CANADA

DEPARTMENT OF MINES

SIR JAMES LOUGHEED, MINISTER; CHARLES CAMSELL, ACTING DEPUTY MINISTER.

GEOLOGICAL SURVEY

WILLIAM McINNES, DIRECTOR.

MEMOIR 123

No. 105, GEOLOGICAL SERIES.

Sixtymile and Ladue Rivers Area, Yukon

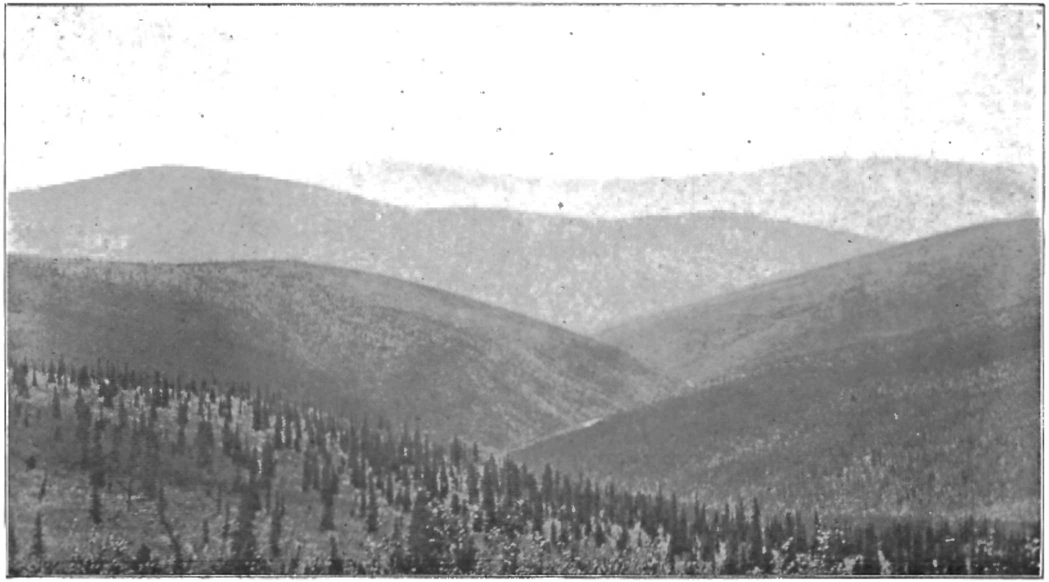
BY

W. E. Cockfield

OTTAWA
THOMAS MULVEY
NTER TO THE KING'S MOST EXCELLENT MAJESTY
1921

No. 1837

12570—1



View down the valley of a tributary to Swede creek, showing the typical V-shaped valley with interlocking spurs, so characteristic of unglaciated regions. (Page 8.)

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Sixtymile and Ladue Rivers Area, Yukon.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

In the spring of 1917 the writer received instructions to go to the district in Yukon known as Sixtymile, and to map the geology and drainage, extending the map to the south along the International Boundary as far as Ladue river. D. D. Cairnes of this department had been instructed to examine the placer deposits, leaving to the writer the areal geology, and an examination of any lode deposits. The unfortunate illness and subsequent death of Cairnes rendered a change of plans necessary, and the writer was forced to spend considerable time in an examination of the mineral resources, thus curtailing the time available for areal survey.

Though the work was undertaken primarily to compile a geological map for the study of the mineral resources, certain other factors contributed to the choice of this district. During 1916 reports were prevalent of tungsten occurrences in Sixtymile district and as tungsten was much in demand, it was decided to investigate them. Further, the original plan was to map all that territory lying between Yukon, White, and Ladue rivers and the International Boundary. Such an area includes both the Sixtymile and Fortymile gold-fields, and would link up areas already mapped, thus affording a basis for correlation.

Owing to the difficulty of covering so large an area in a single season, and to the needs of other districts, it was found impossible to collect all the data desirable, but in order that the material gathered may be available for the opening of the season of 1921, it was decided to publish the results obtained.

The summer season in the region is short, and much time must be spent in travelling to and from the field. Only about one hundred days were available for field work, and of these there were many during which bad weather precluded mapping. Further, the greater part of the region was unmapped and the geological work being contingent upon the mapping, was, therefore, somewhat hastily performed, and frequently under adverse conditions. Thus no matter how obscure the phenomena at certain localities only a limited time was available for their study, and the work is thus purely of a reconnaissance character.

AREA.

The district under consideration lies along the International Boundary between Yukon and Alaska from latitude 63° 15′ to 64° 10′, and extends eastward from the Boundary for varying distances. The area is bounded on the north by the divide between the Sixtymile and Fortymile drainage; on the east by the Boucher Creek wagon road, Sixtymile river, and Matson creek; on the south by Marion creek, Rice creek, and Ladue river, and on the west, by the International Boundary.

MEANS OF COMMUNICATION.

A wagon road from West Dawson leads to Glacier creek, in the heart of the Sixtymile gold fields. This road follows the summits lying between Swede creek and Yukon river, and between Sixtymile and Fortymile rivers. The distance from Dawson to Glacier creek is 60 miles, and during the summer the road is usually in excellent condition. Road houses are maintained along it at convenient intervals. At a point 24 miles from Dawson a trail branches off, leading to Boucher creek.

From Glacier creek, a trail leading to Walkers Fork and connecting with the Boundary pack trial was cut during the survey of the boundary line and was later used during the stampede to Chisana. Though overgrown in places it affords good communication with the western and southern portions of the area.

The southern and central portions of the area may be reached by means of poling boats from Yukon or White rivers. Sixtymile river leading to the central portion is navigable for a considerable distance beyond California creek, and the Ladue leading to the southern portion may be ascended for some distance past the forks.

In winter, the road follows a more protected route up Swede creek and thence down California creek to the Sixtymile. Numerous trails make almost any point readily accessible by means of dog sleds.

PREVIOUS WORK.

Very little geological work has been done in the district. In 1901 McConnell and Keele[1] made a rapid reconnaissance of Fortymile river and across the divide to the Sixtymile. McConnell then made a track survey of Sixtymile river, and Keele traversed the overland route to Dawson. Their reports contain the only available information concerning the district.

In the area lying to the northwest Prindle[2] made a reconnaissance survey and reported upon the geology and mineral resources, and in 1899 Peters and Brooks[3] made a reconnaissance from Pyramid Harbor to Eagle, passing up White river, and, therefore, close to the southern portion of the area. Thus all the previous work included only portions of the northern and southern borders of the district, and a narrow strip along Sixtymile river.

ACKNOWLEDGMENTS.

The writer is deeply indebted to men on the creeks, who rendered assistance in every way possible, placing at the disposal of the writer information otherwise

[1] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 25-39A.

[2] Prindle, L. M., "The Fortymile quadrangle," U.S. Geol. Surv., Bull. 375.

[3] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska," U.S. Geol. Surv., 21st Ann. Rept., pt. 2, 1899-1900, pp. 337-391.

unobtainable. Particular thanks are due to Mr. P. Owens, of Miller creek, who in many ways rendered valuable assistance; and to Messrs. Wm. Schofield and George P. Mackenzie, who afforded data relative to the past production of the area.

The writer is also indebted to Dr. C. H. Smyth and Dr. W. J. Sinclair, who offered many valuable suggestions.

VEGETATION.

The Sixtymile district is sparsely forested. The timberline is at about 3,500 feet.

Only four principal forest members attain the dimensions of trees, but there are several varieties of shrubs. The four varieties of trees are white spruce (*Picea alba*), aspen poplar (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and northern canoe birch (*Betula resinifera*). The more important shrubs include several species of willow, alder, and dwarf birch.

Spruce is the most widely distributed of the trees, growing at all elevations up to timberline. The best groves occur in the valley flats, usually bordering the streams, and in the depressions along the lower slopes of the hills, where the trees grow tall and straight. Individual trees are not generally larger than 12 inches in diameter, measured 3 feet from the ground, but individuals with 18-inch stumps were noted. This tree furnishes sufficient timber of good quality for mining and general constructional purposes.

The two varieties of poplar are found on the valley floors and hillsides, but grow best on the alluvial flats of the main valleys. They are in all stages of growth from small shrubs to forest trees of 8 to 10 inches in diameter. Birch is rare and never large. All these trees make good fuel, but are too irregular in form, or too soft, to be used for purposes of construction.

The shrubs are mostly willow and birch. Willows are very plentiful in the valleys, but are rare far above the level of the larger streams. Dwarf birch which occurs along the streams in the higher stretches of the valleys, and on the upper slopes above timberline, forms a dense undergrowth from 3 to 5 feet in height, making walking very laborious.

Several varieties of wild fruit were noted. Of these, the crowberry or heather berry, the high bush cranberry, the northern cranberry or foxberry, and the blueberry were plentiful. Red currants and raspberries were found occasionally.

A small collection of plants, made by C. E. Cairnes during the course of other work, is far from complete, but gives a general idea of the plants in the district. The late J. M. Macoun, of this department, reported on the collection as follows:

"The species marked with an asterisk have not been recorded from the vicinity of the International Boundary, while one species, *Primula nivalis*, Pall., has not been reported from the Yukon south of the Arctic coast. The following is a list of the specimens collected in 1917."

Equisetaceæ.

Equisetum sylvaticum L.

Liliaceæ.

Lloydia serotina (L) Sweet.
**Tofieldia palustris* Huds

Archidaceæ.

**Covallorrhiya trifida* Chat.

Salicaceæ.

**Salix orbicularis* Andrs.

Polygonaceæ.

Polygonum plumosum Small.
**Polygonum viviparum* L.

Caryophyllaceæ.

Silene repens Patrin.
**Silene Williamsii* Britt.
**Cerastium grande* Greene.
Arenaria arctica Stev.

Ranunculaceæ.

Anemone Richardsonii Hook.
Anemone parviflora Mx.
Anemone narcissiflora L.
Delphinium glaucum S. Wats.
Aconitum delphinifolium DC.

Tumariaceæ.

Corydalis sempervivens (L) Pers.

Papaveraceæ.

Papaver radicatum Rottb.

Cruciferæ.

Cardamine Blaisdalli Eastwood.
**Cardamine pratensis* L.
Parrya macrocarpa R. Br.

Saxifragaceæ.

Saxifraga tricuspidata Retz.
Saxifraga Nelsoniana Don.
Parnassia Kotzebuci Cham and Schlecht.

Rosaceæ.

Dryas integrifolia M. Vall.
Rubus Chamaemorus L.

Leguminosæ.

Oxytropis inflatus Hook.

Umbelliferæ.

Bupleurum americanum C. and R.

Ericaceæ.

Ledum groenlandicum Ceder.
Loiseleuria procumbens Desv.
Pyrola rotundifolia L.

Gentianaceæ.

**Menyanthes trifoliata* L.

Primulaceæ.

**Primula nivalis* Pall.
**Dodecatheon frigidum* Cham and Schlecht.

Polemoniaceæ.

Polemonium villosum Rud.

Selaginaceæ.

Gynandra Stelleri Cham and Schlecht.

Scrophulariaceæ.

Pedicularis sudetica Willel.
Pedicularis capitata Adams.
Pentstemon sp.

Valerianaceæ.

Valeriana bracteosa Bong.

Campanulaceæ.

Campanula lasiocarpa Cham.

Compositæ.

Aster sibiricus L.
Erigeron cæspitosus Nutt.
Solidago multiradiata Ait.
Senecio lugens Rich.
Senecio palustris (L) Hook.
Senecio frigidus Less.
Saussurea remotifolia (Hook) Rydb.
Petasites frigida (L) Fries.
Arnica sp.

FAUNA.

Big game is very plentiful throughout the area. Moose, bear, and caribou are the most numerous of the larger game animals. The moose—the large giant variety, *Alces gigas*—range the valley flats and are particularly abundant on the flats of Sixtymile and Ladue rivers, where they have been little hunted. Black bears are very numerous, but brown and grizzly bears are less common. The caribou range, singly and in large herds, on the open hills and are easily captured, for their curiosity far exceeds their fear.

The smaller animals comprise lynx, wolverine, mink, marten, and red, silver, and black fox. Rabbits, formerly so plentiful, are now exceedingly scarce.

Grouse and ptarmigan, too, are not as abundant as they were. Several varieties of ducks were noted.

The streams are plentifully stocked with fish, principally grayling.

CLIMATE.

The climate during the summer is very pleasant, and similar to that of northern British Columbia. Daylight is almost continuous during portions of May, June, and July, and for five months the weather is warm. The amount of rainfall varies greatly, but on the average about ten rainy days per month are to be expected.

The rivers open early in May, though ice may remain in the lakes until June. Slack water freezes over about the middle of October, but in some years the rivers remain open until well on in November. The Yukon is open for navigation about four and a half months, low water rather than ice usually being the deciding factor. Records show that the river may be closed at Dawson as early as October 23 or as late as November 19.

Though the winters are severe, horses may be successfully wintered out, if turned out in good condition, and placed on valley flats where there is an abundance of feed.

Plant growth along the lowlands is extremely rapid, for the growing season, short in days, is long in sunlight. Many of the miners raise sufficient vegetables for their own consumption. Oats are raised quite generally, but do not always ripen, being as a rule cut green. However, they furnish a good quality of fodder for wintering stock.

CHAPTER II.

TOPOGRAPHY.

REGIONAL.

The valleys of Sixtymile and Ladue rivers lie well within the physiographic province known as the Yukon plateau. This terrane is a northern member of that series of plateaus and mountain ranges stretching through British Columbia, Yukon, and Alaska to Bering sea. The Yukon plateau proper extends north from about latitude 59 degrees, through central Yukon and Alaska, and is flanked on the one hand by the mountains of the Coastal system, and on the other by the ranges of the Rocky Mountain system.

The many geologists who have studied this province agree that it represents a region extensively planated during a long period of crustal stability, and reduced to the condition of a level or slightly undulating plain. This period of stability was terminated by an uplift, and as a result, the streams became rejuvenated, and commenced to incise their channels into the upland surface so formed. The topography thus formed consists of a series of long, branching ridges, occupying the areas between the numerous, irregularly distributed, intersecting streams. The inter-stream areas, well back from the valley walls, are prevailingly flat-topped and stand at a general elevation of 4,000 to 4,500 feet. Occasional peaks rise above the general level of the plateau surface, but these are residual masses unreduced at the time of planation.

Into this upland surface, in Yukon, the drainage courses have cut deep depressions, varying from 1,500 to 4,000 feet in depth, giving a very irregular topography. Those portions of the upland near the master valleys have become maturely dissected so that little of the original plain-like surface remains, whereas farther back from these main depressions, the surfaces are so even and flat-topped that they might be taken for surfaces of construction. This plain, however, bears no relation to rock structures, erosion having bevelled the upturned edges of hard and soft strata alike.

The date of the uplift which terminated the period of stability cannot be determined from the evidence available in Sixtymile district, except that it took place after the deposition of early Tertiary beds. Dawson[1] argues for a movement taking place in the Eocene, but further[2] maintains that after a period of vulcanism, accumulation and deposition, and slight local folding, during the Miocene, denudation again reduced the region to base-level in late Miocene or post Miocene time. Brooks[3] maintains that the plateau was uplifted in the late

[1] Dawson, G. M., "The geological record of the Rocky Mountain region of Canada," Bull. Geol. Soc. Am., vol. 12, p. 79.

[2] Dawson, G. M., Trans. Roy. Soc. Can., vol. III, sec. IV, 1890, pp. 11-17.

[3] Brooks, A. H., "The geography and geology of Alaska," U.S. Geol. Surv., Prof. Paper No. 45, 1906, pp. 290, 292, 293.

Eocene or early Miocene, and agrees with Dawson that the upwarp subsequent to this planation occurred in Pliocene or early Pleistocene time. Spurr[1], however, maintains that the uplift of Yukon plateau was contemporaneous with the deposition of Miocene strata in the lower valley of Yukon river, and concludes that the plateau was planated during the Miocene, and was subsequently uplifted in late Miocene, Pliocene, or early Pleistocene time.

The exact amount of this uplift is also unknown, but apparently it was of a differential nature, being greatest along the margins and least in the centre of the region affected.[2] The plateau thus acquired the shape of a broad, shallow trough, with the axial line corresponding very closely to the present valleys of Lewes and Yukon rivers, from which the surface slopes up gradually towards the Coast range on the one hand and the ranges of the Rocky Mountain system on the other. Cairnes[3] has demonstrated the uplift along one of the flanks—the Coast range—to be from 4,700 to 5,200 feet. If the same line of reasoning be followed, Sixtymile region, lying nearer the axial line of the trough, was uplifted not less than 3,000 nor more than 4,100 feet. Sixtymile river at its mouth has an elevation of approximately 1,100 feet above sea-level. As the grade of Yukon river, which carries the water of the district to the sea, is considerably in excess of the grades of rivers in a district which has reached maturity or old age, and as it is improbable that the former drainage courses were any longer than the present circuitous one, it follows that the surface of Sixtymile region, previous to the uplift, stood at an elevation of less than 1,100 feet above sea-level, since a condition approaching base-level had been reached. As the upland now stands at 4,100 feet above sea-level, the vertical extent of the movement must have been greater than the difference between 4,100 and 1,100 feet, or 3,000 feet, and was less than 4,100 feet, though it probably was much closer to that figure than to 3,000 feet.

LOCAL.

This description of the Yukon plateau applies also to that portion included within Sixtymile and Ladue drainage basins, where the striking features of the topography are the elevated, but level or slightly undulating upland, and the numerous, wide, deep, and irregularly-distributed valleys. Portions of the plateau surface are very well preserved, and mark a gently rolling plain, increasing in elevation towards the south and west.

