THE GOLD PLACERS OF THE TOLOVANA DISTRICT.

By J. B. Mertie, Jr.

INTRODUCTION.

LOCATION AND EXTENT.

The Tolovana district lies in the northwestern part of the Fairbanks quadrangle, in the headwater region of Tolovana River and Hess Creek. (See Pl. XIII.) At present active mining operations are confined to Livengood Creek, a tributary of Tolovana River entering from the north about 2 miles above the mouth of the West Fork, and to several smaller streams which drain the ridge between Livengood Creek and Tolovana River.

PREVIOUS WORK.

The Yukon-Tanana region was covered by reconnaissance topographic surveys in the years from 1902 to 1910. That portion of the Fairbanks quadrangle under present consideration was mapped topographically in 1907 by D. C. Witherspoon and R. B. Oliver on a scale of 1:250,000, and their map constitutes the base for the present report.

Geologic exploration of the headwater region of Tolovana and Hess rivers by the Geological Survey began in 1904, when L. M. Prindle and F. L. Hess, during a reconnaissance from Eagle to Rampart by way of Fairbanks, carried a geologic traverse across the Tolovana district from northeast to southwest. In 1906 R. W. Stone made another geologic reconnaissance across this district, in going from Circle to Fort Hamlin. In 1909 L. M. Prindle and B. L. Johnson crossed the southern edge of the district, in the course of a geologic reconnaissance from Circle to Rampart by way of Fairbanks. Additional geologic information is also available from the traverses of A. H. Brooks made in 1902 and 1906, both of which passed a short distance south of the Tolovana district.

The principal Survey publications that have a direct bearing on the geology and mineral resources of the Tolovana district are as follows:

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

Stone, R. W., A reconnaissance from Circle to Fort Hamlin, Alaska: Bull. 284, pp. 128–131, 1905.

Prindle, L. M., The Fairbanks and Rampart quadrangles, Alaska: Bull. 337, 1908.

Prindle, L. M., Sketch of the geology of the northeastern part of the Fairbanks quadrangle, Alaska: Bull. 442, pp. 203–209, 1910.

Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: Bull. 525, 1913.

Brooks, A. H., Preliminary report on the Tolovana district: Bull. 642, pp. 201–209, 1916.

PRESENT INVESTIGATION.

The present report sets forth the results of a study of the gold placers of Livengood Creek and near-by streams and of the geology and mineral resources of the surrounding territory, here designated the Tolovana district. In all 29 days was devoted to the work, of which 13 days was spent in an examination of the gold-placer mining operations and 16 days in a geologic reconnaissance of the adjoining territory to the north and west. The accompanying map includes an area of 1,835 square miles, about 300 square miles of which was covered by geologic reconnaissance mapping during a part of July, 1916. The geologic data for the remainder of the area were compiled from the work of earlier investigators.

ACKNOWLEDGMENTS.

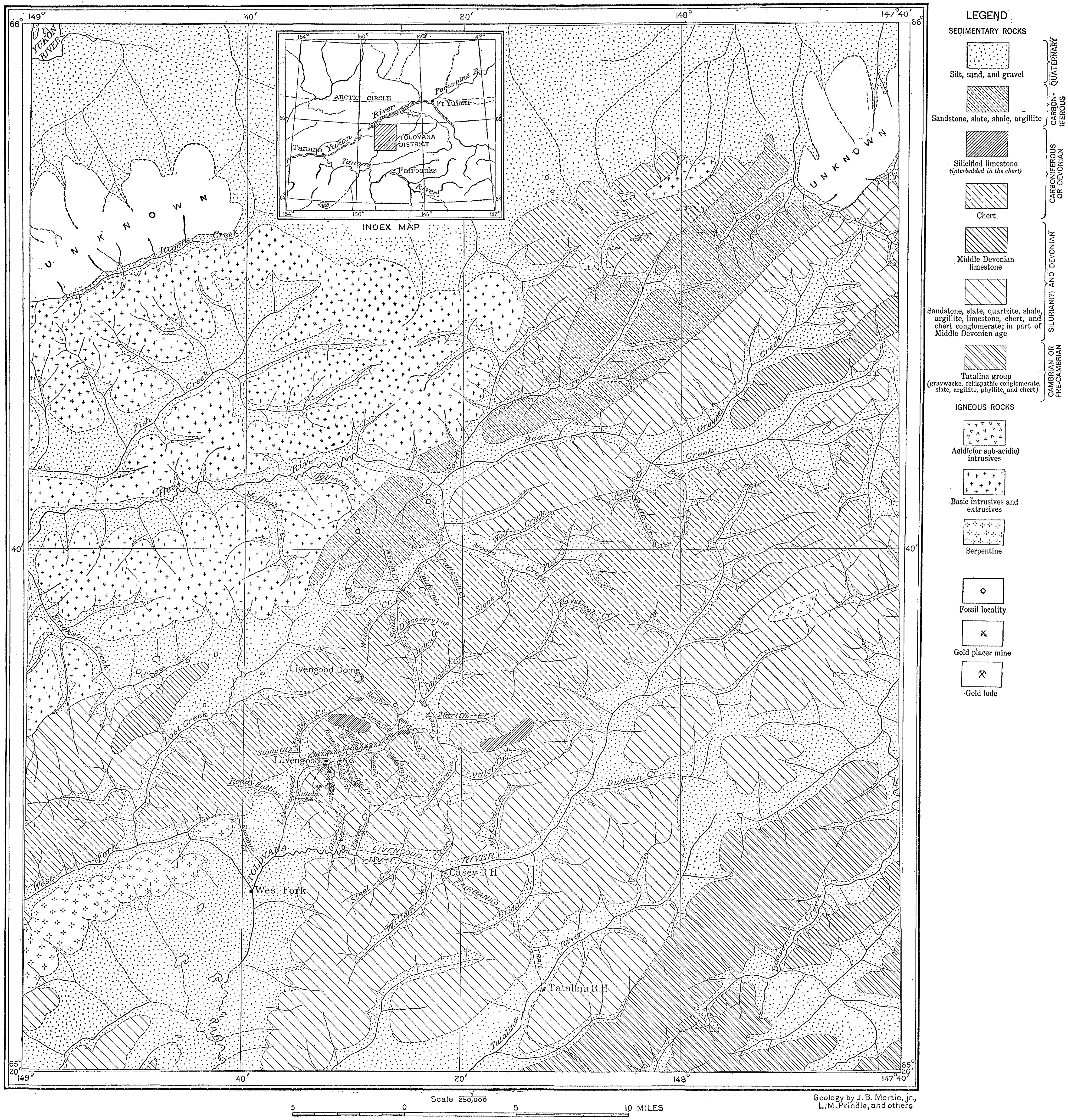
The writer takes this opportunity to thank the operators and prospectors on Livengood Creek and vicinity for their unfailing hospitality and for their willing cooperation in the work. Special thanks are due to Mr. Charles Craig, to whom the writer is indebted for a pleasant home during his sojourn on Livengood Creek, also to Mr. Kelly, who accompanied and materially assisted the writer on a reconnaissance trip to the head of the North Fork of Hess River.

In the investigation and interpretation of the hard-rock geology for the accompanying map, the writer has conferred freely with L. M. Prindle, of the Geological Survey, who has done most of the earlier work in the Yukon-Tanana region; and in the study of the Quaternary history the writer has received a number of helpful suggestions from H. M. Eakin, also of the Survey.

GEOGRAPHY.

RELIEF.

The Tolovana district is a part of the Yukon-Tanana upland. Its topography is characterized by broad, even-topped ridges, which rise to a general elevation of 2,000 feet or higher and from which long, gently sloping spurs descend to the valley floors. The district contains no high mountain groups that rise above the general ridge level, such as the White Mountains, to the east, or the Sawtooth



GEOLOGIC MAP OF TOLOVANA DISTRICT.

Range, to the west. Where the ridges attain an elevation above 2,500 feet, however, there is a marked tendency toward the development of the more precipitous type of mountain topography.

The district is highest in its northern and eastern parts, sloping south and west toward the valley floors of Tolovana and Hess rivers and the lower interstream ridges. The highest locality is in the northeastern corner of the area, where a ridge top rises to an elevation of 3,200 feet. The difference between 3,200 feet and 400 feet, the elevation of the valley floor of Tolovana River below West Fork, represents the maximum relief of this area.

There are a number of elevated prominences in the district, few of which have been named. Two such domes on the ridges north and south of Livengood Creek are known, respectively, as Livengood and Amy domes, and a knoll on the west end of the ridge south of Livengood Creek has been called Money Knob.

DRAINAGE.

Most of the district is drained by Hess and Tolovana rivers, but a minor part, along the eastern edge, lies within the drainage basin of Victoria and Beaver creeks. The watershed between the Yukon River drainage basin, represented by Hess River and Beaver Creek, and the Tanana River drainage basin, represented by the Tolovana, follows an irregular course across the district, owing to the intricate interlocking of these two drainage systems. About two-thirds of the area lies within the Yukon basin. (See fig. 5.)

The present streams are sluggish and meandering, and the water is universally more or less amber colored. Within the hilly areas there is more or less iron-stained gravel in the stream beds, although the gradients are low and the streams are in many places incised between steeply cut silt banks. In places well-developed gravel bars are present, but these appear to be only blanket deposits over fine silty sediments. The impression gained from these bars is that the gravel is transported largely from the extreme headwaters at stages of high water. In their lower courses the larger streams meander over wide alluvium-filled flood plains to the Yukon and the Tanana. In both the headwaters and the lower courses of the several drainage systems the present streams are markedly disproportionate to their valleys, for the valleys are wide and show the effects of vigorous erosion, whereas the streams are sluggish and carry relatively little water. It is apparent that the present streams are the feeble descendants of an earlier and more active drainage system.

Adequate corroborative evidence of the former presence of a drainage system of different character is afforded by topographic features unrelated to present streams, such as high rock-cut benches, by physiographic anomalies of the present drainage, such as broad alluvium-filled valleys, certain higher-level alluvial flats, and low alluvium-filled interstream divides, and by what is known of the bedrock cross sections of the present valleys, as revealed by placer-mining operations.

It is worthy of note that many of the streams in the eastern half of this area flow in general northeast or southwest directions. This feature is evidently in conformity with and a result of the structural

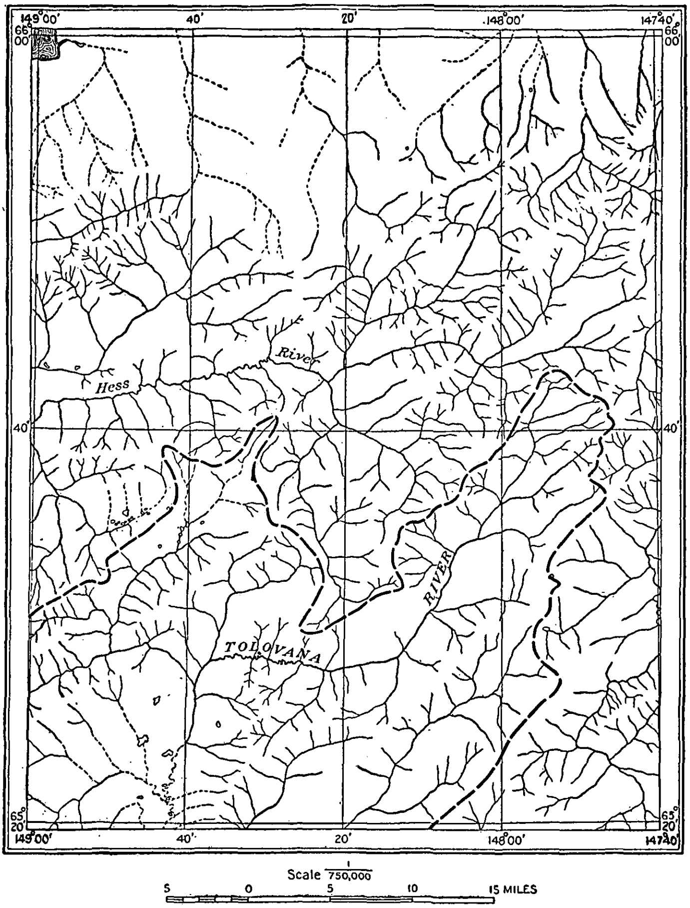


FIGURE 5.—Sketch map showing watershed between Yukon and Tanana drainage basins.

trend of the rock formations. West of 148° 20′ west longitude, however, there is a marked tendency toward the development of east or west courses in the streams. This is exemplified by Tolovana River west of the mouth of Bridge Creek, by Hess River west of the forks, and to a lesser degree by Livengood Creek. This change is the physiographic expression of a change in the regional trend of the rocks, comparable with a similar change noted by Prindle [1] in the Troublesome Creek area, to the west.

[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 55, 1913.

The lower course of Tolovana River, though beyond the limits of the area under discussion, is worthy of separate mention, partly because it is the main approach by water to Livengood and also because the lower and upper courses really constitute a single physiographic unit. A traverse of the lower 110 miles of Tolovana River was made by the writer in a gasoline scow by the time and compass method.

The Tolovana flows in a tortuous meandering course through a broad, flat alluvium-filled valley, which, in its lower part, merges with the valley of the Chatanika, a tributary of the Tolovana from the southeast about 74 miles above its mouth. At the junction the Chatanika is much the larger stream of the two, carrying the combined flow of Tatalina River and Goldstream Creek. The Tatalina does not flow into the Tolovana, as indicated on the earlier maps, but enters Chatanika River 3 miles above the confluence of that stream with the Tolovana.

The only straight stretch of any great length in the Tolovana begins at a point about 62 miles from the Tanana and extends northeastward for 3 miles. Elsewhere the river consists of a continuous series of loops and oxbows, which above the mouth of Chatanika River become more numerous but of smaller amplitude. One of the peculiarities of the river's course is the wide sweep which it makes above the mouth of the Chatanika, extending up into the embayment at the mouth of Uncle Sam Creek and returning across the valley to the southeast side. For 90 miles above its confluence with the Tanana the Tolovana hugs the northwest side of its valley, approaching closely to the hills at several localities. In this stretch and for 10 or 15 miles farther the river is sluggish, except at the mouth of Chatanika River, where there is a decided current. This sluggishness is particularly marked for a distance of about 25 miles above the mouth of the Chatanika, where even in the narrowest parts of the stream it is often difficult to detect the direction of flow. The river appears to be very deep in such sluggish channels. From this point up to the log jam the current is more apparent, the river flowing over a bottom composed largely of interlacing waterlogged trees. At low stages of water this is a very difficult stretch of the river to navigate.

Except where the Tolovana sweeps close to the hills the banks consist entirely of silt and sand and increase in height from a few feet at the Tanana to 50 feet in the vicinity of the log jam at low water. The alluvium appears to be almost entirely silt above the Chatanika. The upper course of the Tolovana, from the log jam to West Fork, was not traversed, but it is reported that the silt banks decrease in height above the log jam, ending a short distance below Trappers Cabin, where sand and gravel bars begin that continue upstream.

TOPOGRAPHIC ANOMALIES.

The topography of Livengood Creek and vicinity shows certain anomalous features worthy of special mention. Livengood Creek, the South Fork of Hess River, and most of the other streams in the vicinity are small in comparison to the wide alluvium-filled valleys in which they flow. The stream gradients are low, except in the extreme headwaters, and the transportation of rock débris is relatively small except at high stages of water. This marked disproportion seems to indicate a lack of adjustment between the topography and the present streams and points to an earlier period of erosion, more active than that of the present.

Several low divides that are distinctly anomalous in character and position separate the headwaters of several of the streams in this area. Thus a low, broad, flat timber-covered divide separates the head of Livengood Creek from the South Fork of Hess River. At the northwest end of this divide, at the head of Snow Gulch, a tributary of the South Fork, a prospect shaft was sunk 205 feet through muck and slide to the chert bedrock. As the difference in elevation between the top of this shaft and the present level of the South Fork of Hess River, at the mouth of Alabam Creek, is but 95 feet, the shaft shows that the northwest end of this saddle, at least, is composed entirely of unconsolidated material, which continues downward to a depth of about 110 feet below the present level of the South Fork; and it seems highly probable that this is the general make-up of this divide as a whole.

