# *The Gold of the Klondike.*

By J. B. TYRRELL, F.G.S.

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The Klondike Gold-bearing district, in which placer deposits were discovered in the summer of 1896, is situated near the extreme north western part of the Dominion of Canada, between North latitudes 63° and 64°, and about fifty miles east of longitude 141° west, which forms the boundary between Canada and the United States territory of Alaska. Its area is not clearly defined, but for the purpose of this paper it may be considered as being about eight hundred square miles, with a width in a north and south direction of 28 miles and a length in an east and west direction of 36 miles.

Strange as it may appear to the majority of readers, this country, though lying so far north, and with an exceedingly rigorous climate, has never been glaciated like the greater portion of Northern North America to the east of it.

During the Glacial Period, the climate must have been severe, and the Rocky Mountains, which form an almost continuous chain running northwest and southeast to the north-east of the Klondike, were at that time covered with glaciers, and the glaciers extended south-westward to the confines of the Klondike country.

At the same time the Coast range of mountains, which forms such a conspicuous feature along the western coast of the continent close to the shore of the Pacific Ocean, was also covered with glaciers, and these glaciers extended north-eastward to the vicinity of the Klondike country, but at no time did they reach it. It therefore lay as part of a long and comparatively narrow region, free of glaciers, except small local ones, between the glacier-covered mountains to the north-east and the higher mountains, also covered with glaciers, to the south-west of it.

Even now, the climate of that country is quite severe, for the mean annual temperature is 22°F.

In winter the temperature occasionally falls to minus 70°F. or even lower, and the mean temperature of December, January and February is—15°F., but in summer the climate is beautifully clear and mild, and the mean temperature of June, July and August is 57°F.

On account of the low annual mean temperature the ground is permanently frozen to a considerable depth, and while this depth does not appear to be the same in all cases, several instances were observed where the permanent frost extended to a depth of two hundred feet, and this may probably be taken as the average depth of frost in the country.

In general character, the Klondike may be considered as being a small and nearly isolated mountainous region lying to the east of the great valley of the Yukon river, to the south of the smaller valley of the Klondike river, and to the west of the still greater valley which runs to the south-west of the Rocky Mountains. On its southern side it is more or less closely connected with irregular mountainous ridges to the south of it, but the valley of the Indian river separates it more or less completely from them, except in the extreme south-eastern portion.

The lowest point in all this region is the bed of the Yukon river, where the Klondike river joins it at the City of Dawson, with an approximate elevation of 1,200 feet above the sea.

The highest point is situated about the middle of the area, twenty-nine miles south-east of Dawson, and is known as the "Dome." This is a hill or mountain with an approximate elevation of 4,250 feet above the sea, or 3,050 feet above the Yukon river at Dawson.

From the Dome the country declines gently in all directions towards the valleys above enumerated, the drainage being carried off by short streams which radiate west, north, east and south, and flow into these larger streams.

The smaller streams are fairly mature in character. Many of them beginning in cirque-like depressions in the vicinity of the Dome, continue outwards with gradually decreasing grades without falls or other sudden interruptions, until they reach their mouths, while the smaller tributaries which join them on both sides flow quietly into them without any sudden changes of grade or without any waterfalls tumbling down from hanging valleys.

The area is completely isolated from any other drainage. No streams cross the district from any mountains or high lands outside of it, and there is no evidence that any streams have ever so crossed the district.

As, therefore, no glaciers have ever reached the country from any of the country to the north, or from the surrounding or adjoining mountains, and as no streams have crossed it, the problems of denudation and transportation which it presents are entirely confined within its own boundaries.

All the loose material which is found on its hills and ridges is derived from the immediate vicinity, and all the sand, gravel, or other detritus which is found in its valleys, was derived from the sides or bottoms of those valleys themselves, and none of it was brought from a distance.

The study of the detrital deposits found in these valleys is therefore comparatively easy and simple, as no extraneous influences have interfered with the regular and ordinary course of natural events that formed them.

*Geology.*—The rocks which underlie most of the gold-bearing district consist of altered quartz-porphyries, and porphyrites, probably of Pre-Cambrian age, which have been squeezed and altered into chloritic and serisitic schists. In most places these are now standing at high angles and are striking in various directions.

Included in these schists, and usually running with their strike, are numerous veins and stringers of light coloured quartz. In some of these veins free gold has been detected, and it would appear probable that most of the gold in the district has been associated with, or has been derived from, these quartz veins.

Both to the north and south of these fissile schistose the rocks are highly altered gneisses or hard quartz-mica schists, containing some bands of limestone. These gneisses, etc., also carry irregular quartz veins, and these veins doubtless also contain a little gold, but they would not appear to contain as much gold as the veins in the chloritic and serisitic schists previously mentioned.

Intrusive masses of igneous rocks, such as granite, peridotite, diabase, andesite, etc., occur here and there around the border of the chlorite schists, but as far as is at present known, there is no definite connection between any of these intrusives and the occurrence of gold-bearing veins.

Overlying all these rocks, except the andesites and their associates, Cretaceous or early Tertiary sandstones and conglomerates occur to the north and south of the chlorite schists. In some cases they would appear to have been somewhat folded and contorted, though not to the same extent as the older rocks.

It has been claimed, apparently on good evidence, that some of these conglomerates contain gold, and they may thus be ranked as ancient placer deposits, but gold has never been found in them in paying quantities, and consequently they have not been studied as fully as the later gravels shortly to be described.

In all these rocks, but especially in the chloritic and serisitic schists, which have been called by Mr. McConnell, of the Geological Survey of Canada, the "Klondike Series," gold is found in greater or less abundance in the quartz veins which traverse them. It has also been found in the schist in minute quantities apparently not associated with the quartz at all.

These facts should be carefully borne in mind, for all the gold in the detrital and placer deposits in the Klondike has been derived directly from these altered rocks occurring in the immediate vicinity of the alluvial deposits.

*Later Dynamic Geology.*—We have seen that the Klondike area is an almost isolated mountain region which has been worn down to its present shape by atmospheric and stream agencies. The history of this area, and the processes by which it arrived at its present condition may be briefly stated as follows:—

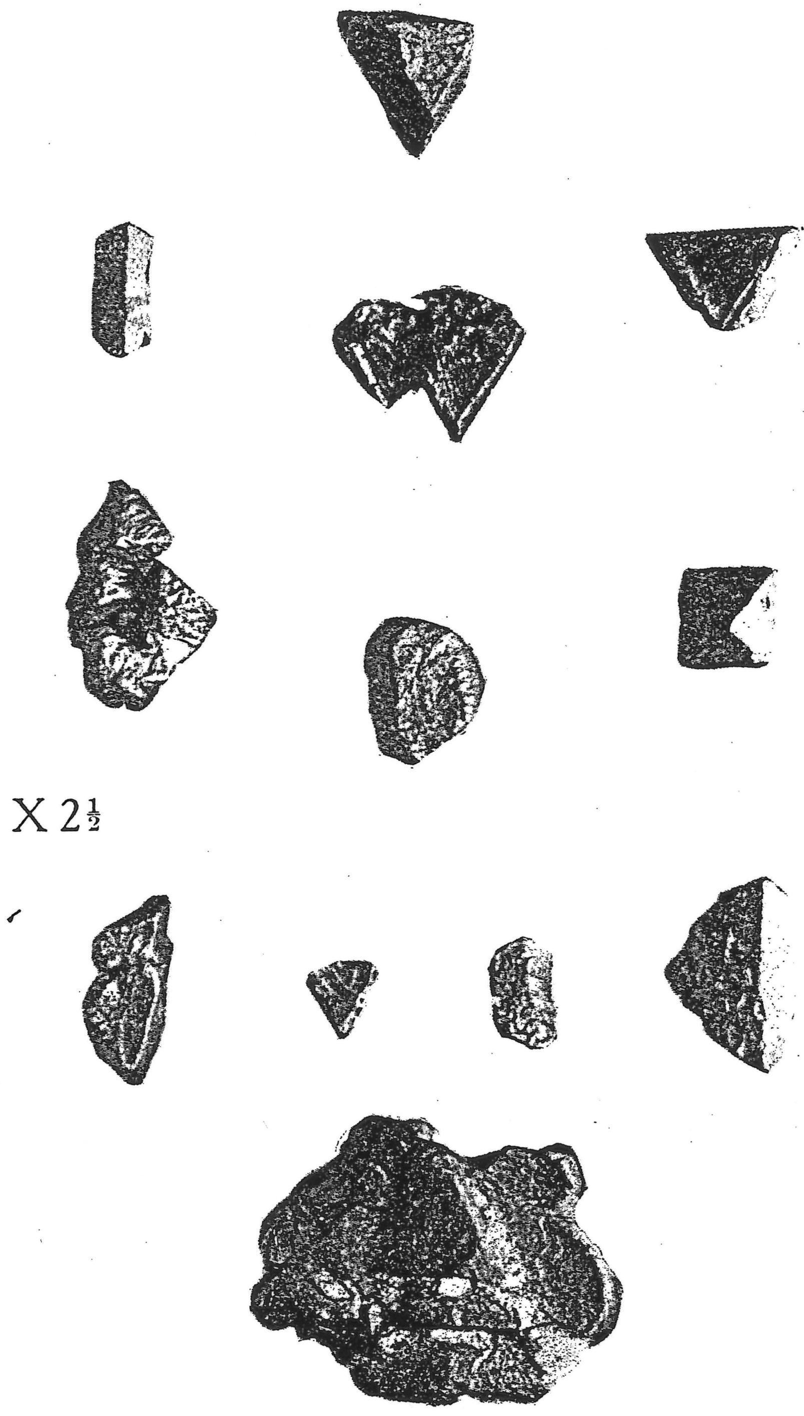
During the earlier part of the Tertiary epoch, probably about later Eocene times, the latest marine sediments were deposited, after which a period of elevation set in which raised the land above sea level. At this time, which was probably about the beginning of the Miocene age, all the rocks which had then been formed or deposited had assumed the crumpled and faulted condition in which they are at present found.

