localities where these rocks lie close to the underlying Paleozoic and Mesozoic rocks their composition varies markedly from the usual composition. At most places the pebbles of the conglomeratic rocks consist of chert of various colors, quartzite, and vein quartz, which are the types of rocks that are practically indestructible, except by abrasion. Locally, and especially near the base of the formation, pebbles and cobbles of granitic rocks, greenstone, schist, argillite, and even limestone have been observed. In most of the conglomeratic rocks, the pebbles are relatively small, the maximum diameter being 4 or 5 inches and the average between 1 and 2 inches. But at certain horizons near the base of the sequence, coarse conglomerate has been observed, as for example on American and Crooked Creeks. The best example of coarse conglomerate, however, is along the ridge that separates Crooked Creek from Trout Creek. Here large residual cobbles and boulders of quartzite as much as 2 feet or more in diameter lie at the surface and represent the debris derived from the surficial alteration or slaking of coarse conglomerate. The sandstones of the series are not materially different from the conglomerates, except for the smaller size of the component grains. Under the microscope the finer rock-forming minerals, both of the conglomerates and sandstones, are found to be quartz, orthoclase, plagioclase, hornblende, and mica, together with iron ores, zircon, garnet, and other heavy minerals derived from granitic rocks and crystalline schists. At places the heavy minerals are concentrated in stratified layers and in general appear to be more plentiful than in their original parent rocks. Most of the shale is sandy, but in the stratigraphic horizons where coal is found clay shales are also found. The coal that occurs in these Tertiary rocks was studied years ago by Collier [6] and was found from numerous analyses to be dominantly a high-grade lignite, with some subbituminous varieties. At the present time, with ample wood for domestic use and with cheap oil for large-scale mining operations, these low-grade coals are of little economic importance.

The lack of continuous or even intermittent exposures across the eastern and widest part of this belt, where the rocks are well indurated, and the uncommon occurrence of indurated rocks at the western or narrower end of the belt render it impossible to draw a structural cross section or even to understand generally the structure of these rocks. The dominant dip is steeply to the south, with the beds dipping generally from 45° to 90°, as illustrated by some of the local details given below. On the south the Tertiary rocks are bounded by early Paleozoic rocks and on the north by younger Paleozoic rocks, but these rocks had been greatly folded in the Mesozoic era before the Tertiary rocks were deposited, so that their distribution has little significance insofar as the Tertiary orogeny is concerned. At numerous localities, and especially between the Seventymile and Yukon Rivers, where the Tertiary belt is widest, small isolated outcrops of

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

these older rocks have been found projecting upward through the Tertiary rocks. For the most part, these islands are too small to be represented on a geologic map drawn on the scale of 1: 375,000. Such intermittent exposures of pre-Tertiary rocks, which constitute the basement upon which the Tertiary sediments were deposited, indicate that there is no continuous homoclinal sequence of rocks across this belt. On the contrary, it seems most probable that the Tertiary rocks have been deformed into appressed folds, so that certain stratigraphic horizons have been duplicated many times. Faulting has also been observed, and strike faulting may be a structural process of great importance. But the bedding of the Tertiary rocks, though locally dipping northward dips dominantly southward. Hence a presumption exists that the Tertiary rocks have been deformed into a series of appressed, folds overturned to the north. The prevalence of islands of older rocks in the Tertiary belt also suggests the presence of appressed folds. For these reasons, the accuracy of any stratigraphic measurements in these rocks, based upon a sequence of intermittent exposures, is subject to considerable doubt. Nevertheless, certain sections, particularly the one on Bryant Creek, suggests that the Tertiary sequence constitutes a great thickness of rocks, at least 3,000 feet, and probably more.

LOCAL DETAILS

MISSION CREEK AREA

Tertiary rocks form the bedrock along the entire south side of the valley of Mission Creek, a tributary of the Yukon that debouches just north of the town of Eagle. Mission Creek has no tributaries of any size entering from the north, but it has a western headwater fork, Excelsior Creek, which was known originally as Twelvemile Creek. The southern tributaries of Mission Creek, named in order downstream, are Wolf and American Creeks, of which American Creek is much the larger stream. Two other small streams, Castalia and Buckeye Creeks, running parallel to American Creek, lie farther east and drain northward directly to the Yukon.

The Tertiary rocks lie in a belt 3 to 4 miles wide south of Mission Creek, from Excelsior Creek downstream, and extend eastward across the drainage basins of Castalia and Buckeye Creeks to the Yukon. A small outlying area of Tertiary rocks also occurs farther upstream on Excelsior and Mission Creeks. Isolated outcrops occur on Excelsior Creek, the headwater fork of Mission Creek, and on Wolf and American Creeks, but there are no continuous exposures. Outcrops of the Tertiary rocks are not known on Castalia and Buckeye Creeks. These outcrops and others between the creeks mentioned are of two general types. One shows the more normal types of Tertiary rocks, as described above. The other, representing deposits close to the base of the sequence, consists of deposits that are made up of detrital materials derived mainly from local sources and show little action by running water. Varying degrees of coherency are also apparent.

Along the west bank of Mission Creek, between a quarter and a half mile upstream from its confluence with Excelsior Creek, is a bluff about 90 feet high composed of angular, slightly consolidated detritus, mainly of granitic character, some of the larger fragments of which are as much as 2 feet in diameter. The finer material of this deposit is likewise of granitic character, and chert, usually the commonest type of pebble in the Tertiary rocks, is absent. Some thin beds of gray sandstone and clay shale containing carbonaceous material are interbedded with the conglomerate. The strike is N. 35° W. and the dip 50° SW. The conglomerate is capped by 20 feet of river gravels, the bedding of which is essentially horizontal. This deposit illustrates the second type of deposits, derived evidently from a local source. The base of this conglomerate probably lies directly upon pre-Tertiary granitic rocks. About 1½ miles farther up Mission Creek, along the same side of the stream, is another bluff, about 150 feet high. This bluff is composed of the normal type of Tertiary conglomerate, made up of small, well-rounded pebbles of chert and vein quartz, with a smaller proportion of quartzite. Fossiliferous brown sandstone is interbedded with the conglomerate. The deposits strike northeast and dip 50° NW.

Another bluff, made up of Tertiary rocks, is visible on the west side of Wolf Creek, about 1½ miles from its confluence with Mission Creek. This bluff, which is about 125 feet high, is similar to the southern one on Mission Creek. The rock at this site varies, both laterally and vertically, from conglomerate to brown sandstone, and the pebbles of the conglomerate, as well as coarse grains of the sandstone, are mainly black and red chert, vein quartz, and more or less granitic rocks. Here, in the same deposit, considerable variation exists in the degree of coherency of the materials that form the rock. This is probably due to differential disintegration of the rock, rather than to differences in the initial degree of induration. About 2½ miles farther upstream, on Wolf Creek, in a small gulch entering from the west, conglomerate, sandstone, and clay shale occur, with which are interbedded one or more thin beds of coal containing some soft, brittle amber. Remains of fossil plants are present here, as at the other site farther downstream.

Tertiary rocks are also exposed in several bluffs along the west side of American Creek, beginning at a point about three-fourths of a mile downstream from the mouth of Bluff Creek and extending intermittently upstream for 1½ miles. At the north end of these exposures conglomerates occur, which consist dominantly of pebbles of vein quartz and quartzite, with little chert, that are as much as 3 inches in diameter. The bedding of these rocks strikes N. 80° E. and dips 20° to 30° S. The deposit is overlain by about 5 feet of coarse river gravels of Quarternary age containing boulders as much as 18 inches in diameter. A short distance upstream, on the same side of the creek, both fine conglomerate and interbedded sandstone occur, dipping gently north. A microscopic examination of this sandstone reveals that the rock is composed of angular, subangular, and subrounded grains, consisting mainly of vein quartz and subordinately of chert, slate, and other kinds of rock. Mineral grains of leached biotite, muscovite, microcline, a little plagioclase feldspar, and iron ores were also recognized. The cementing material of the rock, amounting perhaps to 20 percent, is calcite. Such rock, under the influence of surficial agencies, would rapidly crumble and revert to its original detrital materials. It is definitely known, however, that most of the Tertiary rocks do not have a calcite matrix, and this is doubtless one of the factors that accounts for the observed variation in the coherency of different deposits.

About 3¾ miles from the mouth of American Creek, clay shale and coal crop out along the east bank. The rocks are not well exposed but evidence indicates that several thin beds of coal as much as 10 or 12 inches thick are present. The strike is N. 75° W., and the dip is 45° S. A short distance farther upstream are the southernmost outcrops on American Creek. These consist of both fine and coarse conglomerate, the course conglomerate containing boulders as much as 20 inches in diameter. The coarse conglomerate, which is farthest upstream, must be close to the base of the sequence at this point. The strike is the same as that of the coal beds, but the dip is 20° N. Other deposits of coal are said to have been found and prospected in a small gulch along the west side of American Creek, not far from the mouth of Bluff Creek.

Another set of exposures in the Mission Creek area is worthy of mention. The proposed highway from Eagle to the Fortymile mining district has so far been constructed southward from Eagle up the valley of American Creek for a distance of about 20 miles. Along this route one road cut has exposed the Tertiary rocks, and farther south, along the east side of the road, five or more gravel pits have been opened up for road materials, and some of these expose the Tertiary rocks.

Tertiary rocks are also visible in a road cut beginning nine-tenths of a mile south of Eagle and extending west-southwestward for about 150 yards to the crest of the spur that forms the northeastern boundary of the valley of Bluff Creek. The general strike of these rocks is N. 65° W., and the dip is 40° SW. About 260 feet of strata are intermittently exposed. Most of these outcrops are grit and conglomerate; but near the eastern, or basal, end of the section, are some beds of purplish shale, one of which is 12 inches thick. Another bed of shale occurs about 40 feet stratigraphically above the base of the section, and about 140 feet above the base 5 or 6 thin seams of coal ranging from one-fourth inch to 1 inch in thickness also crop out. Just below the coaly horizons some decomposed residual granite crops out, which apparently represents a part of the basement rock, upon which the Tertiary rocks in this vicinity were deposited. This granite consists of sericitized microline, biotite, a little oligoclase, and calcite, the calcite acting as a matrix for the arkosic material and constituting about 30 per cent of the rock. The uppermost 60 feet of the section, at the west end of the coal cut, consists of grit composed of granitic materials, together with some carbonaceous shales.