At the heads of Pedro, Lost, and Erickson creeks there is a timber-covered flat from 2 to 4 miles wide, at an elevation of about 1,000 feet. McHugh and Myrtle creeks are separated from this wide flat and its included drainage systems by only slightly higher divides that approximate 1,200 feet in elevation. Data on the terranes which constitute these low divides may be obtained only by shafts or drill holes, but it is highly probable that they are likewise composed, to a greater or less depth, of muck and slide similar to the material at the head of Livengood Creek.

Numerous facts indicate that extensive changes in drainage have taken place. In addition to the alluvium-filled saddles there are many well-developed instances of backhand drainage; numerous lakes occur in the low alluvium-filled divides and on alluvium-covered spurs; and along some of the present streams there are constricted portions that approximate gorges in character. Old erosional channels in bedrock benches along the sides of and unrelated to the present streams likewise give ample evidence of the lateral migration of erosional channels within certain stream valleys, induced probably in part by major drainage changes.

The West Fork of the Tolovana affords the best example of backhand drainage on a large scale in this district. This stream runs 32 miles in a general northeasterly direction from its source, and then turns abruptly to join the main Tolovana, which flows in a general southwesterly direction to Tanana River. The valley of Lost Creek seems to be the logical continuation of the valley of the West Fork, with a possible outlet by way of Erickson or Pedro Creek to Hess River; but without a more detailed study of these creeks, a more definite statement can not be made. Another excellent example of backhand drainage is the stream that enters Tolovana River on the west side about 7 miles below the West Fork. This stream also flows northeastward to empty into the southwestward-flowing Tolovana. A low alluvium-filled saddle at an elevation of about 1,200 feet separates the head of this creek from Idaho Creek, to the southwest. Drainage changes are likewise evident at the heads of Erickson, Lost, Pedro, and Livengood creeks. (See pp. 260–262.) It is perhaps highly significant that many of the most pronounced drainage changes are localized at or near the low saddles previously described.

Lakes are numerous in the alluvium-filled valleys, on the low interstream divides, and even on some of the alluvium-covered spurs that descend from the ridges to the valley floors. The lakes in the lower valleys are probably due in large part to processes connected with stream aggradation; but some of these, as well as the high-level lakes on the divides and spurs, indicate a condition of imperfect adjustment to recent changes in drainage. The high-level lakes in particular, such as the group at the heads of Erickson and Lost creeks, give no indication from their form or character that they have ever been a part of any drainage system. In addition to the lakes shown on the map, there are scores of smaller lakes of similar character, hidden in the timber, which are not visible from the ridges and are seen only by accidental visit. Thus on the timber-covered spur between Amy and Goldstream creeks, a short distance above the head of Goodluck Creek, there is a small lake, filled with amber-colored water, which appears to be a watering place for game.

Another such lake, on the flat spur northeast of Patterson Creek, is 500 feet in diameter, is more or less circular in shape, and has steep muck walls about 40 feet high. The water is deep, a depth of 8 feet being attained only a few feet from shore. The elevation of this lake is about 1,100 feet, or about 140 feet above the level of the South Fork of Hess River, at the mouth of Patterson Creek. On the northwest side there is a gap in the silt walls, where the banks are only a little higher than the lake itself. Although no water was flowing from the lake through this gap when it was visited, there is a drainage channel which connects the gap with the South Fork of Hess River. It is probable that this lake was at one time still deeper than at present, possibly as much as 30 or 40 feet deeper, and that the gap at its northwest end represents a break in its walls, due to the general reduction in elevation of the spur below it through erosion by Hess River. In this manner the lake was reduced to its present level, and the continuation of the same process would ultimately drain it.

As indicating readjustments in drainage the presence of a gorge along the course of a stream, with a wide, open valley above and below, may be of significance. Such gorges are reported from several localities, but the only one visited by the writer is in the valley of the South Fork of Hess River about 4 miles below the mouth of Alabam Creek. This gorge is a late feature in the history of the South Fork, for it is in the bottom of the valley and is not apparent from the ridges on the sides.

Readjustments of stream courses within their own valleys are plainly apparent from the presence of old channels cut in bedrock benches above many of the present streams. Such benches are locally visible but in many places are covered by later alluvium and would not be suspected from the present cross sections of the valleys. Thus on Livengood Creek above Livengood there is an old stream channel on the north side of the valley, separated from the present stream by a bedrock reef that crops out at Livengood. Upstream both the reef and the old channel are concealed by a heavy mantle of silt. Placer-mining operations, however, have shown that this reef continues upstream for 3 miles, and above its termination the old channel and the present stream channel gradually merge into each other. It is this old channel in the valley of Livengood Creek that carries the auriferous gravels now being mined.

On the South Fork of Hess River there is likewise evidence that the present course of the stream is quite different from its course during a preceding physiographic cycle. Placer operations have not yet been extensive enough to show definitely the location of the old channel, but the available data indicate that it may have been on one side of the valley at one locality and on the other side at another thus being crossed and recrossed by the present stream.

Remnants of high rock-cut benches are present in some of the present stream valleys. Thus at the lower end of Livengood Creek, on the spur west of Ruth Creek, there are rock-cut benches at elevations of 1,115, 1,150, and 1,200 feet. The lowest of these benches is only 75 feet wide, but each of the others extends backward toward the main ridge for several hundred feet, and the highest rises gradually to an elevation of 1,300 feet. South of the highest bench the ridge rises rather steeply toward Money Knob, the west end of the ridge between Livengood Creek and Tolovana River. There are fragmentary benches of similar character on other spurs descending to Livengood Creek, but these are not susceptible of coordination without detailed topographic mapping. It is uncertain whether such high benches are the remains of old stream channels, or whether they may represent in part old beach lines correlative with various stages in a regional inundation.

Higher flats at elevations from 1,200 to 3,000 feet are present but can not be correlated and are probably due to various agencies. The ridge tops in the Yukon-Tanana region as a whole are probably the dissected remnants of an old peneplain, in the widest sense of that term—that is, an old erosional surface, more or less uniform in elevation but sloping shieldlike to the major drainage channels. The higher prominences may be thought of as monadnocks upon such a surface. The high flats, however, occur at all elevations and are developed probably in part by normal stream erosion and in part by certain erosional processes that are particularly effective in subarctic climates, including solifluction in its various phases.

SETTLEMENTS AND POPULATION.

Livengood, the principal settlement within the district, is on the north side of Livengood Creek about 5 miles above the mouth of the creek, at an elevation of 625 feet. It is a well-placed and substantially built town, with a post office, a wireless station, and a local telephone system connecting with the mining plants on Livengood Creek.

At the junction of the West Fork with the main Tolovana a small settlement called West Fork has grown up. It is essentially a supply point for Livengood, being at the head of navigation for small boats on the Tolovana. It contains a sawmill, a roadhouse, and warehouses.

There are warehouses also at a place called Trappers Cabin, 16 miles downstream from West Fork, at the head of navigation for launches and small scows.

The log jam, 56 miles by river below West Fork, is another stopping point on the river route to Livengood. It is the head of navigation for small steamboats and gasoline scows and is therefore the principal changing point for passengers and freight along the river. Two roadhouses and several small cabins are located there.

CLIMATE AND VEGETATION.

The Tolovana district is a small part of the Fairbanks quadrangle, whose vegetation and climatic conditions have been described at some length by Prindle.[1] There are no exceptional features of the plant life in the district which warrant any further description, and

[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 23-28, 1913.

no new meteorologic data for the district are at hand. For those who are familiar with interior Alaska, it suffices to say that this district is an integral part of the Yukon-Tanana province.

GEOLOGY.

GENERAL FEATURES.

The present geologic knowledge of the Fairbanks quadrangle is based largely on reconnaissance traverses, most of which were made prior to the publication of the reconnaissance topographic map. Hence the knowledge of the stratigraphy is at best fragmentary. It happens also that the new placer camp at Livengood and much of the adjacent headwater region of Tolovana and Hess rivers lies within an area concerning which information was exceptionally meager. The work of 1916 in this area, though likewise reconnaissance in nature, adds new data to the existing geologic knowledge and serves in some measure to coordinate the earlier data.

Several mappable groups of hard-rock formations are present in the Tolovana district. These include the Tatalina group, of Cambrian or pre-Cambrian age; the Devonian and Silurian (?) sequence; a new stratigraphic unit of chert, of Devonian or Carboniferous age; and the Carboniferous sequence of sandstone, slate, shale, and argillite. (See Pl. XIII.)

These rock groups occur chiefly as belts, crossing the district in a general northeasterly direction. The oldest rocks occur to the southeast, and the younger rocks crop out successively to the northwest. The regional trend of the rocks is northeast, and the dips where observed are isoclinal to the southeast. Hence the younger formations dip under the older ones, with the result that a sequence of folds overturned to the northwest is necessary to explain the structure. This explanation, however, is a very generalized induction, and further study may reveal structural details quite at variance with it. A zone of faulting is believed to be present along the northwest side of the chert formation.

Igneous rocks of numerous types are present, though only in the northwestern part of the district do they occupy any large area. They include chiefly basic rocks of various ages, some extrusive and some intrusive. Granitic and intermediate rocks are present in small amounts, the former connected genetically with the mineralization in the vicinity of Livengood.

The hard-rock formations are overlain in the stream valleys by a mantle of unconsolidated deposits, representative of several physiographic eras in the Quaternary. These are the youngest deposits in the region but are not all of the same age. At least two types are recognizable—the present stream deposits and the earlier stream deposits, now forming benches along the present streams. Numerous changes of drainage courses and other data indicate a most complex physiographic history during Pleistocene and Recent time

TATALINA GROUP (CAMBRIAN OR PRE-CAMBRIAN).

DISTRIBUTION AND CHARACTER.

The Tatalina group crosses the southeast corner of the Tolovana district, but little is known of its northwestern limit or of its lithologic character in that locality. The following general description of the Tatalina group is taken from the report of Prindle:[1]

> The Tatalina group can be defined as an aggregate of feldspathic fragmental rocks, including conglomerates, sandstones, and graywackes, interbedded with argillites that are in places altered to phyllites. With these rocks occurs considerable chert. As mapped, the Tatalina includes some limestone, which may or may not represent an integral part of the group. In the White Mountain region the Tatalina group includes considerable greenstone in the form of ancient tuffs and lavas.

The only specific reference by Prindle to the lithologic character of the Tatalina group in the area under discussion is this: "In the west-central part of the quadrangle the group is represented by graywacke, feldspathic conglomerates, phyllites, and cherts."

AGE.

The recent work of Blackwelder[2] has thrown considerable light on the age of the Tatalina group. His stratigraphic work in the White Mountains has shown that the Tatalina group underlies fossiliferous sediments of Upper Cambrian or Lower Ordovician age. Hence the latest information would indicate that the Tatalina group is Cambrian or possibly pre-Cambrian.

DEVONIAN AND SILURIAN (?) ROCKS.

AREAL DISTRIBUTION.

A group of sedimentary rocks with associated igneous rocks, here assigned in part to the Middle Devonian, crop out in a belt crossing the southeastern part of the Tolovana district. It is necessary to separate this group of rocks from the Tatalina group on the basis of lithologic character, and as the lithology of both these groups is only imperfectly understood, the boundary between them, as shown on the accompanying geologic map (Pl. XIII), should be regarded as a suggestion rather than a definite mapping of the contact.

Still farther southeast, within the area mapped as Tatalina, limestone of known Devonian age is present in a narrow disconnected zone, which trends parallel with the regional strike.

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 37-38, 1913.

[2] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

In the east-central part of the district beds at an unrecognized horizon in the Devonian or Silurian (?) are mapped. They occupy a more or less wedge-shaped area, which begins with the limestone on the South Fork of Hess River at the mouth of Pedro Creek and extends in a widening zone to the northeast. The southwestern continuation of this zone is represented by the limestone at the head of Erickson Creek.

LITHOLOGY.

The Tonzona group, one of the geologic units recognized in the Fairbanks quadrangle, was described originally by Brooks [1] from its occurrence along the inland front of the Alaska Range and along the lower Tanana. His summarized description was as follows:

> A series of argillites, in part interbedded with graywacke and associated with cherts, is here classed together under the name Tonzona group. The Tonzona group has at least one striking difference from the older Tatina group in its marked lack of limestone. It is made up of sediments which, as a rule, are coarser grained than those of the Tatina, being derived chiefly from clays and sands. It includes, however, considerable masses of chert.
>
> The argillites, which predominate in this group, vary from shales to slates and phyllites. One of their characteristic features consists in their variegated colors, which include black, red, green, and blue. Fragmental rocks are represented by gray indurated feldspathic sandstone or graywacke, some of which in the field was mistaken for igneous rock. The cherts, which occur in association with the fine-grained argillites, are also varied in color, including black, greenish-white, green, and red varieties.
>
> The facts in hand suggest that the Tonzona group may be divisible into two members (1) a lower, made up largely of bluish phyllites and black slates, some interbedded with massive graywacke, with which are also associated some black cherts, and (2) an upper, which is dominatingly made of black, red, and green slates, locally grading into shales and cherts of various colors.

On the basis of lithologic similarity, certain Devonian and associated rocks in the Fairbanks quadrangle were tentatively correlated with the Tonzona group, the name being used as a cartographic designation. Prindle's description of these rocks [2] was as follows:

> A series of red, green, and black argillites, conglomerate, and sandstone, including some chert, is here correlated with the Tonzona group. Locally some limestones are included in the Tonzona as mapped. In the area mapped by Stone in the northeastern part of the quadrangle the rocks correlated with the Tonzona are made up of rather coarse conglomerates with sandstones and slates of various colors. On the Tanana the group is represented by fine quartz conglomerates, sandstones, and red and green slates.

Sufficient data were collected in the Tolovana district during the season of 1916 to justify a separation of the Tonzona group into two major divisions. The upper of these divisions, described later as chert, is a fairly definite lithologic unit; the lower division, compris-

[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 73, 1911.

[2] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 44–45, 1913.

ing undifferentiated Devonian and Silurian(?) rocks, must be regarded only as a temporary grouping, which is likely to undergo further subdivision with the accumulation of more detailed information.

As mapped, this lower division includes all the rocks from the Middle Devonian to the Tatalina group. That part of the geologic section between Tolovana and Tatalina rivers has not been studied in any detail and may include Lower Devonian, Silurian, or Cambrian rocks, as well as small areas of infolded younger rocks.

The limestone of known and inferred Devonian age is mapped as a separate unit.

The best exposures of the Middle Devonian rocks are to be seen in the creeks, where placer-mining operations have bared the bedrock. Near the lower end of Ruth Creek, and presumably near the top of the Middle Devonian sequence, there is a black, finely crystalline limestone, much seamed with calcite and quartz. Farther upstream and lower in the geologic column the bedrock for a mile is in part sandstone, shale, slate, and limestone. On claim 4 above Discovery, Ruth Creek, about 1¼ miles above the mouth of the creek, Middle Devonian fossils were found in some finely crystalline dark-gray limestone. The spur on the west side of Ruth Creek shows a variety of rock talus, including sandstone, shale, flint, conglomerate, and serpentine and other igneous rocks. The gravels in Ruth Creek are subangular and at the lower end of the creek comprise chert conglomerate, chert, sandy shale, dioritic material, and other rocks, showing that they were derived from the bedrock of Ruth Creek. Serpentine occurs at the mouth of Ruth Creek and is also exposed at the town site of Livengood, opposite the mouth of Ruth Creek. It is possible that the serpentine forms a continuous body across the valley floor of Livengood Creek at this point, separating the known Middle Devonian rocks from the chert formation. The traverse of Prindle and Johnson (1909) shows that this mass of serpentine continues southwestward along the ridge south of the West Fork of Tolovana River for at least 12 miles.

The sedimentary rocks exposed along the ridge at the head of Ruth Creek consist of dark-colored sandstone, shale, slate, quartzite, and finely crystalline dark-gray to light-gray limestone. The knob at the heads of the East Fork of Gertrude Creek and Ester Creek is a much brecciated chert, which, however, belongs probably in the chert formation.

At the west end of the ridge, near the head of Lillian Creek, placer-mining operations have exposed the bedrock in the creek. It consists of dark-gray sandstone and shale, with some slate. A hundred yards downstream the bedrock is dominantly a dark-colored shale. The respective strikes at these localities are N. 65° W. and N. 45° W., and the dip in each place is 55° N. Subangular to angular stream gravels show the presence near by of chert conglomerate, greenstone, sandstone, shale, slate, and quartzite.