A period of active denudation then began and continued until it had reduced the whole of the Yukon plateau, of which the Klondike area originally formed a part, to a vast peneplain, the remnants of which can still be seen in the vicinity of the Dome and at other places, at a present elevation of about 3,500 feet above the sea. Standing on some of the old imperfect terraces which occur at this elevation, the country is seen to extend in every direction with its higher points and ridges at approximately the same level, and with the valleys forming great trenches in the old peneplain.

The period during which this peneplain was formed may be designated as the "First Cycle of Erosion" and we will call the peneplain itself the "Dome Peneplain," taking the name from the "Dome," the high rounded mountain at the head of Bonanza and Hunker creeks, which formed a little hill on the otherwise moderately even surface of the plain. This peneplain corresponds in a general way with the Klamath Peneplain in California, which has been recently described by J. S. Diller[1] of the United States Geological Survey from the Trinity river basin; through the Miocene rocks included in it in the Yukon territory are probably younger than any rocks that have been recognized in the Klamath Peneplain in California.

After the Dome Peneplain was formed, possibly about the end of the Miocene period, the country was gradually elevated to a height of two thousand feet or more above the sea. Drainage along lines approaching closely to those followed by the present streams was begun;

[1] The Auriferous Gravels of the Trinity River Basin, California; J. S. Diller. U.S. Geological Survey, Bulletin 470, p. 14.




CRYSTALS OF GOLD FROM VICTORIA GULCH
Klondike District, Canada

the great valleys were marked out, and "The Second Cycle of Erosion" was inaugurated.

During this Cycle of Erosion the sides of the valleys were worn down by rain and atmospheric agencies to gentle slopes, and the country received something like its present configuration. In the bottoms of the valleys extensive gravel deposits were accumulated, these deposits being what are now known as the "White Channel Gravels."

The exact age of these gravels has not been definitely determined, as no recognizable fossils have been found in them, but from their general character and position they are considered to be of Pliocene age.

The Second Cycle of Erosion appears to correspond in a general way with Diller's Sherwood Peneplain in California, on which most of the high level gravels of that State were deposited, though the resultant gravels would here appear to be of Pliocene rather than of Miocene age.

The Yukon country can hardly be said to have been reduced to a peneplain at this time; but in order that the period may be definitely referred to it may be here called the "White Channel Period."

The valley of Flat creek would seem to have existed previous to this upheaval, for deposits which appear to be of about this age are extensively developed in it, and the great valleys of the Yukon and of the Klondike may also have been marked out previous to this time; but as yet no deposits of that age have been definitely located in them, and such deposits must necessarily have been formed if these valleys existed.

When the "Second Cycle of Erosion" began, and the land was raised to a higher level above the sea than it had occupied during the formation of the Dome Peneplain, old streams were rejuvenated or new ones were formed. Of these the Yukon river seems to have been the largest and it at once began the downward erosion of its valley, while the water which fell as rain on the adjoining highlands carved out smaller valleys to carry the drainage to the larger river. These small streams, such as Bonanza, Bear, Hunker, Dominion creeks, etc., which radiated from *The Dome*, kept excavating their channels to keep pace with the lowering of the bottom of the valley of the Yukon river, which was the master stream into which they flowed.

During all this time the valleys of these smaller streams maintained the general character of gulches or young valleys, with V-shaped cross-sections. But little gravel or loose material remained on the rock which formed the bottoms of their channels, for it was being constantly moved downward by the current towards the Yukon river, and, on the way, was helping to cut deeper and deeper into the rock over which it travelled.

While this process of deepening the valleys was in progress detrital material was being constantly brought into them by wash from their sides, and by smaller streams from the ridges between them, and, as the rocks from which this material was derived were gold-bearing, the detritus contained a small quantity of gold. Thus gold and particles or masses of rock were fed gently into the main streams.

When the Yukon river had eroded its valley down to base level, the smaller inflowing streams were no longer obliged to continue to deepen their respective valleys to keep pace with it, but were able to cut them down to grade, and then to widen and form flood plains in them, thus changing the V-shaped valleys into U-shaped ones, floored by alluvial plains through which the rivers and brooks meandered from side to side.

At the same time the rock on the sides of the valleys was weathered and broken up by atmospheric agencies and the decomposed rock was carried down into the low lands. These processes continued until a general mature form of topography was the result.

Towards or at the close of the White Channel Period or Second Cycle of Erosion, the Glacial Epoch began and great fields of ice accumulated on the Coast Range of Mountains to the south-west and on the Rocky mountains to the north-east. From these mountains, glaciers or ice-fields flowed inwards over the Plateau country, rounding the tops of the hills and scouring the bottoms and sides of the valleys, but these ice-fields never met over the Klondike district. In the valley of the Yukon the glaciers from the Coast mountains extended only as far north as the mouth of the Nordenskiold river, while those of the Rocky Mountains reached only to the valley of Flat Creek. All the intervening country remained free from ice, except possibly for the presence of small local glaciers at the heads of some of the higher valleys.

During this epoch of glaciation the Klondike district was again raised for at least a few hundred feet, and a "Third Cycle of Erosion" began.

The increase of grade seems to have been first felt by the Klondike river, and to have added greatly to its transporting power. In consequence it was able to bring down and spread over the bottom of its wide valley a mixed deposit of gravel, derived doubtless from the decomposed rock and older gravel banks higher up its valley. After it had carried down this load of gravel which had previously been rendered available for it by atmospheric, and perhaps also by glacial agencies, both it and the Yukon river began to quickly deepen their valleys and at the same time the small streams, such as Bonanza and Hunker creeks which flow directly into these larger valleys, also began to cut gorges in the bottoms of the floors of their old sloping valleys.

These smaller streams continued their downward erosion, and the formation of V-shaped valleys, until the larger streams into which they flowed had reached base level, and then they began the process of lateral planation, and the formation of flood-plains, although the sides of the valleys were still steep and rocky, and they presented a young rather than a mature aspect.

The gravel in the flood-plains of these new valleys is rarely deep, and the material of which it is composed is partly derived from the wearing and breaking down of the adjoining rocks, and partly from the older gravels of the White Channel Period.

These gravels of the Third Cycle of Erosion are of Pleistocene age and contain a large number of bones of mammals, some of which are now extinct. The most abundant are those of a bison, *Bison crassicornis* and the mammoth, *Elephus primigenius*, while the following species have also been recorded:—*Bison occidentalis, Bootherium bombifrons, Mastodon americanus, Ovibos moschatus, Symbos Tyrrelli, Cervus Canadensis, Equus* sp., *Ovis* sp., *Alce* sp., *Rangifer* sp., *Arctotherium yukonense, Ursus* sp., *Canis* sp.

The net result of the erosion accomplished during the Second and Third Cycles has therefore been that a moderately mature style of topography was first formed, with very gently sloping hillsides and heavy beds of gravel in the bottoms of the valleys, and afterwards that some of these valleys were re-excavated and gorges as much as several hundred feet in depth were cut down through the old gravels and into the bed rock, and beds of gravel were reformed in the bottoms of these more gorge-like valleys.

In other places, where, for various reasons, the effect of the last elevation was not felt, the valleys maintained their mature character, and in many instances the beds of gravel in the bottoms of these valleys were somewhat increased in thickness.

The gold of the Klondike occurs originally or primarily in quartz veins in the chlorite and serecite schist, chiefly of the Klondike Series, as defined by Mr. R. G. McConnell.