Several broad, deep depressions or master valleys traverse the district. The most important of these are the valleys of Sixtymile river and some of its larger tributaries, and the valley of the North Fork of Ladue river. These are cut to depths of from 1,500 to 3,000 feet into the plateau surface. Rock-cut benches or terraces form a striking feature of the main depressions, and often of the tributary valleys, and can be traced in many instances for the entire length of the valley (Plate III A).

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[1] Spurr, J. E., "Geology of the Yukon gold district, Alaska," U.S. Geol. Surv., 18th Ann. Rept., pt. III, 1898, pp. 260, 262, 263.

[2] Brooks, A. H., "The geography and geology of Alaska," U.S. Geol. Surv., Prof. Paper No. 45, 1906.

[3] Cairnes, D. D., "Wheaton district," Geol. Surv., Can., Mem. 31, 1912, p. 15.

The absence of glacial ice is shown by the lack of glacial deposits, the steep-walled V-shaped valleys, with their interlocking spurs (Plate I), and the absence of that rounding, smoothing, and scouring action on the valley walls, so characteristic of glaciated regions.

DETAILED TOPOGRAPHY.

UPLAND SURFACE.

The summits of the unreduced ranges lying between waterways, mark a gently-rolling plain (Plate II B), best viewed from a point well back from the valley walls. From such a point it is easy to imagine the depressions refilled and the upland surface an undulating plain of relatively slight relief. This plateau surface stands at an average elevation of 4,100 feet. A few summits, generally well-rounded—mount Hart (Plate II A), mount Nolan, Crag mountain, Matson dome, and Rice dome—rise a few hundred feet above the general level and are the only unreduced masses which existed prior to the uplift.

The main topographic features of the upland are the divides between the Sixtymile and Ladue drainage and between the Sixtymile and Fortymile and Yukon drainage. The first of these stretches from White river around the heads of Matson creek and the North Fork of Ladue river, crossing the International Boundary near Crag mountain. On this ridge some of the highest hills in the district form centres from which streams radiate in all directions. The second extends from the mouth of Sixtymile river to Swede Creek dome and thence crosses the International Boundary near the head of Little Gold creek. These ridges afford much better walking than the swampy valley flats, but their irregular outline adds much to the distance travelled.

Bedrock on the upland is nearly everywhere covered by drift, but is occasionally exposed on small jagged summits. Frost is the most active of the erosional force. Huge blocks, split off from the outcrops, accumulate near them or are torn from the bedrock, forced upwards through the drift, and lie scattered over the surface. Land creep or solifluction[1] is very marked, not only on the upland but also on the valley walls, and the bulk of the material reaches the valleys by a slow, progressive creep, the long gentle slopes from the summits of the upland to the valley walls being characteristic of this process.

VALLEYS.

The most striking features of the topography, next to the gentle, rolling character of the upland, are numerous wide deep valleys. These have been sunk into the upland to depths of from 1,500 to 3,000 feet. The smaller valleys are prevailingly steep-walled, sharply V-shaped in outline, and contain beautiful examples of interlocking spurs (Plate I). The larger valleys are broad-floored, with more gentle slopes, but still show a sharply V-shaped outline. Close to them the upland has been much more maturely dissected, and large portions of the original surface have been entirely destroyed.

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[1] Anderson, J. G., "Solifluction, a component of subaerial denudation," Jour. Geol., vol. XIV, pp. 91-112.

Benches form a marked feature of the valleys and occur on one or both valley walls. They are cut in rock, and their walls are always steep, so that they form narrow trenches through which the present streams flow. They support beds of gravel which frequently carry gold in paying quantities; a discussion as to their origin is included under the head of placer deposits.

Climate has had a marked effect in the shaping of land forms, and particularly in the modelling of the valleys. This effect is particularly noticeable on those slopes most exposed to the sun where alternate thawing and freezing make erosion very rapid. Consequently the valleys acquire an asymmetrical shape (Plate III B), particularly in those portions most recently cut, for the streams tend to cut along one side of the valley and especially where benches line the valley walls. On one side of the valley the bench is often entirely destroyed, and a section presents a continuously steep slope; on the other side is a slope broken by a plain of irregular outline, from the surface of which there is a gentle rise to the shoulders of the valley walls.

Most of the streams have clear water, indicating that they are doing very little cutting at present. This is no doubt due to the frozen state of the superficial materials. The material supplied to the valleys by the tributaries and by creeping and sliding processes tends to accumulate there, as it very often freezes before it can be removed, and once frozen the process of its removal is very slow. There is, therefore, a tendency toward the gradual refilling of the depressions, and this is shown in the character of the streams, particularly that of Ladue river, which notwithstanding its grade, has many of the characteristics of older streams. The thickness of this mantle of superficial deposits varies greatly from place to place.

The valley flats, swampy and covered with niggerheads, make travel very laborious. This is in part due to the frozen soil, as the smaller tributaries discharging on to the flats have been unable to cut channels to the main streams, and the water spreads or collects in pools which drain only by slow seepage. The drainage of the valley flats might thus be termed unorganized. Where the insulating layer of moss becomes removed by a slide, or a freshet, or by fire, the underlying muck thaws quickly and channel-cutting proceeds with extreme rapidity, the amount of material removable by a small stream being almost incredible.

DRAINAGE.

The area studied during 1917 is drained almost entirely by Sixtymile and Ladue rivers and their tributaries. Small portions of the area drain directly to the Yukon by means of Swede creek.

The main drainage courses are almost entirely independent of rock structure and cut across the trend of all the formations, but the secondary valleys are largely governed by the strike of the rocks in the localities where they occur.

Sixtymile river rises in Alaska and crosses the International Boundary at latitude 63° 53′. The total length of Sixtymile valley from the boundary to the Yukon is 70 miles, but the distance along the stream itself is nearly 125 miles. The valley is conspicuously terraced, the river occupying a constricted trench sunk in the floor of a much older and wider valley. The width of the valley floor is always less than a mile and is generally less than half a mile (Plate IV A).

Sixtymile river near the Boundary is a small, rapid stream, averaging less than 50 feet in width, and interrupted at frequent intervals by steep bars covered with only a few inches of water connecting the deeper portions of the channel. Down to the mouth of California creek, the Sixtymile cannot be considered a navigable stream; but below that creek the volume of water becomes much greater, and the descent less difficult, although bars and rapids continue. Fiftymile creek and Matson creek, entering from the west and southwest respectively, within 4 miles of each other, almost double the volume of water. Other important tributaries are Big Gold and California creeks from the north, and Boucher and Matson creeks from the south.

Ladue river rises in Alaska and crosses the International Boundary at latitude 63° 16′.

The North Fork of Ladue river, a rapid winding stream with some cut-off meanders, rises in Alaska, and at the Boundary is a very small stream but grows rapidly in size. From the Boundary to its junction with the main Ladue the distance is 40 miles, measured along the valley, but following the stream it is over 80 miles. The average grade between these two points is more than 25 feet per mile, but in the lower reaches is not more than 20 feet per mile, whereas near the Boundary it exceeds 100 feet per mile.

CHAPTER III.

GENERAL GEOLOGY.

INTRODUCTORY STATEMENT.

Various geological formations, widespread throughout the Yukon plateau, are found in the district, and include sedimentary, igneous, and metamorphic rocks. The metamorphic rocks are the dominant type and form what is known as the Yukon group[1]. They are the oldest rocks in the district, and from evidence, which will be presented later, are referred to the Precambrian. They have been subdivided into a number of series, the oldest being composed of sheared and metamorphosed clastics now represented by gneissoid quartzites, quartz-mica, mica and graphitic schists, sheared and mashed conglomerates, and crystalline limestone. A second subdivision is a series of sericitic and chloritic schists largely resembling the clastics but almost entirely of igneous origin. Another subdivision is a series of amphibolites, the origin of which is discussed on page 21.

The remainder of the Yukon group is made up mainly of granite gneisses that vary widely in character and composition but belong to one general period of igneous intrusion and are referred to the general age of the Pelly gneisses.

The Palæozoic is not represented in the region, save possibly by a few small, scattered areas of volcanics of doubtful age but thought to belong to the Mesozoic. Numerous, small, isolated stocks of granitic rocks also belong, probably, to this era, and to the age of the Coast Range intrusives.

The Tertiary is represented by a series of unaltered sedimentary rocks, and by the products of two periods of volcanic activity. Most of the sediments belong to the Kenai series, and consist of shale, sandstone, and conglomerate, with occasional seams of lignite. A period of vulcanism followed, in which rocks of intermediate types were discharged. Dykes and small flows of acid rocks, the most recent consolidated rocks of the district, represent the second period of volcanic activity.

Overlying all the consolidated formations is a mantle of Pleistocene and Recent accumulations, which covers the valleys and extends over large portions of the valley walls and upland.

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[1] Cairnes, D. D., "The Yukon-Alaska International Boundary," Geol. Surv., Can., Mem. 67, pp. 38-44.

Table of Formations.

Era	Period	Formation	Lithological characters
Quaternary	Recent to Pleistocene	Superficial deposits	Gravel, sand, silt, soil, muck, volcanic ash, and ground-ice.
			Rhyolite, quartz porphyry, granite porphyry, with associated tuffs and breccias.
Tertiary		Newer Volcanics	Andesite, diabase, and allied rocks, with associated tuffs and breccias.
	Eocene	Kenai	Shale, sandstone, conglomerate, and lignite.
Mesozoic	Cretaceous to Jurassic	Coast Range Intrusives (?)	Granitic intrusives.
		Older Volcanics	Andesite, diabase, and allied rocks.
Precambrian	Yukon group.	Pelly gneiss (?)	Granite gneiss.
			Amphibolites.
		Klondike series (?)	Sericitic and chloritic schists mainly of igneous origin.
		Nasina series	Quartzite, quartz-mica schists, mica schists, sheared conglomerate, graphite schists, and crystalline limestone mainly of sedimentary origin.

DESCRIPTIONS OF FORMATIONS.

YUKON GROUP.

General Description.

The members of the Yukon group are extensively developed in Sixtymile district and form most of the bedrock. Except where younger rocks occasionally break through or cover the old complex, the Yukon group is prevalent throughout the Yukon plateau. Although these rocks have been studied at a number of points, very little detailed work has been done on them.

They consist of crystalline rocks, widely different in composition and origin, some being altered sediments, and others metamorphosed igneous rocks. In many instances the primary structures have been obliterated by recrystallization, and field relations alone can aid determination of origin.

The formational names into which this group, in adjacent regions, has been subdivided, have been closely followed. No new names have been introduced, the rocks being correlated as closely as possible with those of the Klondike region. The chief subdivisions consist of the Nasina and Klondike (?) series, a series of amphibolites, and granite gneisses (Pelly gneisses?).

Age and Correlation.

Until quite recently members of the Yukon group were classed as pre-Carboniferous, pre-Devonian, or pre-Ordovician, according to the age of the sediments overlying them. Cairnes,[1] however, has shown that they are in all probability Precambrian in age. In his section along the International Boundary from Porcupine river to Yukon river, he found these rocks overlain by the Tindir group, which are in turn overlain by the Middle Cambrian. Concerning the Tindir group Cairnes says in part:[2] "The members of the Tindir group are thus either of Lower Cambrian or of Precambrian age. Considering, however, the great thickness of these rocks, and the fact that they differ so greatly lithologically from the overlying beds of Middle and Upper Cambrian age, and that the Lower Cambrian is probably represented by the lowest beds of the overlying limestone-dolomite formation, from which no fossils have as yet been obtained, it would seem to the writer very probable, either that the Tindir rocks are entirely of Precambrian age, or that this group includes both Precambrian and Lower Cambrian members."

It, therefore, seems that members of the Yukon group which underlies the Tindir group must be Precambrian. Further, these rocks have been traced by Prindle[3] from Sixtymile district along the Boundary to Yukon river, except for a band of phyllites, cherts, limestones, greenstones, quartzites, shales, and tuffs, which Prindle classes as Devonian, but part of which, according to Cairnes[4], belongs to the Yukon group. Members of the metamorphic groups which make up so much of Sixtymile area, can, therefore, be correlated with the Yukon group of Cairnes, and are all of Precambrian age.

In other districts various names have been applied to all or portions of similar formations. In southern Yukon[5] and northern British Columbia[6] the term Mount Stevens group was used to include all the older schistose and

[1] Cairnes, D. D., "The Yukon-Alaska International Boundary," Geol. Surv., Can., Mem. 67, 1914, pp. 38-58.

[2] Cairnes, D. D., op. cit., p. 56.

[3] Prindle, L. M., "The Fortymile quadrangle," U.S. Geol. Surv., Bull. 375, 1909, map, Plate V.

[4] Cairnes, D. D., op. cit., Map 140A.

[5] Cairnes, D. D., "Wheaton district," Geol. Surv., Can., Mem. 31, 1912, pp. 40-51.

[6] Cairnes, D. D., "Portions of Atlin mining district," Geol. Surv., Can., Mem. 37, 1913, pp. 48-51.

gneissoid rocks. The group includes the Nasina series of Brooks[1] and McConnell[2] as well as the Klondike series,[3] the Pelly gneisses,[4] the Birch Creek series,[5] the Fortymile series,[6] the Kloto series,[7] and the Tanana schists described by Brooks[8] and Mendenhall.[9]

NASINA SERIES.

The oldest rocks of the Yukon group are altered sediments first described by Spurr,[10] who studied them in the Fortymile region, where he subdivided them into two main groups, the Birch Creek and the Fortymile series, the prevalence of marble in the upper portion of the formation being given as the basis of the subdivision. This criterion, however, fails in other portions of Yukon and Alaska, and they have been mapped by Brooks, McConnell, and others as a single unit, to which the name Nasina series has been given.

Distribution.

In Sixtymile area this series is exposed in two main belts, trending in a northwesterly direction. The larger occupies the northeastern portion of the area, occurring along the divide between the Sixtymile and Fortymile drainage. The areal extent of this belt is not known, but is believed to reach from Indian river in the Klondike district to Fortymile river, and beyond, widening somewhat to the northwest. The width is at least 15 miles measured across the general strike of the rocks. The smaller belt extends from the right limit of Boucher creek to the Boundary and beyond, with an average width of 6 miles and a length of 18 miles. Intersected by the Tertiary volcanics on Sixtymile river and cutting across the strike of the Nasina series, this belt is economically important, all the important placer deposits occurring in the creeks that cross it. In addition to these two areas, numerous inclusions are to be found in the later igneous rocks of the Yukon group. These inclusions vary from several feet in diameter up to several miles, and locally may become very abundant. The largest occurs on the divide between Marion creek and White river.

Lithological Characters.

The Nasina series is made up of gneissoid quartzites, quartz-mica and mica and graphitic schists, sheared conglomerates, and crystalline limestone. The quartzites and quartz-mica and mica schists make up the bulk of the series, the others being developed only locally. In the least altered portions, the constituents of these various rocks have a parallel arrangement, giving to the rocks a lami-

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1 Brooks, A. H., "A reconnaissance in the White and Tanana River basins, Alaska," U.S. Geol. Surv., 20th Ann. Rept., pt. VII, pp. 465-467.

2 McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 12B-15B.

3 McConnell, R. G., op. cit., pp. 15B-22B.

4 McConnell, R. G., Am. Geol., vol. 30, July, 1902, pp. 55-62.
Brooks, A. H., op. cit., pp. 460-463.

5 Spurr, J. E., "The geology of the Yukon gold district, Alaska," U.S. Geol. Surv., 18th Ann. Rept., pt. 3, 1896-1897, pp. 140-145.

6 Idem, pp. 145-155.

7 Brooks, A. H., "A reconnaissance from Pyramid Harbor to Eagle City, Alaska," U.S. Geol. Surv., 21st Ann. Rept., pt. 2, 1899-1900, pp. 357-358.

8 Brooks, A. H., "A reconnaissance in the White and Tanana River basins, Alaska," U.S. Geol. Surv., 20th Ann. Rept., pt. 7, 1898-1899, pp. 468-470.

9 Mendenhall, W. C., "A reconnaissance from Resurrection bay to the Tanana River basin in 1898," U.S. Geol. Surv., 20th Ann. Rept., 1898-1899, pt. 7, pp. 313-315.

10 Spurr, J. E., op. cit., pp. 140-145.

nated appearance; in the most altered portions the rocks are completely recrystallized into fine-grained gneisses and schists, distinguished only with great difficulty from the altered igneous rocks. In such cases the best criterion as to their origin is afforded by the rapid alternation of these gneisses and schists with bands of crystalline limestone, or with the less altered quartzites, and their gradual transition into the latter.

Macroscopically the rocks consist principally of alternating bands of dark blue to black, and white thinly laminated quartzites that pass gradually into dark grey quartz-mica schists and finally into dark, glossy mica schists. Under the microscope the minerals present are seen to be the same in all cases, but to vary in abundance according to the type of rock. Quartz, the most abundant constituent, appears as a fine mosaic of small compact grains, usually angular to subangular in shape, and divided into bands by parallel lines of biotite and sericite. In many cases the quartz shows an undulous or wavy extinction as a result of strain unrelieved by cracking. A subordinate amount of feldspar is sometimes associated with the quartz. The micas, usually biotite and sericite, are arranged in parallel bands, or sweep in a series of waves through the granulated mass of quartz and feldspar. Biotite is abundant, and occurs in small leaves parallel to the planes of schistosity. Sericite, also abundant, occurs in a manner very similar to that of the biotite. Chlorite, calcite, kaolin, magnetite, and pyrite are also present, and, much more rarely, garnet. Graphite is seen, particularly in the laminated quartzites, where the dark bands are due to this mineral. Locally, this becomes very abundant and the rock becomes a graphite schist. In such rocks, practically the only constituents are quartz, graphite, and sericite. The graphite is most abundant along the planes of schistosity, but it also occurs surrounding the individuals of quartz and penetrating them.

