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BULLETIN No. 3

Fraser River Tertiary Drainage-history in relation to Placer-gold Deposits

by

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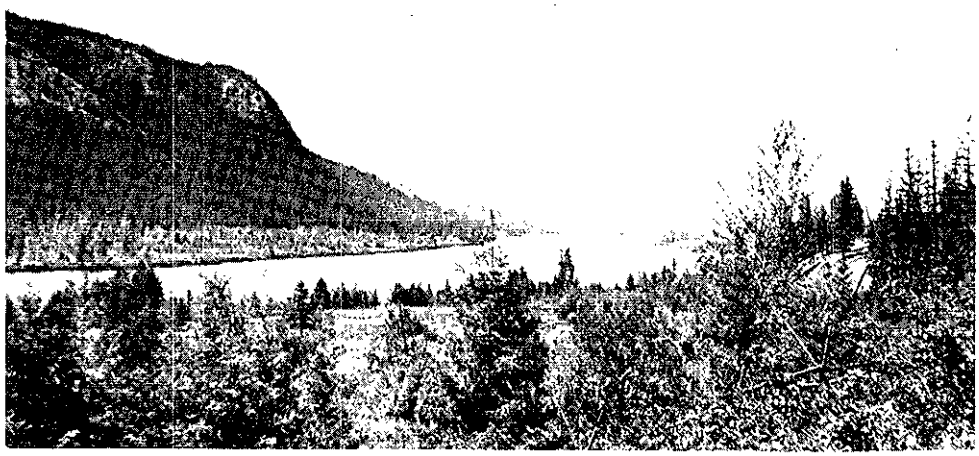
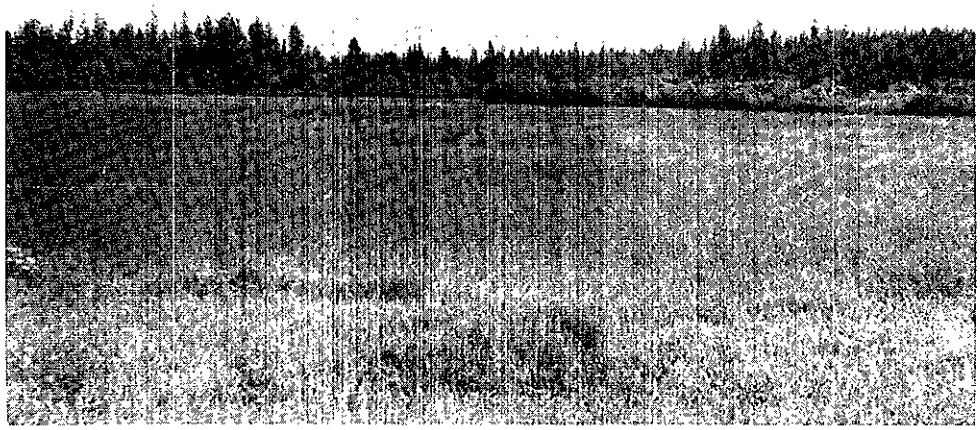
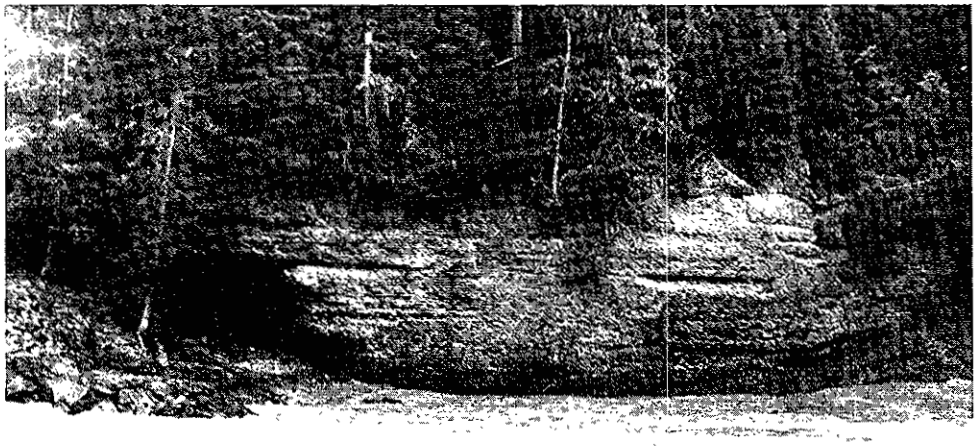


Change in character of Fraser River Valley near Macalister.



High bench on east side of Fraser River, Dragon Mountain Range in background.



Big Canyon, Quesnel River. Tertiary gravel at lower end of canyon.

Cottonwood Canyon, Fraser River.

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FRASER RIVER TERTIARY DRAINAGE-HISTORY

IN RELATION TO PLACER-GOLD DEPOSITS

Introduction.

To supplement the report on Horsefly area published in the Annual Report, Minister of Mines, British Columbia, 1938, field-work was commenced at the early part of the 1939 season in Beaver Creek Valley to delineate further the Tertiary Horsefly River drainage. It then became evident, however, that the Tertiary drainage-histories of the Fraser and Horsefly Rivers were so closely linked, that further investigation in the Horsefly area should be preceded by an examination in the Fraser River Valley. This was done.