These quartz veins are usually lenticular in shape, and rarely continue for more than a few feet in horizontal length. As a rule very little gold can be seen in them. As a result of a number of assays I found that while they usually showed traces of the metal, they rarely contained more than $1 to the ton. In some cases, however, notably in some quartz veins near the heads of Gay and Victoria gulches, two tributaries of Eldorado and Bonanza creeks, these veins were seen to contain coarse nuggety gold associated with pyrite. Some of it was distinctly crystaline in character, and among the crystals were a number of small triangular plates representing "spinel twins," the twinning being parallel to the octahedral face of the crystal. I had found some of these crystals in gold dust brought from Victoria gulch in the early days of mining in the Klondike, and afterwards, while examining the quartz veins at the head of the gulch, in company with Professor Henry A. Miers, F.R.S., we found a few more crystals of a similar character. Some of the crystals found on Claim No. 7, Victoria gulch, are represented on Plate I.

In addition to the gold found in the quartz veins it is possible that some is associated with the schist itself. But none of the quartz veins so far discovered have proved rich enough to be worked at a profit, and the gold production of the Klondike has been derived exclusively from its placer deposits.

## PLACERS.

Placer deposits may be defined as "Detrital deposits of heavy metals or minerals mechanically concentrated by natural agencies."

Professor James Geikie defines a placer as "an alluvial deposit derived from the disintegration of metaliferous rocks and ore-bodies of various origin."

Richard Beck[1] defines placer deposits as follows:—"Placer gravels are deposits of loose, more or less rolled, material derived from the destruction of older deposits, lying on the earth's surface, or at least very close to it, and containing paying amounts of ore or precious stones.

"As the material composing placer gravels has been exposed to all the influences of the atmospheric air and of the water seeping through the upper strata of the soil, placers will be found to contain, in the main, only relatively insoluble, and in general refractory metallic compounds which, moreover, are protected by their great specific gravity against easy removal by water.

"These placer gravels are usually grouped into two classes, according to their position with reference to the deposit from which they are derived, and in part, also, according to the manner of the original process in which they are derived from the primary ore deposit:

"1. Residual gravels, i.e., of local origin.

"2. Alluvial gravels, i.e., formed by washing. These may again be sub-divided according to age into Recent, Pleistocene and Tertiary gravels.

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[1] "The Nature of Ore Deposits," by Richard Beck. Translated by W. H. Weed, 1905; pp. 617-618.

"Residual gravels, the rarer of the two groups and certainly the less extensive, are found in the immediate vicinity of the original ore deposits, and quite independent of water courses, viz., on mountain slopes, plateaus and sometimes even on mountain summits.

"On the contrary, the gravels formed by the transporting and washing action of water are found only in the channels of brooks and rivers, in fresh water lakes or along the sea-coast. They lie for the most part within the present valleys or along the present shore, but are also often found in stretches of fluviatile sediments, sometimes intersecting the present direction of the valley on old river terraces, or in sheets covering plateaus (California, Ohlapian in Transylvania) and finally in old shore terraces above the present level of the sea. Their material is always much rolled, and for the most part is assorted, according to the size of the ingredients, into shingle, gravel, sand, clay, mud, etc."

The Yukon Placer Mining Law gives the following definition:—"Placer Ground means any natural stratum or bed of earth, soil or gravel, containing gold or other valuable mineral or stones, derived from the disintegration of older deposits, and transported to, and concentrated in, their present position by the mechanical agency of water, but does not include mineral in place, or as defined in Part III, or the disintegrated portion of a vein, lode or rock, lying above or about such vein, lode or rock and clearly derived therefrom." This is entirely too narrow for a general definition of Placers, because, while those in the Yukon have been chiefly formed and concentrated through the agency of water, some few are composed of residual or slidden material, while in other countries instances have been recorded of Moraines formed in front of a glacier being profitably worked as Placer Ground. If amended by the addition of the words "or other natural forces "after" agency of water" the definition would be improved.

Generally speaking, however, the Placers of the Yukon are gravels which have been formed by the wearing down and redeposition of the rocks of the immediately adjoining country.

Of the processes which enter into the formation of Placer deposits, the following are the most important:—First, *Rock decomposition and disintegration, or weathering*; Second *Transportation;* Third, *Concentration;* and Fourth, *Deposition.*

*Decomposition* and *Disintegration.*—In considering the disintegration or decomposition of rocks, and especially of the igneous rocks in which the component particles lie close together, it must be borne in mind that these particles are as a rule composed of different minerals which differ in structure, hardness, coefficient of expansion with heat and cold, solubility etc.

The decomposition which we are now considering is that affecting the surface of the rock exclusively, and not that which may be caused at depth by the influence of juvenile waters or other deep-seated agents. It occurs from the surface downwards to moderate distances, and is usually known as *weathering*.

Dry air has little influence in breaking up or altering the texture of rocks, except in so far as it may conduct heat or cold to them, though heat and cold have a powerful influence in breaking the rocks to pieces. In countries such as the Yukon the diurnal changes of temperature are often very great, for the sun at mid-day in the spring or early summer may shine down on the naked surface of the rock and heat it to a temperature of one hundred degrees F., or more, while at night the temperature may fall to zero. With such sudden changes in temperature the different minerals expand differently and soon loosen themselves one from the other and break the rock to pieces.

An instance of this breaking down of the rock with sudden changes of temperature may be seen every year in the steep cliffs over-looking the Yukon river opposite Dawson. About the middle of November the river freezes over and is covered from that time until the following spring with a sheet of ice which extends to the foot of the cliffs. Masses of rock break away from the face of the cliff under the influence of unequal expansion caused by changes of temperature and fall on the ice, and before the ice melts in the spring, a talus, composed of these rock fragments, extends far out over it. When the ice breaks up and is carried away by the stream these rocks are carried away with it. This action doubtless goes on in summer as well as in winter; but in the former season a talus does not accumulate. It is quite probable that water and ice lodged in crevices in the rock has much to do with the breaking away of the rock fragments, but undoubtedly the heating and cooling of the rock itself is the controlling factor.

In some countries the wind carrying a load of sand and dust has also a considerable influence in breaking down the surface rocks; but this influence is not effective to any considerable extent in the Yukon Territory.

While the atmosphere thus exerts some influence in the breaking down of the original hard rocky surface of the earth, the principal agent in the formation of sands, clays and other loose deposits is water, either as it falls in the form of rain, or as it percolates through underground passages, or as it flows away in rivulets and streams.

Pure water has little influence in rock decomposition, but when it falls in the form of rain it dissolves carbonic acid out of the atmosphere, and this carbonated water in its turn readily dissolves any lime carbonates from the rock on which it falls and carries them away with it, rendering the rock porous. Water also exerts a considerable influence on the feldspars and alkaline constituents of the rocks, dissolving out their more soluble parts and leaving the alumina and oxides of iron behind to form a fine clay.

Oxygen in the atmosphere is also carried down by water and is assisted to combine with many of the constituents of the rocks, raising the protoxides into peroxides, etc.

Water also combines with some of the constituents of rocks to form hydrated compounds, and in many cases the earth or soil so formed by combination with water occupies a much larger space than that occupied by the original rock itself.

In addition to the above more or less chemical action of water in the formation of loose earth, the freezing of the water contained in the rock itself, or included in cracks or fissures which have been formed in it, exercises a very powerful influence in its disruption. Some granites contain about half of one per cent. of their weight of water in their composition and quartz occasionally contains a much larger proportion than this. When freezing, water expands about nine per cent. and the force of this expansion is almost irresistible, especially against any pressure which may be exerted near the surface of the earth. The pressure exerted by such freezing is about 150 tons, or 300,000 lbs. to the square foot, and while the spaces occupied by the ice may be very small, if they are confined or tightly enclosed the expansion engendered is irresistible.

In addition to the expansion of water with freezing, the expansion of ice itself after cooling and on subsequent heating is very great, being about .00003 per cent. for every increase of one degree Fahrenheit.

Organic agencies also help to loosen and destroy the surface of the rock. Lichens growing on it keep it damp, and not only dissolve the rock themselves but retain the water which settles on it so that it can have time to dissolve out part of its constituents. Larger plants send their roots into very minute fissures and with increase in growth wedge portions of the rock apart, and in this way break it to pieces.

When hard rock, of which the earth is chiefly composed, has been broken up, loosened and softened by weathering, the material remaining on the surface is known as residual sand, clay etc. In some cases these residual deposits may themselves form workable Placers, especially where all the soluble carbonates and other similar rocks have been dissolved away by percolating waters.

Such residual deposits are known in Southern countries as Laterites.