The sheared conglomerates make up only small portions of the formation and apparently represent a coarser facies of the quartzite. The pebbles, entirely quartz, elongated in the direction of the schistosity, range up to an inch or more in length. The matrix has been metamorphosed into a soft, mica schist, so that its original character is obscure.

The crystalline limestone which is associated with these beds is a grey or greenish-blue to white marble. It is much sheared and disturbed, and in places contains secondary minerals, such as sericite and tremolite. The beds of limestone are usually in the form of lenses, occurring at frequent intervals along the strike.

The development of a gneissoid quartzite, a quartz-mica schist, or a mica schist, is believed to be dependent, not so much upon the degree of metamorphism, as upon original differences in composition. This is evidenced by the variation in the amount of the constituents which is now found in the several types.

Structure.

In no case has the original bedding of these rocks been observed. The angle of the dip of the schistosity is usually low rarely exceeding 30 degrees, but in many cases there are sharp plications; and the planes of foliation are often twisted and corrugated in a most complex manner, and minute corrugations are found in the rocks when examined under the microscope.

The structure is further complicated by the injection of large amounts of igneous material. Innumerable dykes and sills, now reduced to lenticular masses, have been injected into the rocks of Nasina series and have been in part folded with them. The complicated structure of these rocks and the large amount of injected material make it rash to estimate their thickness. Further, both the lower and upper boundaries are transgressive igneous contacts, so that neither the bottom nor the top of the series is actually present in the Sixtymile region.

Age and Correlation.

These rocks are the oldest in Sixtymile district, for they are cut or overlain by all the other rocks.

If the Yukon group as a whole be Precambrian, the Nasina series, the earliest members of that group, must be of Precambrian age. Dawson[1] correlated them with the Grenville series, but such a correlation can be of little value.

Origin.

The strongest evidence that these rocks are of sedimentary origin is the rapid alternation of the quartzites, schists, and limestone; the abundance of graphite; and the occurrence of quartz conglomerates. Microscopic examination shows that they have largely recrystallized into fine-grained schists and gneisses. Although some specimens show granulation, recrystallization is the rule, and in many cases the cracking or straining at right angles to the planes of foliation may be taken as being due to movements which have occurred subsequent to the recrystallization of the rock.

The Nasina series represent siliceous and arenaceous sediments, with some calcareous deposits laid down on the bottom of an early Precambrian sea, but which, as a result of earth movements, have become recrystallized into schists and gneisses. Complete metamorphism, however, was not wholly due to regional movements. In many cases garnet, and in some cases tourmaline, is developed and both these minerals are found only in proximity to the granite gneiss. It is believed that contact metamorphism played its part in the great changes which these rocks have undergone, and that the intrusion of the vast batholiths of granite, with the consequent soaking of the invaded sediments with granitic juices helped in the alteration. But the effects of contact and of regional metamorphism are so similar on rocks of this type, as to make the distinction a problem that can be solved only by detailed work.

Igneous Schists.

The igneous schists are divided for the present into two main groups, sericitic and chloritic schists and amphibolite or hornblende schists, for both of which formational names have already been given.

Sericite and Chlorite Schists.

This group consists of light-coloured sericite schists with subordinate amounts of chlorite schists. McConnell[2] has reported in detail on these rocks, but many difficult problems still remain; amongst these are the age relationships

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[1] Dawson, G. M., "The geological record in the Rocky Mountain region of Canada," Bull. Geol. Soc., Am., vol. 12, 1901, pp. 62-64.

[2] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 15-22B.

of the various members of the two groups to one another and to the granite gneiss. The intimate association of these rocks with the other members of the Yukon group has caused them to be mapped as a complex in many of the surveys of Yukon and Alaska. The writer has endeavoured to effect a separation of the main groups, and though this separation is not complete, it affords information which compensates for the mapping inaccuracies involved.

Distribution. The schists outcrop in three main areas, the largest of which occupies part of the southern portion of the district, extending south along the Boundary from near Deep creek to Ladue river, a distance of 20 miles, and east from the Boundary to Matson creek and Rice creek, a distance of 15 miles. Nasina and later igneous rocks make up a considerable portion of this area.

Two other areas occur along the Boundary, both of them near the northern end of the district. The more northerly crosses the Boundary near Little Gold creek, and extends eastward to Hungry gulch, a distance of 6 miles, following fairly closely the divide between the Sixtymile and Fortymile drainage. Its width is not known as this divide forms the boundary of the present mapping sheet. The second of these two areas occurs on the Boundary in the vicinity of Bedrock creek, and crossing Sixtymile river near the mouth of that creek extends along the south side of the Sixtymile to the mouth of Miller creek, thus having a length of 10, and an average width of about 4 miles.

Lithological Characters. These schists resemble in appearance the most completely recrystallized rocks of the Nasina on the one hand and the most sheared of the granite gneisses on the other. They may be differentiated from the Nasina by the transitions which occur in the latter between limestone, quartzite, and schist. The sericite schists have been derived largely from porphyritic igneous rocks, and in many cases the traces of the porphyritic texture have not been completely obliterated. Rounded blebs of quartz and feldspar, probably the original phenocrysts of the rock, may sometimes be distinguished macroscopically.

The separation of the crushed quartz porphyries and the crushed granite porphyries or augen gneisses, is more difficult, for by the failure of the quartz phenocrysts and the consequent increase in the feldspathic constituents an almost complete transition between the two types may be found. Biotite is, however, conspicuously absent from the sericite schists, and abundant in the granite gneisses, and this fact, coupled with the general appearance in the field, which is of some value, served in differentiating the two types.

The most important and abundant rocks in this series are white, light yellow, or light green sericite schists. These possess a marked foliation accentuated by the development of secondary minerals as a necessary accompaniment to the pronounced dynamic agencies to which they have been subjected. They are soft to the touch, friable, and with a pearly lustre on the cleavage planes, owing to the abundant development of secondary micaceous minerals. The white or yellow varieties are usually more compact than the greenish rocks and have cleavage planes $\frac{1}{16}$ of an inch or more apart, whereas the bands in the greenish varieties are almost paper-thin, and the secondary micas are bent around the white or reddish decomposed feldspar individuals. Rounded blebs of quartz and feldspar are sometimes found.

Under the microscope these rocks are seen to be of simple mineralogical composition, the bulk of the specimens being composed of quartz, feldspar, sericite, and chlorite. Of the feldspar, both orthoclase and plagioclases are present, the plagioclases being usually albite or oligoclase. Numerous minerals of secondary importance occur. These are magnetite, pyrite, hematite, zoisite, epidote, zircon, kaolin, and calcite. Biotite is usually absent. The quartz shows progressive granulation and recrystallization, passing through a stage in which the quartz grains interlock with a sutured texture, into varieties in which the quartz has been largely recrystallized into large, clear areas entirely free from strain shadows and containing inclusions of the granulated material. Sericite is abundant, and occurs in parallel bands sweeping in curves through the rock. The chlorite occurs in small leaves or aggregates.

Macroscopically the chlorite schists are fine-grained rocks showing abundant chlorite and epidote. They occur both as bands alternating with the sericite schists and as masses. The planes of schistosity are not governed by the character of the rock, but pass from one variety to the other at different angles to the planes of contact between them.

Under the microscope the chlorite schists are very similar to the sericite schists, save that the chlorite is relatively much more abundant, and with the chlorite, epidote, and zoisite also increases its importance, and quartz declines. A large amount of granitic material has been injected into these rocks, and so intimately are the two associated that it is frequently impossible to separate the material even in thin section. The zoisite, however, replaces feldspar to some extent, and it is possible that the feldspars are more basic.

Remnants of a porphyritic texture are visible in many of the sections. These appear as lenticular masses of material usually bounded by bands of mica, probably the original phenocrysts of the rock. The material in these lenticular areas is usually granulated, but in some cases recrystallization has taken place.

Structure. The rocks of this series are everywhere foliated, but they have suffered somewhat unequally in this respect. The strike of the schistosity is in a general northwest-southeast direction, but there are many exceptions. The dip is persistently towards the southwest and notwithstanding the high degree of metamorphism which these rocks have undergone, the angles of dip are usually low, very seldom exceeding 30 degrees. In some cases, notably in the area lying along Sixtymile river, high dips were noted.

Age and Correlations. These schists are similar to certain sericite and chlorite schists which make up the bulk of the Klondike series.[1] In mapping that series, however, McConnell included the granite gneisses and consequently these rocks can only be referred to portions of that series. Correlations might also be made with portions of the igneous schists of the Klotassin area[2] which exhibit the same relations to the rocks of the Nasina series as do the sericite and chlorite schists in Sixtymile district. They may also be the equivalents of

[1] McConnell, R. G., op. cit., pp. 15B-22B.
[2] Cairnes, D. D., Geol. Surv., Can., Sum. Rept. 1916, p. 28.

similar rocks in the Salmon River[1] gold field correlated with the Klondike rocks, and they may also be correlated with similar rocks in the Stewart[2] River valley.

The schists exhibit distinctly intrusive relations with the rocks of the Nasina series. Not only are the contacts between the two extremely irregular, with areas of the sericite schists penetrating into the quartzites, but numerous inclusions of quartzites, from a few inches to several hundred feet in diameter, are found in the sericite schists.

There is also evidence that these schists are earlier than the granite gneisses, for patches and small areas of granitic material are folded and sheared with the schists. These patches represent injections of granitic material from the Precambrian batholiths or from the stocks of Mesozoic age, probably from the batholiths.

The fact that there is transition between the sericitic and chloritic schists is no proof as to their relative ages. It may indicate intrusive contact or contemporary age. The alternating bands are strongly suggestive of dykes and sills of the chlorite schists cutting the sericite schists, and it is believed that the former are younger than the latter, but both have been sheared alike, and all signs of eruptive contacts have been obliterated.

Origin. These rocks owe their origin to the extrusion or intrusion of igneous material subsequently deformed. The intrusive contacts with those of the Nasina series, and the porphyritic texture, remnants of which can be readily detected, leave little doubt as to their igneous origin. Further, the mineral composition strongly suggests that many of the rocks were originally quartz porphyries, and that from these there is a gradation to more basic types represented by the chlorite schists.

The deformation has been due to movements in the rock mass, and the microscope shows a progressive granulation proceeding hand in hand with recrystallization, and this was accompanied by the development of secondary minerals, along well-defined planes of pressure. The phenocrysts of quartz have suffered more than the feldspars in the process of granulation but both are crushed to a certain degree.

The fact that the planes of schistosity cut across the planes of contact between the sericite and chlorite schists at varying angles can only lead to the inference that shearing took place subsequent to the consolidation of these rocks and that it was not due to movements while the rocks were still in a molten state. It is, of course, impossible to say whether the rocks possessed an original flow structure, which in certain cases might be emphasized by later movements. All trace of such earlier flow movements has been lost by the later shearing to which these rocks have been subjected.

It is, therefore, probable that the sericite schists are derived from quartz porphyries and allied types of rock, and the chlorite schists from rocks of a more basic composition, which may have represented later intrusion into the quartz porphyries, and that these schists owe their origin to the processes of mechanical deformation known as regional metamorphism.

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[1] McConnell, R. G., "Salmon River gold field," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, p. 25A.

[2] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, p. 16B.

Amphibolites.

This name is used to designate a class of schistose, Precambrian rocks of dark greenish colour and basic composition. Some of them are older than the granite gneiss with which they always occur, but others may be differentiates from the magma which gave rise to the gneiss.

Distribution. The largest area of these amphibolites and gneisses lies along Sixtymile river, extending eastward from the Boundary to the mouth of Pat Murphy creek, forming an area 6 miles long and 5 miles wide.

Many smaller areas occur along the Boundary, one small area on Matson creek near Discovery, and many others suggestive of dykes, too small to be mapped separately, in the schists of the Nasina series.

Lithological Characters. These rocks range from various shades of green to nearly black, and are of a basic composition. Quartz is absent, or present only in small amounts, except in certain cases which will be discussed later. Hornblende, biotite, pyroxene, and plagioclase make up the greater portions of the rocks. They vary greatly in texture, from coarse-grained varieties in which the component minerals are readily discerned with the naked eye, to fine-grained rocks, in which little can be determined even with the aid of a lens. They have a well-developed foliation accentuated by the injection of granitic material along certain definite planes.

Under the microscope, these rocks are seen to fall into two main groups. The first and more abundant type consists of hornblende and plagioclase, with subordinate amounts of biotite and pyroxene, both of which take the place of hornblende to some extent. The plagioclase is not always determinable, but in a few cases where measurements could be made, it was found to be a medium to basic labradorite. The hornblende, which makes up the bulk of the rock, is very strongly pleochroic. In some instances hornblende is almost absent, and the rock consists of pyroxene (diopside and augite) and biotite. The various other minerals present are zoisite, epidote, apatite, sphene, garnet, calcite, magnetite, chlorite, pyrite, and quartz.

The rocks, therefore, vary widely in mineralogical composition, ranging from the equivalents of a diorite to rocks as basic as a pyroxenite. They also vary widely in texture. Notwithstanding the shearing to which they have been subjected, in some cases remnants of what is believed to be original textures are preserved, and if this be the case the rocks ranged from granular to porphyritic. In the more altered types, all traces of the original textures have been completely obliterated.

The second type, generally indistinguishable in the field from the first type, shows under the microscope decidedly different characters. Quartz, one of the essential constituents, occurs as a mosaic of angular or of interlocking grains, and in several cases leaves of sericite are present, thus forming portions of rock which cannot be distinguished from the quartz-mica schists of the Nasina series. Hornblende, zoisite, epidote, and garnet are abundant, particularly the hornblende, which occurs in large individuals arranged in parallel bands; the epidote and zoisite are developed in bands parallel to the hornblende. The garnet, in large grains, occurs as a network of veins enclosing quartz grains[1] that form

[1] Weinschenk, E., "The fundamental principles of petrology," Trans. by Johannsen, New York, 1916, p. 199, and plate 4, fig. 1.

the greater part of the mass. Identical textures were noted in the rocks of the Nasina series near the contacts of the granite gneiss.

On the Boundary[1], rocks similar in texture and composition contain diopside and carbonates, quartz, feldspar, sericite, sphene, and iron ore, and are probably altered, impure sandstones, greywackes, or arkoses.

Age and Correlations. Some of these amphibolites are, probably, metamorphosed rocks of the Nasina series but many are younger. Many, too, have been injected with stringers of granite gneiss (Plate V B), and are, therefore, older than the gneisses, but some are probably differentiation products of the magma that produced the gneisses. Their age relations to the group of sericite and chlorite schists could not be determined.

Amphibolite or hornblende schists elsewhere in Yukon are apparently similar in age relations to those of the Sixtymile district, but in view of the wide range of age represented by the rocks, correlations made at the present time would prove practically valueless.

Origin.—Many of these rocks were doubtlessly derived from basic and intermediate igneous rocks. In the least altered specimens, the remnants of porphyritic structures and the mineralogical composition and their field relations, tend to confirm this view. Many of the occurrences are strongly suggestive of dykes and sills. In the majority of cases, however, the rocks occur as inclusions in granite gneiss and may be considered as basic marginal phases or even basic cognate xenoliths representing the original magma from which the granites are themselves differentiates.

Certain of the amphibolites are, however, metamorphosed sediments. On Matson creek, a band of these rocks injected by numerous stringers of granite contains an abundance of garnets. Inclusions of quartz-mica schist in the garnet may represent remnants of the original rock, probably an impure argillaceous sandstone, converted first into a quartz-mica schist by regional metamorphism and later into an amphibolite by contact metamorphism. The development of garnet with the peculiar sieve-like texture appears to be the result of contact metamorphism, as it is developed only close to igneous contacts. The formation of amphibolite, epidote, and zoisite may also be due to this cause. The planes in which these minerals occur pass around the garnets, giving a pseudo-porphyritic texture, which may mean that these minerals are of later development than the garnet, or that the garnet in growing pushed aside the hornblende and other minerals.

The origin of these rocks is uncertain. They represent in the writer's opinion contact metamorphosed sediments, and if this opinion be correct, it is interesting to note how, through metamorphism, a sandstone can be so altered as to be indistinguishable in the field from a basic igneous rock.

GRANITE GNEISS.

The various views held with regard to these rocks are very interesting, but only the principal can be given here. They were at first believed to form the

[1] Cairnes, D. D., "The Yukon-Alaska International Boundary between Porcupine and Yukon rivers," Geol. Surv., Can., Mem. 67, 1914, p. 39.

Basal granites or Archæan gneiss, but McConnell[1] pointed out that the so-called Basal granite was often intrusive into much older sediments, forming portions of the crystalline schists, and was in consequence younger than they. Areas assigned to the Basal granites are now so restricted that it is doubtful if any of them can be regarded as the basement.

Distribution.

Granite gneiss is the most extensively developed formation in this part of Sixtymile district. It extends from near Sixtymile river on the Boundary south-east to Matson creek, where it disappears under Tertiary sediments and volcanics, and from the Boundary eastward to Sixtymile river and beyond, thus forming an area about 24 miles long by 22 miles wide. In the vicinity of Boucher creek the batholith is split into two arms, one of which extends northwest up Sixtymile river, and the other west towards the Boundary. Many of the numerous, irregular, scattered patches are believed to be connected under a thin veneer of the intruded rocks.

Granite gneiss outcrops again near the southern boundary of the map and along the divide separating Matson creek from White river, and these areas are believed to extend to White river.[2] This distribution and the inclusions of the Nasina series indicate that the present surface is near portions of the roof of the old Precambrian batholith.

Lithological Characters.