Five gravel pits along, or a short distance east of, the American Creek road were observed. The gravels in these pits are merely the gravels of the Tertiary conglomerates, which under atmospheric conditions have reverted to the loose detritus from which they were originally formed. Hence the Alaska Road Commission was able to excavate only a few feet from the surface before hard rock was encountered. It is partly for this reason that so many pits were started for such a short length of road. The most northerly of these pits is located on a side road which leads eastward up the spur that separates the valley of Bluff Creek from that of the Yukon. At this site the pebbles of the conglomerate are fairly uniform in size, reaching 3 inches in diameter but averaging 1 inch or less. They are fairly well rounded and are mainly vein quartz and quartzite but include considerable granite. Some coaly lenses and some thin coal seams are interbedded with the conglomerate. The structure is not clearly apparent, but there is a suggestion here of a compressed syncline.

The next pit to the south is about half a mile north of Bluff Creek. Here the bedrock at the face of the pit consists of coarse conglomerate and reddish-brown sandstone. The pebbles of the conglomerate have an average diameter of half an inch, but the maximum diameter is as much as 3 inches. They are well rounded and consist mainly of vein quartz but include also slaty shale, silicious argillite, quartzite, and schist, with very little true chert. Fragmental plant remains are visible in the sandstones. At another gravel pit, about one-tenth of a mile north of Bluff Creek, the same types of conglomerate and sandstone occur. Here the strike is N. 45° E. and the dip 30° NW. The same general conditions exist at the other two gravel pits south of Bluff Creek but the strike and dip of the Tertiary beds is variable.

All the gravels along the American Creek road were sampled in order to discover whether any of them contained traces of gold. In this work a number of 100-pound samples were transported back to the banks of the Yukon where they were carefully panned. The largest amount of black sand was found in the material taken from the road cut, about a mile from Eagle, but this material contained no gold. Some fine flakes of gold were panned from the gravels taken from the gravel pit about half a mile south of Bluff Creek, but none was found in the other samples.

SEVENTYMILE RIVER AREA

The widest part of the Tertiary belt is the area extending northeastward from Bryant and Crooked Creeks, in the Seventymile Valley, to the Yukon River. It is in this area, also, where the Tertiary rocks are most indurated and where the largest number of exposures may be seen. However, the width of the belt in this vicinity is but 13 miles, and it is only for about 2½ miles in the valley of Bryant Creek that any approximation to a section can be observed and measured. Beds of conglomerate are also exposed along the Seventymile River, but this stream follows the strike of the rocks so that little is added thereby to the Bryant Creek section. Some beds of the sequence have also been exposed by mining operations in the valley of Crooked Creek, but most of these are now concealed by hydraulic tailing piles. Northeastward from Crooked Creek, no continuous exposures are known to the Yukon River, though some isolated exposures occur in the headwaters of some of the short creeks draining to the Yukon. And finally, there are the intermittent exposures along the south bank of the Yukon, downstream from the Seventymile River.

The general course of Bryant Creek is northeast. The "upper trail" from the Seventymile River across to Little Blanche Creek, now called Rock Creek, crosses Bryant Creek about 2 miles from its mouth. About 1,200 feet downstream from this crossing outcrops of Tertiary rocks begin and continue intermittently downstream for 6,000 feet. Except locally at the two ends of this section, the rocks have a rather uniform strike of about N. 80° E. and dip for the most part south, with some reversals to the north. At many places the dip of the rocks is very steep, aproaching verticality. It is not believed that this sequence of exposures should be regarded as a continuous section, because the reversals of dip and the steep inclination of many of the beds, together with ample evidence of faulting, indicate a complex structure, by means of which some stratigraphic horizons may be repeated. The rocks at the south end of this section consist of sandstone, grit, and black sandy shale, with some thin beds of conglomerate. The shales contain numerous heavy ferruginous nodules, some of which contain plant remains, but the plant remains also occur in the sandstones and grits. At the extreme south end of the section the beds strike N. 25° W. and dips 5° W., but farther downstream they strike N. 85° E., with a variable dip raging from 15° to 40° N. For about 3,000 feet downstream from these rocks conglomerate crops out along the walls of the valley and intermittently in the bed of the stream. Some thin beds of sandstone and grit are included in this part of the sequence, and such beds become more prevalent at the north end of the section. The conglomerate is a massive, well-indurated, cliff-making rock occurring for the most part in thick beds. It consists of well-rounded pebbles of chert, black siliceous argillite, and quartzite, as much as 3 inches in diameter. The strike is about N. 85° E., and the dip is close to 90° S. Downstream from the conglomerate the following outcrops were observed, the measurements given being the distances that were paced along the bed of the creek.

Section of Tertiary rocks in the valley of Bryant Creek

	Feet
Sandstone. Strike N. 85° W.; dip 80° S	50
Covered	300
Conglomerate, with 2 thin beds of sandstone	75
Greatly sheared black cabonaceous shale	50
Mainly conglomerate, with some standstone. Strike N. 80° E.; dip 80° S	20
Covered in part, but in part conglomerate. Strike N. 85° E.; dip 90° S	300
Black shale, with some thin-bedded sandstone	40
Conglomerate	10
For the most part covered, but with occasional outcrops of conglomerate	1,050
Covered	180
Conglomerate	20
Shaly sandstone, with several beds of very carbonaceous shale about 6 inches thick. Some of these approach closely in composition to bony coal	40
Conglomerate and sandstone	50
Covered	300
Conglomerate	20
Covered	1,200
Intermittent exposures of sandstone and conglomerate. Strike N. 65° W.; dip 30° NE	80

The covered zones in this section probably represent for the most part the softer beds of the sequence, but too much of the sequence is concealed and the structure is evidently too intricate to warrant the computation of this traverse into a stratigraphic section.

Along the Seventymile River, conglomerate, sandstone, and sandy shale are intermittently exposed from Bryant Creek westward to

Barney Creek, and at many places the conglomerate forms prominent bluffs along the river banks. Along the north side of the Seventymile River, especially upstream from the mouth of Crooked Creek, these rocks also form steep dip slopes, striking generally parallel to the course of the river and dipping about 60° S. The sandstones and shale contain more or less plant remains. The conglomerates consist of well-rounded pebbles of siliceous argillite, chert, quartzite, and a little vein quartz, which have an average diameter of about one-half inch and a maximum diameter of 3 inches or more. Many samples of these conglomerates were mortared and panned, but no gold was found in any of them.

A few natural exposures of the conglomerate occur along the west wall of Crooked Creek, close to the Seventymile Valley, but no continuous sequences are visible. Along the valley floor, however, the general character of the rocks has been revealed by placer mining. In general the rocks appear to be mainly sandstone and shale, with some thin beds of conglomerate up to several feet in thickness. Some thin lenses and beds of coal were also uncovered in the placer-mining operations. The beds have a wavy and irregular structure, but strike generally about N. 75° W. At the present site of mining on Crooked Creek, the beds dip 20° N., but farther down the valley the dip changes to the south and apparently remains so to the Seventymile River. About a mile in an air line from the Seventymile River there is a horizon of shale, in which occur many fine impressions of leaves and other plant remains. This material is so soft, however, that it is difficult to collect, and it tends to crumble on drying. A collection of plants was made by the writer at this locality.

About 2¼ miles from the Seventymile River a coarse, disintegrated conglomerate crops out imperfectly along the west bank of Crooked Creek. This is composed of subangular to subrounded cobbles and boulders of chert, greenstone, and other Paleozoic rocks, as much as 18 inches in diameter. It probably represents a horizon close to the base of the Tertiary sequence and is analagous to the coarse conglomerate found at the south side of the Tertiary belt on American Creek. Ten pans of this material were concentrated, but no gold was found.

The most southerly of the larger eastern tributaries of Crooked Creek is known as Eldorado Creek. No good outcrops of Tertiary rocks occur in this valley, but shale banks and coal blossoms are visible at several localities, and good-sized boulders of coal lie in the bed of the stream. A coal deposit was at one time prospected in this valley. In the headwaters of Eldorado Creek a narrow reef of limestone crops out along the south side of the valley, trending N. 80° W. and extending for a distance of half a mile. This is a dark-gray limestone, veined with calcite and at many places completely recrystallized. It is crushed, fractured, and granulated and is devoid of fossils, but it is probably of Paleozoic age. This limestone constitutes an island of the basement rock upon which the Tertiary rocks in this vicinity were deposited.

The next large eastern tributary of Crooked Creek upstream from Eldorado Creek is Bear Creek. Going up the spur northwest of Bear Creek, no outcrops of Tertiary rocks are visible, but rubble of sandstone, shale, and conglomerate prove their presence. At the crest of the ridge that separates Bear and Eldorado Creeks from Trout Creek no outcrops occur, but the ground is composed of gravelly detritus, apparently derived from a Tertiary conglomerate. Evidently the conglomerate at this point contained some very coarse debris, for boulders of quartzite as large as 2 feet in diameter are present. This conglomeratic debris continues along the ridge around the head of Trout Creek, but east of the headwaters of Trout Creek, Paleozoic greenstone, greenstone tuff, quartzite, and slate appear at the surface, protruding through the Tertiary rocks, and still farther to the north they become the sole country rock. Another example of the protuberance of older rocks through the Tertiary sequence is visible at the south side of the Tertiary belt, on the little spur east of the northern end of Mogul Creek, where greenstone and greenstone tuff are exposed.

SOUTHWEST BANK OF YUKON RIVER

About 2 miles downstream from the mouth of the Seventymile River the Tertiary rocks crop out intermittently along the southwest bank of the Yukon River for a distance of about 19,300 feet. At a distance of 9,135 feet from the northern limit of these rocks a small creek enters the Yukon; 1,780 feet farther south is another small tributary of the Yukon; and 8,390 feet farther south the end of these exposures is marked by a third stream. The Tertiary rocks are not continuously exposed throughout these 3⅔ miles but crop out intermittently along the timbered wall of the valley, with some exposures along the river bank. The northern limit of the Tertiary rocks is a fault contact, where these rocks abut against the rocks of the Calico Bluff formation. The fault is a compound one, with several fault planes striking N. 15° W. and dipping 70° E. The striae on these fault planes are nearly horizontal but dip gently to the south. The strike of the Tertiary rocks close to the fault zone is N. 75° E., and the dip is 45° S. The fault is evidently a cross fault, which represents a structural displacement that took place after the major deformation of these beds. At this northern end of the belt, the rocks

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consist of fine conglomerate, grit, and sandstone, with a few beds of sandy shale. The pebbles of the conglomerate are subangular to rounded and consist mainly of black and green chert, black siliceous argillite, and quartzite. For 6,230 feet south of the northern fault contact no Tertiary rocks crop out along the beach, but in the northern half of this stretch some scattered outcrops are visible along the timbered valley wall. These include beds of coarse brown sandstone, sandy shale, and some thin beds of conglomerate, which strike about N. 65° W. and dip 50° S. These beds contain fossil remains of conifers and angiosperms, the latter including both monocotyledonous and dicotyledonous plants. For the next 2,360 feet southward, to the first of the above-mentioned tributary creeks, some good outcrops of the Tertiary rocks occur along the valley wall. Four beds of conglomerate are visible, which range in thickness from 12 to 25 feet. The next to the lowest of these is the thickest, and the lowest is the thinnest. These beds of conglomerate, which include some thin beds of sandstone, are separated from one another by beds of sandy shale. The pebbles of these conglomerates have an average diameter of about 1½ inches and a maximum diameter of as much as 5 inches. They are well-rounded and consist mainly of quartzite, with some chert and a little vein quartz. The strike of these rocks is about N. 65° W. and the dip about 40° S. One of these conglomerate beds crops out for a short distance along the beach. Several samples of this rock were mortared and panned, and the concentrates were found to contain much pyrite and a few small grains of gold.