On the south side of the ridge on Discovery claim in Olive Creek, about 1½ miles from the crest of the ridge, the bedrock in the creek is a dark impure sandstone. Here the stream gravels consist of black chert, argillite, hard shale, coarse-grained granitic rock, diabase, green flinty mineralized rock, and chert conglomerate, all representative of the rock formation on the south side of the ridge. Limestone bedrock is also reported from a prospect shaft in this vicinity. About a mile to the east, however, placer mining on Ester Creek has exposed bedrock that is dominantly chert.

At the mouth of Gertrude Creek the bedrock is a brecciated flint, which appears to continue upstream, being present in the East Fork of Gertrude Creek, in association with a white silicified limestone. It is likely that the chert continues up Gertrude Creek to the knob at the head of its East Fork.

The bedrock in the beds of Amy and Goodluck creeks is reported to be largely chert, from which it appears that the Middle Devonian beds are not present in these creeks. Certain basic andesites north of Amy Dome, lying between the Middle Devonian rocks and the chert formation, and a basic rock of similar appearance on the ridge at the head of Cleary Creek are not correlative with the serpentine at the mouth of Ruth Creek. They do not possess a greenstone habit and are thought to be intrusives belonging to a later period of volcanism.

At a point 20 miles N. 63° E. from Amy Dome the serpentine and basic igneous rock previously described reappear, as shown by the traverses of Prindle and Hess (1904) and of Stone (1906). The notes from both these traverses agree in describing the country rock at this locality as a serpentine cut by diabase dikes. Southeast of this serpentine area toward Beaver Creek, Stone's traverse shows the country rock to be black shale, grit, and sandstone, with one recorded strike of N. 64° E. and dip of 18° SE. The traverse of Prindle and Hess shows that the country rock south of the serpentine is conglomerate and black slate. These sediments seem to represent the same horizon as that of the beds exposed in Ruth Creek and on the ridge south of Livengood Creek. The traverse of Prindle and Hess also shows another area of serpentine, cut by diabase dikes, about 13 miles N. 53° E. of the one just described, just beyond the Tolovana. This demonstrates the persistence of the serpentine, but its ultimate northeastward continuation is unknown.

These intermittent occurrences of serpentine and locally of a basic igneous rock of greenstone habit, at or near the upper part of the Middle Devonian beds, seem to be a feature of regional significance. Serpentine and greenstone, however, are represented at other horizons in the Devonian sequence, a fact which has been recognized both by Prindle[1] and by Brooks.[2] The recent work of Blackwelder[3] in the White Mountains has also shown that the limestone on the spur just northwest of the forks of Willow Creek is Devonian and is intimately associated with greenstone. Further work may show that this extrusion of basic igneous rocks attained a maximum development late in the Middle Devonian epoch, thus establishing a reliable horizon marker in the Devonian sequence.

Limestone of supposed Devonian age, similar in appearance to that on Ruth Creek, occurs along the South Fork of Hess River, opposite the mouth of Pedro Creek. It is black and crops out in thin beds, which are broken, veined with calcite, and coated with some white salt of calcium. These beds extend upstream for 500 yards or more, becoming thicker and arenaceous. Still farther upstream is the chert formation. The attitude of these limestone beds, measured at two places, was N. 55° W., dip 75° SW., and N. 55° E., dip 35° SE. This discordance in strike and dip, together with the broken and veined appearance of the beds, is taken as evidence that the rocks at this locality have been greatly disturbed.

At the heads of Grouse and Bear creeks limestones thought to be of Devonian or Silurian age crop out. They are associated with sandstone, shale, slate, quartzite, conglomerate, and chert, the whole representing an unrecognized horizon in the Devonian or Silurian (?). The ridge northwest of Crater Creek is composed of sandstone and shale. Stone,[4] on the basis of the lithologic similarity of certain beds of black shale found just below the confluence of Grouse, Bear, and Crater creeks, included the rocks at this locality as a part of the Carboniferous. As there is no fossil evidence for this assignment, and as the strike of the Carboniferous rocks carries them northwest of this locality, this ridge is here mapped tentatively as a part of the Devonian and Silurian (?) sequence. On the basis of lithographic character, then, a wedge-shaped belt of rock of Devonian or Silurian (?) age is mapped, beginning at the limestone locality on the South Fork of Hess River and extending in a widening zone to the northeast. Necessarily the boundaries of such a zone can not be considered final, and internal differentiation of this zone into smaller units is ultimately certain.

A supposed zone of faulting lies southeast of this zone, and along its continuation to the southwest occur the limestones on the South Fork of Hess River and at the head of Erickson Creek. Little is

[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 57, 1913.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 116, 1911.

[3] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

[4] Stone, R. W., unpublished notes, 1906.

known of the rock at the latter locality, but the 1904 traverse of Prindle and Hess show the limestone to be brecciated gray crystalline variety. Of special significance is its brecciated condition, in connection with its position along an inferred zone of faulting.

The limestones at the head of Bear and Grouse creeks seem similar in general character to those at the two localities, just described. Stone,[1] recognizes two different types of limestone, "one of which is white or gray, whether fresh or weathered, shows no distinguishable bedding, is crystalline, finely jointed, and occurs in conspicuous ledges, and the other is gray to blue on the outside, dark blue inside, thin bedded, and weathers with a rough prickly surface." The former corresponds closely to the Ordovician and Silurian limestone of the White Mountains; the latter is comparable with Middle Devonian limestone recognized in the vicinity of Livengood. The traverse of Prindle and Hess (1904) shows considerable limestone of the latter type along the ridge northwest of Bear Creek, interbedded with red and green shale, quartzite, and greenstone. Measurements of strike taken on this limestone by Prindle and Hess are N. 60° E., N. 55° E., N. 76° E., and N. 59° E., which yield an average of about N. 62° E. for the strike of the rocks in this vicinity. The dips are steep to the south. It is probable that this occurrence, 22 miles N. 60° E. from the Hess River locality, is a continuation of the bed at the same general horizon.

It appears that this limestone is not continuous, for a traverse by the writer down the east side of Butte and Crater creeks, and up into the ridge northwest of Crater Creek, as well as the traverse of Stone in 1906, failed to reveal the presence of limestone in this vicinity along the regional strike. This lack is more probably due to structural irregularities than to original nondeposition. It is worthy of emphasis, as bearing on the regional trend of the Paleozoic rocks, that the direction connecting the limestone on the South Fork of Hess River with that at the head of Bear Creek—that is, N. 60° E.—is nearly identical with that connecting the greenstone locality at Amy Dome with that southwest of Beaver Creek, which is N. 63° E.

The writer is unfamiliar with the limestone areas in the southeastern part of the Tolovana district, within the area of Tatalina rocks. They have been intersected by only one traverse, and little is known of them. In the sharp bend of Fossil Creek at its lower end, just east of this district, on the spur to the northeast, Prindle and Hess found fossils of Middle Devonian age and others suggesting a late Silurian age. It is probable that the limestones above mentioned are representatives of the same general horizon, infolded or infaulted into the Tatalina group.

[1] Stone, R. W., unpublished notes, 1906.

IGNEOUS ROCKS.

A variety of igneous rocks are present in the Middle Devonian sequence. It is possible, however, to divide them into two groups, which are mutually exclusive, both in age and in their relation to the associated sedimentary rocks.

Basic igneous rocks, in part serpentine, occur between the Middle Devonian rocks and the chert formation, as well as within the Devonian sequence. Presumably these basic rocks are in large part the altered representatives of basic lava flows, which were extruded more or less synchronously with the deposition of the Devonian rocks. It is probable that these lavas represent intermittent volcanism during Devonian time, culminating at the end of the Middle Devonian.

The igneous rocks of the second group are in large part intrusive. At least some of them are undoubtedly later than the Middle Devonian sequence, but the data available are not sufficient to determine their absolute age. They include granitic, dioritic, and basic types. On the ridge south of Livengood Creek occur intrusives of several types, including albite granite, soda rhyolite, diorite, pyroxene andesite, diabase, and basalt. These rocks were certainly not all intruded simultaneously but represent various stages, perhaps even widely separated epochs, in the igneous history of the region. The sodic rocks, including the albite granite, the soda rhyolite, and the pyroxene andesite, seem to have a certain family relationship. The most acidic types are thought to be closely related to the gold mineralization on this ridge.

STRUCTURAL RELATIONS.

Opportunities for the observation of structural details in the Tolovana district are meager, owing to the dearth of outcrops, and trustworthy generalizations can not be drawn from fragmentary data. The few strikes recorded, however, clearly indicate a regional trend of about N. 60° E. for the Devonian sequence. The observations on the dip of the bedding indicate a general dip to the southeast, but there are wide variations in the degree of dip.

Of special interest is the marked change in direction of the contact between the Middle Devonian beds and the chert formation, on the ridge south of Livengood Creek. For a distance of 3 or 4 miles the contact runs northwest, resulting in a marked offset of the contact line. This structural feature is reflected to a lesser degree in the course of Tolovana River, which for 6 miles or more runs slightly north of west, instead of southeast. Along Lillian Creek also the dip of the rocks is to the northeast, instead of to the southeast, indicating local structural changes. The elongation of the silicified limestone bodies within the chert in the valley of Livengood Creek reflects this change. Finally, the localization of the auriferous mineralization in this vicinity is significant. Evidently the ridge south of Livengood Creek is the locus of some major structural feature, but whether it is to be interpreted as a zone of faulting or whether it represents merely a flexure in the regional structure has not been determined.

The interpretation of the regional structure involves the conception of dynamic thrusts and appressed and overturned folds. Under such conditions, particularly with the present indefinite ideas of the limits of the Paleozoic formations, any estimate of thickness is useless.

AGE AND CORRELATION.

The only fossils from the Devonian-Silurian (?) sequence so far collected in the Tolovana district are a small collection made by the writer during the summer of 1916. They were found in pieces of bedrock taken from the bottom of a prospect shaft in the stream gravels of Ruth Creek. The fossiliferous rock is a very dark gray crystalline limestone. The report of Edwin Kirk, paleontologist, on these fossils is as follows:

East fork of Ruth Creek, a tributary of Livengood Creek, about 1½ miles south of Livengood:

Atrypa reticularis (Linné) var.
Camarotoechia sp.
Cyathophyllum caespitosum Goldfuss.

These fossils are clearly of Middle Devonian age.

The fossiliferous limestone is interbedded with shale and sandstone, and the rocks intervening between this fossil locality and the chert formation are similar in character and appearance. It is believed, therefore, that Middle Devonian rocks adjoin the chert, although this statement is not susceptible of proof at present.

While it is therefore apparent that the upper part of the group mapped in this report is Middle Devonian yet any generalization regarding the rocks lying to the southeast between the known Middle Devonian beds and the Tatalina group would be both futile and premature. The northwestern limit of the Tatalina group is unknown, and hence the southeastern limit of the group of rocks under discussion is doubtful to a corresponding degree. Stratigraphic data are meager, and paleontologic evidence is lacking. Recent geologic work in the White Mountains by Blackwelder[1] has shown the presence of new stratigraphic units in the Paleozoic of this region, and it is certain that the geologic groups heretofore used will ultimately be subdivided, and new formations will be defined. Blackwelder's data

[1] Blackwelder, Eliot, op. cit.

indicate that the Tatalina group may be either Cambrian or pre-Cambrian. Therefore this group, of Middle Devonian age in its upper part, is assigned tentatively to the Devonian and questionably in part to the Silurian. It may even include Cambrian rocks.

The regional strike of these rocks would suggest their continuance to the northeast, in the valley of Beaver Creek. Blackwelder describes a "black slate and graywacke group" in that valley, which in the absence of fossil evidence he assigns tentatively to the Mesozoic. These rocks include slates, graywacke, quartzite, conglomerate composed largely of chert and slate, and certain rocks of pyrito-dolomitic character. It is not improbable that these rocks of the Beaver Creek valley may eventually be shown to belong to the Paleozoic and to be, at least in part, correlative with the Devonian rocks.

CHERT.

AREAL DISTRIBUTION.

A stratigraphic series consisting dominantly of chert crops out in a belt crossing the district in a general direction approximating N. 60° E. The southeastern limit of this belt is fairly well defined, but an inferred fault zone along the northwest side of the belt renders its exact delimitation impracticable at present. This chert series forms the bedrock on Livengood Creek and most of its tributaries.

Northwest of the known Carboniferous beds other rocks of dominantly cherty character occur, but the relation between the two groups is obscure. A contact line has been drawn by the writer, but it is based purely on lithologic data and must therefore be regarded only as tentative. It is possible that these cherty rocks represent the upper part of the chert formation.

LITHOLOGY.

The chert series consists dominantly of chert, associated with a minor proportion of other rocks, which include chiefly silicified limestone and argillaceous rocks. Numerous small intrusive bodies of greenstone are also present in the formation, and some granitic rocks. Where practicable the areas of silicified limestone, greenstone, and granitic rocks have been mapped as separate units.

The chert and the silicified limestone are the two most important units in this group, the former on account of its preponderance as a formational and rock type, the latter on account of its peculiar character and its possible value as a horizon marker. The chert is a microcrystalline rock composed of chalcedonic quartz, which under the microscope shows usually only an aggregate polarization. Much of it is brecciated and recemented with silica. It is believed to be of primary origin—that is, to be a rock formed from original siliceous material. Whether the chert is derived from mechanically or chemically precipitated silica has not been determined. These cherty rocks, however, in common with many of the earlier Paleozoic cherts in the Yukon-Tanana region, show no evidence of secondary origin, either in their internal structure or in their distribution with reference to areas of intensive mineralization. Moreover, the silicified limestone associated with the chert is quite different in character, shows no gradational petrologic features, and occupies areal units clearly distinct from those of the chert.

The silicified limestones are separately mapped. They are pure-white to light-gray or cream-colored rocks, which in most places are greatly silicified. The silicification, however, has not changed their color, which is an important criterion in distinguishing them from the darker-colored chert. Moreover, the silicification has not invariably resulted in the formation of chalcedonic quartz. At several localities, notably on the ridge southeast of Martin Creek, the silicification has produced moderately coarse grained siliceous rocks, which, if gradational phases were lacking, would be difficult to distinguish from pure-white quartzite. It seems most probable that the silicification of these limestones within the chert formation has been due to the circulation of ground water charged with silica derived from the chert.

The chert has been studied in more detail in the valley of Livengood Creek than elsewhere in the district, and this may be considered as its type locality. Mining operations in Livengood Creek and its tributaries have exposed the bedrock at many places and have been very helpful in the accumulation of data regarding the lithologic character of the rocks. Such observations, however, on account of the deep weathering in the chert bedrock below the auriferous gravels, are of little assistance in determining details of structure.

Observations on the rock from the bottom of 25 or more shafts on the bench on the north side of Livengood Creek show that the bedrock is in large part a dark-gray to black chert, in places much brecciated, with a comparatively small proportion of other rock types. The bedrock under the gravels weathers deeply to a red to black clay, which includes numerous particles of unaltered angular chert fragments. The rocks associated with the chert include argillite, shale, greenstone, silicified limestone, and granitic rock. Argillaceous rock in association with the chert was observed only on four claims, of which the Marietta bench shows such rock in largest amount. There it appears as a very carbonaceous shale or argillite, cut by numerous quartz stringers. Five claims showed intrusive bodies of greenstone in the chert. Silicified limestone interbedded with the chert was observed on eight claims, in greatest amount on the Gan and Ready Bullion second-tier benches, north of Livengood, and on an adjoining claim on Myrtle Creek. The silicified limestone is a white to cream-colored rock that weathers to tones of yellow and brown in the bed-rock underlying the gravels. Where silicification has not been complete, circulating ground water has not uncommonly dissolved much of the calcium carbonate, leaving a rock that resembles a siliceous sinter. This phase of weathering, however, was observed only in the bedrock underlying stream gravels. Granitic rock is present in Amy Creek and was observed among the fragments of bedrock taken from a prospect shaft at the extreme head of Livengood Creek.

The ridge north of Livengood Creek, including Livengood Dome, is composed largely of dark-gray chert, but no structural data on it are available. About three-fourths of a mile N. 15° E. from Livengood Dome, in the head of Willow Creek, the chert is well exposed. The beds are much faulted and shattered, but one observation that seemed to typify the general attitude gave a strike of N. 75° E. and a dip of 65° S. The chert on Livengood Dome is dark gray to black, much brecciated, and locally banded.

A body of silicified limestone of considerable size occurs on this ridge between Livengood and Myrtle creeks, extending down the spur between Franklin and Wonder gulches into the valley of Livengood Creek. A small body of such limestone is also present in the saddle at the head of Myrtle Creek.