The gneisses vary greatly in texture, composition, and general appearance in the field, passing from a fine-grained schist, difficult to separate from the other sheared rocks of igneous origin, into a coarse-grained granite gneiss. Areas and bands of augen gneiss, frequently alternating with the granular variety, are light brown to reddish rocks, consisting of porphyritic individuals of feldspar, and occasionally quartz, scattered through a groundmass of fine-grained material, which is highly sheared, with the development of abundant mica on the planes of schistosity, giving to the rock a glistening appearance. The feldspar crystals are drawn out into lenticular areas of granulated material, or, more frequently, exhibit only incipient signs of crushing. The granular varieties, exhibiting great differences in the siz of grain and in the amount of shearing, are frequently coarse, with a well-defined foliation; but more massive varieties occur in which the only sign of shearing is a well-defined cleavage in one direction. They are reddish to grey and macroscopically are seen to consist of quartz, feldspar, biotite, and muscovite; frequently minute crystals of garnet may be observed without the aid of a lens. The varieties containing hornblende have a mottled black and white appearance, and usually only a poorly-defined gneissic structure. In many of these rocks a milky-white quartz, apparently secondary, occurs with rounded or lenticular outlines or filling in the space between foliation planes.

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[1] McConnell, R. G., "Note on the so-called Basal granite of the Yukon valley," Am. Geol., vol. 30, 1902, pp. 55-62.

[2] Brooks, A. H., "The geography and geology of Alaska," U.S. Geol. Surv., Prof. Paper No. 45, 1906, p. 209.

"A reconnaissance of the White and Tanana River basins," U.S. Geol. Surv., Ann. Rept., 1900, pt. 7, pp. 460-466.

Under the microscope the most abundant minerals are seen to be quartz, alkali feldspar, lime-alkali feldspar (oligoclase to andesine), and biotite, muscovite, and more rarely hornblende. The more common accessory minerals are epidote, zircon, magnetite, pyrite, titanite, apatite, and tourmaline, and the secondary minerals are quartz, sericite, chlorite, calcite, hematite, and zoisite.

These rocks furnish transitions from the massive types in which little mechanical deformation has taken place to schists in which all trace of the original structure has been lost. The phenocrysts of the schists have been reduced to lenticular areas of finely-granulated material, or to continuous bands of this material, both of which are bordered by leaves of micaceous mineral such as biotite, muscovite, or sericite, developed along the planes of shearing. Some of the stages of metamorphism can be followed with the microscope. The initial stages are to be seen in rocks which macroscopically are quite massive, save for a pronounced cleavage. Granulated material is rare in such rocks, but the quartz shows undulous extinction. In the more crushed varieties the material is granulated, and still further stress causes the complete recrystallization of quartz and feldspar into a coarse-grained mosaic of grains, which, in the rocks that were originally porphyritic, are arranged in lenticular areas, or in rocks which were originally granular, in broad, broken, or discontinuous bands. Many instances were noted in which the quartz was granulated to an extreme degree, whereas the feldspar suffered only slightly. The processes of shearing were accompanied by the development of sericite, epidote, zoisite, and chlorite, the chlorite being usually secondary after the biotite or hornblende. The zoisite and epidote are present in small grains, crystals, and aggregates, but the sericite is developed in a series of parallel bands, either straight or curved. The biotite and muscovite occur in irregular plates sometimes intergrown, and most frequently arranged in certain definite planes. Both show frequent distortion of the individuals and in numerous cases a telescoping out of the crystals against inclusions of accessory constituents such as apatite and zircon.

With the process of recrystallization the introduction of secondary quartz becomes of great importance. This often completely masks the original structure, cementing the granulated material in the lenticular areas, and assuming the shape of phenocrysts. These, however, show no signs of strain. The quartz also occurs filling in the minute cracks or fissures which traverse the rocks.

Structure.

The granite gneiss is nearly everywhere sheared, and the attitude of the planes of schistosity is somewhat irregular. The strike is in general toward the northwest and has an average southwesterly dip of about 30 degrees. In many cases, however, minor tightly closed folds with steeply inclined axes were noted, and the planes of shearing are frequently twisted and corrugated.

Age and Correlations.

The granite gneisses, the most recent rocks of the Yukon group, may be correlated with the Pelly gneiss of the Yukon valley[1], traced from the Nordens-

[1] McConnell, R. G., "Note on the so-called Basal granite of the Yukon valley," Am. Geol., vol. 30, 1902, pp. 55-62.

kiöld river in a northwesterly direction to the basin of the Tanana, a distance of 380 miles. The northwestern boundary crosses Yukon river a short distance below the mouth of the Pelly, and the rocks are prominent along the lower portions of White river.[1] They are also known in the valleys of Stewart and Fortymile rivers[2], and are included in the Klondike series.[3]

Concerning the age of these rocks and their relations to the sericite and chlorite schists of the Klondike series, McConnell says in part: "Sericite schists identical in character with the Klondike schists occur at various points in Yukon Territory, notably in the Fortymile district, on Henderson creek, and in the Stewart valley. They are closely associated with the Pelly gneiss, and in some instances at least simply represent an extreme schistose phase of these rocks. On Henderson creek the schists and gneisses occur in alternating bands manifestly identical in age and origin, and in the Fortymile district the gneisses are followed crossing the strike by sericite schists agreeing with them in dip and strike."[4] McConnell then points out the transition between the Klondike schists and the Pelly gneisses: "In the Klondike district the sericite schists of the Klondike series in their extension eastward pass into, or are replaced by, granite gneisses, and gneisses also occur on Indian river, along the southern border of the area. At the latter point the gneisses pass gradually, going northward across the strike, into finely foliated schists."[5] He, therefore, concludes that the granite gneiss and a portion of the Klondike schists belong to the same age as the Pelly gneiss, and says that it is probable that the granite gneiss represents the same magma as the quartz porphyries (sericite schists) cooled at greater depth.

Cairnes,[6] however, is led to the conclusion that the granite gneiss is the youngest member of that group. He gives his latest section as starting with the Nasina series, followed by a series of schists of igneous origin, consisting of hornblende and sericite schists, and followed later by granite gneiss. It is by no means certain that the igneous schists of Cairnes in this section are the true equivalents of the Klondike schists, but they have many points of similarity.

The deformed granite and quartz porphyries so closely approximate in composition that they can only be separated partially. An additional complication lies in the fact that granites of Jura-Cretaceous age are present. These, it is believed, have their apophyses as well as the Precambrian granites, and consequently the evidence afforded by dykes, sills, and pegmatites is not always clear. Although the rocks referred to the general age of the Coast Range batholith are not very extensive in Sixtymile district, the dykes and sills believed to be of this age are very widespread. Many of the dykes, sills, and pegmatites were folded, crumpled, and faulted, and are probably the apophyses of the Precambrian granites.

Evidence that the sheared quartz porphyries and the granite gneisses are of the same age is, first, that the two occur in parallel bands, with conformable attitudes; second, that there is gradual and complete transition between the two

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[1] Brooks, A. H., "A reconnaissance of the White and Tanana River basins," U.S. Geol. Surv., Ann. Rept., 1900, pt. 7, pp. 460-466.
[2] McConnell, R. G., op. cit., pp. 55-56.
[3] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 15-23B.
[4] McConnell, R. G., op. cit., pp. 16-17B.
[5] McConnell, R. G., ibid.
[6] Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1916, pp. 27-28.

types. The first argument is not necessarily a proof of contemporaneous origin, for the rocks known as the igneous schists could have been solidified and even sheared with the injection of granitic material. Subsequent shearing might very well result in the deformation of both alike, with the result that the parallel bands would have conformable dips and strikes and all signs of eruptive contact would be obliterated. As regards the second argument, a complete transition between two rock types does not necessarily imply a contemporaneous development. The effects of the injection of large bodies of magma upon the enclosing rocks are well known. The granites then might be regarded as subsequent to the quartz porphyries, even with the two phenomena described above.

As to the relative ages of these two series of rocks, it is probable that dykes, sills, and pegmatites from the granitic magma have penetrated the igneous schists, showing that the granite gneisses are later than the deformed quartz porphyries. The dips and strikes of the two are not always conformable, and in many cases the igneous schists, if followed along the strike, are found to pass into the granite gneiss. This would point to a transgressive batholithic contact.

The writer, therefore, believes that the igneous schists and granite gneisses are not contemporaneous in age, but that the gneiss is intrusive into the schists.

Origin.

The granite gneisses owe their origin to the intrusion of batholiths of granitic material. They vary widely in texture and in composition, ranging from equi-granular to porphyritic and from an acid granite to a diorite. As a consequence of the movements to which these rocks have been subjected, various stresses were developed, with the result that a well-defined gneissic structure has been imposed upon them.

Evidence as to the period at which these movements took place is obtainable from the internal structure of the rocks, and additional evidence is to be found in the larger field relations, the former enabling us to tell whether the movements took place during or after the consolidation of the rock, and the latter, in ideal cases, enabling us to fix the period of these movements with a fair degree of accuracy. The criteria for determining the cases in which foliation is due to movements during consolidation have been discussed at length.[1] A study of numerous thin sections has shown that, except in the porphyritic facies, the normal order of crystallization of decreasing basicity has held good for most of the specimens. That is to say the various accessory constituents such as magnetite, apatite, zircon, etc., were the first to crystallize, followed in order by hornblende or mica, the feldspars, and quartz. From a study of these sections it is seen that all the essential constituents had crystallized out prior to the cessation of the movements, and as the quartz frequently shows a more pronounced granulation than the feldspar, the inference is that the shearing is due to movements which took place after consolidation, rather than to flowage while still liquid or pasty. The mica also shows signs of bending or even fracturing, the plates very frequently telescoping or feathering out against inclusions of accessory constituents which they originally enclosed.

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[1] Adams, F. D. and Barlow, A. E., "Geology of the Haliburton and Bancroft areas," Geol. Surv., Can., Mem. 6, 1910, pp. 78-87.

Barlow, A. E., "Nipissing and Timiskaming region," Geol. Surv., Can., Ann. Rept., vol. X, 1897, pp. 581-611.

The fact that the interstitial spaces in the fractured minerals are not filled with pegmatitic material, though sometimes filled with quartz, supports this conclusion. The writer, however, regards this as something entirely later than the effects of the intrusion, being closely bound up with recrystallization. The close analogy of the structures with those of the Nasina series is a point which should not be overlooked.

Further, pegmatites and quartz veins may be classed as amongst the latest products of a batholithic invasion, and the evidence afforded by these is fully as important as that afforded by the internal structure of the rock. Being found not only in the surrounding rocks but in the granites themselves, their evidence is the most positive of any. They are discontinuous, usually of lenticular outline, and range in size from minute veins to masses of quartz several feet in thickness and 8 or 10 feet in length. These have been folded and faulted with the gneisses, and the pegmatites show the same relations as the quartz veins, sheared pegmatites being by no means uncommon.

It may, therefore, be concluded that the movements which resulted in the foliation of these rocks were later than the solidification of the pegmatites and quartz veins which represent the latest stages in the consolidation of an igneous rock.

Since the Palæozoic is absent, and there are no sedimentary strata belonging to the Mesozoic, the period of earth movements can be fixed only within very indefinite limits. The gneisses were sheared prior to the deposition of the Eocene sediments, for gneiss pebbles are found in them. They were also sheared before the invasion of the batholiths classed with the Coast Range in age, for dykes and sills of these rocks cut across the planes of shearing. Further than this it is rash to go.

MESOZOIC.

Older Volcanics.

These rocks are similar in composition and in age to a group in the White River district[1] where they have been studied in detail, so that a lengthy description need not be given here.

Distribution.

They occur in two areas only, the larger of which was traced for about 4 miles along the ridge to the south of Rice creek, and separates that creek from Ladue river. The smaller area lies to the west of Pine creek, near its head, on an unnamed tributary of the North Fork of Ladue river. It outcrops on the hillsides in a series of pinnacles which overlie, and have apparently cut, the granite gneiss. These pinnacles, 50 to 100 feet high, have evidently been formed by weathering along joint planes.

Lithological Characters.

The rocks of this formation are dull, dense, and compact with colours ranging through various shades of green, grey, or brown. A well-defined lamin-

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[1] Cairnes, D. D., "Upper White River district," Geol. Surv., Can., Mem. 50, 1915, pp. 87-93.

ated structure, due probably to an original flow structure, emphasized, possibly, by subsequent earth movements, alternates rapidly with the more massive varieties. The alteration of these rocks to epidote, serpentine, and actinolite has set in along well-defined shear or fault zones, 200 feet or more in width. The actinolite is usually light to dark green, the serpentine nearly always a dull, greasy, black mineral.

The rocks range from holocrystalline equi-granular, through porphyritic to aphanitic in texture, but the porphyritic facies predominate. The latter have a mottled dark and light appearance, due to the phenocrysts of decomposed feldspar, in a dark aphanitic base, or due to the light-coloured feldspar crystals associated with long acicular crystals of hornblende. The phenocrysts are generally less than one-half inch in length, but are sometimes more than an inch.

Under the microscope, these rocks are seen to consist of both porphyritic and non-porphyritic types, the latter marked by the ophitic texture, in which all the minerals appear to belong to one period of crystallization, whereas in the porphyritic types two generations of crystals are shown, the groundmass, however, being rarely coarser than microcrystalline. Lime-soda feldspars ranging from andesine to labradorite, augite, and hornblende are the dominant minerals. The plagioclase individuals, frequently characterized by zonary structures, are twinned according to the albite and carlsbad laws. Iron ore is the most abundant and characteristic of the accessory minerals, and calcite and chlorite are always present as products of alteration. The groundmass of the porphyritic types is characterized by the orientation of the minute crystals of feldspar in a flow arrangement known as pilotaxitic structure.

These rocks consist almost wholly of hornblende and augite andesites and of diabases; they, therefore, exhibit no great range in mineralogical content or composition.

Age and Correlations.

Evidence as to age is scarce. They cannot be classed with the Newer Volcanics, which they resemble somewhat, for they are cut by the granite intrusives; they are later than the granite gneisses, and, therefore, probably later than the Precambrian; they appear to represent a stage between the Precambrian and the Coast Range intrusives.

But as it is improbable that such volcanics would be limited to areas so small, they may be correlated with certain rocks in the Upper White River[1] and Klotassin River areas[2], which were formed during the interval between these two time limits. In both these areas, the only extrusions between Precambrian and Jura-Cretaceous time are referred to the general age of the Older Volcanics, which are similar in lithological characters to the rocks under discussion. In White River district the rocks cut and overlie Carboniferous-Cretaceous sediments, and from his own studies and those of Alaskan geologists,[3] Cairnes infers they include members which range in age from Pennsylvanian to Cretaceous, and thus represent a long, intermittent period of vulcanism. In Klotassin

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[1] Cairnes, D. D., "Upper White River district," Geol. Surv., Can., Mem. 50, 1915, pp. 87-93.

[2] Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1916, p. 28.

[3] Moffitt, F. H., and Knopf, A., "Mineral resources of the Nabesna-White River district, Alaska," U.S. Geol. Surv., Bull. 417, 1910, pp. 17-27.

district similar rocks are referred mainly to the Jurassic, but may contain older and younger members.

It appears, therefore, that only a portion of these flows are represented in the Sixtymile district, and as those which are present are cut by the granitic intrusives, the earlier rather than the later stages of vulcanism must be represented here. These flows, consequently, are late Palæozoic or early Mesozoic, and possibly members of both are present.

Granitic Intrusives.

Isolated, scattered stocks of intrusives similar in appearance and field relations are grouped under the name granitic intrusives. They form small patches irregular in outline, generally less than 2 miles in length, and a mile in breadth. They outcrop near Crag mountain and Fiftymile creek, along the ridge between Boucher and Fiftymile creek, on Rice and Marion creeks, and on Swede Creek dome.

Lithological Characters.

They do not show any great range of character or composition. Usually grey in colour, although in places light pink due to the feldspar, they are as a rule coarse-grained rocks, but at some localities become fine in grain or even porphyritic in texture. Macroscopically they consist of quartz, orthoclase, plagioclase, and biotite or, rarely, hornblende.

Under the microscope they show quartz, alkali feldspar, some lime-alkali feldspar, biotite, and sometimes hornblende, as essential constituents, and certain common accessory minerals, such as apatite, zircon, and magnetite. The most common secondary minerals are calcite, epidote, and chlorite. The rocks, usually quite fresh and unweathered, range from granites to quartz monzonites, but the granites are by far the most numerous of the types examined. The structure is commonly holocrystalline hypidiomorphic, but certain porphyritic facies consisted of quartz feldspar and biotite in a micrographic groundmass.

Age and Correlations.

Very little definite evidence as to their age can be presented. They do not cut the strata of sediments assumed to be early Tertiary and they are cut by the Tertiary Newer Volcanics; so that they are probably pre-Tertiary. They exhibit intrusive relations with the Pelly gneisses, the youngest rocks of the Precambrian, and they also cut members of the Older Volcanics.

Granitic stocks with similar age relations are common throughout Yukon plateau. In regions where the conditions are more favourable, their age has been determined with some degree of accuracy. Cairnes reports that in Upper White River district[1], pebbles of these granites are contained in the early Mesozoic sediments, that in some places the granites cut the Mesozoic sediments, and that these conditions obtain in similar rocks of the Coast range[2]. From White River

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[1] Cairnes, D. D., "Portions of Atlin mining district," Geol. Surv., Can., Mem. 37, 1913. pp. 93-95.

[2] Cairnes, D. D., "Portion of Atlin mining district," Geol. Surv., Can., Mem. 37, 1913, p. 59.

district which lies 50 miles to the south of Sixtymile district, they have been traced to the Klotassin River area[1] where a batholith over 50 miles in length was found, but neither the northern nor southern extremity of this was reached and it seems likely that the stocks in Sixtymile district are merely outlying portions of this batholith. In the absence of any definite proof to the contrary, these rocks may be safely classed as Mesozoic and as belonging to the general period of intrusion of the Coast Range batholith which began in the Jurassic and continued until well on in the Cretaceous.