In some of the higher gulches, however, and more especially in the upper portions of Victoria Gulch, one of the tributaries of Bonanza creek, where these residual sands and clays are present, they have moved by a creeping motion down the bottom of the gulch, and the gold has gradually sunk to the bottom of the loose material as it moved, so that in this gulch there were at one time several mining claims which contained small but rich pay-streaks of gold, and the material over-lying these pay-streaks was not water-worn, but was rather the slidden material spoken of above.

On all the higher parts of the Yukon country above the level of the White Channel deposits, such residual sand and clay covers the rock to a varying thickness. In some cases the thickness is probably only a few feet, while in other cases it is much greater. I knew a shaft to be sunk in residual material to a depth of sixty feet, and while it is not probable that weathering extended much below that depth, its exact downward extent was unknown.

*Transportation.*—As seen above on page 32, this whole country once formed a moderately even plain at what is now a height of about 3,500 feet above the level of the sea. Since that time it has been reduced to its present configuration. The rocks were softened by weathering and were then transported by the agency of water down the slopes, and finally for the most part into the ocean. The weathering kept well in advance of transportation, so that the hills are still covered with softened rock.

The primary force which causes this downward movement of loosened material is gravity, but the presence of water helps to loosen and separate the particles of the rock from each other, and to allow the force of gravity to be transformed into motion. This influence, of course, differs on different portions of the rock, varying according to the relative weights or specific gravities of the various substances. For instance, the force of gravity exerts a far greater influence on gold, which has a specific gravity of 19, than it does on quartz, which has a specific gravity of only 2·6.

If water is included in the loosened or weathered rock, it causes it to move gently and slowly downwards. This movement is known as "creep," and almost all slopes are affected by it. A typical instance came under my observation on one of the hills adjoining Bonanza creek. A narrow dyke of dark basic rock cut vertically through the light green chloritic schists which formed the country rock of the district. When within ten or fifteen feet of the top, it turned sharply sideways towards the face of the hill and ran horizontally until it reached the surface, being quite clearly distinguishable from the lighter coloured rock all the way. It had been originally vertical throughout; but the creep of the upper softer portion of the schists which enclosed it had turned it over so that its upper portion assumed a horizontal attitude.

This creep has a considerable influence on the formation of Placer deposits, as it tends to constantly move the loosened soil and earth down from the hills into the bottoms of the valleys.

But the principal agent in the transportation of the loosened rock, and also in its concentration, is water flowing on the surface, either in minute rivulets or in larger streams.

After a heavy fall of rain little rills are formed all over the ground, and these flow downwards, carrying a load of mud with them, and gradually join together into larger streams, and finally into brooks and rivers. As they become larger with a constant slope they increase in velocity and consequently have greater carrying power.

*The following table gives the carrying power of a stream as exerted on quartz or rock of similar weight:—

| Velocity of Current. | Size of material moved. |
|---|---|
| 3 inches per second = 1/6 mile an hour. | Fine clay and silt. |
| 6 " " " = 1/3 " " " | Fine sand. |
| 1 foot " " = 2/3 " " " | Pebbles ½ inch in diameter. |
| 2 feet " " = 1·3 " " " | " 1 " " " |
| 2·82 " " " = 1·9 " " " | " 2 " " " |
| 3·46 " " " = 2·3 " " " | " 3 " " " |
| 4 " " " = 2·7 " " " | " 4 " " " |
| 4·47 " " " = 3 " " " | " 5 " " " |
| 4·90 " " " = 3·3 " " " | " 6 " " " |
| 5·29 " " " = 3·6 " " " | " 7 " " " |
| 5·65 " " " = 3·9 " " " | " 8 " " " |
| 6 " " " = 4 " " " | " 9 " " " |

With rocks of equal specific gravity the carrying power of a stream varies according to the square of the diameter of the pebbles; or the volume of the pebbles which can be carried by a stream increases in the sixth power of its velocity; that is if the velocity is doubled, the diameter of a pebble which can be carried is increased four times, and the volume sixty four times. Conversely when the current is reduced one half, the volume of a pebble (weight being equal) is reduced sixty four times.

Thus a very slight increase in velocity greatly increases the carrying power of a stream. For instance, a stream flowing at one mile an hour has power to transport particles of a certain size, and if that stream

*Rivers of North America. By I. C. Russell. New York, 1909, pp. 18-19 increases in velocity to a mile and an eighth an hour, it becomes capable of carrying particles of double the volume, while if the velocity is decreased from a mile and an eighth to one mile an hour its transporting power is cut in two.

In this connection it must be borne in mind that the effective weights of different substances are not the same in water as in air. For instance, quartz which has a specific gravity of 2·6 has a specific weight in water of only 1.6, while gold which has a specific gravity of 19 has a specific weight in water of 18. Gold is therefore 7·3 times as heavy as quartz in air, while it is 11·25 times as heavy as quartz if weighed in water. It is therefore the specific weight in water of different substances which must be considered in connection with their transportation by water, rather than their relative weights in air. If the specific gravity is constant, the diameter of the pebbles which a stream can carry will vary as the square of the velocity, and if the velocity of the stream remains constant, the size of the pebbles will vary according to the specific weight of the substance composing them weighed in water. Thus, if one pebble is of quartz and another is of gold, which is 11·25 times as heavy as quartz weighed in water, the volume of a pebble of quartz which can be carried by the current will be $11{\cdot}25^2$ or 126 times as great as that of a pebble of gold and, assuming both pebbles to be cubes the diameter of the pebble of quartz will be approximately five times the diameter of the pebble of gold.

With pebbles of quartz and gold of equal size it will take a current of $\sqrt{5}$ or 2·24 times the velocity to move the gold which it will take to move the quartz.

Again, if pebbles of quartz and gold of equal size are dropped into water the latter will sink to the bottom with more than three times the velocity of the former.

Now the quantity of material, or load, which can be collected by running water from the ground when it is covered with vegetation is relatively small, but when vegetation is absent and weathered rock is exposed to the direct influence of the rain and running water the load will often be very large, and consequently streams which carry away the wash from bare but weathered surfaces are often loaded to their utmost capacity.

In addition to the work done by water in carrying away weathered and softened rock, the streams themselves cut down their channels into the hard unweathered rock.

Where the water in the streams is clear and carries but little sediment this cutting action is very slow, or almost nil, but where it carries any considerable amount of sediment this sediment is pushed along on the bottom over the rock, and wears it down like a file, so that the bottoms of the streams, which are in this way deepening their channels, rarely, if ever, give evidence of the presence of a weathered layer of rock.

In the Klondike district it is certain that the valleys, both during the Second and Third Cycles of Erosion, were cut down by this process of downward erosion as narrow V-shaped gorges through unweathered rock to base level.

By the processes of erosion and transportation, the old Dome Peneplain has had deep and wide valleys cut in it, and most of the material derived from the cutting out of these valleys has been carried away beyond the limit of the district, either to the Ocean or to some lower-lying land.

The lowest point in the Klondike area, which we are now considering, may be taken as the bed of the Yukon river at the mouth of the Klondike river, opposite the city of Dawson. In 1898 this was calculated by the author to be at a level of 1,200 feet above the sea, the calculation being then based on the assumption that the Yukon river from Lake Bennett to its mouth flowed in a parabolic curve. Since that time no exact measurements of the height of Dawson have been made, but a number of approximate levellings would indicate that the height so calculated in 1898 is not far from correct. The highest point in the area is the Dome, with an elevation of 4,250 feet above the sea.

Some years ago a contour map on the scale of two miles to the inch, with contour intervals every hundred feet, was prepared by Mr. R. G. McConnell and his associates of the Geological Survey of Canada. Some corrections were made to this map by the writer and then the area of each contour line was computed. Summing these areas together it was found that the district had a mean elevation of 2,600 feet above the sea. Assuming that the Dome Peneplain had a mean elevation of 3,500 feet above the sea, which is the elevation of those remnants of it which can be clearly distinguished, the country has been reduced under the influence of atmospheric and water erosion from 3,500 to 2,600 feet above the sea. This computation may be not strictly correct, for the Dome Peneplain may have sloped off towards the surrounding valleys, so that portions of it may have been lower than its remnants which are now recognizable, but on the other hand parts of it may have been higher than those parts which remain, and therefore it is probable that an elevation of 3,500 feet is not far from correct.

Taking a total area of 800 miles for the entire Klondike district and assuming that we are correct in our calculation that the country has been reduced 900 feet on an average, it would appear that 136 cubic miles, or 1,600 billion tons, of rock have been removed from this area since the downward erosion of the Dome peneplain was inaugurated.