On the south wall of the valley of Livengood Creek the chert is essentially the same in character. Bodies of silicified limestone are present in the East Fork of Gertrude Creek, along the west side of Amy Creek near its mouth, and along the north side of Goodluck Creek just above its confluence with Livengood Creek. The limestone in Amy Creek is well bedded, the beds averaging perhaps 1 foot in thickness. It is little silicified. One observation shows a strike of S. 10° W. with a vertical dip. A body of graphitic argillite, similar to that observed on the Marietta claim, intervenes between this limestone and the chert in Livengood Creek.

Reports from many prospect shafts on the South Fork of Hess River, supplemented by examination of the dumps at numerous places, show that the bedrock underlying the gravels is mainly dark-gray or black chert with some argillaceous rocks. One body of silicified limestone is known to be present along the west wall of the valley about a quarter of a mile above the road house opposite the mouth of Alabam Creek.

The rock along the ridge east of the South Fork of Hess River is universally chert, but good exposures showing structure are lacking. The chert on the point of the spur northwest of Alabam Creek is worthy of especial note on account of its extremely brecciated and recemented character. A little red slate was noted in talus at the heads of Patterson and Slope creeks. A large body of silicified limestone, resembling pure-white quartzite, occurs along the ridge southeast of Martin Creek.

The ridge around the head of Moose Creek is almost entirely chert. One structural observation shows the chert to strike N. 65° E. and dip 80° SE. Small amounts of cherty grit and chert conglomerate are also present on this ridge.

On the slope of the spur on the east side of Butte Creek a good deal of shale and slate and a little sandstone were found in association with the chert. This spur is mapped as a part of the chert formation. The bedrock of Crater Creek is mainly chert. The shaly and sandy beds above mentioned may be part of another formation infolded or infaulted, or they may indicate a change in the character of the sediments to the east. The former hypothesis seems the more probable.

That the chert series continues to the northeast is indicated by the following facts: The ridge forming the divide between Tolovana River and Victoria Creek is shown by the traverses of Prindle and Hess (1904) and Stone (1906) to consist of chert, white quartzite, and shaly beds. It is not improbable that the white quartzite recorded represents the silicified limestone recognized farther west. Stone's traverse also shows many outcrops of quartzite in the valley of Victoria Creek, together with some chert, which may possibly indicate the continuation of the chert series that far northeast, in a more metamorphosed phase.

Southwest of the Tolovana district the chert continues along the ridge north of the West Fork of Tolovana River, as shown by the traverse of Prindle and Johnson (1909). Chert as a formational unit, however, seems to end at about meridian 149° 20′, at the head of Mud Fork of Troublesome Creek, apparently not continuing southwestward into the Rampart district.

Little is known of the cherty rocks adjoining the Carboniferous rocks on the northwest, partly because this occurrence of chert has been studied only near the Carboniferous series and partly because of lack of exposures along the ridge northwest of the North Fork of Hess River. The line drawn between the chert and the Carboniferous rocks is based only on differences in lithologic character and is not considered final.

One observation taken on the chert northwest of the Carboniferous rocks shows a strike of N. 40° E. and a dip of 35° SE. The presence of numerous dikes and some fairly large bodies of basaltic igneous rock, including diabase and basalt, in this chert area indicates that the large area of basic intrusives known farther west and southwest lies in close proximity to these rocks.

IGNEOUS ROCKS.

Intrusive rocks, similar in part to those which occur in the Middle Devonian sequence, are likewise represented, though to a much less degree, in the chert. There are many basaltic intrusives in the chert in Livengood Creek and at other localities to the northeast. Many such dikes, particularly in the valleys where circulating waters have been most active, have developed a decided greenstone habit, but similar rocks on the ridges are not invariably altered to the same extent. Basic intrusives are abundant and large in the chert northwest of the Carboniferous sequence.

The chief known occurrence of granitic rock is in Amy Creek, where a body of albite granite intrudes the chert formation. On the ridge east of Butte Creek a syenite porphyry intrudes the country rock.

STRUCTURAL RELATIONS.

The few structural observations so far obtained on the chert serve to show the structure only in a most general way. There appears to be a general strike of about N. 65° E. with fairly steep dips to the southeast. Enough observations have not yet been obtained to prove this general dip to the southeast, but the evidence in hand suggests it strongly. If this is the true dip the main body of chert can not be thought of as a simple synclinal or anticlinal occurrence.

This southeastward dip causes the chert formation to pitch under the Middle Devonian beds, thus at first sight suggesting that the chert stratigraphically underlies the Middle Devonian rocks. This interpretation, however, is deemed untenable, because if such were the case the chert would have been recognized in the stratigraphic sequence exposed in the White Mountains and vicinity. The idea is advanced therefore that the chert probably represents part of a sequence of Paleozoic rocks, overturned to the northwest. In the light of this interpretation the chert is believed to lie stratigraphically above the Middle Devonian rocks. It will require a much more detailed study to determine whether the chert lies conformably or unconformably on the Middle Devonian.

The width of outcrop of the main chert belt in the South Fork of Hess River (between 8 and 9 miles), together with the isoclinal dips, suggests strongly that there is much duplication of beds. It is likely that close overturned folding is the major structural feature, but whether the folds are dominantly anticlinal or synclinal is not known. Extreme brecciation at certain localities suggests faulting within the chert. The recognition of these facts without the details necessary to determine the magnitude of the duplication renders any estimate of thickness very unreliable. In general, however, the absence of any considerable area of infolded beds over a belt 8 miles or more wide, in rocks having such a structure, argues for a very considerable thickness of the beds, amounting probably to several thousand feet.

AGE AND CORRELATION.

Although the chert is interpreted to lie stratigraphically above the Middle Devonian beds, the relation between the two is obscure. However, the age of the chert formation is known within certain limits—that is, it is believed to be not older than Middle Devonian nor younger than Pennsylvanian. The latter inference is based on the presence of Pennsylvanian fossils in the Carboniferous rocks northwest of the main chert belt. These Pennsylvanian beds are believed to overlie the chert and older rocks of the district unconformably.

The chert is a new unit in the stratigraphy of the Fairbanks quadrangle, and hence no formational correlation is possible. It is worthy of note, however, that Blackwelder,[1] in his traverse down Beaver Creek, noted in its lower course a series of rocks the most abundant of which were "basic lavas, tuffs, and breccias, associated with massive chert, cherty dolomite, siliceous slate, and black slate, and graywacke flags." He recognizes the lack of similarity of such a sequence to anything observed by him in the White Mountain section and does not attempt to assign it to a definite stratigraphic horizon. It is possible that the chert formation may be represented in part by these rocks.

CARBONIFEROUS ROCKS.

AREAL DISTRIBUTION.

A belt of rocks of Carboniferous age extends from the northeast corner of the Tolovana district in a general southwesterly direction into the valley of Hess River. This belt is about 2 miles wide and has a known extent of about 15 miles. Its lateral limits, however, are defined only on lithologic grounds.

LITHOLOGIC CHARACTER.

This Carboniferous series was first recognized by Prindle[2] and described as "greenish, grayish, and black slates, with siliceous material." Rocks of similar appearance were observed by the writer at the head of Wilson Creek, near the line of the Prindle and Hess traverse of 1904, and along a narrow zone northwest of the North Fork of Hess River. The rocks in that vicinity are sandstone, slate, shale, and argillite, with a minor amount of chert. Basic intrusives are also abundant.

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[1] Blackwelder, Eliot, Geology of the northern part of the Yukon-Tanana region: U. S. Geol. Survey Bull. — (in preparation).

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

STRUCTURAL RELATIONS.

No structural data were collected on the low ridges in this part of the district, and the only hope of procuring further data of this sort is by hunting outcrops in the timber and tundra-covered valleys. Prindle[1] reports that these rocks dip southeastward under the older formations. This structure is in accord with the regional structure as observed in the chert belt and in the older rocks.

This belt of Carboniferous rocks, as mapped, trends about N. 50° E., which is from 10° to 15° at variance with the regional strike of the older rocks. It is possible that this variation may denote an unconformable relation to the underlying rocks. The Carboniferous rocks are believed to end in the South Fork of Hess River, along the fault zone previously postulated.

AGE.

Three fossil collections have been made by Prindle[1] and Hess, and it is upon these that the age determination is based. Lists of these fossils have been twice published and need not be included in this paper. It suffices to say that Mr. Girty regards the fauna as representative of the Pennsylvanian or possibly of the Permian.

IGNEOUS ROCKS.

The igneous rocks of the Tolovana district are divisible broadly into two general types, the extrusive and the intrusive rocks, which, however, are not altogether mutually exclusive. Much detailed petrographic and stratigraphic study in the Yukon-Tanana region will be necessary before any comprehensive discussion of the igneous rocks will be possible.

The distribution of certain basic extrusive lavas of Devonian age is discussed on page 237. Little is known of their original petrographic character. In the vicinity of Livengood they are serpentine rocks, cut by other serpentinous veinlets and stringers. Considerable magnetite is also present. This serpentine is greatly crushed and altered, a fact which is most apparent at Livengood, where such rock is well exposed. It is quite patent that the serpentine is a secondary product, derived from the alteration of some basic rock of unknown original character. This serpentine resembles petrographically the long ridges of serpentine mapped by Prindle[2] and the writer in the Circle quadrangle, to the east of the Fairbanks quadrangle. It is a well-known fact that basic volcanism has been a recurrent event in

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 46, 1913.

[2] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913.

the Paleozoic and Mesozoic history of the Yukon-Tanana region and in the Tertiary history of southwestern Alaska. Hence general petrographic similarity can not be accepted as the sole basis for correlation of these rocks over large areas, but subsequent work may demonstrate the presence of distinctive petrographic features which will justify such correlation.

Certain other basic igneous rocks, described generically as greenstone by earlier workers, occur in the Tolovana district and in the areas to the east and west. Some of these are doubtless extrusive lavas in the Devonian sequence, and others may be intrusive rocks of various ages. The greenstone sequence along the Yukon from Fort Hamlin to the mouth of Hess River is thought by Prindle to belong to the extrusive type. Likewise the greenstones in the Devonian rocks northeast and southwest of the Tolovana district are probably in large part flows contemporary with the including sediments. On the other hand, certain bodies of basic igneous rock in the Tolovana district, and doubtless others in near-by areas, which are younger, are probably post-Paleozoic. Within the Tolovana district proper these rocks seem to be mainly intrusive, but it is likely that in unexplored areas they have extrusive phases. It is difficult and at present quite impracticable to separate the basic rocks on the basis of age for two reasons—first, because Mesozoic rocks in large mappable units have not been recognized in this district, and second, because the degree of alteration of the basic intrusives is not dependent alone on their relative age and is therefore an unsafe criterion for drawing age distinctions over large areas. Hence all the basic intrusives and extrusives, with the exception of the serpentine, are mapped as a unit.

It is worth while, however, to describe briefly the basic rock at certain localities in the Tolovana district where it appears to be intrusive. The body of basaltic rock lying along the north side of Amy Dome ranges in character from a basalt to a pyroxene andesite. At the east end of the area mapped the rock is typically basaltic, being composed essentially of labradorite, pyroxene, and magnetite. Much yellowish-green and colorless chloritic material is present in veins and seams and in the body of the rock, indicating considerable alteration. At the west end the rock appears to be a porphyritic pyroxene andesite, composed essentially of augite and oligoclase-albite, with magnetite. It shows little or no alteration. Though these two rocks are mapped as a single unit, more detailed work may serve to differentiate them as separate types, perhaps of quite different age. The sodic character of the feldspar seems to indicate that the pyroxene andesite is to be correlated with other sodic rocks on this ridge, which are almost certainly of Mesozoic or Tertiary age.

Thin sections of two dikes found in the chert bedrock in Livengood Creek show a basalt and a diabase. The basalt is much shattered and seamed by veinlets of calcite and chloritic material and has a general greenstone habit, the feldspars being chloritized and indeterminate and the mafic minerals, with the exception of magnetite, being entirely chloritized. The diabase is less altered, the feldspar showing only partial chloritization, and the pyroxene, a titaniferous augite, being comparatively unaltered.

A basic rock that cuts the silicified limestone on the spur between Franklin and Wonder gulches, in the Livengood Valley, showed considerable alteration but is nevertheless clearly determinable as an olivine basalt.

Another dike rock of diabasic affinity cuts the Carboniferous rocks on the spur east of Half Moon Creek. This rock contains labradorite, augite, chloritized biotite, quartz in the interstices, and magnetite. It is a quartz diabase, as nearly as it may be described.

Only one thin section of the basic intrusives northwest of the North Fork of Hess River was studied. This section, however, seemed to be typical of these rocks. It is a granular rock, composed of augite and labradorite, both partly altered; biotite, a little chloritized; quartz; and magnetite. It should also be described as a quartz diabase. Similar rocks on the ridge north of the forks of Hess River seem to be coarser in grain, approaching more nearly a gabbroic type. Neither of these types could be considered as showing a greenstone habit.

All the basic rocks, including both intrusives and extrusives, irrespective of age, are mapped collectively as a unit.

Intrusives of acidic and intermediate types are also present in the Tolovana district and surrounding areas. It is believed that these are in part of Mesozoic age and possibly in part of Tertiary age. It is likely, however, that they represent several epochs and numerous stages of intrusive volcanism.

Dioritic rock crops out in one place on the spur between Lillian and Olive creeks, forms the top of Amy Dome, and is present in the valley of the North Fork of Hess River. There are some differences in these occurrences, though a general family resemblance is observable. The rock between Lillian and Olive creeks is a hornblende diorite, somewhat altered. It consists of cloudy plagioclase of the composition of basic oligoclase or acidic andesine, hornblende, a little pyroxene largely altered to secondary hornblende, epidote, sericite, and calcite, the last two derived largely from the feldspar. Several specimens from Amy Dome show the presence of hornblende diorite and quartz-hornblende diorite, both much chloritized, kaolinized and sericitized. Epidote is also developed. The rock in the Hess River valley is likewise an altered hornblende diorite.

Of particular interest are an albite granite exposed on Amy Creek and a soda rhyolite which intrudes the Middle Devonian sediments on the top of the ridge at the heads of Ruth, Lillian, and Olive creeks. The rhyolite is a porphyritic acidic rock found in association with a lode deposit, described on page 274. The phenocrysts are albite ($Ab_{91}An_9$), and the groundmass is composed of similar albite, quartz, and prismatic and irregular areas of iron hydroxides, suggesting the presence of original hornblende or biotite. This rock is heavily mineralized by pyrite and is cut by veinlets of quartz.

The dioritic and more acidic intrusives, including the two types above described, are mapped as a single unit.

QUATERNARY DEPOSITS.

TYPES.

Three general types of Quaternary deposits have been recognized in the Tolovana district—fluviatile deposits, silts, and residual material.

The fluviatile deposits are those which have formed and are still in process of formation in stream valleys, under the influence of running water. They are divisible into two subtypes, the older and the younger deposits, which are represented, respectively, by the bench deposits and the present stream deposits. The bench deposits occupy the bottoms of old erosional channels. Along the present streams that occupy the same channels as their predecessors and have cut through the older deposits it is in places possible to observe details of their character and structure, but on account of extensive changes in drainage, the overlying mantle of later sediments and residual material, and the covering of vegetation in the valleys, the places where observations can be made on the bench deposits are very few. Over much of the Tolovana district the valleys are open, many of the interstream divides are low, later sedimentation is widespread, and changes in the stream channels have been common. Hence, knowledge of the bench deposits is dependent in large measure on excavations resulting from placer-mining operations. At present the only bench deposits that are open to examination are those in the old stream channel along the north side of the valley of Livengood Creek.

The silts are the fine sediments which mantle many of the fluviatile deposits and extend upward onto the spurs and the low interstream divides.

The residual material comprises talus, material accumulated through solifluction, and rock débris nearly in place.

BENCH DEPOSITS.

The bench deposits on Livengood Creek occur in a single well-defined channel, which begins at some undetermined point in the upper part of the Livengood Valley and extends down the valley to its junction with the valley of Myrtle Creek. At this point there is a decided steepening of the grade of the old channel, and it has been established by drill holes and prospect shafts that the gravels continue downward on this grade to join with similar gravels which are deeply covered in the lower part of Livengood Valley.