TERTIARY.

These rocks referred to the Tertiary are both sedimentary and igneous, but it is not practicable to map them separately on a small scale and some of the rocks mapped as Newer Volcanics include patches of sediments. The Tertiary is divided into three main divisions, the Kenai series, the Newer Volcanics, and the Acid Volcanics.

Kenai Series.

The sediments provisionally assigned to the Kenai consist of shale, sandstone, conglomerate, and lignite. Their areal extent is not known, for only the border of what appears to be the main basin of deposition was mapped.

Distribution.

The most complete section of these beds was obtained on Matson creek, from the mouth of Nettie creek as far downstream as explorations were carried. Smaller areas were found on the low-lying spurs bordering the North Fork of Ladue river, nearly opposite McElfish creek. Outcrops of what apear to be the uppermost members of these beds are found near the head of California creek, and small areas, covered by drift, are reported from Big Gold creek, where they were discovered by mine workings. Other small areas occur on and near mount Hart; their distribution in small patches, particularly on the summits of the upland, suggests that the greater part of the deposits have been removed by erosion.

Lithological Characters.

The occurrence on Matson creek shows shale, sandstone, and conglomerate, and possibly some lignite, although the lignite was not found in place, but in pebbles in the creek bed. The shale is a dark, dense, compact rock, containing abundant fossil wood, though no other fossils could be found. It is overlain by a soft, friable, coarse sandstone or arkose, consisting of quartz and decomposed feldspar with abundant ferruginous matter. These sandstones contain a few scattered pebbles of quartz, quartzite, or schist, and towards the upper portion of the deposit the pebbles become more numerous, the rock grading into a conglomerate.

On the North Fork of Ladue river the beds consist of conglomerate and conglomeratic sandstones. The rock at this point is typically a very coarse

[1] Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1916, p. 28.

arkose, with grains of quartz and decomposed feldspar, and much ferruginous matter, containing pebbles of quartzite, schist, or quartz. In places these pebbles become very abundant and the rock may be classed as a conglomerate with a friable sandy matrix much resembling mortar. At the head of California creek, heavy beds of a compact indurated conglomerate occur, overlain by loose sands and gravels, probably derived, in part, from the destruction of the conglomerate. The pebbles consist of quartz, quartz-mica schist, and mica schist, and vary in diameter from 1 to 6 inches. The pebbles of quartz and quartz-mica schist are typically well-rounded; the schist pebbles are usually angular to subangular. The pebbles are embedded in a matrix of quartz and mica, and the rock probably owes its indurated character to the infiltration of siliceous solutions as a result of the extrusion of volcanics close at hand. The conglomerate beds near mount Hart consist almost entirely of well-rounded quartz and quartzite pebbles, embedded in a very coarse sand, and are also indurated, probably owing to the infiltration of silica from the volcanics which cut them.

According to Prindle[1], the lower beds of these sediments are usually fine-grained but become coarser towards the top and the upper beds are almost always conglomeratic. The lignite does not appear to be confined to any particular horizon in these beds, nor in the beds of similar rocks throughout Yukon and Alaska. The sediments are always friable and slightly coherent, except where they have been invaded by, or are close to, masses of igneous rocks. At such points they become exceedingly hard and compact, being probably indurated by the infiltration of siliceous waters as a result of volcanic activity.

Structure and Relations.

These rocks are usually bent into easy folds with low dips, but in some cases they are considerably disturbed, and even faulted. They cover the metamorphic rocks of the Yukon group, and have been extensively invaded—in some instances covered—by members of the Newer Volcanics. They are also cut by dykes of quartz porphyry. Near the summit of mount Hart a bed of conglomerate, about 30 feet thick, has been intruded by andesites of the Newer Volcanics which have spread out both above and beneath it, thus leaving a bed of sediments resting on, and overlaid by, rocks of the same period of intrusion. Their occurrence in scattered patches on the upland suggests that they participated in the movements of the Yukon plateau prior to its planation.

Age and Correlations.

Though the absence of fossils in these beds makes their age difficult to determine, their structural relations show they participated in the movement of Yukon plateau prior to its uplift and subsequent planation. Spurr[2] believes that the uplift and planation of the Yukon plateau was probably contemporaneous with the deposition of Miocene strata in the lower valley of Yukon river, and that the beds are pre-Miocene. These rocks are probably con-

[1] Prindle, L. M., "The Fortymile quadrangle," U.S. Geol. Surv., Bull. 375, 1909, pp. 23-26.

[2] Spurr, J. E., "The geology of the Yukon gold district, Alaska," U.S. Geol. Surv., Ann. Rept., pt. 3, 1898, pp. 260-263.

tinuous with McConnell's Kenai series in Klondike[1]; and equivalent to certain beds in the Fortymile district which, from fossil evidence, have been referred to that age.[2] Similar beds occur in Upper White River[3] and Kluane mining districts[4].

These correlations place the rocks as Kenai, which is probably upper Eocene. As the rocks have been apparently deposited in separate basins, it is not likely that sections taken at different points will correspond, nor that the characteristic lignite seams will always occur at the same horizon. No diagnostic fossils have been found in these beds, but their similarity to the beds in the Klondike, their structural relations, and their content of fossil wood and lignite render it likely that they should be assigned to the Kenai.

NEWER VOLCANICS.

This name was applied to Cairnes in Upper White River district[5] to cover a series of andesites, diabases, basalts, and allied rocks of Tertiary age. Several areas of similar rocks in Sixtymile district have been provisionally assigned to this group. The largest lies in the vicinity of the creeks producing placer gold along Sixtymile river between Bedrock and Fivemile creeks. It outcrops for less than 2 miles up Miller creek; for about the same distance up Glacier creek; up Big Gold creek to the divide between the Sixtymile and Fortymile drainage; and along this ridge to the head of California creek.

Another area of importance, not yet fully explored, extends from Swede Creek dome across Fish creek and beyond. This is believed to be continuous with another area on Sixtymile river near the mouth of Fiftymile creek. Another area, or possibly a portion of the same area, occurs near the forks of Matson creek as far downstream as explorations were carried. The exposures here are on the benches and exhibit excellent sections through a vertical range of at least 100 feet. Many smaller areas—on mount Hart, Bedrock mountain, and elsewhere—as well as numerous dykes and sills, particularly in the vicinity of the surface flows, apparently belong to one general period of igneous activity.

Lithological Characters.

The rocks, consisting of andesites and diabases, have a bright, fresh appearance, but when examined closely are seen to be deeply weathered, and alteration has made it almost impossible to obtain a fresh hand specimen. Black and various shades of green and grey predominate, but reds, ranging from a dull brick colour to bright vermilion or even lavender are by no means rare. The texture ranges from glassy through aphanitic or porphyritic to granular. The porphyritic facies are most abundant and contain large crystals of feldspar,

1 McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., 1901, pp. 23B-24B.

2 Prindle, L. M., op. cit., pp. 23-26.

3 Cairnes, D. D., "Upper White River district," Geol. Surv., Can., Mem. 50, 1915, pp. 95-97.

4 McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol XVI, 1904, p. 7A.
Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1914, pp. 15, 32-33.

5 Cairnes, D. D., "Upper White River district," Mem. 50, 1915, pp. 97-101.

usually decomposed, and hornblende or pyroxene. Bedded tuffs, usually banded white and green, are intercalated with the flows, and are frequently pierced by dykes belonging to later flows. These have been folded and in some instances faulted.

Under the microscope, the andesites, which make up the greater part of these flows, are seen to consist of basaltic hornblende, augite, diopside or hypersthene, and more rarely biotite, and lime-soda feldspars of intermediate composition, ranging from oligoclase to labradorite. Amongst the accessory constituents iron ore is the most abundant, with some zircon and apatite. The most common secondary minerals are calcite, epidote, chlorite, and kaolin. The feldspars are frequently decomposed, and in some cases have disappeared leaving casts of the crystals with remnants of the original material lining the walls of the cavities. The fresh feldspars show a decided zonary banding and are frequently filled with inclusions oriented parallel to the sides of the crystals. The groundmass is rarely coarser than microcrystalline, and in some sections small amounts of a brownish glass are present. Pilotaxitic structures characterize the groundmass of many of the sections, but where glass is present, this is designated as hyalopilitic. The reddish varieties of these rocks owe their colour to an oxide or hydroxide of iron derived from the oxidation or hydration of the magnetite.

The diabases are dominantly holocrystalline rocks. The minerals developed are intermediate feldspars, most commonly labradorite, and augite olivine, hornblende, and biotite. Black iron ore is the most abundant and characteristic of the accessory minerals, and certain secondary minerals such as serpentine and chlorite are developed. Contrasted with the andesites these rocks are fresh, the feldspars being usually clear. The specimens are marked by the development of the ophitic structure, characteristic of diabases.

Age and Correlations.

Portions of these rocks cut the Eocene (Kenai) sediments and are, therefore, later than they in age, and there is evidence that portions of them were contemporaneous with the Kenai sedimentation, for tuffs were found interbedded with some of the sandstones. It is probable, therefore, that this period of vulcanism began in the Eocene. Evidence as to when these extrusions ended is less satisfactory. Most of the areas in the Sixtymile appear to have been eroded along with the rest of the plateau, for their surface is concordant with that of the remainder of the plateau surface. At one point—mount Hart—however, these volcanics are to be found 500-700 feet above the general level of the plateau surface, and now stand at an elevation of 4,900 feet. Here, however, Eocene sediments are present with the volcanics, occurring in a bed about 30 feet thick near the summit, and as these sediments were eroded during the reduction of the plateau surface to base level mount Hart must be a monadnock or residual, and not a mountain of accumulation. Since it is believed that the planation of the Yukon plateau was complete towards the close of the Miocene, these volcanics cannot be later than that period. This conclusion does not agree with that reached by Mendenhall for the Wrangell lavas[1] which are thought to belong to the same

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[1] Mendenhall, W. C., "The geology of the Central Copper River region, Alaska," U.S. Geol. Surv., Prof. Paper No. 41, 1905, pp. 54-62.

period of vulcanicity, and which Mendenhall assigns to a period of igneous activity extending from the Eocene to the Recent, and of certain of the flows his conclusions are, "These flows, therefore, instead of preceding the deformation of the early Tertiary plain, are later than the dissection which followed its uplift, and are to be regarded as very recent indeed." There is, however, no evidence in Sixtymile district to show that any of these flows are of Recent age, and if these rocks are to be correlated with the Wrangell lavas, the later flows of those rocks are wanting in Sixtymile area.

These rocks may also be correlated with the Newer Volcanics of Upper White River district[1] and with similar flows in the Nabesna-White Rivers district,[2] and also with some andesites in the Klondike district[3]. They may also be correlated with the Chieftain Hill volcanics of Wheaton district[4] and with certain volcanics occurring in Klotassin area[5]. These correlations are made in order to show that they are by no means a local feature but are widespread throughout Yukon plateau.

Origin.

These flows are believed to be local in origin, welling up through the fissures which are now found as dykes cutting the underlying formations, and even piercing older members of the flows. There is apparently no progressive change in character between the oldest and most recent members. The flows are apparently in part synchronous with the movements of the Yukon plateau preceding its planation, but it is impossible to say whether the igneous activity is to be connected genetically with the crustal disturbances which developed as the result of that uplift. The two, however, appear to be very closely associated. The rocks occur at intervals throughout the plateau, and the age appears to coincide closely with the date of uplift. The evidence in favour of genetic connexions between the two is strong, and it is believed that the volcanic activity began with and owed its origin to the crustal deformation which culminated in the uplift of Yukon plateau previous to its planation.

Rhyolites, Quartz Porphyries, and Related Rocks.

Rhyolites, quartz porphyries, and granite porphyries occur at many points within Sixtymile district, but are most common in the form of dykes, though several small areas with the characteristics of surface flows were mapped. The largest of these occurs along the Boundary, a short distance south of Deep creek, forming an area a few miles broad, and of unknown length, for it was traced into Alaska. Other areas occur on the ridges to the south of Matson creek and its tributaries, Marion creek and Thompson creek. In addition, small areas occur on the ridges leading from the upper part of Matson creek to Rice dome, on the ridge lying to the north of the East fork of Rice creek, and in the vicinity of Bedrock mountain, but most of these lie across the Boundary.

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1 Cairnes, D. D. "Upper White River district," Geol. Surv., Can., Mem. 50, 1915, pp. 97-101.

2 Moffit, F. H., and Knopf, A., "Mineral resources of Nabesna-White Rivers district, Alaska," U.S. Geol. Surv., Bull. 417, 1910, pp. 32-36.

3 McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 26B-27B.

4 Cairnes, D. D., "Wheaton district," Geol. Surv., Can., Mem. 31, 1912, pp. 59-64.

5 Cairnes, D. D., "Klotassin area," Geol. Surv., Can., Sum. Rept., 1916, p. 28.

Lithological Characters.

The most abundant of these rocks, namely the quartz porphyries, are yellow and compact rocks, having very much the appearance, on the fractured surface, of a brick. They range from white, light grey, or yellow to greenish grey in colour, and when struck with a hammer break with a clear, ringing sound. The phenocrysts of quartz are dull and smoky, and the feldspars are usually decomposed. Biotite is frequently absent. The groundmass is usually aphanitic.

In thin section the rocks show quartz, alkali feldspar, lime-alkali feldspar, and occasionally biotite as phenocrysts. The quartz is developed either in rounded, corroded forms, or in perfect dihexahedral crystals. The feldspars usually exhibit good crystallographic outlines. The groundmass is microgranitic or micropegmatitic, rims of micropegmatite frequently surrounding the feldspar crystals. The accessory constituents are apatite, zircon, and iron ore. Calcite and chlorite are developed as secondary minerals. These rocks include some granite porphyries, but quartz porphyries are the most abundant.

The rhyolites are typically sugar-grained rocks, the grain being developed largely as a result of the structure. They range from dark brown to light yellow, and frequently have a greasy lustre, resembling pitchstone. Microscopically they consist of quartz, alkali feldspar, and biotite as essential constituents. The quartz occurs in rounded or corroded forms and the feldspar usually exhibits good crystallographic outlines. Both quartz and feldspar individuals are shattered and the cracks filled with glass, the interiors as well as the exteriors of the crystals being corroded. Biotite occurs as large flakes and shreds, and iron ore and zircon as accessory constituents. The groundmass is glassy and marked by a well-defined perlitic cracking; but in a few cases it is cryptocrystalline.

Evidence of hot-spring action in connexion with the quartz porphyries is very marked, and in many places large masses of these rocks have been converted into chert, an alteration found in various stages of completion. The silica first replaces the groundmass, leaving the phenocrysts of quartz and feldspar; the feldspars are next attacked and in some places the rock consists of chert, in which are the original phenocrysts of smoky quartz, the obliteration of which completes the alteration.

Some mineral springs were noted on Bedrock and Little Gold creeks. The waters are strongly carbonated and effervesce on reaching the surface. No analyses have been made of these waters, but they contain abundant iron in solution, for a reddish deposit of limonite is deposited as the waters lose their carbon dioxide. These springs may be possibly connected with the extrusion of the volcanics, and represent the last stages of expiring vulcanism.

Age and Correlations.

These rocks cut all the other consolidated formations of the district and are, consequently, later than the early Miocene, and possibly extend from the Miocene to the Recent. Evidence in other regions that they are at least preglacial[1] is lacking in the non-glacial Sixtymile area.

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[1] Cairnes, D. D., "Portion of Atlin mining district," Geol. Surv., Can., Mem. 37, 1913, p. 102.

Many other correlations might be made. In fact, throughout Yukon there are similar rocks, which are the latest of the consolidated formations. In southern Yukon[1] and nothern British Columbia[2], they were originally subdivided into the Wheaton River Volcanics and the Klusha Intrusives, but this subdivision was without value and was consequently abandoned.[3] These rocks are found also in the Lewes-Nordenskiöld,[4] Mayo[5], and Klotassin areas[6] and in the Klondike[7], but the original place names have been dropped from the later literature.

Origin.

These rocks are believed to be local in origin. They were extruded through fissures at or near the localities where they are found, and the magma from which they were formed being highly fluid, small dykes extend for great distances.

QUATERNARY.

Superficial Deposits.

The superficial deposits of Sixtymile district consist of gravels, sands, soil, silts, muck, volcanic ash, and ground-ice, covering to varying depths much of the valleys and upland. Though most of these deposits have been formed through rock disintegration and decay, some are due to volcanic activity. The volcanic ash is developed only locally, but the ground-ice is a prominent feature and generally remains throughout the year.

The colour representing these deposits on the map is confined to the thick accumulations in the wider portions of the valleys, and is not, as a rule, extended to the valley walls or upland. This colour scheme is not strictly accurate, but has certain advantages: it limits the colour to the areas of thick accumulations, but it does not cover those portions where outcrops disclose the nature of the underlying bedrock and it shows clearly the valley systems.

The gravels, sands, and silts deposited by the present and former creeks are derived by disintegration and decay from the various rocks within the district, disintegration proceeding with greater rapidity than decay. By sliding, land creep, or by the agency of the smaller gulches, this material reaches the valleys, and accumulates faster than it can be removed. In Sixtymile valley the depth of these sediments averages about 14 feet; in Ladue valley it frequently exceeds 90 feet.

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1 Cairnes, D. D., "Wheaton district," Geol. Surv., Can., Mem. 31, 1912, pp. 66-72, Sum. Rept., 1915, p. 42.

2 Cairnes, D. D., "Portions of Atlin mining district," Geol. Surv., Can., Mem. 37, 1913, pp. 67-68.

3 Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1915, p. 42.

4 Cairnes, D. D., "The Lewes-Nordenskiöld coal area," Geol. Surv., Can., Mem. 5, 1910, pp. 43-44.

5 Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1915, p. 13.