The work of removing this enormous quantity of rock must have taken a very long time, for it is not likely that rock weathers as quickly in that far Northern country as it does farther South, and streams which are frozen to the bottom for half the year cannot cut down their valleys as quickly as those which have the whole year to work in. Besides that, the ground in the north has a tendency to be covered by a thick growth of sphagnum moss and other low vegetable organisms which prevent the water from wearing the surface away. In the valley of the Mississippi it has been found that the country is being worn down at an average rate of about one foot in 4,000 years. If this rate is applied to the Klondike district it would mean that it has taken 3,600,000 years to reduce the Dome Peneplain down to the present configuration of the country. However, I am satisfied that the Yukon river does not carry away as much sediment as the Mississippi, and especially is this so if the glacial mud, which is brought down by the White river and other similar streams from the mountains, is eliminated from the computation. If the Yukon and its tributaries have eroded and reduced their valleys in past times at the same rate that they are eroding to-day, it is probable that a rate of one foot in 6,000 years, or even more, should be applied, in which case the time needed for the erosion of the Klondike district to its present shape would be 5,400,000 years or more.

*Concentration and Deposition.* I have shown that the Klondike area was gradually worn down as an individual unit from the Dome Peneplain to its present shape in two successive periods, which have been here called respectively the "White Channel Period" or "Second Cycle of Erosion" and the "Recent Period" or "Third Cycle of Erosion." Both these periods may have been made up of two or more sub-periods, though that question has not been discussed here. Of the two main periods, the former, or White Channel Period, was very much the longer, and the greater portion of the erosion was performed during it.

While the erosion was in progress the eroded material was being carried down into the valleys and thence outwards to or towards the sea.

At first the streams were actively deepening or wearing down the bottoms of the valleys. Therefore these valleys were in the form of V-shaped gulches, from which all the finer and lighter material was being carried away, while the heavier particles, such as gold, magnetite, etc. were being scattered along the bottoms of these narrow valleys.

The particles of gold contained in the gravel or sand would be carried along by the water of the streams, over any smooth rock, until they would settle into crevices in the rock itself or into spaces between or among large loose rock masses, from which places they could not be dislodged except by upward currents. Such currents would first lift pebbles of quartz or similar rock less than five times the diameter of nuggets or particles of gold, before they would lift the particles of gold, even if the quartz and gold were equally accessible. But as a rule they are not equally accessible, for the lighter rocks being larger would stand higher than the particles of gold, and the spaces between them would hold and protect the smaller masses of the heavier metal from the current.

Thus the removal of gold by currents, after it has once been lodged, becomes exceedingly difficult as long as the crevices or spaces in which it is lodged persist.

While a stream keeps cutting its channel downwards new crevices or lodgment places are being constantly developed in the rock beneath the old ones which are being cut away. The gold keeps working down or dropping into them, and thus it moves almost vertically downwards with the deepening of the valley. In this way a streak or band of rich gold-bearing gravel would be formed in the bottom of the narrow valley, distributed in the crevices of the rock and in protected places immediately on top of it.

After the stream had cut the bottom of its valley down to grade or base level, and had ceased the process of vertical erosion, it would begin to cut laterally and to widen the bottom of the valley so formed, and to deposit sand and gravel in the form of flood-plains on it.

During this process of lateral erosion, the gold, which had already been collected from all the surrounding country into the bottom of the V-shaped valley, would be, to a large extent, below and out of reach of the influence of the meandering stream with its slower current. The stream would, however, continue to widen its valley and to extend its flood-plain and in many cases to build this flood-plain up to greater and greater thickness.

In this way we can see how such pay-streaks as that of the White Channel gravels of Bonanza Creek have been formed. They represent the gold collected in the old V-shaped valleys of that period, while the great thickness of gravel above and on both sides of them was deposited after these pay-streaks were formed.

Gold is usually not entirely absent from the upper and lateral gravels, for some of the precious metal was being constantly washed down from the adjacent hills with pebbles of quartz, schist, and other rocks; but the coarse gold of the pay-streak on and in the bed-rock was collected into its present position before the gravel was deposited on top of it, and it was not concentrated out of the gravel above it, as has often been assumed.

It may therefore be accepted as a definite law, that *pay-streaks were formed on, and indicate the positions of, the bottoms of old V-shaped valleys.*

If the bottoms of the present valleys are much wider than the pay-streaks, this greater width represents the amount to which these valleys have been cut out by lateral erosion after they had been originally outlined to their present depth, and the gravels with which these valley bottoms are covered are later in age or newer than the pay-streaks.

For instance, the old pay-streaks in the White Channel gravels on Bonanza and Hunker creeks which are well shown on Mr. McConnell's map accompanying his "Report on Gold Values in the Klondike High Level Gravels," run in very straight lines approximately down the middle of the old valleys, though possibly a little nearer their western than their eastern sides. The outlines given on that map for the approximate original boundaries of the White Channel gravels show the widths of the old flood-plains, and the extent of the gravels deposited over and around the pay-streak. The pay-streaks mark the positions of the bottoms of the original V-shaped valleys, and the gravels are flood-plain deposits which were subsequently laid down over and around them.

Similarly the pay-streak can be traced down the bottom of the present valley of Bonanza creek, marking the line of the bottom of the old V-shaped valley. In places this old valley bottom at one time crossed terraces in the present valley and then short strips of the pay-streak were left across these terraces. Later, as the stream deepened its valley the bottom swung round the terraces. Very often the pay-streak is not so rich around these curves, for it had to start anew without any gold to work on. The gold which is contained in this new portion of the pay-streak is therefore not that which descended vertically with the growth downwards of the valley, but is rather that which was brought down the valley by the stream after the terrace was formed, or the little which was brought into it from the sides.

At the present time I am collecting information on the presence of these low terraces and their influence on the value of the pay-streak in the adjoining deeper valley; but the matter is not yet ready for publication.

In this connection attention may be drawn to the fact that while the gold and the heavy minerals associated with it in the pay-streak, represent a concentration from the whole of the material first eroded from the Dome Peneplain, that in the overlying and surrounding gravels only represents a concentration from the surface of the country after the present valleys were cut down to base level at practically their present depths, and after flood-plains began to form in them.

It may also be interesting to point out that the law above annunciated, namely, that the pay-streak marks the bottom of the old V-shaped valley, should be of interest to all students of Physical Geography, since, wherever it can be found, it furnishes a datum line from which the growth of the valley outwards can be followed and studied. Even where a pay-streak carrying gold is not present in a valley, a band of heavy minerals or coarse rock fragments might be detected which would indicate the original position of the bottom of the V.

It is not improbable that gold may have a tendency to settle down through gravels and to collect on the bed-rock below them; but this tendency exerts a minor influence in the formation of workable placers.

In McConnell's Report, pages 9 and 10, the gold values per cubic yard of two columns of gravel are given, taken from the hills beside Bonanza and Last Chance creeks, one 159 feet high and the other 90 feet high. These columns were unfortunately taken over the pay-streaks in which the gold existed before the gravel was deposited over it; but omitting the lowest 6 feet in each column which appear to contain the pay-streak, the rest shows an increase in value downwards, in the one case from .6 cent to the cubic yard to 18 cents a cubic yard, and in the other from .7 cent to the cubic yard to 11.4 cents to the cubic yard.

In the first column the total amount of gold contained in the upper 51 yards is \$1·27, while the lowest 2 yards contained \$8·26. In the other column the upper 28 yards contained \$1·07, while the lowest 2 yards contained \$4·40.

These values may give some indication of the relative amount of gold which was concentrated into the valleys, first, in the earlier stages of erosion when the pay-streak was formed, and the lighter material was carried away, and secondly, in the more mature stages of erosion, when the pebbles of quartz and other rocks were deposited with the gold.

The upper gravels probably contain almost all the gold that was eroded out of the rocks of the surrounding country while these gravels were being deposited, and if we knew the relative sizes of the particles of gold in the gravels and in the pay-streak, we might be able to form some idea of the percentage of the gold which had been worn out of the rock of the country and had been collected in the pay-streak; but unfortunately this information is not available at the present time. However, it is quite certain that the gold in the gravel is, on the average, much finer than in the pay-streak, and as the gravel gold doubtless represents closely the general character of that contained in the country rocks, we must assume that in the pay-streak much of the finer gold has been carried away, and that the coarser particles are all that have been left.

It is hoped that it may be possible to compare these two runs of gold more fully at some future time.

If the erosion of a valley were to continue downwards uninterruptedly in rock of similar character throughout until its bottom should have reached base level before the stream which formed it began to erode laterally, the gold would be distributed in a continuous line along the bottom of such a valley and when the stream had afterwards widened it and had formed alluvial flats and flood-plains the pay-streak would be continuous through and under these alluvial flats.

But streams rarely, if ever, deepen their channels uninterruptedly in this way. Harder bands of rock cause obstructions, and elevations and depressions of the land cause the water to flow with different velocities at different times, so that at one time, or in one part of its channel, a stream may be cutting into the bottom of its valley, while at another time and in another part of its channel it may be filling it up and covering it with alluvial sand and gravel.