Underground mining on these bench gravels has not been carried far enough to make any generalization concerning their width or concerning the position of the tributary channels that must have joined the main channel from both sides of the valley. Yet the general alignment of the mining plants along the auriferous channel on this bench and the offset of certain plants toward the creek indicate the presence of such subsidiary channels.

The older fluviatile or bench deposits of Livengood Creek consist essentially of well-rounded gravels, commonly ranging from half an inch to a foot in diameter. They are composed largely of dark-gray and black chert, with a smaller proportion of basic igneous rocks and some silicified limestone. The average thickness of the gravels in the main channel, calculated from 13 observations in the underground placer workings, is about 15 feet, but the thickness is by no means constant, the minimum and maximum measurements being, respectively, 6 and 40 feet. At every locality except one the gravels formed a solid sheet, without any important interstratification of finer material. On the Ready Bullion, a second tier bench opposite the lower part of Discovery claim, the section in the shaft shows 9 feet of gravel on bedrock, overlain by 4 feet of muck, which in turn is overlain by 16 feet of gravel.

On the spur between Franklin and Wonder creeks, about 1,000 feet north of the auriferous bench channel, the depth of bedrock is only 4 feet. A series of drill holes extending up this spur at intervals of 100 feet for a distance of 600 feet have disclosed the presence of a still higher body of gravel, lying in a channel-like depression that attains a depth of 106 feet. The northern limit of this gravel up the spur has not been determined. The exact significance of this high gravel deposit is not known. If drilling shows such gravel to be present on the other spurs along the north side of Livengood Creek, in a bedrock channel, it will be taken as evidence of the existence of an old channel of Livengood Creek formed still earlier than the auriferous bench channel. If present only on a single spur, this body of gravel may be interpreted as a delta deposit, under assumed conditions of lacustrine or estuarine inundation. The gravelly material in this deposit is composed largely of white flint and quartz, differing noticeably from the auriferous bench and stream gravels of Livengood Creek, which are composed mainly of dark flinty material. This white gravel resembles most closely the lighter-colored chert that forms Livengood Dome, to the north.

PRESENT STREAM DEPOSITS.

The present stream deposits occupy the erosional channels of the existing streams and have been laid down under the action of running water during the latest cycle of erosion, subsequent to the period of general silt alluviation. It is believed that these deposits, beginning at the headwaters, extend downstream as alluvial blankets, overlying the heavy deposits of silt that fill the valley bottoms. The deposits differ in character at different localities, owing in large part to the adjustment of the recent streams to a new base-level. This adjustment has worked progressively upstream, resulting in the simultaneous deposition of coarse and fine sediments at different localities. Local conditions, such as superimposed drainage and stream piracy, have also operated to cause abnormal conditions of erosion, resulting in differences in the character and distribution of the deposits.

The recent deposits are composed at some localities of gravels alone, but more commonly they consist of gravels overlain by finer sediments, largely muck, or silt containing a large quantity of plant remains. It is only where the overlying silt is absent or where mining operations have exposed the gravels in the creeks that the gravels may be seen. Thus the larger streams, such as Tolovana and Hess rivers, have well-developed gravel bars in their upper courses. Likewise some of their larger tributaries, in their lower courses, flow over gravel beds. But the headwater tributaries flow usually between cut banks of silt and carry only a thin veneer of iron-stained gravel in their beds, the main body of gravels being buried beneath the silt.

The main gravel sheets of the present streams are not materially different in character from the bench gravels, being of moderate size, well rounded, and made up of rock débris of the same sort. The overlying muck, in the headwater tributaries, is thought to be reworked sediment derived largely from the heavy body of silt that mantles the region. It is likely that sediments of intermediate grade lie between the stream gravels and the overlying silt at many localities. This condition is known to exist in Livengood Creek, at the mouth of Gertrude Creek. A shaft at this locality exposed 10 feet of gravel lying on bedrock and overlain by fine gravel and sand (the "chicken feed" of the miners), which in turn is overlain by 6 feet of muck. The iron-stained gravels that occur as a thin veneer in the beds of some of the headwater streams are only imperfectly rounded and show the effects of rapid transportation at stages of high water. Such gravels are relatively insignificant.

SILTS.

The silts form a general covering over the older fluviatile deposits, filling the valleys and mantling the lower spurs and interstream divides. They have been observed up to an elevation of 1,200 feet in the saddle between Livengood Creek and the South Fork of Hess River. Later excavations on higher divides may prove the existence of such silts at still higher elevations. It is of interest in this connection to note that Prindle[1] maps terrace deposits up to an elevation of 1,800 feet in the valley of Beaver Creek, up to 1,600 feet on the east, at the head of Tolovana River, and up to 1,400 feet at the head of the West Fork of Tolovana River. It may not be affirmed positively, however, that the silt was deposited uniformly up to an elevation of 1,200 feet or higher. It is quite possible that the alluvial surface, at the end of the period of silt sedimentation, was a sloping one, attaining an elevation of 1,200 feet or higher on the interstream divides but descending gradually to some unknown lower level in the lower valleys.

On Livengood Creek the original silt is a very fine sediment, ranging in color from black to blue-black, with local brown or yellow-brown phases. Specimens of the black silt after drying become an ordinary earthy yellow-brown color. The silt is bedded, but on the Livengood bench, where it was seen most often, it is frozen and seamed with ice, and its examination in the mining shaft gives most unsatisfactory results. Detailed microscopic studies of the silts have not been made, but they appear to be composed mainly of quartz grains, with considerable amounts of mafic minerals, including mica and some clay.

RESIDUAL MATERIAL.

The Tolovana district has a heavy covering of residual débris produced by weathering, ranging in size from clayey material to coarse rock talus. The talus, however, is restricted to the sides of high knobs that stand above the general ridge level. The tops and sides of the low ridges and the sides of the high ones are for the most part covered by a mantle of residual material, derived from the underlying bedrock. This material is produced by the action of frost and water and is not rounded or sorted. Such material on the sides of the ridges moves gradually downhill, producing, in localities where the conditions are favorable, solifluctional slopes. Much of the muck covering the present stream gravels doubtless migrated from the hills downward into the valleys in this manner.

[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pl. 8, 1913.

QUATERNARY HISTORY.

As no Tertiary deposits are known to be present in the Tolovana district, the conditions existing at the beginning of the Quaternary period can not be fully understood. The oldest unconsolidated deposits of which there is any record are the older fluviatile gravels, such as those on the bench along the north side of Livengood Creek. At the time of their deposition the hills and valleys showed a mature topography having the general configuration of the topography of to-day. The master streams, however, had a much lower base-level than at present, and the streams were more deeply incised in their valleys. Normal stream gradients with the characteristic headward steepening were the rule, and aggradation of gravelly material had worked progressively upstream into the headwaters. In their lower courses the streams were in the stage of late maturity, had widened their valleys somewhat by lateral planation, and were aggrading with fine sediments.

At this stage in the physiographic history the base-level of the master streams began to be elevated, and aggradation of the valleys by silts became the universal condition. As a result, all the valleys were deeply buried with silt, which at many localities was deposited up to an elevation of 1,200 feet. The initiation of this new base-level, however, was in general a gradual process, but certain observations in the Tolovana drainage basin show that there was at least one long intermission in the process during which the base-level remained constant.

On Ready Bullion, a second tier bench opposite the lower part of Discovery claim on Livengood Creek, the deepest shaft shows a depth to bedrock of about 100 feet. On claim No. 3 below Discovery on Myrtle Creek, near the mouth of that stream, the depth is 240 feet to bedrock. The Ready Bullion adjoins on the downstream side claim No. 1 below Discovery on Myrtle Creek. Hence within three claim lengths there is a difference in depth in the shafts of 140 feet, and this, in addition to the surface slope from the Livengood bench to the Myrtle Creek claim No. 3 below Discovery, would produce a gradient of about 200 feet in that distance, or about 265 feet to the mile. This steep gradient in the lower part of the old Livengood channel is due mainly to the fact that this locality was very close to the head of Livengood Creek, as it existed at that time. The preservation of this steepened grade was due apparently to such a pause in the sedimentation, whereby the deposition of silt was temporarily discontinued at an elevation of about 625 feet. It was during this period of stability of the regional base-level that the valley of Livengood Creek by headward erosion was extended northeastward, eventually tapping the headwater drainage of the South Fork of Hess

River. It was also during this pause that the auriferous bench gravels of the Livengood Valley were deposited.

Additional evidence of this period of stability during the silt alluviation is shown on Olive Creek, a tributary of Tolovana River heading against Ruth Creek. On Discovery claim, about a mile from the head of the creek, the bedrock is covered by 10 feet of gravel; yet two claim lengths downstream the depth to bedrock is 94 feet, and the auriferous gravels, 14 feet thick, continue out into the valley of Tolovana on a normal grade, being separated from the underlying silt by a seam of clay. This locality likewise has an elevation of approximately 600 feet and evidently affords another example of a steep headwater grade preserved by the silt alluviation.

A feature of the same sort is reported at a similar elevation on Ester Creek, about a mile to the east.

Features almost identical with this have been found at numerous other localities in interior Alaska, where silt sedimentation has been prominent. Thus on Long Creek, in the Ruby district, near the mouth of Snow Gulch, an abrupt steepening of the bedrock grade has been observed by Harrington.[1] Eakin [2] reports a similar steepening on lower Midnight Creek, also in the Ruby district. In this locality, as on Olive Creek, the richest auriferous gravels lie some distance above bedrock. Likewise in the Hot Springs district, according to Eakin,[3] on American Creek bedrock lies at a depth of 18 feet for a distance of a mile and then within half a mile drops to a depth of 165 feet. Still other examples of this physiographic anomaly could be mentioned, such as the abrupt increase in the depth of the gravels reported to occur on Chatanika River and Cleary Creek, in the Fairbanks district. It seems very significant that all these features are at or near the 600-foot elevation.

After this period of stability progressive elevation of the base-level was again renewed and resulted in the further burying of the old erosion channels up to an elevation of 1,200 feet or higher. It is likely that another period of stability of the regional base-level may have succeeded the termination of the silt sedimentation, but its effects are not so evident. The high rock-cut benches on the spur west of Ruth Creek, previously described, may be correlated with such a second period of stability. Further evidence on this point is lacking, perhaps owing to any one or all of three reasons—first, because the base-leveling may not have developed to any marked degree, on account of the reduction of erosion to a minimum through the extreme elevation of the base-level; second, because such high-

[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[2] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 41-42, 1914.

[3] Eakin, H. M., oral communication, 1917.

level features have been exposed to erosive agencies for a longer period of time than the lower ones, subsequent to the removal of the silt; and third, because mining and prospecting have not been carried on in this district at the 1,200-foot elevation, and hence old stream gradients, if still preserved, remain concealed.

The ultimate cause of the changes in base-level that brought about the silt alluviation is not yet definitely known; nor are the physical and climatic conditions under which the silt was deposited entirely free from question. Eakin [1] has explained the silt as a fresh-water lacustrine deposit, laid down in one of a series of great interior lakes, which were caused by glacial damming of the trunk drainage channels of interior Alaska during the glacial epoch. Brooks, in his preface to Eakin's report, suggests the possibility of crustal warping as a causal agency. Harrington [2] shows the probable existence of marine terraces in the lower Yukon, at an elevation of 600 feet. If the existence of these marine terraces is eventually proved, there will be good reason for correlating them with the period of stability of base-level at the 600-foot elevation in the valley of Livengood Creek. Under this interpretation the silts of the Tanana and Yukon valleys would have to be regarded as estuarine deposits. It seems best at present to allow this question to remain open; but the assumption that these silts were deposited in quiet water seems to the writer to be almost a necessary beginning to any interpretation.

The origin of the high-level lakes in the silt is not entirely understood. They may occupy in part original depressions in the alluvial silt plain, but, on the other hand, subaerial erosion may have been a potent factor in the modeling of such depressions.

It is almost necessary to assume that sediments as fine as these, if they were exposed to the action of the winds subsequent to their deposition, were redistributed to a marked degree. It should be possible by microscopic examination to determine the size and character of the grains and the degree of sorting, and in this way to learn something of the climatic conditions subsequent to their deposition and of the amount of subaerial redistribution which they have suffered. It is hoped that subsequent detailed studies of this kind may yield valuable information as to the genesis of these deposits.

After the deposition of the silt the base-level of the region was again lowered, and active erosion immediately began. One of the most striking effects of the new cycle of erosion, acting on the silt deposits, was the frequent occurrence of stream superposition. Thus Livengood Creek began to cut a channel in the silt along the south side of its valley and, after eroding through the silt, was superposed upon hard bedrock, in which it was obliged to cut a new

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 73-74, 1916.
[2] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683 (in preparation).

channel. Stream piracy likewise became common, many streams cutting back across silt-covered divides and claiming drainage systems other than their own. In this manner the South Fork of Hess River, cutting back through an antecedent divide in its valley about east-northeast of Livengood Dome, regained a part of its upper drainage which had previously been stolen by Livengood Creek. Such readjustments have produced most of the present drainage anomalies.

The immediate result of the rejuvenation of the streams was the removal of a large part of the silt deposits, particularly in the headwater tributaries. It is not known exactly to what extent the removal of the silts was carried, but it is certain that they were not completely removed in the lower parts of the master streams, because the regional base-level has never been lowered to the position it held prior to the deposition of the silts. It was lowered to a certain intermediate position and remained approximately there, and the streams have readjusted themselves to a normal stream gradient. In so doing the recent stream gravels were laid down upon stream bottoms of silt. These constitute what Eakin [1] has designated "inlaid gravels." This base-level, which still continues, must have been in existence a very long time, for the present streams have lowered their grades until they have become generally sluggish, except in the extreme headwaters. Not only was a body of stream gravel deposited progressively upstream, but the present condition of the streams indicates that the deposition of this gravel was followed by extensive silt aggradation in their lower courses, the silt being derived from the older silts. The natural silt levees along the lower course of the Tolovana, the swamps and lakes extending toward the hills from the levees, the meandering course of the river, and the network of logs in the river bottom prove that the silt beds in which it is now flowing were deposited by river action and indicate extensive silt aggradation in the lower river courses, superimposed on the river gravels.

Tolovana River below Trappers Cabin, where the river leaves the gravel bars, has a well-developed system of intrenched meanders in the fluviatile silts. These meanders extend downstream to a point about 30 miles below the log jam, where the high silt banks become lower and the current very much less. This is an anomalous feature, difficult to explain. It is possible that the present and earlier log jams in the channel have had sufficient effect to produce this result. Of special significance, as bearing on this interpretation, are the interlacing water-logged trees that cover the bottom of the river below the log jam.

The fluviatile silt deposits in the headwater streams are due to headwater aggradation. The present streams have reduced their grades to a point where they can no longer transport gravels, even in

[1] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, p. 61, 1916.

their headwaters; and the headwater silt deposits represent detrital material which has accumulated at the bases of the steep headwater grades.

MINERAL RESOURCES.

GENERAL FEATURES.

At Livengood, as in every new mining camp, attention has first been directed to the mineral deposits most easily and cheaply won—in this camp the gold placers. Only the older and richer auriferous bench gravels have so far been mined. The present stream gravels may later prove worthy of attention.

In 1916 twenty-one plants were engaged in mining the bench gravels of Livengood Creek and one in mining the creek gravels. These operations were carried on by underground mining. On Gertrude, Ruth, Lillian, and Olive creeks five small plants were engaged in open-cut mining, and four other plants were planning to begin operation late in the season or early in 1917. In all 27 plants were operated, compared with 10 operated in 1915. The value of the gold produced in 1916 is estimated at $700,000, compared with a production of $80,000 in 1915.

Development work has been attempted on one gold lode prospect, but little has yet been accomplished. A number of minerals other than gold have been found in the concentrates, showing at least the presence of such minerals in the neighboring hills. It may be that bodies of these minerals worthy of exploitation will ultimately be located and mined.

ECONOMIC CONDITIONS.

MEANS OF COMMUNICATION.

Livengood, the principal settlement in the Tolovana district, is reached by two general routes—overland by trail from Olnes, on the Tanana Valley Railroad, or by water by way of Tolovana River. The trail from Olnes is used both in summer and in winter, and the winter mail reaches Livengood by this route. In summer only the first-class mail comes overland, most of the second-class matter coming up the Tolovana. As a route for the transportation of supplies, however, the trail is little used in summer, owing to its poor condition; and even as a winter trail it is open to serious objections because it crosses several drainage systems and the intervening hills, including Wickersham Dome, and is therefore very hilly and exposed for considerable distances to the wind and drifting snow.