6 Cairnes, D. D., Geol. Surv., Can., Sum Rept., 1916, p. 28.

7 McConnell, R. G., "Report of the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 27B-28B.

The soils are mingled rock débris in various stages of decomposition. The bedrock is easily decayed, the depth to which decay has proceeded being governed by the nature of the rocks. Thus the gneissoid quartzites are always fresh, even at the surface, but certain soft, fissile mica schists are always deeply weathered.

The muck represents accumulations of vegetable material mixed with sand and soil. It is usually black in colour, and frequently contains layers and bands of gravel, sand, and silt. No general layer or bed of gravel which would indicate a change in the conditions of deposition was observed.

The volcanic ash forms a bed at or near the surface, the vegetation being always rooted in it. This bed, 1 inch to 2 inches thick, is a white to light grey, coarse sand, and its deposition is of very recent occurrence, as the ash has fallen since the waterways have cut their courses to approximately their present depth. This volcanic ash is a feature throughout southern Yukon, extending as far south as lake Bennett, where it is about 1 inch in thickness; and it increases in thickness towards the north and west. Near lake Laberge it is 5 inches thick and at Five Fingers rapids 11 inches.[1] It extends down Lewes river to near Selkirk, being a conspicuous feature of the high silt banks of the river. From Selkirk, the boundary swings to the northwest and crosses White river 50 miles from its mouth.[2] The occurrences in Sixtymile district appear to lie well toward the northern limits of this material. The ash appears to belong to one great eruption, for it has fallen quite tranquilly, much like snow, drifting into the irregularities of the land surface and containing no foreign material.

The ground-ice, which often underlies the vegetation, frequently contains soil and vegetable matter. In a few cases it has been encountered in deep shafts. On Sixtymile river, a shaft 90 feet deep struck a large mass of this ice, which, owing to the danger of slumping as the ice thawed, blocked further progress.

In most places the superficial materials are frozen to great depths, usually to bedrock. Vegetation, however, acts as insulating material, and when removed the frozen zone thaws rapidly during the summer. This frozen belt is due to the intense cold which preceded the glacial epoch, for if vegetation acts as an insulator, preventing the entrance of heat to thaw these materials, it will also prevent the loss of heat necessary to freeze them, particularly when the ground is protected by snow. Tyrrell[3] believes that the frozen muck of the Klondike is due to the almost complete cessation of erosion and transportation, and the formation of bogs owing to the freezing of the gravels; these conditions obtaining as a result of the gradual refrigeration which preceded the glacial epoch.

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[1] Cairnes, D. D., "Lewes and Nordenskiöld Rivers coal area," Geol. Surv., Can., Mem. 5, 1910, p. 47.

[2] Brooks, A. H., "A reconnaissance from Pyramid Harbor to Eagle City, Alaska," U.S. Geol. Surv., 21st Ann. Rept., pt. 2, pp. 365-66.

[3] Tyrrell, J. B., "The frozen muck in the Klondike district, Yukon Territory," Trans. Roy. Soc. Can., vol. XI, ser. III, sec. IV, 1917, pp. 39-46.

CHAPTER IV.

MINERAL RESOURCES.

Placer gold is the only mineral of this area of present economic importance. None of the quartz veins are important when mining conditions are considered. Coal is found within the area, but supplies of a much better grade, where conditions are more favourable, are capable of supplying domestic needs for some time to come.

PLACER GOLD.

The discovery of the Sixtymile gold fields antedates that of the Klondike by four years, and although the discovery of the Fortymile field took place slightly before that of the Sixtymile, the greater part of the Fortymile field was subsequently found to lie in United States territory. In 1892 the Fortymile fields were extended across the divide to certain tributaries of Sixtymile river, C. Miller getting the credit of the discovery. The first real work on Miller creek, however, was performed by a party of four; Nolasque Tremblay, Joe Lemay, Joe Roi (King), and Louis Boucher washed about $4,000 worth of gold during the summer of 1892; an additional $2,000 worth was obtained from the rest of the creek. During the same summer the discoveries were extended to Glacier creek and later to Big Gold creek. These three creeks have been the principal producers, although several other creeks were staked. With the discovery of the Klondike, interest in the Sixtymile area waned; and from the year 1896 the production has steadily decreased except during 1915 and 1916, when a dredge, operating on Miller creek, restored production to almost the maximum figure.

The total estimated production of the Sixtymile area, not including a small amount of gold obtained from Matson creek, is $2,541,600. The following table gives the annual production, estimated for the writer by Mr. Geo. P. Mackenzie, Gold Commissioner, Dawson. These figures, though carefully compiled, are estimates only, for no records were kept in the early days. Since 1906 the amount of royalty is accepted as the basis of production.

Estimated Production of Sixtymile Gold Fields.

Year.	Production in dollars.	Year.	Production in dollars.
1892	6,000	1905	70,000
1893	47,000	1906	60,000
1894	200,000	1907	60,000
1895	225,000	1908	57,300
1896	200,000	1909	61,500
1897	150,000	1910	54,000
1898	150,000	1911	33,500
1899	130,000	1912	48,000
1900	120,000	1913	30,000
1901	110,000	1914	35,700
1902	100,000	1915	221,500
1903	90,000	1916	152,050
1904	80,000	1917	50,000

GOLD-BEARING GRAVELS.[1]

The gold occurs both in the gravels lying in the present valley bottoms and on the benches or terraces along the streams. Important amounts of gold have been recovered from the bench deposits.

All the gravels are local in origin. The pebbles and boulders are consequently composed mainly of the metamorphic rocks of the Yukon group. The schist pebbles have a very distinctive shape, being usually flat, round-edged disks, 1 to 2 inches thick, and from 2 to 6 inches long. They are associated with numerous subangular and angular blocks of quartzite, rounded and subangular pebbles and cobbles of quartz, and pebbles and boulders derived from the later eruptive rocks. These last, in places, make up the bulk of the deposit. The thickness of the creek gravels varies greatly. They are generally covered by black muck, with which layers of sand and gravel are sometimes interbanded.

The bench gravels are in nearly all cases similar to the creek gravels, but show, as a rule, more wear. They present very little sorting or stratification, but are in many places roughly shingled upstream. The bench gravels are usually thin, but are in many places overlain by great thicknesses of talus and other detrital accumulations, and by muck. They differ from the White Channel gravels of the Klondike and other mining districts[2] not only in character, but in age, being a much more recent development.

The origin of the bench gravels and their gold; their relationship to the creek gravels of the present day; their place in the development of the present drainage of the district; and the influence which they have had in the development of the placer deposits of the creek gravels present interesting and important problems, the solution of which is necessary if a clear idea of the surficial geology, the recent geological history, and the origin of the placer deposits is to be obtained.

The grades of the benches are slightly less than those of the streams. This fact and the frequent shingle-like arrangement of the pebbles show that the benches are stream, and not lake, features, and that they are remnants of the former valley bottoms. Also, since the grades are less than those of the present streams, since the valley floors they represent are wider than the present valley bottoms, and, since the gravels show more wear, the bench gravels represent a relatively longer period of concentration than do the creek gravels. Moreover, if gold was available for concentration at the time of their formation, as it apparently was, the bench gravels should contain gold distributed more uniformly than in the creek gravels, although the total content be no higher. This view appears to be correct, although not definitely proven. The creek gravels are thought to represent, in part at last, a reconcentrate from the bench deposits.

The benches, therefore, represent remnants of the former valley bottoms, and the gravels were formed in circumstances that permitted a long period of concentration under stable conditions. When these conditions were interrupted,

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[1] In this report the term "creek gravels" is used for deposits in the present valley bottom, and the term "bench gravels" for the elevated gravels on the benches. The word "gravel" is used in its broad mining sense.

[2] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, p. 31B.

Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1915, pp. 14-15.

a rejuvenation of the streams permitted a rapid cutting through the older and wider valley bottoms to the present constricted channels, leaving portions of the old valley bottoms as benches. The gorge-like character of the valley bottoms shows that this cutting was rapid.

This cutting has been ascribed to an uplift or upwarp,[1] but it is now generally recognized that profound changes have taken place in the drainage systems of Yukon and Alaska, and that these changes may account for the formation of the benches.[2] Large portions of these territories remain unexplored, or only cursorily examined, but certain of these changes are fairly well proven, and causes may be assigned for them.

The valley of the Lewes-Yukon river being much younger below than above Rink rapids, it is probable that the Lewes formerly turned sharply near these rapids to the east and flowed to the east of the present Yukon, cutting across the present drainage channels diagonally. This valley thus formed has been described by McConnell in the following passage[3]:

"The principal feeders of the Macmillan below the forks are Kalzas river, Moose river, and Russel creek. These streams are all northern tributaries, no important feeders entering the river from the south. Kalzas river, which joins the Macmillan 27 miles above its mouth, is a large rapid stream about 60 feet in width. It forks a short distance above its mouth, the principal branch occupying a wide, terraced valley, which extends in a northeasterly direction for a distance of 40 miles. The northwesterly branch empties Kalzas lake, a sheet of water about 6 miles in length, lying behind the Macmillan mountains. This branch follows part of an old valley, which has been traced from the Pelly in a northwesterly direction to the Klondike and beyond. This valley is occupied in different portions of its course by the Pelly, a branch of Kalzas river, Crooked creek, a portion of Stewart river, Clear creek, Flat creek, and the lower portion of the North Fork of the Klondike river. This ancient drainage channel is an important topographic feature of the country, and may prove to be of economic importance, as gold may be concentrated along portions of its course. It runs in a northwesterly direction, crossing the present drainage channels diagonally, and has a width of from 2 to 10 miles or more. In the glaciated area, it is bordered by wide terraces, built up of silts, sands, gravels, and boulder clay, and in the unglaciated area, north of Stewart river, it is filled to a depth of at least 600 feet with sand and gravel."

Wide terraces of silt, sand, and gravel line the valley of the Lewes upstream from near Rink rapids, but do not occur below that point. It is significant that these terraces are found along the ancient drainage channel described above, and that this channel was, probably, blocked by the extension of valley glaciers during the Pleistocene. Below these terraces, the Lewes flows in a steep, rock-walled valley, a distinctly new cutting. Below the mouth of Stewart river, this valley is lined by a bench or terrace that has a totally different origin. It is rock-cut, supporting beds of gravel, and its grade is less than that of the river. At Stewart city it is only a few feet in elevation above the Yukon, at Dawson it

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[1] McConnell, R. G., op. cit., p. 31B.

[2] Cairnes, D. D., "Scroggie, Barker, Thistle, and Kirkman creeks," Geol. Surv., Can., Mem. 97, 1917, pp. 14-16.

[3] McConnell, R. G., and Keele, J., Geol. Surv., Ann. Rept., vol. XV, p. 24A. See also Map 805.

is 300 feet, and at Fortymile 700 feet[1]. This bench is the remnant of a former valley bottom through which the river has cut, apparently rapidly.

Moreover, the studies of Alaskan geologists have recently established the fact that a large river formerly occupied a portion of the present valley of the Yukon, lying below Yukon flats, and that this stream flowed in the opposite direction to the present stream. This older stream probably drained to the Arctic ocean, possibly following up the valley of Porcupine river for a considerable distance, and possibly also receiving the waters of the river lying to the east of the present Yukon, the course of which has been previously outlined. Very extensive drainage reversal is postulated by Eakin[2] for the lower Yukon region, and the cause assigned for these changes was the extension of glaciers in the Pleistocene epoch. It is known for example that a lobe of the Keewatin ice-sheet extended along the Arctic coast as far as Mackenzie bay, and possibly as far as the 141st meridian. Such an extension would effectually block any drainage to the Arctic.

Other main drainage channels of Yukon have been similarly affected. Brooks[3] claims that the waters of the Upper White and Upper Tanana rivers formerly drained to the Pacific. He states that these rivers joined to form a stream which followed the valleys of Mirror, Snag, and Beaver creeks to the valley of the present White, thence turned up White River valley to Koidern river, and continuing up this stream crossed the Donjek and found its way to Kluane lake. From the southern end of that lake the stream followed Schwack valley, a depression skirting the base of the St. Elias range, and the valley of Creadon river to Tatshenshini river and thence to the Alsek. Cairnes[4] combats this view, and outlines a course for the ancient stream as follows. The White followed its present course to the Boundary, but there swung to the north and joined the Beaver. The Genero persisted on its present course and was joined by the Koidern and the waters of the Upper White and possibly the Tanana. These combined streams may have flowed down the Tanana to the Yukon, or followed the valley of the White as far as the mouth of the Donjek. In any case the valley of the White from the mouth of the Donjek to the Yukon is a distinctly new cutting. Cairnes points out that these changes probably took place owing to the blocking of the valley of the White by glacial, and glaciofluvial accumulations.

These changes support a theory of drainage diversion to account for the rock-cut benches that exist on some of the present streams. A large stream diverted to a lower outlet, or given a greater grade, will cut rapidly to establish an equilibrium of conditions, and when so cutting, benches, representing portions of the former valley bottom, will appear. These changes also affect the tributaries, which have to adjust themselves to the new conditions. Owing to the recency of these changes, many of the smaller and more sluggish streams have not yet cut to the head of their valleys.

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[1] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., vol. XIV, 1901, p. 8B.

[2] Eakin, H. M., "The Yukon-Koyukuk region," U.S. Geol. Surv., Bull. 631, 1916, pp. 70-74.

[3] Brooks, A. H., "A reconnaissance from Pyramid Harbor to Eagle City, Alaska," U.S. Geol. Surv., 21st Ann. Rept., 1899-1900, pt. ii, pp. 354-55.

[4] Cairnes, D. D., "Upper White River district," Geol. Surv., Can., Mem. 50, pp. 61-62.

These widespread changes of drainage are due to the extension of the Pleistocene glaciers. All the older valleys mentioned in this connexion have suffered glaciation alone sufficient to effect the changes; and it is significant that the Yukon today occupies a valley which was not glaciated. With the retreat of the glaciers, many minor changes linked the drainage system into a unit, but the rivers were too firmly established in their new courses, and the older channels too much obstructed by glacial accumulations, to permit of the streams resuming their former courses.

Either the theory of an uplift or the theory of diverted drainage will account for the benches. The uplift theory has little evidence to support it other than the benches themselves. That those portions of the continent subjected to the action of continental ice-sheets were uplifted subsequent to the retreat of the ice is common knowledge, but of the behaviour of those portions lying towards the margins of the ice-sheets very little is known.

It remains to be established whether the diverted drainage was due to glaciation or to uplift.

METHODS OF MINING.

Mining methods in Sixtymile district are almost identical with those employed in the Klondike[1] and other mining districts in the Yukon.

In only one case is an hydraulic monitor used on the creek gravels in Sixtymile district. This is done on J. P. Miller's group on Sixtymile river near the mouth of Miller creek. Here the gravels are dislodged by means of water thrown from the nozzle and washed towards the sluice boxes, where they are elevated by means of an hydraulic elevator and passed through the boxes. This arrangement is necessary in order to get sufficient grade to dispose of the tailings (Plate V A).

The tailings on some of the creek claims are got rid of by self-dumping scrapers or other conveyors operated by steam. The gravels and boulders are carried to the top of the waste pile and dumped automatically. Such an arrangement has been installed on Claim No. 1 below Discovery on Glacier creek.

DESCRIPTION OF CREEKS.

Miller Creek.

Miller creek, rising in a steep-walled gulch near the Boundary, flows into Sixtymile river. Its length is 6½ miles, and its width, in the lower reaches, where its grade is about 100 feet per mile, is about 200 yards. The depression has been cut in the floor of an older valley, but the cutting has not been symmetrical, having taken place along the western wall. One slope is, therefore, broken by a plain of irregular outline, the other is continuously steep.

The larger portion of the valley is underlain by rocks of the Nasina series (See page 14), which in the lower portion of the valley have been invaded and covered by andesites of the Newer Volcanics.

[1] Geol. Surv., Can., Ann. Rept., vol. XIV, pt. B, pp. 56-61.
Geol. Surv., Can., Mem. 97, pp. 16-19.

The gravels contain pebbles and boulders of all these rocks, but are composed chiefly of flat pebbles of quartzite and schist.

Mining has been carried on since 1892 and nearly all the paying portions have been worked over once, and sometimes twice. The lower 3 miles, from Discovery to the mouth, form the Healy Hydraulic Concession, leased by the North American Trading and Transportation Company. The creek gravels on this stretch have been dredged, and no further payable production can be expected. Above the concession claims yield wages or sometimes better, but future production from this source must be small.

On the eastern side of the creek, a short distance above Discovery, an old channel has yielded important amounts of gold, and, as large portions remain untouched, should continue to do so for a number of years.

Discovery claim is situated on a small gulch known as Discovery pup, on the western side of the creek. On claim No. 1 above, the bench gravels have a thickness of 4 feet, but this thickness increases greatly as the hillside is approached. A shaft sunk on the adjoining claim 64 feet back from the rim shows that the deposit at this point is 64 feet thick, but the greater part of this section is made up of detrital material from the hillside. The gold is distributed through 4 feet of gravel overlying bedrock, and extends as much as 2 feet into the bedrock. The paystreak[1] has thus a maximum thickness of 6 feet, and its width is not definitely known. The distribution of the gold is fairly uniform. Rich spots, of course, occur, but a general average of $100 to the box length[2] is claimed. The gold is coarse and shotty. Panning showed little or no fine flaky gold.

Claim No. 2 above, was staked in 1898 and has been largely worked over. There are portions of virgin ground where the depth to bedrock is 10 feet. The section consists of 2 or 3 feet of muck and 6 to 7 feet of gravel. Pay is found through a vertical range of 6 feet, including 2 feet of bedrock. Galena is common amongst the concentrates. Insufficient work has as yet been done on the bench deposits to prove their value, but results already obtained are satisfactory.