At the end of this stretch, at the first of the above-mentioned creeks, a few exposures show that the structure of the Tertiary rocks changes suddenly, the strike veering to N. 75° E. and the dip becoming vertical. It is believed that the valley of this small creek is the site of another cross fault similar to the one at the north end of the Tertiary sequence. For the next 1,780 feet to the south there are no exposures, but in the next 2,950 feet both the structure and lithology again change. The rocks are largely sandy shale, with which are interbedded, at the south end, several beds of sandstone. The strike is N. 10° W., and the dip is 45° E. At the southern extremity of this stretch the second of the above-mentioned creeks enters the Yukon. This gulch probably marks another cross fault.

For the next 3,125 feet to the southeast some other outcrops of Tertiary rocks occur along the valley wall, consisting mainly of conglomerate and sandstone, but the intervening beds are concealed. In the last 2,860 feet of the sequence the rocks are almost continuously exposed. The stratigraphic thickness in this part of the section, beginning with the youngest rocks, was estimated to be as follows:

Section of Tertiary rocks on southwest bank of Yukon River about 2½ miles downstream from mouth of Seventymile River

	Feet
Shaly sandstone	30
Conglomerate and sandstone	8
Shale	10
Sandstone	2
Shale	25
Sandstone	3
Shale	120
Sandstone	3
Shale	100
Sandstone	5
Shale	100
Sandstone and conglomerate	25
Shale	75
Conglomerate and grit, much cross-bedded	8
Shale, faulted against the rocks of the Calico Bluff formation	200

From the stratigraphic and structural features above outlined, it is clear that both the top and the bottom of this sequence of rocks are marked by fault contacts and that the sequence is also interrupted by at least two cross faults. The exposures are not continuous, and therefore still other faults may also be present. These factors render it impracticable either to deduce a complete stratigraphic section or to estimate the total thickness of rocks here exposed. It is not even known whether this sequence lies near the top or the base of the Tertiary stratigraphic column, but the absence of islands of the older basement rocks may be cited as presumptive evidence that this sequence does not lie at or near the base of the Tertiary sequence.

FOURTH OF JULY CREEK

Fourth of July Creek, between its headwaters and the mouth of Crowley Creek, has three small tributaries, which enter from the southeast. These, named in order downstream, are Ruby Creek, Seventeen Gulch, and Union Creek. The camp of the mining company that is operating on this stream is located along the northwest side of Fourth of July Creek, a short distance below the mouth of Union Creek.

The Tertiary rocks form the bedrock on Fourth of July Creek, from the extreme headwaters to a point about a mile downstream from the mouth of Union Creek. On the ridges on either side of Fourth of July Creek the presence of these rocks is indicated by a mantle of gravelly detritus, derived from conglomeratic rocks, but the proportion of these rocks in the stratigraphic sequence is not known. In the valley of Fourth of July Creek some exposures of conglomerate occur upstream from Union Creek. The uppermost of them is located along the southeast side of the valley, about 1,000 feet downstream from the mouth of Seventeen Gulch. This conglomerate, though partly disintegrated, is still fairly hard and stands up as a vertical wall. It is fairly coarse, containing well-rounded pebbles of chert and quartzite as much as 6 inches in diameter. A short distance downstream, a high bluff of similar rock is exposed, but this is soft enough to be easily broken up with a pick into its original gravelly materials. Just above Union Creek is a third exposure of conglomerate, consisting of a vertical bank against which Fourth of July Creek is cutting. This bank is about perpendicular but is nevertheless soft enough to be readily disintegrated with a pick. All three of these exposures of conglomerate were panned to determine if they contained gold. The two upper localities yielded none, but the conglomerate just above Union Creek gave a small color of gold to nearly every pan. The slaked conglomerate is also visible at several places among the old placer workings of Fourth of July Creek, where the bedrock has been bared and excavated below its upper surface. At one such locality a well-indurated sandstone bed containing many carbonized plant stems was seen. No gold was recovered by panning any of the conglomerate bedrock in the placer workings.

In general, it may be stated that few exposures of the Tertiary rocks occur in the valley of Fourth of July Creek. Practically the only visible bedrock is conglomerate, and most of these rocks are greatly slaked and decomposed, so that they may be readily disintegrated with a pick to the original detritus from which the conglomerate was formed. The pebbles of the conglomerate range in size from a fraction of an inch up to 6 inches, averaging perhaps 1 or 2 inches. They are well-rounded and consist dominantly of chert and quartzite, with more or less vein quartz.

COAL AND WOODCHOPPER CREEKS

No good outcrops of Tertiary rocks occur in the valleys of Coal and Woodchopper Creeks, but the northern and southern limits of the Tertiary belt are fairly well known from the character of the local topography and from the rubble found along the tops of the bounding ridges. Some artificial exposures have also been made by the older open-cut mining operations in these creeks, though these are now largely concealed by stream gravels or by slumping. The drilling records of the two companies, Gold Placers, Inc., and Alluvial Golds, Inc., have also served to locate the contacts in these two stream valleys.

Judging from the amount of gravel on the ridges bounding Coal and Woodchopper Creeks and by the fact that these ridges are normal to the general strike of the series, it is believed that a considerable part of the Tertiary bedrock is conglomerate. This conclusion is supported by the character of the bedrock that has so far been excavated by these dredges. Some finer-grained rocks, however, are known to be present, for a shale bank with a coal blossom occurs along the automobile road along the northwest side of Coal Creek, opposite the mouth of Boulder Creek, an eastern tributary of Coal Creek. Disintegrated sandstone and shale have also been uncovered in the older mining operations on Boulder Creek and also at places by the dredging operations. It is apparent that the Tertiary rocks in this western part of the belt are generally less cohesive than those in the eastern part. This may be due in part to original differences in the degree of induration of these rocks, but it may also be due in part to differences in the conditions of erosion.

AGE

Fossil leaves and other plant remains are visible at most places where the Tertiary rocks are exposed, and at some localities well-preserved fossils occur. Such fossil remains have been collected by several geologists during the last 40 years. The localities where these plants were collected are listed below:

Spurr 3(1555). Southwest bank of Yukon River, about 5 miles downstream from Calico Bluff. Collector, J. E. Spurr, 1896.

2AC40(2966). American Creek, 100 yards downstream from crossing of the Eagle-Valdez trail. Collector, A. J. Collier, 1902.

2AC57(2973). Southwest bank of Yukon River, 2 miles downstream from mouth of Seventymile River. Collector, A. J. Collier, 1902.

3AH4(3243). Southwest bank of Yukon River, about 3 miles downstream from mouth of Seventymile River. Collector, Arthur Hollick, 1903.

3AP330. Wolf Creek, tributary of Mission Creek, Collector, L. M. Prindle, 1903.

3AP336. Branch of Wolf Creek, tributary of Mission Creek. Collector, L. M. Prindle, 1903.

3AP348(3227). Bryant Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP349(3228). Bryant Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP350(3229). Bryant Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP355(3230). Mogul Creek, tributary of Seventymile River. Collector, L. M. Prindle, 1903.

3AP432. Mission Creek, 2 miles upstream from mouth of Excelsior Creek. Collector, L. M. Prindle, 1903.

Kindle 11h. Yukon River, 1½ miles upstream from mouth of Seventymile River. Collector, E. M. Kindle, 1906.

Kindle 20. Coal mine on Washington Creek, about 16 miles from Yukon River. Collector, E. M. Kindle, 1906.

7AA10(4711). Seventymile River, half a mile downstream from mouth of Mogul Creek. Collector, W. W. Atwood, 1907.

7AA11. Bryant Creek, 3 miles from mouth. Collector, W. W. Atwood, 1907.

14AMn80(6815). Southwest bank of Yukon River, at mouth of a gulch about 1½ miles downstream from mouth of Seventymile River. Collector, G. C. Martin, 1914.

7407. Southwest bank of Yukon River, first gulch downstream from mouth of Seventymile River. Collector, G. C. Martin, 1919.

7408. Southwest bank of Yukon River, half a mile northwest of the first gulch downstream from the mouth of Seventymile River. Collector, G. C. Martin, 1919.

Schlaikjer 2(8682). American Creek, a quarter of a mile downstream from mouth of Marion Creek. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 3(8683). Rock Creek (formerly Little Blanche Creek), at the bridge where the Eagle-Seventymile trail crosses. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 4a–c(8684). Seventymile River, about 2 miles downstream from mouth of Crooked Creek. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 5a–d(8685). Crooked Creek, below Hagan's lower cabins. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 6(8686). Broken Neck Creek, a short distance upstream from its mouth. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 8(8687). Small tributary of Yukon River, which enters on southwest side, about 2 miles downstream from mouth of Seventymile River, about 2 miles upstream from mouth of creek. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 9(8688). Southwest bank of Yukon River, about 1½ miles downstream from mouth of Seventymile River. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 10(8689). Small tributary of Yukon River, which enters on southwest side, about 2½ miles downstream from mouth of Seventymile River, about 2 miles upstream from mouth of creek. Collector, E. M. Schlaikjer, 1936.

Schlaikjer 27(8693). Sam Creek, at the mouth of Ben Creek. Collector, E. M. Schlaikjer, 1936.

38AMt20 (8630). Crooked Creek, a tributary of Seventymile River. About 1 mile from mouth, where bedrock has been bared by old hydraulic mining operations. Collector, J. B. Mertie, Jr., 1938.

Twenty-eight collections have so far been made, and the general consensus of opinion among the paleobotanists who have examined them is that most of these fossils are of early Tertiary age. Nine of these collections, however, have been made along the southwest bank of the Yukon River, about 2 miles downstream from the mouth of the Seventymile River. Regarding these nine collections, a marked difference of opinion exists. The collections in question are designated as Nos. 1555, 2973, 3243, 6815, 7407, 7408, 8687, 8688, and 8689. The first three of these, namely, 1555, 2973, and 3243, were examined originally by F. H. Knowlton and were determined by him to be of Tertiary age. Subsequently, some of the plants from these three collections were reexamined by Arthur Hollick, by whom they were determined to be of Upper Cretaceous age. In this connection it is also of interest to observe that no genus or species originally determined by Knowlton was subsequently recognized by Hollick. Collections 6815 and 7407, from the same general locality, were determined originally by Knowlton and Hollick and subsequently by Hollick to be of Upper Cretaceous age, but differences exist in the number and character of the genera and species in the earlier and later lists. Collections 8687, 8688, and 8689, however, made by Schlaikjer from the same general locality, have recently been determined by R. W. Brown to be of Tertiary age. Collection 7408, from the same locality, was examined only once and it was determined by Hollick to be of Upper Cretaceous age.