In this way a stream with a valley of any considerable depth has probably formed a number of flood-plains at different periods in its history, and remains of these flood-plains may often be seen as terraces on the sides of its valley.

When a stream has formed a flood plain the pay-streak will, as we have seen, run beneath that flood plain on a line marking the original bottom of the old V-shaped valley and if, when the stream again begins to cut through this flood plain and into the rock beneath it, it follows the line of the former stream, or, in other words, if it follows the line of the pay-streak, it carries the pay-streak down with it; but if it diverges from this line, a portion of the pay-streak remains on the terrace. If it continues to deepen its channel until all the terrace is removed, or at least until that portion of it is removed which contains the pay-streak, the gold will also all be in the pay-streak in the bottom of the new valley, but if it reaches a new base level before the pay-streak is all removed from the terrace a new condition is introduced. The stream may begin to cut into the side of its valley and may cut into and remove the old terrace containing a portion of the old pay-streak. In that case, the gold may drop down into the bottom of the valley with the eroded rock and gravel and form a rich pocket at one side of, and often quite off the line of the original pay-streak or it may be distributed along the channel which the stream happens to be following at the time. If the renewed stream happens to cut into the old valley bottom to one side of the original pay-streak, or across it at several places and to diverge from it at a number of other places, the new pay-streak may be weak and indefinite, or it may be rich in spots and very poor between those spots, with other rich spots to one side or the other. In fact, it may assume a variety of characteristics, according to the manner of growth of the valley in which it has been formed.[1]

From these considerations it may be seen that continuous and regular formation of a valley will tend to the existence of a regular pay-streak, while discontinuous and irregular growth of a valley will form an irregular and disjointed pay-streak with many lateral apophyses.

In some cases it may happen that the rejuvenated stream will abandon the old valley altogether and in this way be removed from the influence of the old pay-streak. An example of this condition occurs on the lower portion of Bonanza creek, where, at about claim 80 below Discovery, the new valley leaves the old one, the stream having turned Westward to cut out an independent channel through the country rock. As the creek during this later stage of its existence gathered but little gold from the rocks of the surrounding country, but rather depended for the richness of its placers upon that which had already been collected into the pay-streak of the White Channel period, and as in leaving the old valley it had here left this old pay-streak entirely, the gold which occurs on this lower portion of Bonanza Creek has either been carried down the Creek itself from the higher parts of its valley, or has been brought into it by the stream flowing from Lovett Gulch which taps the White Channel pay-streak. The pay-streak is consequently not as rich here as it is farther up Bonanza creek, where it is directly beneath the former position of the old White Channel pay-streak, and contains much of the gold which that pay-streak formerly contained.

When we recognize that a pay-streak was formed in the bottom of a V-shaped valley at a time when that valley was being actively deepened, and when the bottom of the channel of the stream was composed of the hard unweathered rock of the country, we can readily appreciate the influence that the character of the rock would have on its richness or poverty.

If the rock were hard and smooth the gradient of the stream would in that case continue higher that the average until base level had been reached throughout, the current would consequently be stronger, and the gold and coarse gravel would tend to be carried down to a more favourable location for settlement.

If, on the contrary, the rock were soft and fissile the gradient would be lower than over hard rock, the current of the stream would be slacker and the gold would have a better opportunity to settle down into the fissures and joints that form riffles to collect it.

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[1] See paper by the same author on *The Law of the Pay-streak*, with illustrations, in Trans. Inst. Mining and Metallurgy, Vol. XXI (1912) pp. 593-605.

The conditions would be similar to those in a sluice-box. If the water flowed over a smooth bottom the gold would be carried away, and if it flowed over a rough and broken bottom with many openings in it, the gold would settle down in these openings.

As the stream cuts down into the bottom of its valley it will not under ordinary conditions, again pick up this gold that has settled into the fissures, except in cases where the supply of gold becomes too great for the natural riffles to hold, but rather as the surface of the rock is gradually worn down by the stream, the gold will be allowed to settle deeper and deeper below its original point of sedimentation. For instance, if gold particles have settled in fissures in a schistose rock these particles will continue to sink vertically for hundreds of feet if the fissures continue to persist, as long as the stream continues to deepen its channel on the same course.

*Local Characteristics.*—The placers of the Klondike which have all been formed by fairly continuous erosion and sedimentation in the bottoms of valleys, divide themselves naturally up into two sub-divisions namely, the gravels of the "White Channel Period" or "Second Cycle of Erosion" and the gravels of "The Recent Period" or "Third Cycle of Erosion."

*Gravels of "Second Cycle of Erosion."*—These gravels have been well described by Mr. R. G. McConnell, and we cannot do better than quote his description of them:—

"The White Channel gravels differ somewhat from the ordinary type of stream deposit. They are very compact as a rule and in some of the hydraulic cuts stand up in almost vertical cliffs, even when the face is unfrozen. The white or light grey coloration from which the deposit derives its name is very conspicuous in most of the sections but is not universal, as red, yellow and dark grey beds frequently occur. The deposit is highly siliceous, the principal constituent consisting of rounded pebbles and rounded and sub-angular boulders of vein quartz. Flat schist pebbles and boulders, usually in a more or less advanced stage of decomposition, occur with the quartz, and also occasional pebbles derived from the various dikes and stocks outcropping along the valleys. No material foreign to the district occurs in the deposit. The pebbles and boulders are usually small, seldom exceeding eighteen inches in diameter, and are embedded in a compact matrix consisting essentially of small sericite plates and fine angular quartz grains. A few large angular blocks from three to four feet in diameter are occasionally met with but are rare and usually occur on or near bedrock.

"The uniformity of the deposit in composition and general character throughout sections a hundred feet or more in thickness is very striking.

The bedding planes, as a rule, are inconspicuous, and there has been no sorting of the various constituets into separate beds.

"The deposits, unlike the creek and gulch gravels, appear to be destitute of vegetable and animal remains. None were found by the writer and the few reported discoveries by miners lack confirmation.

"The thickness of the White Channel gravels varies from a few feet to 150 feet and the original width from a couple of hundred yards to over a mile. The volume of the deposit on both Hunker and Bonanza creeks increases steadily down stream.

"On Gold, Adams and other hills on Bonanza creek the typical compact white variety of the White Channel deposit is replaced towards the sides of the old valley by flat rusty coloured gravels, more loosely bedded and containing a smaller proportion of quartz than the ordinary white variety. These probably represent flood plain deposits. They have the appearance of overlying the white variety and were formerly, in the absence of sections, considered to be younger. The long exposures, however, now available for study in the various hydraulic cuts, show that the two varieties pass gradually one into the other both horizontally and vertically and in places are interbanded, evidence of contemporaneous deposition. The loose yellow variety is seldom productive.

"The age of the White Channel gravels has not been determined, but they must take back to the Pleiocene at least. They were certainly deposited before the advent of the present severe climatic conditions, as the white coloration is largely due to the leaching out of the greater portion of the iron by circulating surface waters, and this must have taken place before they were permanently frozen."[1]

"On Dominion creek and its tributaries, Sulphur and Gold-run creeks, white gravels, almost identical in character with the high level White Channel gravels of Bonanza and Hunker creeks, occur in the bottoms of the valleys underlying the present stream gravels. Their low position is due to the fact that the present valley of Dominion creek, corresponds, not to the present valley of Bonanza and Hunker creeks, but to the old valleys cut through by them."[2]

On the tributaries of the Klondike river these White Channel gravels are, as far as at present known, confined to one level, but on Indian river in the vicinity of the mouth of Australia creek, they are found not only on the bottom of the valley, but they also occur on a wide terrace.

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[1] Rep. on Gold Values in the Klondike High Level Gravels, by R. G. McConnell, Geol. Sur. Can. Ottawa, 1907, pp. 7 and 8.

[2] Rep. on the Klondike Gold Fields, by R. G. McConnell, Geol. Sur. of Canada, 1905, p. 32.

which runs along its south side from 150 to 250 feet above the level of the river. The gravels in the terrace are, as a rule, from 10 to 30 feet or more in thickness and are quite loose and uncemented. In fact, they are so easily broken down and so dry and well drained that it is difficult at times to believe that they are actually somewhat older than the tighter and more compact gravels near the river.

These upper gravels, therefore, apparently represent an old flood-plain deposit of the White Channel period or Second Cycle of Erosion. Like the rest of the White Channel gravel, they have a small quantity of gold distributed through them, but up to the present time no pay-streak has been found on this terrace, so that probably the bottom of the V-shaped valley of that early terrace period ran to the North of them.