The river route is the more practicable for freighting. At ordinary stages of water supplies may be taken by gasoline scows and small steamboats up the Tolovana as far as the log jam. A tram has been built around the jam, and supplies are therefore unloaded, trammed around, and reloaded into small barges and launches, which relay the freight upstream to Trappers Cabin or to West Fork, according to the amount of water in the river. In stages of low water it is often necessary to transport supplies from Trappers Cabin to West Fork by means of poling boats. In the past supplies have been freighted by teams from West Fork to Livengood, but during the summer of 1916 a tramway was in process of construction between these two points. When completed, this should materially cheapen the transportation.

One of the great difficulties of the river route is the low water which often prevails in the Tolovana for considerable periods. For 30 miles below the log jam the river is difficult to navigate in low water, being tortuous and lined along its bottom with water-logged timber and snags. Above the log jam low water causes even greater difficulties. Largely for this reason a winter trail, known as the Happy trail, was built during the winter of 1915–16 up the east side of the Tolovana Flats to West Fork, connecting at its lower end with the Fairbanks-Hot Springs trail. This is an excellent trail and should become a valuable means of access to the Tolovana district. It is expected that the Happy trail will be much used to bring from the log jam to West Fork in winter supplies that were landed at the log jam by boat in summer, and some supplies may be freighted all the way from Fairbanks by this route.

SUPPLIES.

The cost of freighting supplies from Fairbanks to West Fork by way of Tolovana River is 3½ cents a pound, and by team from West Fork to the mines on Livengood Creek about 3½ cents more. The tramway between West Fork and Livengood should reduce the latter rate. The cost of winter freighting from Fairbanks to Livengood, by the trail from Olnes, is 5 cents a pound. The summer rate over the same trail is 15 cents a pound. Supplies were scarce and costly in Livengood during the early part of the summer of 1916, but this condition should not exist again.

TIMBER.

Good-sized timber for mining purposes and general construction is available in the valley bottoms, and a sawmill at West Fork is already at work utilizing it. Trees of a diameter of 2 feet at the base may be had in the bottom land of the Tolovana Valley, and even larger ones at some localities. There is plenty of timber between 1 and 2 feet in diameter. In the upper valley of Livengood Creek, near the mines, the trees are smaller, being for the most part less than a foot in diameter and becoming smaller still up the sides of the valley.

The timber at the mines is needed most for fuel, and for this purpose as well as for timbering in the mines the supply is quite adequate.

The district is naturally well supplied with timber, but gross carelessness on the part of woodchoppers near Livengood resulted during the summer of 1916 in extensive forest fires, which destroyed large amounts of standing and cut timber, badly damaged several mining plants, and seriously threatened many others.

Prior to the fires, wood for fuel cut in 16-foot poles and delivered to the mines cost $7 a cord. On adding the cost of sawing and considering the resulting shrinkage of the cord, it is figured that wood in 4-foot lengths costs about $10 to $12 a cord. The forest fires will ultimately increase the cost of fuel materially.

WATER.

Water for sluicing on Livengood Creek is obtained from ditches that tap the creek and its northern tributaries. During periods of dry weather, however, this source of supply is inadequate, and steps have been taken toward procuring a part of the water from the South Fork of Hess River. A low divide of unconsolidated material separates the head of Livengood Creek from the South Fork of Hess River, and if a deep channel can be ground-sluiced through this divide, a large amount of water from the South Fork will be available. The possibility of sluicing out such a channel depends on the character of the material in the divide. If the divide is largely muck and fine sediment, the plan will be practicable; if much heavy slide rock is encountered, it will be very costly. During the summer of 1916 a ditch was dug, leading water from Hess River onto this divide, and the process of ground-sluicing was begun.

Two or three mining properties on Livengood Creek just above Myrtle Creek are now obtaining water from the valley of Myrtle Creek.

GAME AND FISH.

The herds of caribou that are so plentiful in the interior part of the Yukon-Tanana region do not approach very closely to the low country near Livengood, but some caribou are killed for food. The moose have been plentiful, but many have been killed, and it is likely that the future will soon show a marked decrease in the supply. Fish, chiefly grayling, are plentiful in Tolovana River near West Fork and form an important source of food.

WAGES.

Men are paid $5 a day besides their board, which during the summer of 1916 amounted to about $3 a day. Thus the cost of labor to the operator may be figured at about $8 a day.

GOLD PLACERS.

PRINCIPAL FEATURES.

The Tolovana placers are not so widely distributed as those in the Fairbanks and Ruby districts, where gold in greater or less amount is found in the valley bottoms of many creeks over a considerable area. On the contrary, mining and prospecting to date in the Tolovana district tend to show a decided localization of the rich ground. Thus, gold placers of commercial value have been found only on Livengood Creek and in the streams draining the ridge between Livengood Creek and Tolovana River. So far no gold placers worthy of exploitation have been found in any of the tributaries of Livengood Creek on the north side, nor on Myrtle, Ready Bullion, or Rosebud creeks, though considerable prospecting has been done on these streams. Prospecting has shown the presence of gold in the South Fork of Hess River and in some of its tributaries, but so far no continuous pay streak, such as that on Livengood Creek, has been uncovered.

The placers are of two types, which are quite distinct on Livengood Creek but grade into each other on the smaller streams. It is apparent also on the South Fork of Hess River that both bench and stream gravels are present, but the courses of the old and new channels appear to cross and recross one another, with the result that the two are apparent as separate units only at certain localities.

Both bench and stream placers are being worked at the present time, but the bench placers have proved the richer and will doubtless continue to furnish most of the gold produced.

LIVENGOOD CREEK.

GEOGRAPHY.

Livengood Creek heads against the South Fork of Hess River, flows in a general direction of S. 70° W. for about 6 miles, turns abruptly at the mouth of Myrtle Creek, and flows S. 20° W. for about 4 miles to Tolovana River. In its upper 6 miles the present valley floor is narrow and the creek is small. Below the mouth of Myrtle Creek the valley floor becomes a mile wide, and it broadens continuously toward the Tolovana. The valley of Myrtle Creek at its mouth is wider than that of Livengood Creek, and it seems evident that Myrtle Creek and the lower Livengood constituted originally the master stream of this drainage system, the upper part of Livengood Creek being only a tributary.

The gold placers so far found occur in the upper stretch of 6 miles, in which several tributaries enter the creek on both sides. Those on the south side, all of which contain auriferous gravels, are Goodluck Creek, Amy Creek, Lucille Gulch, Gertrude Creek, Alder Gulch, and Ruth Creek, named in order going downstream. Lillian Creek, another small tributary containing auriferous gravels, enters Livengood Creek in its lower 4-mile stretch, at the west end of the ridge between Livengood Creek and Tolovana River. The town of Livengood is in the lower part of the upper Livengood Valley, at the mouth of Ruth Creek.

The valley of Livengood Creek is asymmetric in cross section, the creek flowing along the south side. The ridge on the north side descends in long, gently sloping spurs to the present valley floor, whereas on the south side similar spurs of gentle slope but not so long terminate abruptly in rather steep bluffs along the creek. The view of Livengood and the valley of Livengood Creek (Pl. XIV) illustrates clearly this asymmetry.

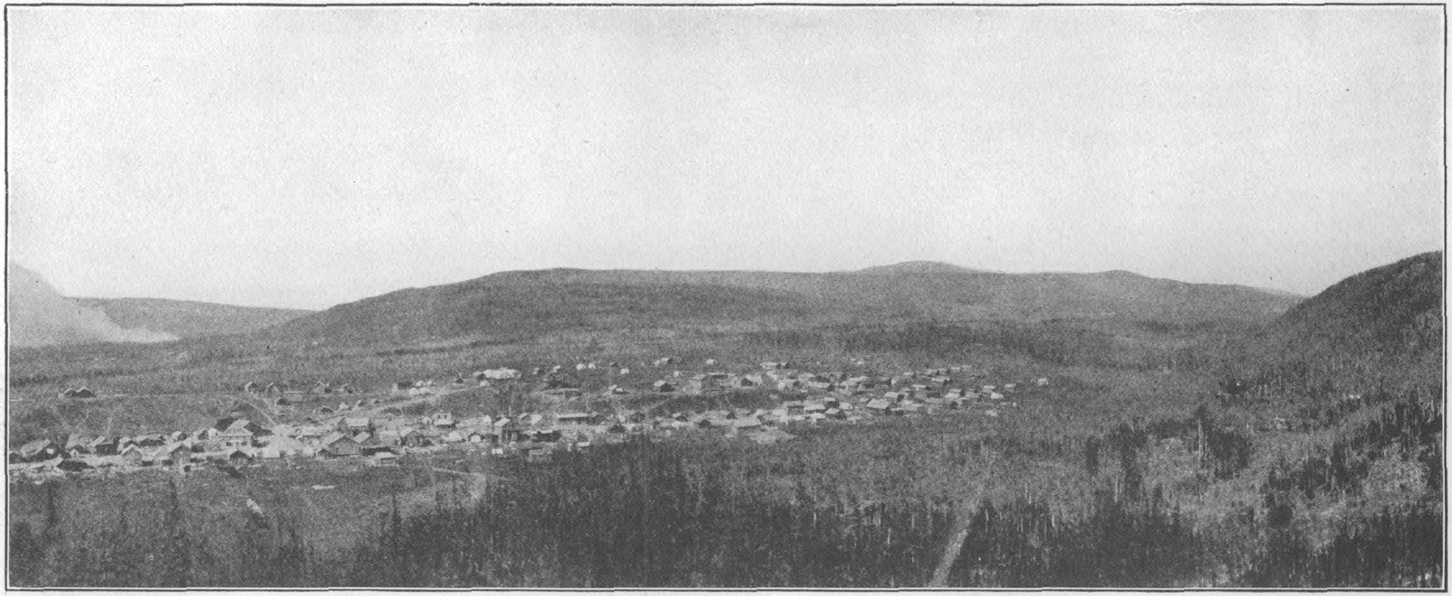
PHYSIOGRAPHIC HISTORY.

The physiographic history of a placer-mining district has an important bearing on the economic geology of its gold placers. This is particularly true of the area drained by Livengood Creek and the adjoining drainage systems. It is believed that an understanding of the principal events in the development of the present drainage may help materially in mining operations and prospecting.

The physiographic history of Livengood Creek and the neighboring drainage channels is complicated. The essential features of the regional physiography are understood in a general way, but only where mining operations have exposed the character and depth of the unconsolidated deposits is it possible to discern the details of drainage changes and associated phenomena.

At the earliest time recorded by the available physiographic data Livengood Creek was a much shorter creek than at present. The bedrock grade of the lower part of the auriferous bench channel is about 265 feet to the mile. With this grade the original stream above the mouth of Livengood Creek must have been very short, the divide being below the mouth of the present Amy Creek. As bearing on this point, the backhand drainage of Wonder, Heine, Goodluck, and Amy creeks, particularly in their headwaters, is of much significance. It seems entirely within reason to believe that these four streams, during this stage of their history, drained northeastward into the South Fork of Hess River.

Then followed the stage of silt alluviation, brought about by an elevation of the regional base-level. When the silt deposits had accumulated to a depth of approximately 600 feet in the Livengood basin, there was a long period of stability, during which the base-level remained unchanged. This silt alluvium preserved the old grade of Livengood Creek up to that elevation and provided for upper Livengood Creek a new temporary base-level. Under this condition of equilibrium Livengood Creek cut back through the rock divide below



LIVENGOOD AND ASYMMETRIC VALLEY OF LIVENGOOD CREEK.

Amy Creek and gradually captured the drainage of the South Fork of Hess River. There are two means of determining just how much of the Hess River drainage was captured. First, a drill hole in the present silt-filled divide at the head of Livengood Creek shows a depth of 205 feet to bedrock. As the elevation of the divide is a little over 1,200 feet, this means that the old channel through this divide has an approximate elevation of 1,000 feet. Theoretically, therefore, it was not possible to capture any of the Hess River drainage below that level, and practically, on account of the headward steepening of every stream gradient, it was not possible to capture all of it above that level. The second piece of evidence is found in the valley of the South Fork of Hess River east-northeast of Livengood Dome, at an elevation of about 1,100 feet, where the creek flows through a narrow gorge. At this point, on claim No. 4 below Discovery, a series of shafts across the valley bottom reveal the fact that in the deepest place bedrock is but 15 feet deep. The overlying deposits are entirely gravel. This, evidently, is the head of the old Livengood drainage system. From this point on the South Fork upstream to the mouth of Alabam Creek the bedrock becomes lower and the unconsolidated deposits become thicker. Just above Alabam Creek, on the second-tier bench claim opposite claim No. 4 below Discovery on Goldstream Creek, the depth to bedrock is 150 feet.

Therefore, subsequent to the silt alluviation in the lower Livengood Valley, up to the 600-foot level, during the ensuing period of regional stability of base-level, Livengood Creek eventually captured all the upper drainage of the South Fork of Hess River and its lower drainage down to the present gorge. It was during this period that the present bench channel in upper Livengood Creek was excavated and auriferous gravels deposited therein.

Subsequently the regional base-level was again progressively elevated, and eventually silts were deposited up to an elevation of 1,200 feet or higher, deeply burying the old Livengood gravels. It was probably at the end of this process of alluviation that the rock-cut benches west of Ruth Creek were evolved.

After the period of silt deposition active erosion was again begun by a lowering of the base-level. Both Livengood Creek and the South Fork of Hess River began to cut channels in the soft silt, and the present silt-filled divide was finally established as the watershed between the two drainage systems. Livengood Creek, however, instead of reexcavating in its old channel was superposed on the south wall of its old valley and after quickly cutting through the silts was obliged to cut a new channel through the solid rock. This superposition explains the rapid steepening of the bedrock grade in Livengood Creek below the town of Livengood. Opposite the wireless station the depth to bedrock is 20 feet, whereas two claim lengths downstream it is 180 feet. The present course of Livengood Creek evidently carries it abruptly off the end of an old spur extending from the south wall of the valley. Lower Livengood Creek eroded in the silts more rapidly than upper Livengood Creek, and the result for a considerable period was the development of rapids just below the present town of Livengood.

The South Fork of Hess River, during the general stream rejuvenation subsequent to the deposition of the silt, established a system which reclaimed a large part of the drainage area it had previously lost, but it has not succeeded in recovering Wonder, Heine, Goodluck, and Amy creeks. After the removal of only 100 or 150 feet of the silts, the South Fork was superposed on bedrock at the present gorge, and this high bedrock barrier has prevented much subsequent erosion in its upper basin. A fact in strict accord with the above interpretation is that of the two rock divides, one just below the present Amy Creek in Livengood Valley and the other at the 1,100-foot elevation in Hess River; the latter and more recent one is the better preserved. The old divide in Livengood Valley has been entirely obliterated, its previous existence being entirely inferential. It is probably owing in large part to the superposition of both Livengood Creek and the South Fork of Hess River on hard rock that the silt-filled divide between the two drainage systems is so perfectly preserved.

The present stream gravels of Livengood Creek were laid down during the period of stream rejuvenation above described. They were formed as a gravel sheet extending progressively upstream. The covering of muck on these gravels is the reworked silt, eroded from the neighboring spurs at a rather late stage in the erosional history, when the headwater tributaries had so reduced their grades that they were no longer able to transport gravels.

BENCH PLACERS.

Pay streak.—The auriferous bench gravels on upper Livengood Creek lie in an old stream channel, which has been traced from a point below the mouth of Wonder Creek downstream to a point below the town of Livengood, a distance of 4 miles. This channel is separated from the present channel of Livengood Creek by a bedrock reef, which crops out at the town of Livengood and is traceable underground upstream almost to the mouth of Amy Creek. Upstream from this point the bedrock barrier between the two channels probably connects with the underground continuation of the spur between Amy Creek and Lucille Gulch. At the lower end of upper Livengood Creek there is another reef, the southwestward and underground continuation of the ridge between Livengood and Myrtle creeks. The old channel passes between these two reefs, apparently hugging close to the north wall of its old valley, as shown by drill holes and prospect shafts on and near the Ready Bullion bench claim. The gravels in this old channel will be found to connect with deeply buried gravels in Myrtle Creek, but as they spread out into what was formerly the larger valley of the two, it is uncertain how well defined a pay streak will be found. It is not unlikely that the gold is too widely scattered in these gravels to be recovered profitably at the present time.