If the earlier and later determinations of 1555, 2973, and 3243 and of 6815 and 7407, were made from exactly the same specimens, it might be desirable to discard the earlier and present only the later determinations. But the later determinations, taken from Hollick's published works,[7] represent only certain specimens that were sufficiently complete or well-preserved to serve the purpose of botanical description. Hence not all of the original determinations are replaced by the later ones, and it is not possible to say exactly which of the original specimens were renamed. For this reason, separate lists of the several determinations are given. The first and principal list includes all those plants which are said without question to be of Tertiary age. The second and third tables give the conflicting data on collections 1555, 2973, and 3243, and on 6815 and 7407. Collection 7408 is presented separately.

Tertiary flora of Eagle-Circle district

[K, Determined by F. H. Knowlton; H, determined by Arthur Hollick; B, determined by R. W. Brown]

	2AC40(2996)	3AP330	3AP336	3AP432	3AP348(3227)	3AP349(3228)	3AP350(3229)	3AP355(3230)	Kindle 11h	Kindle 20	7AA10(4711)	7AA11	Schlaikjer 2(8682)	Schlaikjer 3(8683)	Schlaikjer 4a–c(8684)	Schlaikjer 5a–d(8685)	Schlaikjer 6(8686)	Schlaikjer 8(8687)	Schlaikjer 9(8688)	Schlaikjer 10(8689)	Schlaikjer 27(8693)	38AMt20(8680)
Fern, fragment	K								K													
Equisetum arcticum Heer	H						H															
Equisetum langsdorfii (Brongniart) Heer															B							
Sequoia brevifolia Heer							H															
Sequoia brevifolia? Heer								K														
Sequoia langsdorfii (Brongniart) Heer					K	K	H					K	B	B				B	B			B
Taxodium distichum miocenum Heer	K																					
Taxodium dubium? Heer		K			K																	
Taxodium tinajorum Heer												K										
Populus artica Heer						K					H				B	B				B		B
Populus artica? Heer					K							K										
Populus hookeri Heer							H															
Populus latior Alex. Braun							H															
Populus cf. P. richardsonii Heer			K																			
Populus richardsonii? Heer					K	K																
Populus zaddachi? Heer											H											
Populus sp		K						K														
Platanus? sp										K												
Juglans nigella? Heer						K																
Juglans? sp										K												
Hicoria magnifica Knowlton																						B
Corylus macquarrii (Forbes) Heer				K	K	K		K				K										

[7] Hollick, Arthur, The Tertiary floras of Alaska: U. S. Geol. Survey Prof. Paper 182, 1936; The Upper Cretaceous floras of Alaska: U. S. Geol. Survey Prof. Paper 159, 1930.

Tertiary flora of Eagle-Circle district—Continued

	2AC40(2996)	3AP330	3AP336	3AP432	3AP348(3227)	3AP349(3228)	3AP350(3229)	3AP355(3230)	Kindle 11h	Kindle 20	7AA10(4711)	7AA11	Schlaikjer 2(8682)	Schlaikjer 3(8683)	Schlaikjer 4a-c(8684)	Schlaikjer 5a-d(8685)	Schlaikjer 6(8686)	Schlaikjer 8(8687)	Schlaikjer 9(8688)	Schlaikjer 10(8689)	Schlaikjer 27(8693)	38AMt20(8680)
Fagus deucalionis Unger				K																		
Quercus platania Heer					K																	
Quercus steenstrupiana Heer							H															
Ulmus pseudobraunii Hollick															B	B	B					B
Hamamelis clarus Hollick											H											
Semecarpus prindlei Hollick							H															
Grewiopsis congerminalis Hollick											H											
Pterospermites alternans Heer											H											
Pterospermites conjunctivus Hollick																B						
Pterospermites spectabilis Heer											H											B
Nyssidium ekmani Heer															B							
Fraxinus yukonensis Hollick											H											
Viburnum antiquum (Newberry) Hollick					H																	
Viburnum whymperi Heer				H							H											
Palaeanthus prindlei Hollick							H															
Dicotyledonous leaves, fragments	K		K						K	K			B	B	B			B	B		B	B
Coniferous stem										K												

Flora from three collections determined originally as Tertiary

[K, Determined by F. H. Knowlton]

	Spurr 3 (1555)	2AC57 (2973)	3AH4 (3243)
Aspidium oerstedi? Heer		K	
Sequoia langsdorfii (Brongniart) Heer	K		
Taxodium distichum miocenum? Heer		K	
Taxodium tinajorum Heer			K
Glyptostrobus europaeus? (Brongniart) Heer		K	
Populus arctica Heer			K
Corylus macquarrii? (Forbes) Heer	K		
Ficus? alaskana Newberry	K		
Pterospermites dentatus Heer	K		
Pterospermites cf. P. dentatus Heer			K
Dicotyledonous leaves, fragments		K	

Flora from same three collections determined subsequently as Upper Cretaceous

[H, Determined by Arthur Hollick]

	Spurr 3 (1555)	2AC57 (2973)	3AH4 (3243)
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun			H
Ginkgo sp		H	
Cephalotaxopsis microphylla laxa Hollick	H		
Cephalotaxopsis sp		H	
Nymphaeites exemplaris Hollick			H
Menispermites septentrionalis Hollick	H		
Credneria? parra Hollick			H
Protophyllum? sp	H		
Pseudoaspidophyllum latifolium Hollick			H
Pseudoprotophyllum comparabile Hollick			H
Pseudoprotophyllum dentatum Hollick	H		
Pseudoprotophyllum emarginatum Hollick			H
Pseudoprotophyllum venustum Hollick			H
Pseudoprotophyllum viburnifolium Hollick			H

Flora from two collections determined originally as Upper Cretaceous

[K, Determined by F. H. Knowlton; H, determined by Arthur Hollick]

	6815	7407
Asplenium dicksonianum Heer	K	
Podozamites lanceolatus distans (Presl.) Heer		H
Podozamites sp	K	
Cephalotaxopsis sp		H
Sequoia rigida Heer	K	
Populus? sp	K	
Platanus heerii Lesquereux	K	
Platanoid leaf, fragments		H
Protophyllum sp		H
Aspidophyllum sp		H
Hedera sp		H

Flora from same two collections determined subsequently as Upper Cretaceous

[H, Determined by Arthur Hollick]

	6815	7407
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun	H	H
Cephalotaxopsis microphylla laxa Hollick	H	
Cephalotaxopsis sp		H
Platanus sp		H
Pseudoaspidiophyllum platanoides Hollick	H	
Pseudoprotophyllum sp		H
Hedera platanoidea Lesquereux	H	

Flora determined as Upper Cretaceous

[Determined by Arthur Hollick]

7408:

Podozamites lanceolatus (Lindley & Hutton) C. F. W. Braun.
Cephalotaxopsis sp.
Castaliites sp.
Platanus sp.

The meaning of these conflicting botanical data and of the stratigraphic interpretations thereof is not clear to the writer. It has already been shown that the Tertiary rocks along the southwest bank of the Yukon River, below the Seventymile River, are much faulted, and the conflicting data are restricted to this faulted area. It is, therefore, possible that some rocks of Upper Cretaceous age are faulted into contact with others of Tertiary age and that rocks of both these ages are present. This interpretation, however, is not borne out by the stratigraphy, as no distinctive differences in the lithology or in the degree of induration have been observed in these rocks. Moreover, the latest botanical evidence, as presented by R. W. Brown, indicates that the whole sequence is of Tertiary age. Until more decisive evidence is obtained, it seems best to map all these rocks as Tertiary.

STRATIGRAPHIC AND STRUCTURAL HISTORY

The origin and mode of formation of the Tertiary rocks is not a problem in geomorphology, because the disposition of these rocks long antedates any of the present topographic features. These rocks are known to be of terrigenous origin. From their highly folded structure it is also known that they were at one time buried by superjacent strata, which have subsequently been removed by erosion. And this in turn suggests that the original formation had a much wider extent in interior Alaska than it now has. The lithology of the beds also furnishes clues to their origin and mode of formation, but it raises other questions the answering of which leads into the realm of speculation.

The Tertiary deposits were originally laid down in some kind of an alluvial basin of unknown size, shape, and character. A large part of the beds, both in the eastern and western part of the belt, are conglomerates and grits composed of well-rounded pebbles, mainly of chert, quartzite, and vein quartz. Locally, and usually at or near the base of the formation the conglomerates contain pebbles and cobbles of other kinds of country rocks, such as greenstone, schist, and granitic rocks. At some localities gold is sparsely distributed in certain horizons in the conglomerates. Another part of the Tertiary sequence, which is present principally in the eastern part of the belt, consists of fine-grained beds, including sandstone, sandy and argillaceous shales, and beds of coal. The coarser deposits were evidently laid down by running water having a fairly rapid rate of flow, but the finer-grained deposits suggest deposition in more sluggish types of streams, and also marshy conditions. Such diverse conditions did not occur simultaneously and generally throughout the same area, nor is it likely that they alternated rapidly. It is much more likely that most of the conglomerate was laid down under one set of conditions, and that most of the finer-grained rocks were deposited under other conditions.

The granitic pebbles and the gold contained in certain conglomeratic beds are significant elements in the history of these deposits. South of the belt of Tertiary rocks there is now exposed a great batholith of granitic rocks, which has a length, from east to west, of about 80 miles, and a maximum width, in the longitude of Charley River, of nearly 50 miles. In all directions from this principal batholith are smaller bodies of granitic rocks, which may be regarded as apophyses from the main mass. Some of these smaller bodies of granitic rocks form part of the basement which lies stratigraphically below the Tertiary rocks. Their presence is illustrated by the exposures on the American Creek road, about a mile from Eagle. These granitic rocks are therefore known to be older than the Tertiary rocks. But granite and quartz diorite are coarse-grained intrusives, which are intruded at a considerable distance below the surface of the earth, at depths seldom less than 1,000 feet and as much as several miles. Hence from the time when these granitic rocks were intruded to the time when they were first bared to erosion a long interval must have elapsed. Making due allowance for this interval and remembering that the Tertiary beds were formed after the granitic rocks were exposed to erosion, it seems certain that these granitic intrusives are of Mesozoic age.