On claim No. 5 the chief work is where a shaft, 55 feet deep, has been sunk to bedrock. The section in this shaft may be taken as follows: slide rock, 19 feet; gravel, 30 feet; slide rock, 9 feet; gravel, 7 feet. The paystreak had an average width of 25 feet, and a thickness of 5 feet, including 2 feet of bedrock. The average value of the gravels was $125 per box length, but in some spots a very much higher content was found.

On claim No. 7 above, the paystreak is about 40 feet wide and most of the values lie in bedrock, penetrating to a depth of from 12 to 18 inches. The gold is coarse, and reckoning as nuggets all pieces over 25 cents in value, the percentage of nuggets would be about 50. Nuggets as high as $8 in value have been found.

On claim No. 11 coarse gold was obtained at the lower end and the average value was $20 per box length, but towards the upper end the values decrease 50 per cent and the gold is fine and pockety. Mining above this claim would prove costly, owing to the small supply of water.

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1 Although the term "paystreak" is used when describing these properties, the term is only relative. Frequently so irregular is the distribution of the gold, that there can hardly be said to be a paystreak at all.

2 It is the custom of miners in Yukon to estimate values per square foot of bedrock or per box length, 12 feet square, rather than in terms of cubic yards.

Glacier Creek.

Gold was discovered on Glacier creek a short time after the discovery of Miller creek, and the stream has been producing steadily ever since. Though the creek was worked over in the early days, many of the claims are still yielding wages or better. The benches on the left limit have been shown to contain important amounts of gold. The existence of an older channel has been demonstrated at a number of points. Benches also exist on the right limit of the creek some distance below Discovery, but these are not being worked. Large volumes of these untouched deposits should contribute to the production of the creek.

Discovery claim is situated about 3 miles from the mouth of the creek, at the end of the wagon road from West Dawson.

Claims Nos. 17, 18, 19, and 20 below are fairly close to the mouth of the creek. The depth to bedrock varies greatly from the rim of the bench back towards the hillside, but the bed of gravel overlying bedrock, where exposed by mining, is about 6 feet thick. The gravels are composed mainly of schist pebbles, and bedrock is an andesite, in many places deeply weathered, and in others quite fresh. The width of the paystreak had not been ascertained, and the content was stated to be from 60 cents to $1 per square foot.

No mining is in progress from claim No. 17 to claim No. 1 below. On the latter the depth to bedrock is 20 feet, and the section exposed consists of from 8 to 12 feet of muck, and about the same thickness of gravel. The paystreak is about 200 feet wide and the values are fairly uniform across it, an average of about $100 per box length being claimed.

On Discovery and Nos. 1 and 2 above, the depth to bedrock is 10 feet and the section consists entirely of gravel. The values lie right through the gravel and extend 6 to 8 inches into the bedrock. The paystreak is 100 to 125 feet wide and the average content from $50 to $75 per box length.

On claims Nos. 6 and 7 above (Plate IV B), the depth to bedrock varies from 8 to 12 feet, with a section composed of from 4 to 6 feet of gravel, overlain by various thicknesses of muck. The pebbles of the gravels are small, and possess a shingle-like overlap, due to current action. They are embedded in a loose micaceous sand. The paystreak averages 65 feet wide, and the distribution of the gold is pockety. In some places it lies almost entirely on bedrock, in others it is found practically throughout the gravels.

On claims Nos. 9, 10A, 12, and 13 rich deposits were found on the benches lying on the left limit of the creek. The depth to bedrock varies greatly. On claim 10A it is 40 feet; on claim 12, 30 feet; and on claim 13, 7 feet. On claim 10A the section consisted of 10 feet of talus and 30 feet of gravel. The old channel here had an elevation of 75 feet above the creek level, and was separated from the creek by a rock ridge 27 feet high and 200 feet wide. The paystreak averaged 50 feet in width and about 5 feet in thickness, including 1 foot to 18 inches of bedrock. The gold averaged from $125 to $150 per box length, and was coarse, about 15 per cent of it being nuggets. The bench deposits are by no means exhausted.

On claims Nos. 14, 15, and 16 above, the depth to bedrock averages 13, 13, and 18 feet respectively. On No. 16 the section is composed entirely of gravel, but on the other two claims a layer of 1 to 6 feet of muck overlies the gravel.

The average width of the paystreak is 70 feet and its average thickness 3 feet, including 1 foot of bedrock. Within the 70 feet of the paystreak an average of $100 to the box length is claimed.

From claims Nos. 17, 18, 19, 20, 23, 24, 25, and 26 above, the results so far obtained are very encouraging. All the work has been done on the bench lying on the left limit of claim No. 18. On the rim, the depth to bedrock was 3 to 4 feet, and 50 feet back from the rim the depth was 7 feet, with about 5 feet of gravel and 2 feet of muck exposed in the cut. The paystreak is known to be 150 feet wide, but the work done is not sufficient to justify an estimate of its value.

On claims Nos. 21 and 22 above, the depth to bedrock is from 8 to 12 feet in the creek bottom and 21 feet on the bench. The pay is concentrated in a narrow streak less than 80 feet wide, and from 4 to 6 feet thick. The gold is coarse, round, and solid.

Big Gold Creek. 116C/12 Au 3

The only part of Big Gold creek now worked lies in a broad, flat-bottomed valley from the mouth of Glacier creek to Sixtymile river. Rocks along this stretch are mainly andesites belonging to the Newer Volcanics. Remnants of the older channels in the form of benches are found along this part, occurring chiefly on the right side (looking downstream). Some portions of the former valley bottom still exist on the left limit, but are not so marked in their development.

The gold has a much more spotty distribution than is usual in this district.

Discovery claim is situated at the mouth of Glacier creek, and its width of 2,000 feet embraces not only the valley of Big Gold creek, but parts of the valley of Glacier creek. Mining is being carried on in the angle formed by the junction of the two creeks, a bench at this point being worked. The workings include an open-cut and drift into the gravels from the hillside facing Big Gold creek, and a shaft and ventilation drift near the extreme southern portion of the bench. The depth to bedrock in the shaft is 30 feet showing the following section: muck 7 feet, gravel 10 feet, muck 6 feet, gravel 7 feet. The pay is irregular and scattered. It is distributed through 6 feet of gravel, and in places extends as much as 2 feet into the bedrock, a weathered andesite. No accurate estimate of the average value can be given, but very rich spots have been struck.

On claim No. 6 below Discovery, two shafts near the right bank of the creek have been sunk to bedrock. The depth to bedrock was 24 and 25 feet; in the first the section showed 21 feet of muck and 3 feet of gravel; in the second, no gravel was found, the muck extending to bedrock, a deeply weathered andesite pitching towards the eastern side of the valley. The distribution of the gold is erratic and values range from 30 to 75 cents per square foot.

On claim No. 7 below, the depth to bedrock varies from 18 to 30 feet at this point. On the left limit of the creek the section consisted of from 6 to 8 feet of muck and 18 feet or more of gravel, and on the right limit of 20 feet of muck and 8 feet of gravel. No decided paystreak has as yet been found, the values being somewhat irregularly distributed. Insufficient work has been done to prove the value of this property.

On claims Nos. 8, 83, 9, 10, 11, and 12 below, the most recent work has been done on the bench gravels lying on the right limit of Big Gold creek on claim 8. The depth to bedrock on this claim is 16 feet, the upper 2 feet being muck and the remainder gravel. The paystreak, which has not been crosscut at this point, is claimed to average $100 per box length. On the creek gravels a drift 60 feet long showed values of from 30 cents to $100 per square foot.

LITTLE GOLD CREEK. 116 C/2 Au 4

Little Gold creek rises about 2 miles east of the Boundary and about the same distance north of Glacier creek. Its length is about 6 miles, but it is of slightly larger volume than Glacier creek. It rises in a number of steep-walled, narrow gulches, and near its head the grade is steep, but in the lower reaches approximates 75 feet per mile.

The rocks exposed belong chiefly to the Yukon group of metamorphic rocks. Gneissoid quartzites, quartz-mica schists, sericitic schists, and granite gneisses are most abundant. Near its junction with Big Gold creek, these rocks are invaded by an extensive area of andesitic rocks, and some Tertiary sediments (Kenai series) containing lignite occur.

Little Gold creek was very extensively prospected in the early days, but was generally considered too poor to work. The gold is distributed uniformly in a narrow and continuous streak, which is nowhere very rich. Heavy boulders make successful mining here difficult.

On Discovery claim an open-cut has a width of 75 to 100 feet and a length of 800 feet. The width of the paystreak is the same as that given for the cut, and the depth to bedrock is about 8 feet, the ground on the left side being slightly deeper than that on the right. The gold occurs in the gravel, or, much less frequently, in bedrock. The values are very uniform and average from 8 to 9 cents per square foot, the higher values being obtained in the gravels on the left limit.

On claim No. 2 below, the depth to bedrock is from 4 to 6 feet. Bedrock consists of the gneissoid quartzites and quartz-mica schists of the Nasina series. The paystreak has a width of 100 feet and the gold is usually found in the gravel lying immediately above bedrock, rarely extending upwards more than 7 inches, and the greater part of the values lie within 1 inch of bedrock. The average value is about 5 cents per square foot.

BEDROCK CREEK.

Bedrock creek rises in Alaska and flows east and southeast to Sixtymile river. Its length is less than 7 miles and the volume of water is very small. It rises in a series of narrow gulches, but opens out slightly, though it is narrow throughout its entire length.

Bedrock creek forms for a part of its length the contact between the quartzites, quartz-mica schists of the Nasina series, and the sericitic schists which are tentatively correlated with the Klondike series. Near the mouth a small area of andesites and similar rocks, and, towards the head, numerous bodies of rhyolite and rhyolitic tuffs, occur.

Some prospecting, but very little mining, has been done. There is no geological reason why gold should not be found along certain parts of this creek.

The depth to bedrock is very variable; reefs of rock are exposed in the creek bottom, and at other points the rock is covered by superficial deposits of varying thickness.

On claims Nos. 25 and 26 above, the depth to bedrock is 5 feet on the rim of the bench, and bedrock consists of broken and decomposed sericitic schists of the Klondike series, striking across the direction of flow of the former channel, and offering excellent riffles to catch and retain the gold. The bedrock on the bench is 50 feet above the creek. The gravels are coarse and boulders 12 inches or more in diameter are the rule. Pay has been found on the bench extending back 200 feet from the creek, and also extending along the right side of the creek. The values obtained during prospecting work were encouraging, and there is little doubt these claims will be producing in the near future.

On claim No. 2 below, the depth to bedrock is 20 feet, and there are two paystreaks, one 30 feet wide and the other of unknown width. The thickness of the paystreak is about 4 feet, including 2 feet of bedrock. The values across the paystreak so far prospected run about 20 cents per square foot of bedrock.

Sixtymile River.

In the upper portion of its course the Sixtymile (See page 10) is a small, rapid stream, with numerous shallow riffles or bars. It receives many large tributaries and below the mouth of California creek is quite practicable for poling boats.

The gravels, both of the river itself and of its benches, have yielded important amounts of gold, but only the short stretch from the mouth of Miller creek to near the mouth of Big Gold creek has been prospected thoroughly. It seems probable, however, that some parts as yet almost untouched may prove productive.

The rocks occurring along Sixtymile river, where mining operations are in progress, belong to both the Yukon group and to the Newer Volcanics (See pages 12 and 31).

The first gravels to be worked at all thoroughly on the Sixtymile were the bench gravels lying between the mouth of Miller creek and the mouth of Big Gold creek, but more recently the creek gravels have received some attention. Discovery claim may be taken as lying near the mouth of Big Gold creek, as the claims are numbered up and down stream from this point.

On claims Nos. 1a and 2a below, a considerable amount of prospecting has been done. Seven drill holes and fifteen shafts have been sunk to bedrock, but as yet no drifting has been undertaken. The depth to bedrock varies from 5 to 14 feet, the average being about 12 feet. The section consists almost entirely of gravel, and the bedrock is an andesite, having a fairly flat surface, with no decided pitch towards either side of the valley. A paystreak 300 feet wide is claimed with values ranging from 60 to 90 cents a cubic yard. The thickness of the paystreak is 5 feet, the gold lying entirely in the gravel. Coarse gold in addition to fine gold is present; nuggets ranging as high as $8 in value have been found.

On claim No. 1 below, a little prospecting work has been done, both on the bench on the left limit, and on the creek gravels. On the bench, the depth to bedrock was 30 feet, of which 5 feet was muck and the remainder gravel. The results obtained in the shaft on the bench indicate a value of from 20 to 60 cents per square foot of bedrock. On the creek, the depth of bedrock is 17 feet, 4 feet of gravel overlying the bedrock, the remainder being muck. The values ran from 12 cents to $1 per square foot of bedrock.

Claims Nos. 3 to 10 above are owned by the North American Trading and Transportation Company who leased them for dredging. Preliminary prospecting, however, failed to show satisfactory results, and in consequence dredging was abandoned.

The gold is almost invariably fine. Portions of the benches on this group of claims have been worked, and considerable amounts of gold have been recovered from them, but large volumes of these gravels still remain, and should prove a source of future production.

On claim No. 10a above, the depth to bedrock was 16 feet, and the section was composed of 3 feet of muck and 13 feet of gravel. The paystreak was found to be 150 to 200 feet wide and most of the gold lay within 2 feet of bedrock. The average value claimed was 50 cents per square foot of bedrock, and the gold recovered was nearly all fine. A second paystreak is presumed to enter this property from the claim above, but thawed ground prevented work.

The bench gravels of claims Nos. 11 to 19 above have been worked extensively. From the bench gravels much gold was recovered. The bench is situated on the left side of the stream 50 feet above river bed. The gravels range from 20 to 50 feet in thickness, the deposit getting rapidly thicker towards the hillside. These gravels are similar in many respects to the creek gravels, and show little or no sorting or stratification, coarse and fine being found together, mingled with sand. The finer gravels possess a shingle-like overlap, indicative of stream action. Stumps and trunks of trees, and the bones of various extinct animals were found in the top of the gravels, and in the muck overlying them. L. M. Lambe determined these to be: the posterior part of cranium of a bison; a large splinter of the shaft of limb bone of mammoth; a fragment of mammoth tusk and bones of horse as follows, left femur, left tibia, right radius with part of shaft of ulna. The horse represented stands somewhat lower than *Equus Scotti* Sidley of the Pleistocene of Texas and is of much lighter build. The gravels on the rim of the bench are 20 feet in thickness and, several hundred feet back towards the hillside, a shaft 90 feet deep failed to reach bedrock. The section in this shaft is as follows: muck 65 feet, gravel 15 feet, muck, moss, tree remains, and volcanic ash 5 feet, ground-ice 5 feet. The width and value of the paystreak are not known, but those portions worked were profitable.

The creek claims have been prospected by borings, which show that there are two paystreaks, 200 and 400 feet wide. The depth to bedrock is 16 feet and most of the pay lies within 2 feet of the rock. The average content would be slightly over 50 cents per square foot. The gold is prevailingly coarse. The workings at present lie on claims 15 and 16. Amongst the concentrates galena and cinnabar are common.

Matson Creek. 115 N/14 Aul

Matson creek, sometimes known as the South Fork of Sixtymile river, is a large stream, draining the country lying in the southern portion of the region. It rises within 10 miles of the Boundary and flows southeast for a distance of 8 miles where it is joined by Marion creek, the combined streams flowing in a northeasterly direction to Sixtymile river. The volume of water in Matson creek is greater than in any of the other tributaries to the Sixtymile and it approaches the parent stream itself in size.

Matson creek[1] and all its tributaries were staked from end to end in 1911. Notwithstanding this, very little prospecting work has been done, and most of the claims have been abandoned. Above the mouth of Marion creek, the valley of Matson creek is floored largely by the metamorphic rocks of the Yukon group. Granite gneiss predominates, but smaller areas of both igneous and sedimentary schists and gneisses are to be found. Below the forks the valley is underlain largely by Tertiary volcanics and sediments. Andesites, diabases, rhyolites, and quartz porphyries are all to be found.

On Discovery claim situated near the mouth of Weide gulch, about 5 miles above the forks of the creek, the depth to bedrock varies from the rim back towards the hillside. The maximum thickness exposed is 7 feet, the section being as follows: muck, 14 inches; gravel, 2 inches; sand, 9 inches; gravel, 5 feet. The bedrock consists of the broken and decomposed schists of the Yukon group (Plate VI), A cut has been made across the bench 115 feet in length, and the paystreak has been found to extend for the whole of this distance. The total width of the paystreak is, therefore, unknown, but it probably does not extend much farther as the bedrock rises sharply towards the end of the cut, and this rise, if continued, would entirely pinch out the bed of gravel underlying the muck. Values range from 18 cents to $1.00 per square foot. The values lie entirely in the rock, and extend into it to a depth of 4 feet. The production for 1917 averaged about $400 per month. Both coarse and fine gold are found, and the former shows scarcely any signs of wear, but is rough and flat. Pay has also been found in the creek gravels at this point. The depth to bedrock here is 20 feet, and the gold appears to be even more irregularly distributed than on the bench.

Other Creeks.

Parts of some of the creeks tributary to Fortymile river lie within the area mapped, but the stretches at present worked are all in United States territory.

Some prospecting has been done on Boucher and California creeks and good values are claimed at certain points, but no mining has, so far, been done. On Rice creek, Deep creek, Otter creek, and at other points within Ladue valley desultory prospecting has been carried on, but though float gold has been found at several points, no important deposits have been discovered. Gold may yet be found in paying quantities on some of these creeks.

SOURCE AND ORIGIN OF THE PLACER GOLD.