The width of this body of old gravels is not yet known. The width of the pay streak or productive placers, however, may be fairly judged by the lateral extent of the underground workings. The average width of the auriferous channel, as obtained from 15 observations underground, is 127 feet; the maximum is 300 and the minimum 60 feet.

There is a general alignment of the mining plants up and down the bench claims, but certain plants are offset to the south and thus indicate the presence of tributary auriferous channels entering the main channel from that side of the valley. Among these are the auriferous channel on the first-tier bench opposite Discovery claim and on the adjoining Nelson bench; that on the Eagle, a first-tier bench opposite claim No. 3 above Discovery; and possibly also that on the Eldorado bench, about 1½ miles above Livengood.

Placers.—The average depth to bedrock in the auriferous channel, obtained from 20 observations, is 80 feet, and the overburden shows little or no tendency to thicken downstream. The average thickness of the gravels, obtained from the same observations, is 14 feet, and there is a marked thickening of the gravel sheet on the last four or five claims at the lower end of the channel. The overburden is mainly muck or silt, commonly with some slide rock and here and there containing thin seams of fine gravel and sand ("chicken feed"). The gravels commonly range from half an inch to a foot in diameter. The bedrock is at most places a deeply weathered, locally much brecciated dark-gray to black flint or chert. It is in some places strongly mineralized with pyrites. The bedrock at a few localities is greenstone and at a few others silicified limestone. Only on the Marietta claim, where the bedrock is a carbonaceous shale or argillite was any argillaceous bedrock observed.

At most localities all the gravel carries more or less gold, but only the lower part carries enough gold to warrant its removal under present conditions. The upper part of the decayed bedrock likewise contains gold. Observations from 15 working shafts show that about 3 feet of gravel is being regarded as workable, on the average, and about 1½ feet of decayed bedrock. It is in places necessary, however, to remove more than 5 feet of material in order to give working room. The highest gold content is in the lowest part of the gravel and on the surface of the bedrock. Where the bedrock is limestone the gold penetrates but a few inches into the rock.

Information given by the mining operators leads to the belief that the average tenor of the productive ground is at least $1 a square foot of bedrock. Above Amy Creek, however, the gold content of the gravels is lower. On the assumption that an average thickness of 5 feet of gravel and decayed bedrock is removed, the returns would be $5.40 to the cubic yard of material mined and sluiced. If dredging or hydraulicking methods are ever used the entire overburden must also be included in the yardage. On the assumption that 1½ feet of bedrock and 80 feet of overlying gravel and overburden are removed the average tenor would be 33 cents to the cubic yard.

The gold.—Considerable differences exist in the color, shape, size, and porosity of the gold on Livengood Creek. Gold ranging from light yellow to a very dark iron-stained color is present; well-rounded and angular gold is found at places on the same claim; the gold on some claims is porous and on others dense; and both fine and coarse gold are often uncovered together. The coarse gold is darker, much of it being covered with a dark iron stain, and is localized in small spots. Pieces of gold worth $50 are the largest so far found on the creek. These differences in character are due largely, it is believed, to the fact that tributary auriferous channels entered the main Livengood channel from the south and contributed gold of various sorts. In support of this idea, it was noticed that the gold above Amy Creek is more uniform in character. At the lower end of the Livengood bench channel also there is a tendency toward greater uniformity in the gold, due presumably to stream sorting. Certain differences in the gold are also due to the fact that the underlying bedrock is mineralized in places, as indicated by pyritization.

The following table comprises all the information available at the present time regarding the value of the gold on Livengood Creek:

Value of gold on Livengood Creek.

Sample.	Fineness.		Value per ounce.		
	Gold.	Silver.	Before melting.	After melting.	Net value after deducting assay and exchange charges.
1				$18.92	
2	0.9175	0.078	$18.60	19.00	$18.14
3	.914	.075	18.17	18.93	17.72
4					17.75
5	.9225	.068	18.55	19.10	18.09
6	.9075	.0825	18.27	18.80	17.82
7				18.63	
8					18.00
Mean	.915	.076	18.40	18.90	17.92

It will be noticed that the Livengood gold is of high grade. The mean value of the Fairbanks gold [1] is given as $17.73, but this figure is derived in part from values given for "crude dust" and for the gold after melting, both of which are considerably higher than the "net value." Yet the Livengood gold is worth 19 cents an ounce more than the admittedly high value given for the Fairbanks gold. This difference is not due to any particular freedom from the base metals in the Livengood gold, which has an average content of 9 parts per thousand of these, compared with 5 to 10 parts in the Fairbanks gold. The higher value is due evidently to the smaller content of silver in the Livengood gold, the mean proportion being about 76 parts per thousand, compared with 82 to 172 parts per thousand in the Fairbanks gold.

The concentrates.—A study of the concentrates, or heavy sands, recovered with the gold may throw considerable light on the origin of the placers and is certain to give advance information regarding any other minerals of value likely to be found in the drainage basin of the stream that deposited the auriferous gravels. With this idea in mind, representative samples of the heavy sands were collected at eight localities from the Livengood bench channel, at more or less regular intervals from the Red claim, opposite claim No. 15 above Discovery, down to the Nelson bench, opposite Discovery claim. These samples show that magnetite, ilmenite, limonite, picotite, and hematite are universally present in the heavy sands. In addition, barite was found on the Sunnyside, Etna, Gold Dollar, Eldorado, and Nelson bench claims, and pyrite on the Sunnyside, Etna, Sunny, Gold Dollar, and Nelson bench claims.

The iron minerals magnetite, ilmenite, limonite, hematite, and pyrite are not unusual, but the presence of picotite (chrome spinel) was not expected. Its universal presence shows that considerable chromium is associated with the rocks in the basin of Livengood Creek as it existed when the auriferous gravels were laid down. In this connection it may be mentioned that chromite (iron chromate) has been found on the spur west of Ruth Creek. It seems likely that both the picotite and the chromite are associated genetically with the serpentine in the Middle Devonian rocks, which outcrop at Livengood and may be traced northwest and southeast for long distances The presence of barite (barium sulphate) is of interest. It occurs at numerous other localities in interior Alaska, among which may be mentioned Little Minook Creek,[2] in the Rampart district; Poorman Creek, in the Ruby district; and the North Fork of Hess River. Neither chrome nor barium ore, however, could be of commercial value in this district at the present time.

[1] Prindle, L. M., and Katz, F. J., Geology of the Fairbanks district: U. S. Geol. Survey Bull. 525, pp. 113–114, 1913.

[2] Eakin, H. M., oral communication, 1917.

Mining operations.—The history of the discovery of gold placers on Livengood Creek by Jay Livengood and N. R. Hudson during the summer of 1914 has been narrated by Brooks.[1] These men, however, staked for the most part creek claims on Livengood, Gertrude, Ruth, Lillian, and Olive creeks. The richest gold-bearing gravels, on the second and third tier benches on the right bank of Livengood Creek, were staked by later prospectors, and the original discoverers of the district did not profit in fullest measure by their work.

Twenty-one plants, employing between 225 and 250 men, were at work during the summer of 1916 mining the auriferous gravels on the Livengood bench claims. The accompanying sketch (fig. 6), showing the approximate position of the bench claims, is compiled from descriptions by the miners and is not meant for an accurate chart of the placer claims. It is introduced merely to show the relative position of the different claims.

The placer mining on the Livengood bench is accomplished entirely by underground methods. A shaft is sunk to bedrock and tunnels are driven in two directions from the bottom of the shaft, along the line of the pay streak, as far as it is expected that the ground will be worked from that particular shaft. From the ends of the two tunnels crosscuts are made to the lateral limits of the auriferous gravel, and, the piece of ground to be worked having thus been blocked out, the gravel is removed by a retreating long-wall system, working toward the shaft. It is feasible to work 150 or 200 feet in either direction, and hence blocks of ground 30,000 to 40,000 square feet in extent are commonly cleaned from a single shaft.

The underground conditions for mining are excellent. The ground is solidly frozen from top to bottom. No water is present in the workings, because so far no thawed ground or underground watercourses have been encountered. The ground is therefore solid, and little or no timbering is necessary. Examination of untimbered workings a year old, from which all the gravel has been removed, show no tendency of the roof to cave. These favorable conditions have rendered mining much more economical than in the Fairbanks district.

In thawing ground in the tunnels 8-foot steam points are commonly used. These are placed 2 feet apart, thus rendering the duty of each point 4 square feet on a face, or about 1.2 cubic yards. It is estimated that 1 horsepower is required to each steam point.

After thawing, the gravel and bedrock is picked loose and conveyed by wheelbarrow to the shaft, whence it is elevated to the surface, conveyed by an overhead cable to the desired spot, and dumped from self-dumping carriers. Sluicing is carried on in the usual manner. Tailing room is usually procured by groundsluicing off a channel in

[1] Brooks, A. H., Preliminary report on the Tolovana district: U. S. Geol. Survey Bull. 642, p. 201, 1916.

the muck, in the direction of Livengood Creek, but occasionally it is necessary to elevate the sluice boxes in order to obtain sufficient grade.

Ground that is owned by the operator may be worked at a profit if it will yield 50 cents to the square foot of bedrock, and under favorable conditions and economical management ground as low in value as 35 cents to the square foot may be mined. Operations under a lease, however, must be confined to higher-grade ground, the exact value depending, of course, on the percentage due to the owner.

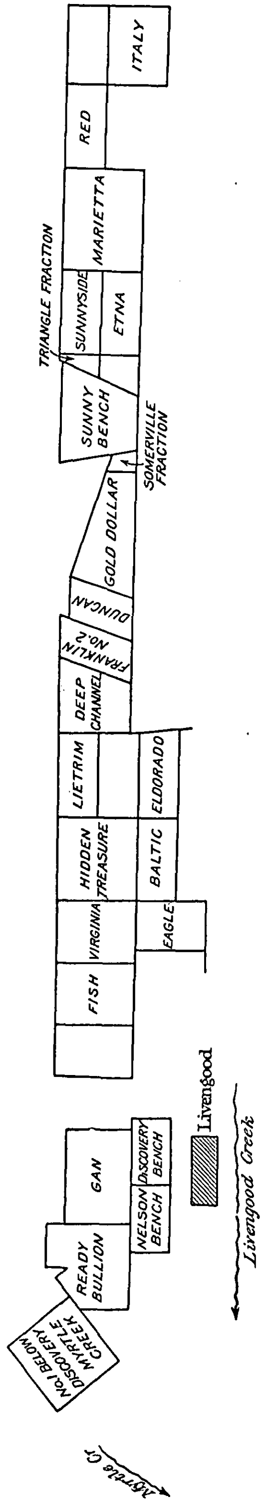


FIGURE 6.—Sketch map of placer-gold bench claims on Livengood Creek.

CREEK PLACERS.

Only one claim has thus far been worked in the present channel of Livengood Creek, and little is known of the length, width, or character of the pay streak. It was reported to the writer that material carrying 40 to 50 cents a square foot has been found at certain localities by drilling.

The claim now being worked is claim No. 5 above Discovery, at the mouth of Gertrude Creek. At this point the distance to bedrock is 16 feet, there being 6 feet of muck overlying 10 feet of gravel. The gold is in the lower 4 feet of gravel and the upper foot of decayed chert bedrock, and the tenor is reported to be higher than the figures above mentioned. The gold is said to be rough and shotty, and much pyrite is reported to occur in the concentrates. Mining is carried on by drifting operations.

Some prospecting has been done on the present stream gravels of Livengood Creek, with the idea of their possible exploitation by dredging. Much of the ground is frozen, and it seems likely that the operator of a dredge would be obliged to figure on a thawing plant in order to reclaim any large part of the gold.

Prospecting has revealed certain additional facts regarding the location of the pay channel on the lower portion of Livengood Creek. About 1,500 feet downstream from the mouth of Ruth Creek and 300 feet south of Livengood Creek a shaft 32 feet deep showed 25 feet of muck and slide overlying 7 feet of well-rounded gravel. Another shaft 600 feet upstream and close to the present Livengood Creek exposed 28 feet of muck and slide overlying 7 feet of similar gravel. Gold is present in the lower 4 to 5 feet of gravel, as well as in 1 to 2 feet of the decayed slate bedrock. Farther downstream the depth to bedrock becomes very great.

TRIBUTARIES OF LIVENGOOD CREEK.

GOODLUCK CREEK.

No mining has yet been done on Goodluck Creek. On the fourth claim downstream from the summit at the head of the creek a shaft has been sunk 60 feet to bedrock. In this shaft 50 feet of muck is exposed, overlying 10 feet of angular wash. The bedrock is a brecciated dark-colored flint. Some flaky porous gold is obtained just above the bedrock.

About 1,500 feet farther upstream some fine gold is present in angular wash almost at the surface, being overlain by only a few feet of muck and underlain by a deep body of the same material. It appears from this occurrence that gold has been eroded from the ridge to the south and deposited comparatively recently.

The bedrock on the southwest side of Goodluck Creek is largely silicified limestone; on the northeast side flint or dark chert. There seems to be a body of greenstone, perhaps a dike, lying between these two rock formations.

AMY CREEK.

No mining has been done on Amy Creek, but a number of prospect shafts along the east side of the creek show the presence of auriferous gravels, lying on bedrock. The owners of claim No. 4 above Discovery expect to begin open-cut work during the summer of 1917, and other claims on this creek will also doubtless be worked.

Several different kinds of bedrock are present in the basin of Amy Creek. The main bedrock is chert, but at the mouth of the second tributary on the east side, above Livengood Creek, a body of albite granite crops out, and it continues apparently eastward to the top of the ridge. At the extreme head of Amy Creek basalt porphyry occurs with the chert, and at the lower end some limestone is present on the west side and in the bedrock under the gravels. At the mouth of the creek the limestone is succeeded by graphitic argillite, similar to the bedrock on the Marietta bench claim.

It is believed that Amy Creek has been an important contributor to the gold content of the Livengood bench and stream gravels. It must also have contributed considerable gold to the basin of the

South Fork of Hess River, at the time when it was tributary to that stream.

LUCILLE GULCH.

One or two prospect shafts have been sunk on Lucille Gulch, but no work was in progress during the summer of 1916. It is reported that prospecting will be continued.

GERTRUDE CREEK.

Discovery claim, at the mouth of Gertrude Creek, was being groundsluiced in August, 1916, preparatory to the beginning of open-cut placer mining. A dam has been constructed upstream to provide a water supply for sluicing. The depth to bedrock is about 25 feet at this point. The thickness of gravel is 14 feet, of which the upper 12 feet will be groundsluiced off with the overlying muck, and the lower 2 feet will be run through the sluice boxes.

The bedrock is chert. A specimen of the concentrates collected with some gold from this locality shows the presence of magnetite, ilmenite, picotite, and pale-yellow zircon.

About a mile from its mouth Gertrude Creek is formed by the junction of two forks, the eastern one of which is known as Glen Gulch. Discovery claim, at the lower end of Glen Gulch, was being worked by open-cut methods in 1916. The cut showed from 2 to 4 feet of gravel, covered by 10 to 25 feet of muck. The bedrock is silicified limestone. The gold is fine, angular, and shotty, although pieces worth $1 have been found.

RUTH CREEK.

Open-cut work was begun at the lower end of Discovery claim, Ruth Creek, during the spring of 1916. The bedrock is a black, finely crystalline limestone, much seamed with calcite and quartz. This is overlain by 5 feet of gravel, which is covered by 12 feet of muck and slide. Farther up on the same claim the depth to bedrock is much less. The gold lies in the gravel and in 2 feet of bedrock. The gravels are angular and comprise chert conglomerate, chert, sandy shale, diorite, and other rocks. The pay streak, so far as known at present, is 30 to 40 feet wide. The gold is of high grade, netting $18 an ounce or more after deducting all charges. It is partly rough and partly well worn. The largest piece so far found is worth $3. At present the gravel is shoveled into the sluice boxes. Later a ditch will be dug around to Gertrude or Amy Creek, and a hydraulic plant may be installed. Four men were at work on this claim at the time of visit, but probably more were employed later in the season, when the supply of water became adequate.

On the lower end of claim No. 3, above Discovery, two men were sinking a shaft to bedrock, with the intention of drifting, hoisting, and sluicing.