It has been found in many areas in Alaska that the apical parts of granitic rocks are favorable sites for mineralization, particularly for the formation of gold-quartz veins, and that such sites, with their attendant ore deposits, are eroded in an early stage of the denudation of granitic intrusives. By the time the Tertiary deposits began to be formed, these apical lodes, and perhaps the granatic rocks at still lower horizons, had been bared to erosion, thus delivering gold to the Tertiary streams. As earlier stated, the courses, sizes, gradients, and other characteristics of these streams have not been traced, because the early Tertiary sedimentation of this region antedates the geomorphic record. Ordinarily, during a single cycle of erosion, with streams of moderate gradient, the downstream vector of motion for gold is small, and if only one cycle of erosion were considered, this might be a potent argument that all the gold was derived from apophyses of the batholith, north of the northern limit of the granitic batholith and in the vicinity of the present site of the Tertiary rocks. But probably the gold was handled and rehandled by streams throughout several cycles of erosion. Moreover, the headwater gradients of the ancient streams, in whose valleys the gold was liberated from bedrock, may have been as steep or steeper than the gradients of the present streams. Under such conditions, placer gold may have originated in lode systems above or along the margins of the batholith and may subsequently have been moved northward for a considerable distance. The exact location of the original gold lodes may therefore have been either in the vicinity of the batholith or north of it; in any event, much of the gold finally came to rest in the conglomeratic beds of the Tertiary formation north of the batholith.

The character of the pebbles found in the conglomerate is also a significant feature bearing upon the genesis of the Tertiary rocks. For the most part, these pebbles are chert, quartzite, and vein quartz, which are practically indestructible, except by abrasion. The other types of country rock are commonly absent. This condition suggests that the climate preceding and possibly during the accumulation of the Tertiary rocks was such that the pebbles and cobbles of country rock, other than these siliceous gravels, were almost entirely disintegrated to form finer sediments. Such chemical decomposition of the country rock could readily take place under a condition of deep residual erosion existing generally throughout a region.

One other condition has been observed, which may have a bearing upon the formation of the Tertiary rocks. Along the Yukon River, north of the Tertiary rocks but also west of most of them, there occurs a group of Lower Cretaceous rocks, known as the Kandik formation. This formation is composed dominantly of slate and quartzite, with considerable conglomerate in its upper horizons. The Lower Cretaceous quartzites, both in this vicinity and in other parts of the Yukon-Tanana region, weather out and ultimately become rounded boulders and cobbles, which are visible in all the streams draining areas containing such rocks. In this water-worn condition these quartzites exhibit numerous semielliptic markings, which resemble the form of fossil shells but are really conchoidal fractures. These structures are so characteristic of the Lower Cretaceous quartzites that it is possible to recognize the rocks even when they lie at some distance from their bedrock source. Now the drainage basins of certain streams, as, for example, the headwater part of Fourth of July Creek, lie entirely within the area occupied by Tertiary rocks; yet these Lower Cretaceous quartzite cobbles and boulders are very common among the gravels forming the gold placers in this valley. Similar boulders are found as residual Tertiary detritus along the ridge that separates Crooked Creek from Trout Creek. Hence it follows that these gravels, derived from Lower Cretaceous rocks, are of common occurrence at certain horizons in the Tertiary rocks. But the localities cited lie a considerable distance southeast of those places where the Tertiary rocks lie closest to the Lower Cretaceous rocks. It is therefore inferred that these distinctive gravels have been moved southeastward from the site of the Lower Cretaceous rocks to their present sites in the Tertiary sequence. Hence it follows that the course of the master stream in the old Tertiary drainage system, or the courses of its larger tributaries, may have been southeastward. This ancient Tertiary valley is therefore not necessarily the ancestor of the present Yukon drainage.

One of the puzzling features of these Tertiary rocks is their great thickness. The minimum thickness of the sediments comprising the Tertiary sequences is 3,000 feet, and it is possible that the maximum thickness is as much as 10,000 feet. Russell [8] has summarized the available data regarding the total thickness of sediments in the

[8] Russell, R. J., Physiography of the lower Mississippi Delta: Louisiana Geol. Survey, Dept. Conservation, Geol. Bull. 8, pp. 148–156, 1936.

lower Mississippi Delta. One of these estimates, made originally by Shaw and afterward accepted by Miser,[9] gives the thickness of the Tertiary sediments as 5,500 to 8,500 feet; adding to this the thickness of the Upper Cretaceous rocks, a total thickness of 10,000 to 12,000 feet of sediments is postulated in the Mississippi Delta. Some later evidence, however, is cited by Russell, which suggests a total thickness from the surface to the old pre-Comanche basement of as much as 30,000 feet at New Orleans. Hence there seems to be no difficulty in explaining the great thickness of the Tertiary rocks if a downwarped basin is postulated that was in the process of subsidence throughout Tertiary time. But the lithology of the Tertiary rocks of the Eagle-Circle district and their location far from the present sea present differences that render doubtful any comparison with the conditions existing in the Mississippi Delta. Beds of conglomerate, for example, aggregating perhaps 1,000 feet, are exposed in the valley of Bryant Creek. No deposits of gravel of similar thickness are to be expected in the lower Mississippi Delta. Also, a sinking basin of this magnitude is more likely to occur close to the sea, or at least between the sea and the old crystalline rocks, than in the midst of the latter. A sinking basin of some sort, however, must necessarily be postulated to account for the thickness of these Tertiary rocks. The crustal movement that produced this subsidence must at certain stages have been rapid to account for the deposition and rapid accumulation of conglomerate. The present structure of the Tertiary beds, with their appressed folds, resembling locally an overturned sequence, must also be considered, as it is likely that some of this deformation took place before the Tertiary sedimentation was finally completed. And it must be recalled that the site of the present Yukon River, to the north of the Tertiary belt, coincides roughly with a line separating the complexly deformed rocks to the south from the little-deformed rocks lying immediately to the north. The final answer to the structural problem that is formulated by all these considerations cannot be definitely or finally stated, but considering together the data now available, a geosynclinal structure rather than a simple down-warping is strongly suggested.

If the Tertiary rocks represent sediments that were deposited in some ancient stream valley, even if such a valley were of the magnitude of the present valley of the Mississippi River, a certain linearity might be expected in the present outcrops of these rocks. And over a distance of 100 miles a wider and a narrower part of the belt might also be expected, corresponding to a difference in the width of the original valley at different places. The Tertiary belt of the Eagle-Circle district shows these features, but on the other hand there are other features

[9] Idem, pp. 150–151.

that throw doubt upon the exact correlation of the present site of this belt with an original elongation of the old Tertiary valley. The conglomerate deposits, for example, appear to be prevalent throughout the belt and to be no less prevalent at the narrow end of the belt than at the wide or eastern part. In fact, the wide part of the Tertiary belt appears merely to include a greater proportion of sandy and shaly rocks, possibly of later age, which are not represented at the west end of the belt. These facts are best explained on the basis of the postulated geosynclinal structure. Under such a hypothesis, the western end of the belt may well be interpreted as a pinching out of the geosynclinal structure; the conglomeratic horizons regardless of their apparent position in the section, may be interpreted as the primitive basal horizons at or near the base of the sequence; and the elongation of the belt may be interpreted as marking a structural axis, which may or may not coincide with the general course of the original Tertiary valley. The smaller degree of cohesiveness of the Tertiary rocks in the western part of the belt, under this hypothesis, may also be interpreted as due to their smaller degree of compression and induration, since in this area the deformative forces were smallest. These structural interpretations cannot be proved, but they are the necessary result of a structural hypothesis that seems most probable.

ASSOCIATED PLACERS

The Tertiary deposits are of importance because they have acted as a proximate source of gold, from which gold placers have been concentrated in various tributaries of the Yukon River. The following streams contain workable gold placers of significant importance, which have been derived mainly from the erosion of Tertiary rocks: Several northern tributaries of the Seventymile River that head in the central part of the Tertiary rocks, the principal ones being Barney, Broken Neck, Crooked, and Fox Creeks, which lie in the eastern part of the Tertiary belt; Fourth of July Creek, about 15 or 20 miles farther west; and Coal and Woodchopper Creeks, near the western end of the Tertiary belt.

Placer gold, though derived mainly from the Tertiary rocks, has also been found at numerous other localities within this belt, but either in the form of small placer bodies that were quickly mined out or as deposits of too low tenor to be profitably exploited at the present price of gold. Among such localities should be mentioned Mission Creek and some of its tributaries; Washington Creek, which is tributary to the Yukon; Charley River and some of its tributaries; and Sam and Webber Creeks. In other words, some gold may be found in almost every stream that crosses or heads in the Tertiary belt, but only certain of these streams contain workable placers. A detailed description of the history, character, and methods used in working these placers has recently been published by the writer,[10] so that it will not be necessary to repeat it here. However, certain features of these placers need to be reviewed.

The important gold-bearing streams of the Tertiary belt are of two classes. The streams of one class, exemplified by Seventymile River and Coal and Woodchopper Creeks, head in the granitic rocks that lie south of the Tertiary belt and cut completely across this belt. The streams of the other class, exemplified by Fourth of July Creek and by certain tributaries of the Seventymile River, such as Barney, Broken Neck, Crooked, and Fox Creeks, head in the Tertiary belt, so that most or all of their drainage basins lie within the area occupied by Tertiary rocks. The streams that head in the granitic rocks might be expected to have two types of gold placers, one derived directly from pre-Tertiary bedrock sources and the other derived from the Tertiary conglomerates. For Seventymile River and for American Creek, a tributary of Mission Creek, this condition actually obtains, and workable placers have been discovered and worked upstream from the Tertiary belt. But for Coal and Woodchopper Creeks this is not true, as all the workable placers lie either within or slightly downstream from the Tertiary belt. Streams of the second class, such as Fourth of July Creek, afford the best opportunity for studying placers that have been derived exclusively from Tertiary rocks, but Coal and Woodchopper Creeks, because of the absence of gold placers upstream from the Tertiary rocks, are almost as satisfactory.