It is now almost universally accepted that placer gold is detrital in origin. The nuggets of the Sixtymile field frequently contain particles of vein quartz, or are contained in quartz derived from veins. Some evidence as to solution and redeposition of the gold in the Klondike and Sixtymile regions has been

[1] In Yukon, when gold is found on a creek and claims are located on it, the creek is said to be discovered.

offered. McConnell[1] described a boulder found in the workings on Miller creek "the upper surface of which was partially covered with specks and scales of crystalline gold. The crystals were arranged in dendritic forms, and while some of them were firmly attached to the rock, others separated quite easily from it. The angles of the crystals were sharp and showed no wear of any kind, while the boulder itself, an autoclastic quartz-mica schist, was well rounded. The gold evidently did not belong to the rock originally, and the only explanation of its occurrence under the conditions stated, seems to be that it was taken up by some solvent, and redeposited on the surface of the boulder in the position in which it was found." McConnell mentions similar occurrences on other Klondike creeks. This process is, however, to be assigned only a very subsidiary place in the formation of the placers.

Quartz veins are abundant in the metamorphic rocks of the Yukon group. These veins are nearly always small, and non-persistent, and in the majority of cases of lenticular form. They follow very closely the planes of foliation of the schists, and in the majority of cases are apparently barren of mineral, but in some cases, iron minerals, galena, and zinc blende are found. Gold is sometimes visible to the naked eye but more frequently is not. McConnell[2] shows that the bulk of the Klondike gold is derived from rocks of the Klondike series, but this does not hold outside that district, for in Sixtymile region the producing creeks are floored by the older sedimentary gneisses of the Nasina, and in Stewart River district the same is true to some extent.[3] Consequently, any of the members of the Yukon group may contribute to the formation of the placers.

It seems likely that veins of more than one age are present. The creeks producing in Sixtymile region are near points where the metamorphic rocks are invaded by Tertiary greenstones, but this may be accidental. Many of the veins, probably, owe their origin to the injection of the Pelly gneisses, which were later metamorphosed along with the containing rocks; but veins, though repeatedly faulted, are decidedly later than the foliation of the enclosing rocks. The part played by the Mesozoic granites is not clear, but in any case they are too small to have affected the formation of these veins, unless it be conceded that they are the peaks of a huge batholith underlying the whole region.

The fact that no payable veins have been found does not disprove these statements. To show the great concentration which has taken place, and the amount of material removed to form the placer deposits, McConnell[4] has made some interesting calculations, and he concludes that to form the abnormally rich Klondike placers, the original quartz veins need have carried values of only a few cents per ton. That this view is correct is shown by the sampling carried out by McLean.[5]

The absence of glaciation is also of great importance, since it means that wherever gold has been concentrated in the steam gravels, it remains

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[1] McConnell. R. G., Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, p. 35A.

[2] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pt. B.

[3] Cairnes, D. D., Geol. Surv., Can., Sum. Rept., 1915, p. 13.

[4] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, p. 61B.

[5] McLean, T. A., "Lode mining in Yukon," Dept. of Mines, Mines Branch, 1914, pp. 17-61.

undisturbed, and that the gold-bearing gravels are not overlain by vast accumulations of glacial detritus. Very little is known of the climate in Yukon during the Glacial epoch, but apparently it began with a period of intense cold, with the freezing of the gravel deposits, and the formation of thick beds of muck.[1] The muck deposits have been only casually studied, but seem to represent an almost complete cessation of erosion and transportation during the period of their formation, and a consequent close to the formation of the placers. Although at many places layers of gravel and sand are interstratified with the muck there is no general stratum indicative of a change in conditions.

The quartz stringers in the metamorphic rocks of the Yukon group are, therefore, considered as the source of the gold, which was freed from the enclosing rocks by the ordinary processes of disintegration and weathering, and slowly, by means of land creep, or quickly, by means of the gulches, it reached the creeks and was concentrated by gravity. The first concentration took place in a series of wide depressions, and fragments of these deposits still remain in the form of benches. With the disturbance of stable conditions, either by an uplift or by means of a widespread diversion of drainage (See page 39), large portions of these earlier deposits were destroyed, and the gold in them along with additional material supplied by weathering, was concentrated in the present valley bottoms. The bench deposits, therefore, represent the first concentration, and the creek gravels are in a large measure a reconcentrate from them. It is possible that a much earlier concentration took place in the Kenai conglomerates, but there is no evidence to show that these conglomerates are gold-bearing, although several attempts have been made to mine them. These conglomerates are frequently confused with the much more recent White Channel gravels, from which, however, they differ both in lithological character and in origin.

If this view of the deposits of Sixtymile district be correct the creek gravels should be richest opposite, or immediately below, those points where the benches are broken through and most thoroughly destroyed, either by tributary gulches, or by the superimposition of the present stream upon the channel of the older, and from these points there should be a gradual decrease in value until another enrichment takes place. This is well shown in the case of Sixtymile river. At the mouth of Miller creek, where the bench has been destroyed, the values in the creek gravels run slightly over 50 cents per square foot, on claim 10a they are slightly less and there is then a sudden decrease which continues until Big Gold creek breaks through and destroys the bench. Here the values rise again.

Additional evidence is found in the size of the gold. On J. P. Miller's claims at the mouth of Miller creek, coarse gold is found; on H. G. Mulvane's claim coarse gold is exceptional and on the claims below only fine gold is obtained. Below the mouth of Big Gold creek, however, coarse gold is again found. There are, of course, other factors such as enrichment from the bedrock of the creek itself, or the gold brought down by tributaries.

It follows that in prospecting in Sixtymile district, it is advisable to try, first, those portions of a creek where the benches are most thoroughly destroyed, such points being usually where tributary gulches or creeks enter, or where the stream in meandering has destroyed the bench deposits. If gold be found at these points a concentration of gold on the bench immediately above and below

[1] Tyrrell, J. B., "The frozen muck in the Klondike district, Yukon Territory," Trans. Roy. Soc., Can., vol. XI, ser. III, sec. IV, 1917, pp. 33-46.

the point where it is destroyed is to be expected. Though certain factors may affect this rule, it is a fairly safe one to follow, and will prevent the random sinking of prospect shafts.

SUMMARY AND CONCLUSIONS.

Placer deposits occur along the various creeks named in this report, both in the creek gravels and in the bench gravels, but the producing area has been limited largely to Miller, Glacier, and Big Gold creeks, and a short stretch of Sixtymile river. Portions of the gravels still remain untouched, but the production has been steadily decreasing, and this decrease will continue unless energetic prospecting is undertaken. The geological conditions on Boucher, California, and many other creeks are identical with those on Miller and Glacier creeks and there is no apparent reason why the placer gold should be confined to those creeks already producing. With regard to Ladue valley it may be said that none of the creeks has been thoroughly tried. The shafts that have been sunk are no test of such a great area. Float gold has been found at a number of points, but whether payable deposits occur can be told only by prospecting. The ground in the main valleys is deep, the thickness of the superficial deposits frequently exceeding 75 feet, but equally good returns may be obtained from the tributary valleys which are more easily worked.

Regions where the metamorphic rocks of the Yukon group have been invaded by later granitic, andesitic, and basaltic rocks have proved good gold producers and should in this case prove favourable also, particularly as the region has not been glaciated.

LODE DEPOSITS.

Very little attention has been paid to lode deposits because only the very rich ores would be profitable. It is impossible to consider as economic deposits any ore-bodies worth less than $100 per ton, unless their size ensures a material decrease in cost. The mantle of drift which covers most of the hillsides and upland renders prospecting difficult. The more easily worked placer gold undoubtedly detracts from lode prospecting. Some prospects, however, have been located, and signs which indicate the presence of other bodies were noted.

The abundance of galena amongst the concentrates obtained from Miller creek indicates that veins or disseminations of this mineral are numerous in the bedrock of the creek. On the prospect near the head of the creek, a little trenching and open-cutting have been done. The country rock consists of the quartz-mica schists of the Nasina series, with many bands or lenses of limestone. These lenses do not generally exceed 500 feet along the outcrop, and are usually less than 50 feet thick, with the depths unknown. Small quartz veins cut and replace the limestone, but do not penetrate far into the schists. They carry small bunches of galena and zinc blende but pyrite is absent. The amount of the sulphides is small. A sample cut across several of the stringers, but not including the intervening rock, was taken by the writer, and assayed in the Territorial Assay Office, Whitehorse, with the following results.

Gold..	Trace.
Silver..	1·40 oz. per ton.
Lead..	3·60 per cent.
Zinc..	4·40 " "

This may be taken as a fair indication of the content of these veins. The ore is much too poor to work, even with concentration, and the lead and zinc would have to be separated before shipping. The silver content varies with the lead; a high percentage of zinc giving low values in silver. The deposit is not of sufficient size to warrant further development.

Close examinations of the placer concentrates were made for indications of the minerals occurring in the district. Tungsten minerals, sometimes in paying quantities, have been found at several points in Yukon, notably Canadian creek[1] and Dublin gulch.[2] Consequently, chemical tests for these minerals were made, but always with negative results. The minerals most common in the concentrates are hematite, magnetite, zircon, garnet, titanite, galena, and pyrite, and, in one case, cinnabar (mercury). The cinnabar was found in the sluice boxes of J. P. Miller's group of claims on Sixtymile river, near the mouth of Miller creek. This mineral occurs as grains and fragments ranging from less than a millimetre up to a centimetre in diameter. The grains are angular and show only slight wear.

From what is known of the occurrence of cinnabar in other countries, and from its frequent association with volcanic rocks, it is believed that it is in this case connected with the Tertiary volcanics, which form the bedrock in the vicinity. As this mineral is soft and brittle, it is not probable that it has travelled far from its point of origin. The small area of Tertiary volcanics occurring around Miller creek should, therefore, be carefully prospected for this mineral, particularly when bedrock is removed by mining. The chances are great, however, that this mineral will be found in veins or disseminations where it actually occurs in the gravels, and it should be carefully looked for when cleaning off bedrock.

COAL.

Lignite occurs in the sedimentary rocks of Tertiary age (Kenai series) at a number of points in Yukon, and in Sixtymile district lignite has been found at one or two points. No outcrops were observed, but its presence has been noted in excavations made during mining operations or road construction. One such deposit occurs near the junction of Little Gold and Big Gold creeks. The presence of other deposits is suspected on Matson creek and its tributaries, as pebbles of this material are found in the gravels. As far as is known, the lignite seams are not confined to any particular horizon of these sediments.

These deposits have no present economic importance, for other deposits of a much better grade at Tantalus are capable of supplying requirements for many years to come.

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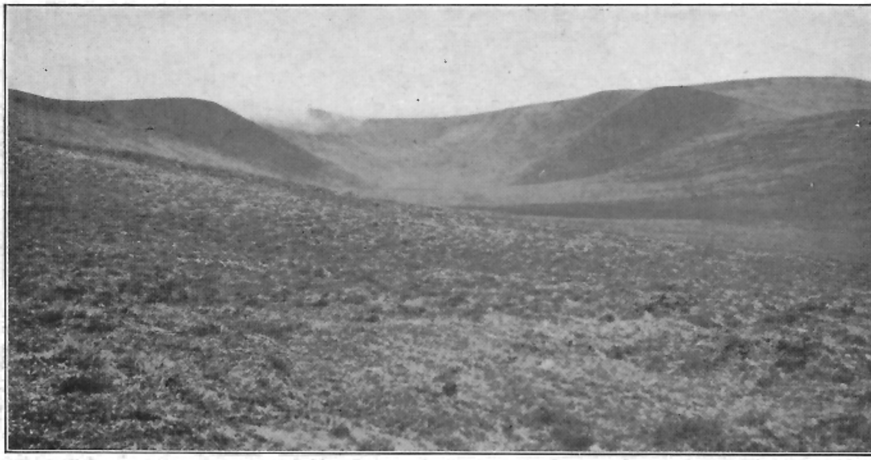
[1] Cairnes, D. D., "Klotassin area," Geol. Surv., Can., Sum. Rept., 1916, p. 30.

[2] Cairnes, D. D., "Tungsten deposits of Dublin gulch and vicinity," Geol. Surv., Can., Sum. Rept., 1916, pp. 12-14.

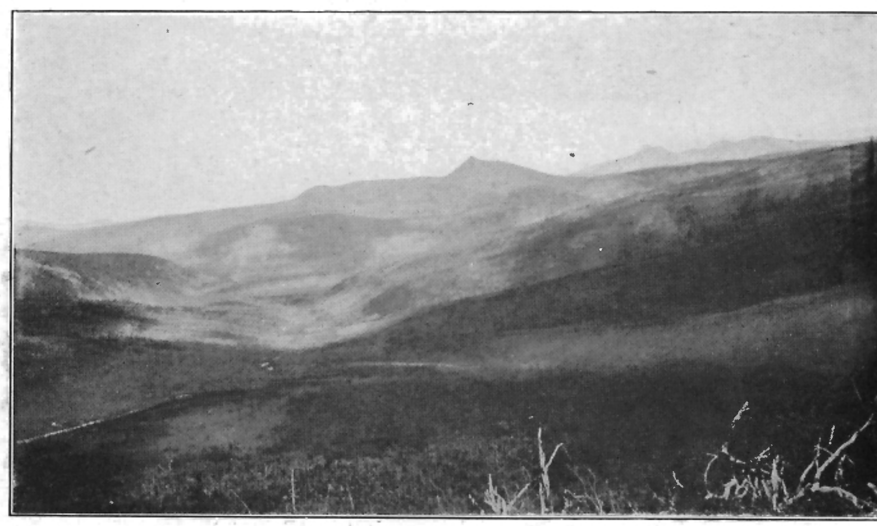
PLATE II.

A. View across the valley of Fiftymile creek towards mount Hart. (Page 8.)

B. Looking east toward Matson dome. (Page 8.)

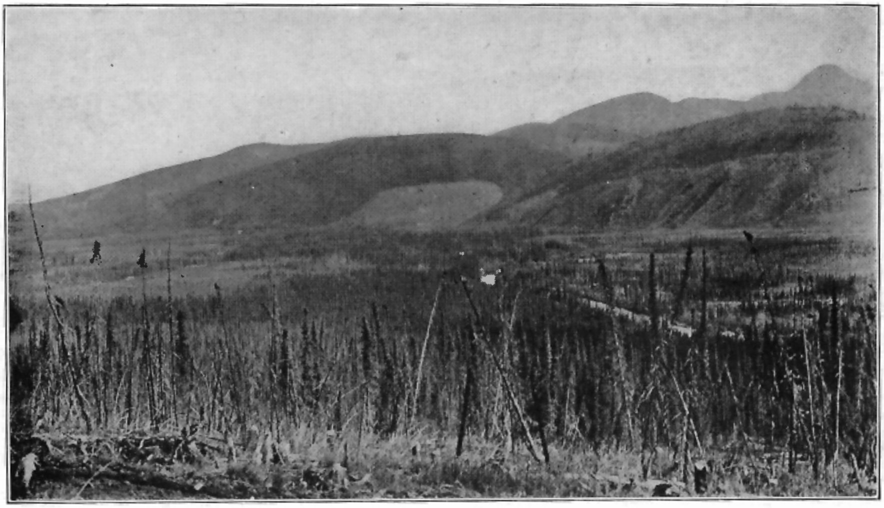


A. Looking up towards the head of a tributary to the North Fork of Ladue river. (Page 7.)



B. Looking down Glacier creek towards Big Gold creek and Sixtymile river. (Page 9.)

PLATE IV.



A. View down the valley of Sixtymile river from near the mouth of Big Gold creek. This view shows the general character of the valley of the Sixtymile. (Page 9.)

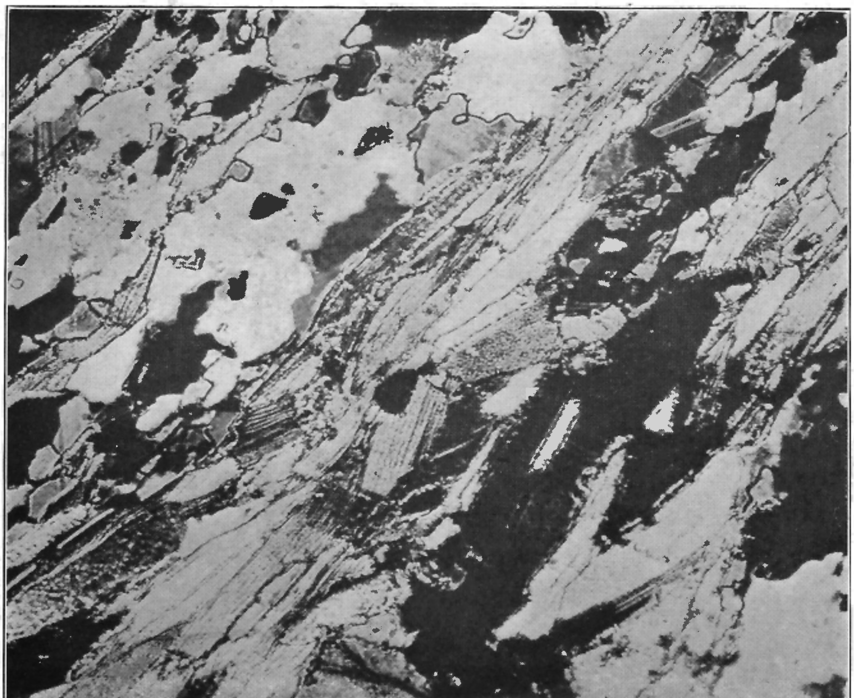
B. Open-cut on claim No. 6 "above" Glacier creek. (Page 43.)

PLATE V.

A. J. P. Miller's claims on Sixtymile river. (Page 41.)

B. Amphibolite injected with granite gneiss and pegmatite veins. (Page 21.)

PLATE VI.



Quartz mica schist. Crystal of mica broken against an inclusion of apatite. Quartz is recrystallized showing sutured texture. Crossed nicols X 80. (Page 48.)

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