Upstream on the same claim another operator has sunk a shaft to bedrock, a depth of 20 feet, and was also planning to drift and sluice. At this point on Ruth Creek the surface of the bedrock appears to dip away from the creek on each side, so that there are two deeper auriferous channels. Evidently superposition of drainage, due to the general process of silting already described, has occurred on the tributaries of Livengood Creek, as well as on the main stream.

Preparations are also being made to do placer mining in claim No. 4, above Discovery, where the depth to bedrock ranges from 5 to 18 feet. Some of the ground will be mined by drifting and some of it by open-cut work.

LILLIAN CREEK.

Mining operations by open-cut methods were in progress on two claims on Lillian Creek, Nos. 1 and 2, above Discovery. Both stream and bench placers have been worked, but the creek is so small that operations of both types have been done on creek claims.

On claim No. 2, where the writer obtained most of his data, sufficient work has been accomplished to show the general character of the pay streak, which is well developed in the present creek but slopes away into the hill on the south side, thus grading into an older channel. The width of this pay streak is at least 168 feet, but its extent downstream is not known. On the north wall of the creek another pay streak, 100 feet wide, is present on a bench about 60 feet above the creek and sloping toward it. This bench and its auriferous gravels appear to continue downstream into the adjoining claim, No. 1 above Discovery.

In the creek where the present work is being carried on there is an overburden of 4 to 5 feet, covering about 18 inches of gold-bearing slide gravel, which overlies the bedrock. Farther south, in the slope of the hillside, the depth to bedrock is 30 feet, the lower 15 feet of which is gold-bearing gravel. The gravels in general are angular to subangular and are composed of conglomerate, greenstone, and a variety of sedimentary rocks, including sandstone, shale, slate, and quartzite. The bedrock is chiefly sandstone and shale, with some slate, and is commonly mineralized with pyrite. Gold occurs in all the gravels and in 1 foot of bedrock. The gold is angular, coarse, and even grained. It is said to render a net return of $17.50 to $18 an ounce.

The concentrates taken with the gold on this claim are most remarkable on account of the variety of minerals they contain. The following minerals, named roughly in their order of abundance, have been identified: Magnetite, ilmenite, picotite, limonite, cinnabar, scheelite, zircon, pyrite, stibnite, and barite. The presence of picotite is not surprising, in view of its universal presence in Livengood Creek, but this is the only creek in this district from which scheelite (calcium tungstate) and stibnite (antimony sulphide) have been taken. Cinnabar (mercury sulphide) is also present on Olive and Ester creeks, and is reported from the head of Ruth Creek but is nevertheless also worthy of special mention. A vein of stibnite is reported to have been uncovered in the mining operations. The head of Lillian Creek is only a short distance above this claim, and it follows that neither these heavy minerals nor the gold has traveled very far downstream. This is also shown by the angularity of the gold. It is judged from the presence of so many minerals in the concentrates that the mineralization at the head of the creek may be very complex in character.

The present work in Lillian Creek is accomplished by open-cut methods, the gravel being shoveled into sluice boxes. Two small dams have been used to store water for use in the bench and creek mining, but a ditch has recently been completed, which will deliver water from the Olive Creek slope, with a pressure of 200 feet, and a hydraulic plant is being planned.

The present work on claim No. 1 above Discovery, is being done on the bench gravels on the north side of the creek, where there appears to be about 6 feet of auriferous gravel, overlain by 2 to 3 feet of muck. The bedrock slopes toward the creek, as on the adjoining claim upstream. The gold is distributed in the gravel and in 6 inches to 1 foot of bedrock.

The value of the ground on the two claims on Lillian Creek is rather higher than that in the other tributaries of Livengood Creek. In fact, this ground compares favorably in value with some of the Livengood bench placers.

TRIBUTARIES OF TOLOVANA RIVER.

OLIVE CREEK.

On Discovery claim on Olive Creek three men were engaged in open-cut mining during the seasons of 1915 and 1916. At this locality the pay streak is known to be 300 feet wide, of which 100 feet was planned to be worked. The material overlying the bedrock consists of angular to subangular slide gravel, having a thickness of 10 feet or more. There is no overlying muck. These gravels consist of black flint, argillite, coarse-grained granitic rock, diabase, green flinty mineralized rock, quartzite, and chert conglomerate. The bedrock is a dark impure sandstone. The gold is distributed mainly in the lower 7 feet of gravel, though it has been noted that certain horizons in the gravel were particularly productive.

The gold is rough and unworn and is also very fine, no pieces of a value exceeding 15 or 20 cents having been found. The gold has a net value of $18 an ounce, after deducting all charges. The concentrates taken with the gold include magnetite, ilmenite, cinnabar, picotite, and limonite. Cinnabar is plentiful.

The ground is frozen, but it is opened up and allowed to thaw naturally. The thawed ground is washed into the cut by a hydraulic nozzle and directed into the sluice boxes by means of shear boards. The stream of water also aids materially in the process of thawing. Water is obtained from Ester Creek by means of a ditch. When water is scarce a dam in Olive Creek is used, which supplies enough water for ten minutes' sluicing.

On claim No. 2 below Discovery two men were opening a 4,000-foot cut, 60 feet wide at the upper end and 30 feet wide at the lower end, which was intended to be sluiced. The pay streak here is at least 350 feet wide. There is 14 feet of gravel at the surface, all of which carries gold. Under the gravel is a seam of clay, and between the clay and bedrock about 80 feet of barren muck. A little coarse gold is found at bedrock, but not enough to warrant the removal of the overlying muck, or to pay the expense of drift mining. Only the upper 14 feet of gravel will be mined.

ESTER CREEK.

Prospecting and mining in a small way was being carried on by two men on a fractional claim above Discovery, on Ester Creek. The pay streak has not yet been definitely located, but the owners believe they are on the edge of it. Conditions are similar to those on Olive Creek, but the distance to bedrock is 20 feet, and the work is being accomplished by drifting from the bottom of a shaft. The bedrock here is flint. About 3,000 feet downstream the depth to bedrock drops rather abruptly to 90 feet.

The gold recovered is said to assay $18.85 an ounce after melting. The concentrates taken with the gold include magnetite, ilmenite, picotite, cinnabar, limonite, and zircon.

SOUTH FORK OF HESS RIVER.

Prospecting has been carried on for two years on the South Fork of Hess River and its tributaries, but so far no continuous pay streak has been located, though fairly productive pockets of gold have been found in the gravels at several localities. In the light of the drainage history of this district this condition is not surprising nor difficult to understand. The South Fork in its earliest history flowed in the same direction as at present but included also the present head-water tributaries of Livengood Creek. During that period doubtless considerable gold was carried into the drainage system of the South Fork from the ridge south of Livengood Creek, which appears to be the source of most of the gold in this vicinity. Subsequently, however, Livengood Creek tapped the Hess River drainage system, and a rock divide was established in Hess River east-northeast of Livengood Dome. After this divide was established most of the gold previously washed down into the South Fork was retransported into Livengood Creek and concentrated in the present bench channel. At a still later date, after the period of silting, the South Fork reclaimed much of its former drainage basin but did not succeed in reclaiming Goodluck, Amy, Wonder, and Heine creeks and has therefore obtained gold only by means of Goldstream Creek and from the erosion of any auriferous bedrock in its basin. From the reported presence of small amounts of gold on Alabam and Moose creeks, it seems probable that mineralized bedrock must exist in the drainage basins of these streams but the extent of such mineralization and its potential significance in the formation of commercial placers in these and other tributaries of the South Fork remain to be proved. It seems to the writer that there would be more probability of finding commercial placers on the benches in the upper part of Goldstream Creek than farther downstream.

GOLD LODE PROSPECTS.

At the heads of Ruth, Lillian, and Olive creeks a group of lode claims have been located. Two men, interested in 16 of these claims, have been engaged for over a year in prospecting and have done a certain amount of development work.

On the spur west of Ruth Creek, at an elevation of about 1,400 feet, a mineralized area begins that extends southward to the top of the spur, a distance of several hundred feet. In this area quartz stringers are numerous, most of them striking from S. 20° E. to S. 60° E. Such veinlets are as a rule nearly vertical, but at one locality they dip steeply to the west. They range from a fraction of an inch to 2 or 3 inches in width and are mineralized with pyrite, arsenopyrite, and gold. Some of them are reported to carry as much as $12 to the ton in gold and $2 to the ton in silver, but the average value would probably be much lower. Calcite veins carrying some gold and sulphide minerals are also present. These apparently cut the quartz veins and are therefore later.

Where the quartz stringers have been exposed there is commonly also an intensely mineralized zone on both sides. Thus at one locality about halfway up the spur, a quartz vein 1 inch thick is bordered by such a zone of mineralization, which extends on each side for a distance of 18 inches, gradually merging into the country rock. This zone is in part much decayed and in part a hard green-stained rock, composed of a mixture of crystalline dolomite, quartz, calcite, and sulphides. The green material is plainly an oxidation product, derived from numerous grains of chromite that are scattered throughout the mineralized rock. It may be mariposite, a chromiferous chlorite.

The country rock on this spur is a part of the Middle Devonian stratigraphic sequence and hence is made up of many rock types, including sandstone, shale, slate, quartzite, crystalline limestone, and dolomite, as well as a variety of intrusive rocks. The more intense mineralization so far discovered appears to have been localized in and near the quartz veins, but diffuse mineralization has occurred in much of the surrounding country rock. Considerable white opaque quartz is also present on this spur, but it seems to have no genetic connection with the gold, and is mineralized only where it occurs near the mineralized zones above described. A soda rhyolite porphyry, which intrudes the country rock near the upper end of the mineralized area and is itself heavily mineralized and veined with quartz, is believed to have a genetic connection with this lode deposit. At the upper end of this spur, on Money Knob, the country rock is greatly sheared and shows a well-developed vertical cleavage striking S. 20° E. This rock also is diffusely mineralized.

As far as may be judged from the present developments, a large body of rather low grade gold ore is present in the lode at the heads of Ruth, Lillian, and Olive creeks. It is unlikely that under present conditions this lode as a whole can be worked at a profit; but more development work may reveal zones of higher-grade ore that might possibly be worked, even under present conditions.

The presence of chromite within this area of mineralization is particularly worthy of note. One small excavation at the surface has exposed a body of chromite, but neither the extent of the deposit nor its relation to the surrounding rocks is apparent from the small amount of work done. It is believed that the chromite has a genetic connection with bodies of serpentine in this vicinity and its presence in association with the gold is therefore regarded merely as a fortuitous circumstance. It appears, however, that the gold-bearing solutions have dissolved and redeposited some of this chromite, as is indicated by the presence of its oxidation products in the mineralized zones near the quartz veins.

On the south side of the ridge between Livengood Creek and Tolovana River, on the headwater slope of Olive Creek, a small landslide has exposed a body of much weathered granitic rock, from which cinnabar was panned.

MINERALIZATION.

There can be little doubt that the mineralization that produced the placers on Livengood Creek was localized mainly on the ridge between Livengood Creek and Tolovana River. The presence of gold in all the streams draining this ridge and its absence in the other tributaries of Livengood Creek afford sufficient proof of this general statement. The occurrence of intense mineralization in the lode deposit at the heads of Ruth, Lillian, and Olive creeks serves as corroborative evidence.

There remains, however, the question of the outer limits to which the mineralization extended. The pyritized condition of the bedrock underlying the bench placers at certain claims on Livengood Creek is essentially similar in nature, though more diffuse, than the mineralization at the gold lode above referred to. It seems probable, therefore, that north of the ridge the bench placers of Livengood Creek may mark the outer limits of mineralization. It is believed, however, that only a very small amount of the Livengood bench gold was residual—that is, derived from the weathering of the underlying bedrock. All the evidence goes to show that it has been transported some distance to its present position.

The presence of a small amount of gold in the upper drainage basin of the South Fork of Hess River and in Moose Creek lends strength to the belief that a diffuse phase of the same mineralization may have extended a considerable distance to the east and northeast. The regional trend of the rock formations lies in this direction, and if, as seems probable, the mineralization was related to structural features, it is not to be expected that the mineralizing effect would be sharply delimited in this direction. Yet in the course of a traverse around the head of the South Fork drainage basin the writer was unable to see any indication of intense mineralization along the ridge tops, nor any bodies of acidic intrusive rocks that would indicate the presence of a gold mineralization. This information, however, is by no means conclusive evidence of the absence of commercial gold placers in that area, for the valleys are wide, and a traverse along the ridge tops represents only a hasty examination of a small area. Nevertheless, the writer is inclined to believe that the more intense phase of the gold mineralization was confined to the ridge between Livengood Creek and Tolovana River.

To the south of this ridge the mineralizing effect is probably rather sharply delimited, as to the north. That this is true is indicated by the failure of the gravels of Steel Creek (south of Tolovana River) to become productive placers, as expected. To the west and southwest, in the Tolovana Flats, the bedrock lies at a great depth, and the continuation of this zone could lie in the basin of the West Fork of Tolovana River. Whether other gold placers lie in that direction has not yet been proved.

The close relation between the mineralization in the vicinity of Livengood Creek and the regional structure is well shown by the geologic map. The regional structural trend in this district is about N. 60° E., but it will be noticed that in the area of the mineralization there is a marked flexure in the rock formations, resulting in the development of a well-defined cross structure that trends about

N. 60° W. The ridge northwest of Amy Dome reflects this structure in its direction of elongation, as does also the contact between the Middle Devonian rocks and the chert formation in the same vicinity. The presence of these two major tectonic lines has also determined the course of Tolovana River, which for 11 or 12 miles flows in a general westerly direction. The valley of upper Livengood Creek also shows a tendency toward a westerly elongation.

The lode deposit above described also shows a structure at variance to the regional structure. The quartz veins have a general strike ranging from N. 20° W. to N. 60° W., and the mineralized country rock has been sheared in a northwesterly direction, to the extent of developing locally northwesterly a cleavage.

The immediate cause of the gold mineralization in the vicinity of Livengood Creek is related to the intrusion of igneous rocks, with the subsequent migration of mineralizing solutions therefrom. Igneous rocks of several kinds occur on the ridge between Livengood Creek and Tolovana River, and the relations existing between the different types are obscure. Consequently, to an even greater extent, are the mineralizing processes difficult to decipher. Certain observed facts, however, have influenced the writer to the belief that the gold mineralization had a more intimate genetic connection with the more acidic types of intrusive rocks on this ridge. One of these facts is the intimate association of soda rhyolite porphyry with the lode deposit and the heavy mineralization of that rock; the second is the presence of cinnabar in decayed granitic material at the head of Olive Creek; and the third is the presence of the conspicuous body of albite granite in the basin of Amy Creek.

Even if the assumption of this genetic association is correct, there yet remain other puzzling features. First of all, there seems to be considerable diversity in the mineralizing effects within the same zone. At the west end of the mineralized ridge cinnabar is present in the concentrates from three creeks, and stibnite and scheelite in the concentrates from one of these creeks; yet at the east end of the same ridge none of these minerals have been reported, and even if they are present they must occur in minor amounts. The type of occurrence at the west end of the ridge suggests a certain similarity to the type of mineralization prevalent in the Iditarod district. Yet no residual placers occur here, as at Iditarod, and the gold mineralization seems to have been connected directly with quartz veins, and only indirectly with the acidic intrusives. The mineralization at the east end of the ridge, however, with the lack or paucity of cinnabar in the concentrates, seems to resemble more nearly the Fairbanks type. Finally, the total absence of cassiterite everywhere in the Tolovana district tends to show that this mineralization is entirely different from the Hot Springs type.

With these anomalous features in mind, the writer does not feel warranted in making any very definite statements regarding the geologic age of the Livengood mineralization, nor regarding its correlation with the mineralization at localities near by. The presence of stibnite, and particularly cinnabar, is interpreted as indicating a Tertiary age for at least a part of the gold deposition, but it seems entirely possible that such an area, characterized by divergent structure and igneous intrusion, might have been subjected to mineralizing effects at more than one period in geologic time. The occurrence of chromite and chrome spinel in the district has a bearing on this point. These two minerals are with little doubt connected genetically with the bodies of serpentine in the Middle Devonian rocks near Livengood, and the serpentine is interpreted as evidence of Paleozoic volcanism. It is not unlikely that this locality was a zone of weakness and a site of chromium mineralization during Middle Devonian time. If this is true, it would not be unreasonable to infer that such a zone of weakness may have been localized in this particular area for geologic ages. The possibility therefore remains that the Livengood mineralization is composite in character and represents the total effect of more than one period of mineralization.