The placers in all these streams may again be classified into two kinds, on the basis of their relative ages. All the placers of any considerable significance are located in the present valley floors, and therefore from the standpoint of the gravels comprising these deposits they might be called the younger placers. Other less significant though workable placers have been located on bedrock that lies well above the level of the bedrock in the present streams, and at many places there is no topographic reflection of these higher erosional surfaces. All these higher placers may be designated as older or bench placers. The older and younger placers may be correlated roughly, but not definitely, with the Pleistocene and Recent geologic epochs. But in studying the older and younger placers, it is quickly apparent that all gradations exist between these two kinds of deposits. No fixed interval exists, for example, between the bedrock level of the bench deposits and the bedrock level in the streams. At some places bedrock benches exist at several levels above the present streams, and at other places the bedrock of a main valley floor may rise either gradually or

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[10] Mertie, J. B., Jr., Gold placers of the Fortymile, Eagle, and Circle districts, Alaska: U. S. Geol. Survey Bull. 897, pp. 133–261, 1938.

abruptly to a slightly higher level on either side of the valley, where other placers exist. On Fox Creek, a tributary of Seventymile River, a bedrock surface covered by a gold placer lies 70 feet above the level of the present stream, and this is the highest of the older placers so far observed. From these conditions it is apparent that the present placers have been in process of formation throughout the Quaternary period and that the gold found in these placers has probably been handled and rehandled by the streams many times, both during the period of deposition of the Tertiary rocks and intermittently since that time. It is therefore necessary to differentiate sharply between the age of these gold placers and the age of the gold contained in them, for the gold must have been, at one time or another, an integral part of many gold placers of many ages.

Another significant feature is the north-south distribution of gold placers in those streams that cross either or both of the northern and southern contacts of the Tertiary belt. On Coal and Woodchopper Creeks, as already mentioned, no placers are known upstream from the southern limit of the Tertiary belt, and it might therefore be expected that the southern limit of the gold placers on these two streams would be sharply marked, as it is. But the sharp cut-off of high-grade placers at the northern end of the Tertiary belt on Coal, Woodchopper, and Fourth of July Creeks is an interesting feature, which applies not only to these streams but also to all other placer-bearing streams that cut across the north end of the Tertiary rocks. This feature shows clearly that the downstream vector of movement for gold, in streams with gradients like those mentioned above, is small, for throughout the entire Quaternary period, aggregating between one and two million years, these streams have been unable to move any considerable part of this gold for any considerable distance downstream. Yet gold does have an appreciable downstream movement, and the Quaternary interval is short compared with the span of time that has elapsed since the original gold lodes were first bared to erosion. Therefore, even with a small downstream movement of the gold it is possible that various cycles of erosion operating over a period of time many times as long as the Quaternary may still have moved the gold a long distance northward from its original bedrock sources.

An apparent contradiction to this law of restricted downstream movement may occur to some of the miners familiar with conditions in this area. A small gold placer, for example, was found on Dome Creek, an eastern tributary of Woodchopper Creek, which enters Woodchopper Creek 2 miles or more downstream from the northern limit of the Tertiary rocks. This is due to the fact that a small and almost completely eroded body of Tertiary rocks occurs in the valley of Dome Creek, the presence of which is indicated by residual gravels on some of the subsidiary spurs. Similarly, workable gold placers are found on Coal Creek, north of the limit of the present Tertiary belt, but the outline of the northern contact of the Tertiary rocks indicates that a lobe of such rocks has rather recently, certainly within the span of Quaternary time, been eroded from the east wall of the valley, north of the present Tertiary contact.

The presence of gold in the Tertiary rocks has been suspected for many years, though little direct evidence of its presence has been available, such as the extraction of gold from the conglomerates. However, the gold placers of Fourth of July Creek afford almost indisputable indirect evidence of a proximate source of the gold, as all the headwater drainage basin of this stream, upstream from the placers, lies within the Tertiary belt. During the field season of 1938 the writer attempted at many places to pan gold directly from slaked conglomerate, or from conglomerate so hard that it had to be mortared before panning. These efforts were rewarded with success at several localities, as heretofore noted. But the amount of gold thus recovered was extremely small, ranging from one small color in a pan to the same amount in 200 pounds of gravel. Gold is therefore actually present in some of the Tertiary conglomerate, but it is sparsely and evidently very irregularly distributed.

The erratic distribution of gold in the Tertiary conglomerate is best appreciated by noting the localities of the placers within the Tertiary belt. Some streams cut entirely across the Tertiary rocks; some head in the Tertiary rocks and discharge beyond them to the north; others head in areas of older rocks and terminate in the Tertiary belt; and still others have their entire drainage basins within the Tertiary belt. Of these many streams, only a few contain workable gold placers. Between the international boundary and the Seventymile River no important placers have been found within the Tertiary belt, though placer gold has been mined in a small way for many years on American Creek and its tributaries, about 8 miles south of the Tertiary belt. A little gold was also recovered from Boundary Creek, just south of the Tertiary rocks. Along the Seventymile River, within the Tertiary belt, Barney, Broken Neck, Crooked, and Fox Creeks, which are northern tributaries, contain workable placers. But the valley of Washington Creek, lying between Barney and Broken Neck Creeks, contains no important gold placers. The southern tributaries of the Seventymile River, within the same stretch, are essentially barren. But three southern tributaries of the Seventymile, known as Flume, Alder, and Nugget Creeks, which lie a short distance south of the Tertiary belt, contain gold placers in their valleys. On Fourth of July Creek, the valley of the main headwater fork contains placers that have been worked for years, but Crowley Creek, another headwater creek, has no pay streak. East of Crowley Creek are Michigan and Trout

Creeks, which head in the Tertiary belt and discharge northward to the Yukon. Both of these streams are devoid of workable gold placers. On Washington Creek, a larger tributary of the Yukon, a little placer ground was found on three small tributaries, Nugget, Surprise, and Eagle Creeks, but Washington Creek in general has no important commercial placers. Some gold was found on Irish Gulch and Drayham Creek, tributaries of Charley River, but in general Charley River, within the Tertiary belt, has not produced any considerable amount of placer gold. The valleys of Coal and Woodchopper Creeks contain the most important placers of the Tertiary belt, but on Sam Creek, just east of Coal Creek, small placer deposits have been found on Ben and Sawyer Creeks, but not elsewhere in this valley. Some placer ground was also worked in Alder Creek, an eastern tributary of Webber Creek, but in general both Webber and Thanksgiving Creeks have no commercial placers.

Prospecting and mining in the valleys that contain gold placers have also shown marked irregularities in the distribution of the gold. On some streams the gold is found to come mainly from one or the other side of the valleys; on others the auriferous ground ends upstream at some definite line within the Tertiary belt; or again, it may be evident that the gold has come out of some one particular tributary. One example of this localization of gold placers may be seen in Crooked and Fox Creeks. An eastern tributary of Crooked Creek, known as Eldorado Creek, heads against a western tributary of Fox Creek, called Lucky Gulch. No workable gold placers have been found on Crooked or Fox Creeks upstream from these tributaries, but Lucky Gulch itself has been mined. In this example there seems to be an auriferous zone in the Tertiary belt, lying approximately in the site of Eldorado Creek and Lucky Gulch, though the gold content of the Tertiary bedrock in this zone appears to be more concentrated in the vicinity of Lucky Gulch. On Fourth of July Creek a large part of the gold appears to have come out of Union Creek, a small tributary from the east, and it was at the mouth of this little stream where the writer was able to pan gold from the Tertiary bedrock. On Woodchopper Creek the western side of the pay streak approaches a straight line, parallel with the course of the valley, but on the east side marked irregularities occur, causing considerable variability in the width of the pay streak. Mineral and Iron Creeks, on this eastern side of the valley, have been worked for their content of gold, and it is therefore evident that much of the gold in the valley of Woodchopper Creek has come from these two streams and from the next eastern tributary south of Iron Creek. South of Iron Creek the principal pay streak of Woodchopper Creek ends. The bedrock sources of the gold on Coal Creek are not so evident, but apparently much of the gold has come from the southeastern side of the valley. This inference is further supported by the occurrence of gold placers in Boulder Creek, a tributary from the southeast.

Several reasons exist for the irregular distribution of the gold placers that have been derived from the Tertiary rocks. The first of these is an initially irregular distribution of gold in the Tertiary conglomerates. The sparse distribution of gold in these conglomerates indicates that marked concentration of gold, like that in the present pay streak, was lacking in the Tertiary deposits. Instead, it is probable that a large quantity of gold was sparsely and irregularly distributed through a great volume of gravel and that at many places little or no gold was deposited. It is possible that most of the auriferous zones of the ancient Tertiary gravels were localized in the lower courses of the stream that flowed northward from the granitic rocks.

Another reason for the present irregular distribution of gold within the Tertiary rocks, and therefore in the placers reconcentrated therefrom, is that the gold-bearing horizons were subsequently intensely deformed. It has already been shown that after the Tertiary gravels and associated sediments were deposited they were buried by later deposits, presumably in a sinking geosynclinal basin. During some later epoch in the Tertiary, they were intensely folded, and to some extent faulted. Still later, when these folded rocks were bared to erosion, their upturned edges became exposed at the surface. As a result of these processes, any lineal elements in the original zones of gold deposition now took on the form of space curves, and thereby any initial tendency toward regularity in the localization of gold-bearing areas was further modified. Hence, even if a locality could be found where a Tertiary conglomerate shows any considerable concentration of gold it would be difficult to trace such a zone at the surface, first, because it may not follow the present surface; and second, because the structure in this wooded country is too obscure to be deciphered, so that the underground continuation is equally indefinite. The erosion of the country rock has added still another element of uncertainty to the localization of auriferous zones in the Tertiary rocks, for auriferous zones may have been eroded that had no continuous connection with the Tertiary rocks now exposed at the surface.

The following theoretical considerations may throw light upon the concentration of the present placers from the Tertiary conglomerates. In most small streams much of the alluvial material is in course of progressive movement from the headwaters downstream. In the uppermost stretches all this alluvium, from the surface to bedrock, at times of flood is moved downstream and redeposited. But in most small streams there is a zone in the valley downstream from which the alluvial material on or near bedrock will not be further disturbed, even at the highest flood stages, unless the stream is rejuvenated by a lowering of its base level of erosion. The position and length of this critical zone varies with the strength of the current, the size and specific gravity of the alluvial materials, and with several other factors; yet its existence is fairly well substantiated. If a gold lode occurs at or near the head of a valley, the gold on being liberated by the process of weathering migrates downstream with the other stream detritus, gradually working its way toward bedrock. Somewhere in the critical zone, however, most of this gold, and all the coarse gold, finally comes to rest; from this zone downstream the current of the stream is slower and the detritus becomes thicker, so that the stream can no longer erode to bedrock. This critical zone, which lies between the headwater stretch of intermittent movement of all debris and the downstream stretch of no movement of the debris near bedrock, marks the downstream terminus of the pay streak; but gold in process of downstream migration is also present upstream from the critical zone, and such gold may or may not constitute a pay streak, depending upon various factors. But stream erosion is a continuous process, in the course of which the valley is either extended backward into its divide, or, if another headwater stream is flowing in the opposite direction, the divide between the two streams is lowered. In either case, the net result is a change in the longitudinal profile of the stream bed, such that the headwater gradient is diminished and the critical zone of deposition migrates slowly upstream. Hence that stretch of gold placers, no longer subject to downstream movement, is lengthened, and a pay streak is deposited progressively upstream. The concept thus results that the part of a placer farthest downstream was deposited first and that the formation of the pay streak took place progressively upstream, as a series of overlapping wedges. This mode of pay-streak formation is particularly applicable in areas where the local base level of erosion has remained sensibly constant over a long period of time, and such conditions have apparently obtained during certain erosional cycles in parts of interior Alaska. It should also be emphasized that after such a pay streak has once been formed successive changes in the local base level of erosion are not likely to alter materially the areal distribution of the gold.