*Gravels of the Third Cycle of Erosion.* These gravels are found in the bottoms of the more recent valleys and on the terraces on the sides of these valleys below the level of the White Channel gravels.

As we have seen, the streams flowing Northward into the Klondike river have cut gorge-like valleys into the bottoms of the old mature valleys of the Second Cycle, while those flowing southward into the Indian river have not been able to cut such gorges but have continued to flow in the old valleys, and for the most part at the old levels.

In the Klondike tributaries the new valleys are narrow, and there has been little opportunity for the development of terraces in them, but nevertheless a few small terraces were developed and have not since been worn away. Across some of these the pay-streak was formed, and rich and productive mines have been worked on them.

The gravel on them is somewhat similar in character to that of the White Channel, but, as might be expected in pebbles and loose rock particles which had been cut down by the mechanical action of running water, rather than by the weathering of atmospheric agencies, the pebbles are much fresher and more nearly approximate to the average character of the rocks of the adjoining country. For instance, quartz pebbles do not entirely preponderate, but associated with them are a large number of schist and other rocks which occur within the watersheds of the individual streams.

Such terrace gravel is not usually more than 10 or 15 feet thick, and is often covered by a deep bed of moss and decayed vegetable material similar to that found covering the bottoms of the valleys.

On the tributaries of Indian river, the lower reaches of the streams still flow over the top of the White Channel gravel, but as these streams are ascended, and as the gradient increases, the gravel of the White Channel period is found to have been washed away and the water is

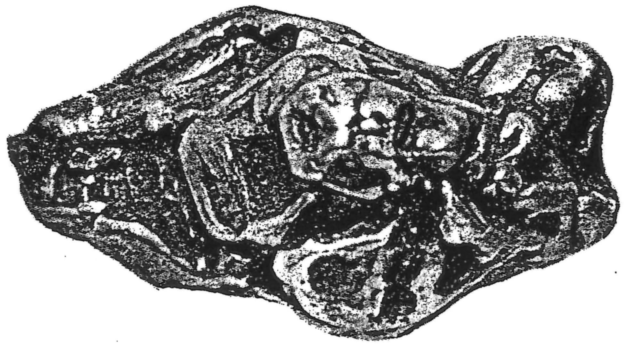
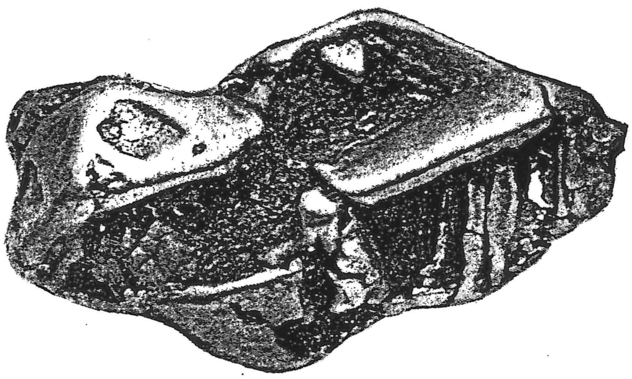


FIG. 1



X 2½

FIG. 2

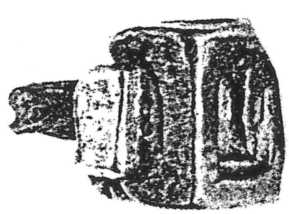


FIG. 3

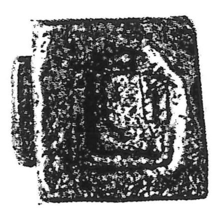


FIG. 4

FIGS. 1 and 2—SPINEL TWIN WITH HOLLOW FACES
FIGS. 3 and 4—CUBE WITH HOLLOW FACES, &C.

Crystals of Gold from the Klondike

now flowing in valleys in which the deposits of the Third Cycle are the only ones recognizable. For example, on the upper portions of Dominion creek, the gravel, both of the benches, and of the flood plain in the bottom of the valley, belong to the Third Cycle. In the upper portions of Gold Run valley any gravels of the Second Cycle that may have once existed have either been washed away or have been reassorted, and those that remain clearly belong to the Third Cycle.

On Quartz creek, the conditions are somewhat more complicated. The present stream has cut down into the gravels of the Second Cycle almost to, or into, bed-rock. In some places terraces may exist composed entirely of gravel of the Second Cycle, while the adjoining valley may be underlain by gravel of the Third Cycle. In other places the stream has cut sufficiently deep into bed-rock to leave the bed-rock terrace on which the gravel of the Second Cycle rests almost exactly at the same height as the surface of the flood-plain composed of gravel deposited during the Third (or last) Cycle of Erosion.

As with the terrace gravels, these streams gravels are usually well rounded, and the pebbles are composed of quartz and all the other rocks that occur above them in the valleys.

In most places these gravels are covered by a considerable thickness of frozen muck and moss, in which are often more or less extensive horizontal beds of ice or *chrystosphenes*, formed by the freezing of water that has risen through unfrozen channels in the frozen ground beneath.

Gravels in the bottoms of the small lateral gullies, or V-shaped valleys, are particularly interesting, as they are the prototypes of the pay-streaks which underlie portions of the flood plains of the wider valleys. They are composed of large and small particles of gold associated with more or less rounded pebbles or masses of such rocks as the country is composed of, but as these loose fragments of rock are near the localities from which they have been derived they are not as well rounded as those in the flood plains of the wider valleys. The gravel is also generally quite shallow, and in most cases it is being moved down the gulch intermittently by the stream.

In some of the gulches in the Klondike district, however, active erosion has ceased for the present, and they have been filled by muck and moss which has either grown in the valley itself or has slidden into it from the sides. In parts of Lovett Gulch this covering of muck is as much as 100 feet in depth, and the present stream flows with a fairly swift current on the top of it. As such gulches have formed embayments where erosion has not lately been active, and where the growth of moss and vegetable material has been particularly rank, they have provided favourable places for the preservation of bones of animals, many of them now extinct, that lived and died in the valleys. The bones of mammoth, bison, etc., are therefore particularly abundant in them.

*River Bars.*—Gold-bearing gravel bars on the flanks of rivers are rarely found in the Klondike district itself, but they occur on many of the larger streams in the Yukon Territory and may be noted here especially as it was on these bars that gold was discovered on the Yukon river and its tributaries. Among these tributaries may be mentioned the Lewes, Pelly, Stewart, and Fortymile rivers.

These bars have been the most recently formed of any of the placer deposits of the country, not excepting the gravels in the bottoms of the gulches, for the gulch gravels, and the bed-rock beneath them, contain gold which was gradually lowered down from higher levels as the bottoms of the gulches were deepened, while bar gravels have been carried to their present position and formed by existing streams, are entirely above bed-rock and are without connection with it.

The processes engaged in the formation of river bars are too well known to need description here. Such bars are formed on the insides of the curves of meandering streams, and are therefore features of rivers which have ceased the process of downward erosion and have begun lateral planation and the building up of flood-plains. The gravel composing them, and the gold associated with it, are either derived from the sides of the enclosing valleys, or are brought down by the streams themselves from above, and deposited on the flood-plains where the current has decreased in velocity.

Therefore the gold which occurs on the bars has been brought by the stream to its present position at a later date than that in the pay-streak below them. In fact, it is the gold that is now being carried into the stream from day to day, and is being moved along by it.

The occurrence of rich gold-bearing bars on a stream would therefore indicate that a certain amount of gold was being fed into the stream at the present time, and that it was being assorted and concentrated by it rather than that there was any rich pay-streak beneath the gravel on bed-rock, though the presence of these bars would not preclude the existence of such a pay-streak.

As an example, the placer known as the Cassiar bar on the Lewes river may be cited. Rich gold-bearing gravels were found on the surface from which, at certain seasons, men with rockers could wash out from $10.00 to $20.00 a day. From this it was inferred that richer gravels would be found on bed-rock, and consequently a dredge, owned by the Lewes River Dredging Company, was installed on the property. The enterprise was disappointing, for, as I was informed by Mr. J. M. Elmer, who was in charge of the dredging operations, the gold was confined entirely to the surface gravels and there was none in the deeper layers close to the underlying rocks. It had evidently been fed into the stream in very recent times and had nothing to do with an earlier supply which might have formed a bed-rock pay-streak; and it had not worked its way from the surface down to bed-rock.

*Character of the Gold.*—The general character and value of the gold found in the Klondike has been given in Mr. McConnell's "Report on the Gold Values in the Klondike High Level Gravels" and need not be repeated here. It all contains a considerable percentage of silver, but the quality varies to such an extent in different places that while the value of the gold on parts of Dominion creek is as high as $17.75 an ounce some of that from Last Chance creek is not worth more than $12.-50 an ounce. The average value of the gold exported from the Klondike in 1905 was $16.02 an ounce after it had been melted.