Another condition that may be expected generally to exist is that the intrusion of granitic rocks produced thermal effects, which were reflected in a localized induration and hardening of the invaded sediments. Thereafter the drainage channels, regardless of their original character, would ultimately become adjusted to such resistant rocks, so as to become essentially subsequent streams. Hence, the mineralized zones, before they were eroded, would tend to be localized in the headwaters of streams or of their tributaries. Assuming this localization of the lode systems and the geomorphic conditions cited, most of the placer gold should be found near, on, or in bedrock as elongate pay streaks. This is actually true for most of the placer streams of Alaska, the gold being found in the lowermost few feet of gravel, on the surface of bedrock, and if the latter is greatly fractured, to a depth of as much as 6 feet in bedrock.

The Tertiary rocks form the bedrock in the medial or lower portions of certain placer-bearing valleys, but in certain other valleys the placers lie entirely within the area occupied by such rocks. Yet in both types of valleys it has been shown that the auriferous horizons in bedrock are restricted to narrow discontinuous zones, which in large measure occur in the medial parts of these gold-bearing valleys. Hence the localization of the proximate sources of gold in the Tertiary belt is different from what may ordinarily be expected, where the placers are derived directly from bedrock sources and in the manner above postulated. It then follows that the distribution of placers in the Tertiary belt should not conform with the distribution of the more usual types of Alaskan fluviatile placers. This is found to be true, for not only are the placers of the Tertiary belt restricted to areas where the Tertiary rocks crop out but also these placers are outstanding examples of the absence of a pronounced concentration of gold on, in, or near bedrock. Instead, the placer gold in most of these valleys is found throughout the stream gravels, as well as on bedrock. And because of the soft and unshattered character of the Tertiary rocks little gold occurs within the bedrock.

The Tertiary gold-bearing conglomerates may be regarded as extremely low-grade lodes, which are genetically analogous to the gold-bearing conglomerates of the Witwatersrand district, in the Transvaal region, Union of South Africa, though geologically they are much younger than the latter. Miners and prospectors are particularly interested to know whether any of these conglomerates may possibly be mined, either at the present time or in the near future. The theoretical considerations above presented, together with the prospecting operations of the writer, especially in localities that should be favorable, such as at the mouth of Union Creek, in the valley of Fourth of July Creek, lend little or no encouragement to the belief that commercial lodes will be found. Gold is definitely present in some of these Tertiary conglomerates, but evidently it is sparsely and erratically distributed. Such deposits cannot be regarded as commercial lodes.

CHARACTER OF THE GOLD

Sufficient gold for study or analysis has not been panned or washed directly out of the Tertiary conglomerates, so that no statements can be made from data acquired in this manner. But most of the gold contained in the placers within this belt has been eroded from these conglomerates. Hence some idea of the character of the gold as it existed in its bedrock source can be obtained by an examination of the placer gold. Such descriptions have already been given in some detail by the writer in an earlier publication.[11]

The granularity of the gold varies from stream to stream, but it is usually well-worn and is nearly everywhere of high grade. On Crooked Creek, about 3,200 ounces of gold are known to have been recovered in the last 20 years, but no single piece weighing in excess of 80 grains has been found during this period. On Fourth of July Creek most of the gold is likewise fine-grained, and the largest nugget so far found weighed about half an ounce. On Woodchopper Creek, however, the gold is coarse and shotty, and on Mineral Creek, a tributary of Woodchopper Creek, nuggets weighing up to 2½ ounces have been recovered. In general, therefore, the gold derived from the Tertiary rocks appears to be coarser near the western end of the Tertiary belt; and inasmuch as this western part of the Tertiary belt is closer to the granitic batholith to the south, a causal relationship may exist.

The fineness of the gold found in the different placers lying within the Tertiary belt is a matter of considerable interest, not only to those engaged in mining but also to the economic geologist. As earlier stated, most of the gold has been recovered from placers lying in the present valley floors, and consequently most of the information on fineness applies to such gold. The available data for the different valleys are given below.

Fineness of gold in the Tertiary belt

	Number of assays	Parts per thousand		
		Gold	Silver	Dross
Seventymile River	2	828	163	9
Fox Creek	5	882	109	9
Broken Neck Creek	4	829	165	6
Crooked Creek	20	908	88	4
Barney Creek	1	875	122	3
Fourth of July Creek	24	892	99	9
Ben Creek, tributary of Sam Creek	1	896	100	4
Coal Creek	16	897	96	7
Woodchopper Creek	6	932	62	6
Mineral Creek, tributary of Woodchopper Creek	13	925	71	4
Mean of individual values	--------	898	95	7

The arithmetical mean of the 92 values given above, without any weighting either for the number of assays or the number of ounces mined, shows the fineness to be 898 parts gold, 95 parts silver, and 7

[11] Mertie, J. B., Jr., Gold placers of the Fortymile, Eagle, and Circle districts, Alaska. U. S. Geol. Survey Bull. 897, pp. 133–261, 1938.

parts dross in a thousand. The present value of such gold after melting, disregarding the value of the alloyed silver, is $31.43 an ounce. Twelve of these assays, however, represent gold from the Seventymile River, Fox Creek, Broken Neck Creek, and Barney Creek. The gold on Seventymile River is a mixture of gold from the Tertiary belt with gold that originated directly from bedrock sources west of the Tertiary belt, and the gold from the other 3 streams mentioned is mainly bench gold. Eliminating these 12 assays, and averaging the remaining 80 assays, the fineness is found to be 905 parts gold, 89 parts silver, and 6 parts dross in a thousand, corresponding to a value of $31.67 an ounce. This is closer to the true mean value of the gold now being mined in the placers of the present valley floors within the Tertiary belt.

Some comparative data on the fineness of gold in other parts of this region is furnished by an examination of the gold found southwest of, but close to, the Tertiary belt. Such gold has been derived from bedrock of pre-Tertiary age and has probably been concentrated directly from such bedrock without going through the intermediate stage of being deposited in the Tertiary conglomerates. Four such sets of assays are given herewith:

Fineness of gold southwest of the Tertiary belt

	Number of assays	Parts per thousand		
		Gold	Silver	Dross
Boundary Creek	1	850	145	5
American Creek and tributaries	10	865	130	5
Nugget Creek	1	851	143	6
Alder Creek	9	841	153	6
Mean of individual values		853	141	6

These four sets of assays, without any weighting with regard to number of assays or number of ounces mined, show a mean fineness of 853 parts gold, and 141 parts silver, and 6 parts dross in a thousand. The present value of such gold, disregarding the value of the alloyed silver, is $29.85 an ounce. Most of this gold, however, has been recovered from Alder Creek, and the mean value, weighted with regard to ounces mined, is actually 845 parts gold, 149 parts silver, and 6 parts dross in a thousand.

This decidedly lower value of the gold that occurs just south of the Tertiary belt leads to an interesting speculation. It has already been stated that this gold is believed to have been concentrated directly from pre-Tertiary bedrock sources, without first being deposited in the Tertiary conglomerate. If this is true, such bedrock sources were probably uncovered to erosion at a much later date than the bedrock that was eroded to produce the Tertiary rocks. It then follows that such more recently uncovered bedrock should represent lower horizons in the lode systems that were connected with the granitic intrusives which were the original sources of the Tertiary gold in this region. This suggests that the gold that came from the apical parts of the original lode system was of distinctly higher grade than the gold occurring in lower horizons; yet even if this is true, it may be interpreted in two ways. One explanation is that the grade of the primary gold in the original lode system varied vertically as a result entirely of hypogene processes, which were effective at the time of its deposition. A second explanation would ascribe the observed differences to supergene processes, which were effective in the zone of oxidation and enrichment long after the gold was deposited in the lodes. But interior Alaska is an unglaciated country, and, therefore, a zone of oxidation and enrichment has existed throughout Tertiary and Quaternary time. Consequently, under the second interpretation, it would follow that this process of enrichment was more effective during some geologic periods than during others. Certainly under the frozen conditions of the ground that have existed during the Quaternary period, it should be expected that supergene enrichment would be least effective, but it is doubtful if supergene enrichment was more effective in the Eocene than in the later Tertiary epochs. Moreover, a considerable part of the gold southwest of the Tertiary belt may have been freed from its bedrock sources before the beginning of the Quaternary period. Consequently, the second explanation seems to be less probable than the first one; the writer is, therefore, inclined to believe that the observed differences between the gold of the Tertiary belt and the gold southwest of the Tertiary belt is due to primary differences in the grade of the gold in the original lodes, due principally to hypogene processes.

In all the assays above presented there occurs a small percentage of metallic impurities, which collectively are designated as the dross. Though these impurities may consist in part of metals of man-made origin, such as solder, lead shot, and similar materials, the dross usually consists largely or wholly of metals that are alloyed with the gold and silver. The percentage of dross throughout the Tertiary belt is rather low, aggregating, on the average, only six- or seven-tenths of 1 percent, and for this reason it is considered to consist almost entirely of alloyed metals of natural origin. Thousands of commercial assays have been made of the lode and placer golds of Alaska to determine the intrinsic value of these natural alloys or of the melted bullion. But few complete chemical analyses have been made with the primary purpose of identifying the metals of the dross, because these metals are present in such small amounts that they would probably be unimportant, commercially, even if they were precious metals. For scientific reasons, however, which might ultimately have an economic application, complete chemical analyses were made of three samples of placer gold from the Tertiary belt. The results were surprising, for they revealed the presence of significant amounts of platinum, which heretofore had been unknown even to the producers of these placer golds.

In selecting the samples for analysis, two samples of placer gold were taken that were believed to have been derived wholly from the Tertiary conglomerates. The third sample was taken from a locality where the gold from the Tertiary conglomerates was known to be mixed with other gold derived directly from bedrock sources south of the Tertiary belt. The first sample was taken from the headwater fork of Fourth of July Creek, where mining operations are now in progress. The drainage basin of this fork, at and upstream from the site of mining, lies wholly within an area occupied by Tertiary rocks. The second sample was taken from Woodchopper Creek, at the site of the present dredge mining. Woodchopper Creek rises 10 miles south of the southern contact of the Tertiary rocks, so that the headwater part of its valley is occupied by pre-Tertiary rocks. But as previously mentioned, no gold placers have been found in the headwater part of this valley south of the Tertiary contact. Hence there is little chance that the gold derived from the Tertiary conglomerates in Woodchopper Creek has been mixed with gold of another origin. The third sample is gold that was panned from the Seventymile River, at the mouth of Broken Neck Creek. Most of this gold was derived from the Tertiary conglomerate in the valley of Broken Neck Creek, but probably some of it was washed down the Seventymile River, coming perhaps from pre-Tertiary bedrock sources south of the Tertiary belt. These three analyses are given herewith, followed by another tabulation, wherein the SiO_2 has been eliminated and the analyses recomputed to 100 percent.

Complete analyses of placer gold

[R. E. Stevens, analyst]

	38AMt57	38AMt90a	38AMt27
Gold	87.53	92.69	80.59
Silver	11.12	6.16	18.21
Platinum	.28	.42	.20
Iridium	.05	Trace	.02
Palladium	Trace	None	None
Rhodium	None	None	None
Lead	.07	.08	.06
Mercury	.05	.02	.10
Iron	.07	.07	.08
Copper	.01	.04	.03
Zinc	.03	.01	.04
Cobalt	None	None	None
Nickel	None	None	None
Bismuth	None	None	None
Tin	Trace	Trace	Trace
Silica	.40	.77	.43
Total	99.61	100.26	99.76

38AMt57. Fourth of July Creek, 7 miles air line from mouth.
38AMt90a. Woodchopper Creek, 4 miles air line from mouth.
38AMt27. Seventymile River, at mouth of Broken Neck Creek.

Complete analyses of placer gold

[Recomputed]

	38AMt57	38AMt90a	38AMt27
Gold	88.23	93.17	81.13
Silver	11.21	6.19	18.33
Platinum	.28	.42	.20
Iridium	.05	Trace	.02
Palladium	Trace	None	None
Rhodium	None	None	None
Lead	.07	.08	.06
Mercury	.05	.02	.10
Iron	.07	.07	.08
Copper	.01	.04	.03
Zinc	.03	.01	.04
Cobalt	None	None	None
Nickel	None	None	None
Bismuth	None	None	None
Tin	Trace	Trace	Trace
Total	100.00	100.00	100.00

The data given below summarize the general physical character of these samples:

38AMt57:

- Average size of grains, 1.5 millimeters.
- Grains rather uniform in size.
- Discoid in shape, well-worn.
- Specific gravity, 16.00 (determined by R. E. Stevens).

38AMt90a:

- Average size of grains, 2.5 millimeters.
- Greater range in size than in sample 38AMt57.
- Shotty and moderately well-worn.
- Deep yellow, with considerable adhering hematite, which was dissolved in hydrochloric acid before analysis.
- Specific gravity, 15.87 (determined by R. E. Stevens).

38AMt27:

- Average size of grain, 0.5 millimeters.
- Grains rather uniform in size.
- Flaky, well-worn.
- Bronzy yellow.
- Specific gravity, 15.18 (determined by R. E. Stevens).

None of the three samples, when freed of surficial iron, was in the slightest degree electromagnetic, even in an extremely intense magnetic field.

All three of these samples were prepared for analysis by hand picking of the individual metallic grains, and no grains of platinum were observed. Moreover, the sample which was found to contain the largest amount of platinum consisted of grains that were larger than those in the other two samples, so that it is unlikely that any grains of platinum could have been overlooked. For these reasons it is reasonably certain that no free platinum metals were present in the samples. It is therefore concluded that the platinum identified by the analyst represents alloyed platinum, existing in the same relation to the gold and silver as the other elements comprising the dross.

This discovery may possibly be of some economic significance. A large amount of placer gold, corresponding to sample 38AMt90a, is now being mined on Woodchopper and Coal Creeks. The producers at present are not being paid for the platinum contained in their product, as the Federal assay offices make no return for platinum contained in gold bullion. Instead, the platinum metals are subsequently recovered by the Federal electrolytic refineries at New York, Denver, or San Francisco and are claimed by the United States as seigniorage. Hence the question arises whether it would be profitable to the producers to send their bullion to a commercial refinery for separation of the platinum before submitting it to a Federal assay office. At the present market price of platinum it is doubtful if such a procedure would be profitable because of refining costs, but it is near the margin of a profitable venture, and at a higher market price for platinum this procedure might be worthy of consideration.

In addition to the unexpected presence of platinum, these analyses show other features of interest. In most native gold the common metals of the dross are copper and iron. These occur in variable proportions, such that either copper or iron may be the dominant metal. But in a considerable number of analyses of gold compiled from other parts of the world, the average ratio of copper to iron was found to be nearly 1 to 1. Hence the predominance of iron over copper in these samples is not unusual. But the dominance of other metals over iron and copper is anomalous. In these samples, for example, the ratio of the average total content of lead, mercury, and zinc to the average total content of iron and copper is 17 to 10. One of the surprising features of the analyses is the occurrence of mercury in all of them. And in this connection it should be emphasized that all of the gold in these samples was recovered by purely mechanical methods and not by amalgamation. The mercury deposits of Alaska, so far as known, are related genetically to Tertiary granitic rocks, for which reason mercury might be expected in analyses of Tertiary gold. But in Mesozoic gold it is unexpected and until more data are obtained inexplicable.

These analyses reveal still another feature of interest. Placer gold is known to be a natural alloy of gold and silver with small percentages of base metals. In the alloys under present consideration, however, platinum is the principal metal, other than gold and silver, and its inclusion as a part of the dross is of questionable propriety. In any event, all the metals shown in the three analyses constitute natural alloys. Little is known of the state of aggregation of such natural alloys, though much investigative work has been done on artificial alloys of different metals, including gold and silver. Raydt[12] has studied the binary system of gold and silver and has derived an equilibrium diagram, relating composition to temperature. This diagram shows continuous solidus and liquidus curves, without maximum and minimum points. Therefore, in such dry artificial melts, gold and silver are continuously miscible in all proportions, like alcohol and water, and remain so after solidification, forming a solid solution analogous to the plagioclase feldspars.

The phase relation shown by Raydt's diagram and other phase relations known to exist between binary and ternary systems of gold, silver, platinum, copper, iron, and other elements studied as artificial melts do not necessarily hold for the corresponding natural alloys, because the effects of still other components, such as quartz, water, other base metals, and the so-called mineralizers have not been evaluated. It seems likely, however, that the relationship observed in dry melts will in some measure, perhaps in large measure, apply to the natural alloys of gold and silver; for this reason placer gold should be considered to be altogether or in large part a solid solution of crystalline gold and silver, with small quantities of other metals, in unknown phase relationships. But certain significant differences between natural and artificial alloys have been observed, notably in connection with the analyses given above, which seem worthy of emphasis. These differences relate to the specific gravities of these samples.

If any two metals were completely immiscible in the solid state, so that they solidified as individual grains in a eutectic or mechanical mixture, it should be possible from a chemical analysis to compute those physical properties, such as specific gravity, which are functions of additive quantities like mass and volume. But gold and silver crystallize from dry melts as solid solutions or, in other words, as atomic mixtures; and if the natural alloys of gold and silver are likewise solid solutions it should not be possible from chemical data alone to compute their specific gravities. This is found to be true. But it is a matter of considerable interest to assume that the eutectic relationship holds and to compute either from artificial mixtures of known weights of gold and silver or from chemical analyses of the natural alloys of these two metals the specific gravities that should result. These theoretical values can then be used as standards with which to compare the respective alloys in order to determine whether the alloys show contraction or expansion in volume and the order of such changes as compared with mechanical mixtures of the two components. For

[12] Raydt, U., Über Gold—Silberlegierungen: Zeitschr. Anorg. Chemie, vol. 75, pp. 58–62, 1912.

artificial alloys of gold and silver this has been done by Matthiessen[13] and by Hoitsema.[14]

The computation of the specific gravity of an alloy from its chemical composition, if the component metals are considered to be mechanically mixed, is done by means of the following formula:

$$S = \frac{(M_1 + M_2 + M_3 \ldots + M_n)(S_1 S_2 S_3 \ldots S_n)}{(M_1 S_2 S_3 S_4 \ldots S_n) + (M_2 S_1 S_3 S_4 \ldots S_n) + (M_3 S_1 S_2 S_4 \ldots S_g) + \ldots}$$

$$\frac{1}{\ldots + (M_{n-2} S_1 S_2 \ldots S_{n-3} S_{n-2} S_n) + (M_{n-1} S_1 S_2 \ldots S_{n-3} S_{n-2} S_n) + (M_n S_1 S_2 \ldots S_{n-3} S_{n-2} S_n)}$$

In this formula M_1, M_2, $M_3 \ldots M_n$ are the weights and S_1, S_2, $S_3 \ldots S_n$ are the corresponding specific gravities of the several metallic components. The specific gravities of the three samples of placer gold were computed by this method, and in the following tabulation these computed specific gravities and specific volumes are shown, together with the true specific gravities and specific volumes, as determined by laboratory measurement.

Specific gravities and specific volumes of placer gold

Sample number	Specific gravity		Specific volume		
	True	Computed	True	Computed	Differences
38AMt57	16.00	17.61	0.06250	0.05679	−0.00571
38AMt90a	15.87	18.31	.06301	.05461	−.00840
38AMt27	15.18	16.69	.06588	.05992	−.00596

The experimental work by Matthiessen shows that when pure gold and pure silver are melted together in definite proportions there results a contraction in volume of small magnitude, regardless of the proportions of the two metals. Hoitsema's results show both a contraction and an expansion of volume for different compositions, but the differences between the true and computed specific volumes are at least of the same order of magnitude as those found by Matthiessen. The above table shows for placer golds an expansion of volume of relatively large magnitude. The reason for these differences between the artificial and natural alloys of gold and silver is not known, but such differences suggest that complex phase relationships, hitherto unsuspected, may exist between the several metallic components.

Finally, it needs to be reiterated and emphasized that the placer gold found in the Tertiary belt is "dated gold," which was deposited originally as auriferous lodes sometime within the Mesozoic era. It

[13] Matthiessen, A., On the specific gravity of alloys: Royal Soc. London Soc. London Philos. Trans., vol. 150, p. 183, 1859.

[14] Hoitsema, C., Die Dichte von Goldkupfer- und Goldsilberlegierungen: Zeitschr. Anorg. Chemie, vol. 41, pp. 66–67, 1904.

is believed that placer gold of pre-Tertiary age is also present at many other places in Alaska, but at few localities is it possible actually to prove this point by means of stratigraphic data. Tertiary gold, or gold which originated during the Tertiary period, is also widespread in Alaska, but at many places this age assignment is not difficult to prove by geologic reasoning. It is hoped that subsequently samples of Alaskan Tertiary gold will also be analyzed, and it is possible that the comparison of Mesozoic and Tertiary golds may bring to light some significant genetic features.

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