That in the bottoms of the valleys is generally well rounded and water-worn, or perhaps it would be more correct to say beaten round while it had been carried along by the water. But much of the gold in the White Channel gravels is more or less angular, and some of it is quite clearly crystaline. Many of the crystals are feathery and very delicate, and it is possible that some of these may have been deposited on the sides of other fragments, or around nuclei through the agency of water carrying gold in solution, which percolated downwards through the overlying gravel. But other crystals were undoubtedly formed in quartz veins and have been mechanically removed to the positions which they now occupy in the gravel. Those represented on Plate II are clear examples of this class. Figures 1 and 2 are two views of a twinned octahedron. Figures 3 and 4 show a cube with hollow faces and with the angles modified by the faces of the rhombic dodekahedron. Other crystals found by the writer have already been recorded by Professor Miers. They occur in a vein of quartz at the head of Victoria Gulch, and similar crystals have also been washed out of the gravel on some of the mining claims on the Gulch itself. They are octohedra twinned parallel to the octohedral face, and are usually in the shape of flattened triangular plates. Those show on Plate I were obtained from Mr. Philip Holloway's claim Number 7, on 7 Pup, Victoria Gulch where Mr. Holloway very kindly allowed me to sort over his gold and take away these crystals.

*Associated Minerals.*—The minerals associated with gold in the camp are the following:—Meteoric Iron, Native Copper, Graphite, Magnetite, Haematite, Pyrite, Cassiterite, Quartz, Rutile, Garnet, Epidote, Kyanite, Scheelite, Awaruite, Almandite, etc.

*Production.*—The ordinary creek claims in the Klondike had a length of 500 feet up and down the creek, and several of these yielded more than a million dollars, or an average of more than two thousand dollars to the running foot. Fraction A on Bonanza creek, at the mouth of Skookum gulch, had a length of 86 feet, and Richard Low, the owner, informed me that he had extracted gold to the value of between half and three quarters of a million dollars from it, giving an average yield of from $5,800 to $8,700 a running foot of the claim. I was present at one clean up on this claim, after thirty hours work by six men, and the clean gold recovered filled eight gold pans as full as it was possible to carry them without breaking.

Up to the present time placer gold mining in the Yukon territory has produced gold to the value of $140,879,500, about 99 per cent. of which has been taken from the Klondike district.

The following tables show the production to date.

Gold production of Yukon Territory before the Discovery of the Klondike gold-fields:

| Calendar Year. | Ozs. (fine). | Value. |
|---|---|---|
| 1885. } 1886. } | 4,387 | $ 100,000 |
| 1887. | 3,386 | 70,000 |
| 1888. | 1,935 | 40,000 |
| 1889. | 8,466 | 175,000 |
| 1890. | 8,466 | 175,000 |
| 1891. | 1,935 | 40,000 |
| 1892. | 4,233 | 87,500 |
| 1893. | 8,514 | 176,000 |
| 1894. | 6,047 | 125,000 |
| 1895. | 12,094 | 250,000 |
| | 59,463 | $1,238,500 |

Gold Production of Yukon Territory since the discovery of the Klondike Gold-fields:

| Calendar Year | Ozs. (fine). | Value. |
|---|---|---|
| 1896. | 14,513 | 300,000 |
| 1897. | 120,937 | 2,500,000 |
| 1898. | 483,750 | 10,000,000 |
| 1899. | 774,000 | 16,000,000 |
| 1900. | 1,077,553 | 22,275,000 |
| 1901. | 870,750 | 18,000,000 |
| 1902. | 701,437 | 14,500,000 |
| 1903. | 592,594 | 12,250,000 |
| 1904. | 407,938 | 10,500,000 |
| 1905. | 381,001 | 7,876,000 |
| 1906. | 270,900 | 5,600,000 |
| 1907. | 152,381 | 3,150,000 |
| 1908. | 174,150 | 3,600,000 |
| 1909. | 191,565 | 3,960,000 |
| 1910. | 220,105 | 4,550,000 |
| 1911. | 221,555 | 4,580,000 |
| | 6,655,129 | $139,641,000 |

These are the official figures as given by the Geological Survey and the Bureau of Mines of Canada computed from the Returns of the American Mint and the banks and Government offices in the Yukon with reasonable allowance for gold that could not be accounted for through these channels. Some people are inclined to add largely to these figures for gold lost and unaccounted for, but a residence of seven years among the miners of the Klondike convinces me that such enlarged figures are mostly gross exaggerations and that the official estimates are quite high enough to account for all the gold that has come out of that country.

In addition to the figures given above, it is not unlikely that the creek gravels may still contain gold to the value of sixty million dollars, making a total of two hundred million dollars for the original gold contents of the gravels of the Klondike country.

As we have shown on page 46 this gold has been concentrated by ordinary stream and atmospheric agencies into the bottoms of the valleys from the rocks of the surrounding and adjoining country. As far as we know, it was first concentrated into the bottoms of the valleys of the White Channel period or Second Cycle, and part of it was again reconcentrated into the bottoms of the valleys of the Third Cycle.

Altogether there has been removed since the age of the Dome Peneplain about 136 cubic miles of rock, and the gold which was contained in these 136 cubic miles has, to a large extent, been concentrated into the pay-streaks and gravels in the bottoms of the valleys. The exact proportion of gold that has been retained in the valleys and that which has been carried away is not known, but the two hundred million dollars worth or ten million ounces of gold which was retained in the valleys would, if evenly distributed through the rock from which it was derived, amount to ·013, or approximately 1/75 of a cent to the ton. It is thus clear that the Klondike placers owe their richness entirely to the peculiarly favourable conditions of concentration which have existed through a long period of time in that unglaciated district, rather than to any particular richness of the rock from which the placers were originally derived.

Another feature of interest may be worthy of mention. The rocks in the Klondike are schists and slates of Pre-Cambrian age, such as are generally recognized as being favourable to the occurrence of gold-bearing veins. Many quartz veins occur in these rocks, and in many of these quartz veins gold is distinctly visible, while in other veins it can be recognized in small quantities by assaying. The rock of the country is therefore distinctly a gold-bearing rock.

One hundred and thirty-six cubic miles of this gold-bearing rock were put through nature's mills and the gold contained in it was concentrated in nature's sluices, and from it a total of ten million ounces of gold, worth about two hundred million dollars, was extracted, proving the belt along Big Salmon valley has a greater per cent. of larger and more angular pebbles but they are still of the same composition. The Tantalus Conglomerates frequently stand in steep cliffs with castellated crags and in this respect differ in their behaviour to erosion from other rocks of the Laberge area.

*Thickness*. An estimated thickness of 650 to 750 feet of white quartz pebble conglomerate containing some white quartz sandstone beds outcrop along the valley of the creek draining Claire lake. White conglomerate and sandstone with a thickness of 200 feet outcrop on a small hill on the west side of Lewes valley six miles south of Fyfe creek. The same type of beds have a thickness of 500 feet or more near the confluence of Teslin and Lewes rivers. Cairnes gives the thickness of the Tantalus Conglomerates in the Lewes and Nordenskiold Rivers Coal district[14] as 1,000 feet or more, and in the Wheaton district[15] as 1,700 to 1,800 feet.

*Relations of the Tantalus Conglomerates to the other rocks*. The general relations indicate that the Tantalus Conglomerates are in some places overlain with angular uncomformity by andesitic volcanics assigned to the Hutshi-Schwatka group. The relations are best shown along the creek draining Claire lake. Here the Tantalus Conglomerates strike northwest parallel to the valley and dip 73° W. They outcrop on the lower westerly slope of the hills bounding the valley on the east. The upper half of the hills is covered with andesites. The actual contact of the two rocks is not exposed but little doubt remains of the relations.

The contact of the Tantalus Conglomerates and the Laberge series was not exposed in that portion of the area examined by the writer, nor were outcrops of the two series found close together. The outcrops of Tantalus Conglomerates were for the most part isolated from the Laberge series by volcanics.

The Tantalus Conglomerates of the belt along Big Salmon lie adjacent to a thick formation of massive limestone assigned to the Lewes River series without fossil evidence. The Laberge series was not found in the close vicinity.

*Palaeontology and age of the Tantalus Conglomerates*. Fossils were not found during the course of the present work in the Tantalus Conglomerates. The fossils obtained from the Laberge series indicate a range for that series from Lower Lias to Lower Inferior Oolite. Fossils obtained from the Tantalus Conglomerates have been variously inter-

[14]Cairnes, D. D. Lewes and Nordenskiold Rivers Coal District, Yukon Territory, G.S.C. Mem. 5, 1910, p. 36.

[15]Cairnes, D. D. Wheaton District, Yukon Territory, G.S.C. Mem. 31, 1912, p. 58.