During the year, time only permitted field-work within that part of the Fraser River Valley between Chimney Creek and Cottonwood Canyon. Conclusions reached are therefore based upon the definite evidence afforded by exposures in this part of the valley coupled with general knowledge of the remainder. There is, however, reason to believe that the part of the valley examined is highly important, but as critical exposures therein are numerous and large, all of them could not be examined. Although the result of the examination was to remove much from the realm of mere conjecture, certain conclusions cannot be other than tentative until a complete examination of the river has been made.

With regard to the Lower Lavas, Fraser River formation, and Upper Volcanics mentioned in this report, the respective ages assigned herein are those given by Cockfield in Geological Survey, Canada, Summary Report, 1931, Part A, entitled "Oil Possibilities between Soda Creek and Quesnel," and by Cockfield and Walker in Geological Survey, Canada, Summary Report 1932, Part A1, pages 84 and 85. Paleontological evidence cited under "Horsefly Area," Annual Report, Minister of Mines, British Columbia, 1938, supports this assignment.

Concerning the drainage-history of the lower part of the Fraser River, and its large tributaries the Thompson, North Thompson, and Clearwater Rivers, information will be found in the following publications of the Geological Survey, Canada: "Geology of the Thompson River Valley below Kamloops Lake," 1912, by Charles W. Drysdale; Guide Book No. 8, Part II, 1913, "Savona to Lytton" by C. W. Drysdale, and "Lytton to Vancouver" by Charles Camsell; Summary Report, 1921, Part A, "Geology of

the North Thompson Valley Map-Area" by W. L. Uglow; and Summary Report, 1930, Part A, "Clearwater River and Foghorn Creek Map-Area" by J. F. Walker.

To designate the Fraser River at different periods in its history the prefixes "pre" and "inter" are used in the ordinary geologic sense. The term "pre-volcanic Fraser River" designates the river antedating the volcanism expressed by the Lower Lavas. The term "inter-volcanic Fraser River" is applied to the river flowing between the two periods of volcanism expressed respectively by the Lower Lavas and Upper Volcanics. The term "intra-Lower Lavas Fraser River" is applied to the river flowing during or before actual cessation of the volcanism expressed by the Lower Lavas.

It is of course apparent that deposition of much glacial debris within the Fraser River Valley during the Pleistocene period might have caused the river to deviate from its late Tertiary channel. Several such deviations were noted in the course of this examination but time was not available for their individual study or delineation. Moreover, as the described Tertiary drainage-history is not obscured by changes consequent upon the Pleistocene period, the effects of the latter are not discussed herein other than very briefly. It is not of course to be inferred that, in the northern part of the river not yet examined in detail, and not covered by this report, changes consequent upon the Pleistocene period are necessarily likely to prove unimportant.

It is desired to emphasize the fact that the annual yield of placer-gold from the many bars and benches of the Fraser River more than eighty years after its first discovery still forms a contribution of major importance to the total output of placer. For this reason, and also because it is the master drainage of the Cariboo district, a detailed investigation of its very complicated drainage-history seems well warranted because it is calculated to throw light on placer deposits which engage attention at the present time.

Summary.

For clarity, an outline of the present Fraser River drainage is first given, followed by a summary of the more important facts ascertained in the course of this examination. Details follow in the body of the report.

The most obvious features of the present drainage are:

(a) The great bend of the river at its most northerly point,

where it leaves the Rocky Mountain Trench, and changes the direction of its flow from north-westerly to southerly at Prince George.

(b) The striking contrast between the subdued relief of its valley between Macalister and Prince George, and the gorge-like character of the valley south of Macalister.

(c) The drainage pattern of all major tributaries north of the mouth of the Chilcotin River is not consistent with a southerly-flowing parent stream.

(d) Flanking the east or left bank of the river between Ten Mile Lake and Soda Creek, a distance of over 50 miles, is an immense bench with a central depression now occupied by lakes and meadows. The height of this bench above the river varies from about 700 feet at the north end to 1800 feet at the south end. It will be noted that this bench, the average width of which is about 5 miles, slopes downwards to the north, and that it is in close alignment with the large northerly-trending valley now occupied by the lower part of Canyon Creek (Feature "f," Fig. 1).

Features (a) and (b) considered in conjunction with (c) strongly suggest stream-piracy of a once northerly-flowing parent stream, and reversal of flow in the Fraser River north of the mouth of the Chilcotin river. The great extent of feature (d) and its slope downward to the north suggest that it may be the preserved erosion remnant of the ancient northerly-flowing Fraser River, and that the earliest channel of this river may lie buried beneath this bench.

Quite independent of the question of reversal of drainage, however, is the positive evidence of interruption caused by lava damming, afforded by a number of exposures. This damming took place at two widely-separated periods; by the Lower Lavas of Eocene or earlier age, and by the Upper Volcanics of Miocene(?)age as instanced in the Horsefly River area. A long period of sedimentation expressed by the Fraser River formation in the Fraser River Valley followed the earlier eruption. These formations are discussed at length by Cockfield in "Oil Possibilities between Soda Creek and Quesnel, Cariboo District, British Columbia," pages 58A to 65A of Summary Report 1931, Part A, Geological Survey, Canada, and a résumé is given in Annual Report, Minister of Mines, British Columbia, 1938, pages C20 and C21.

In the course of the present examination it was dis-

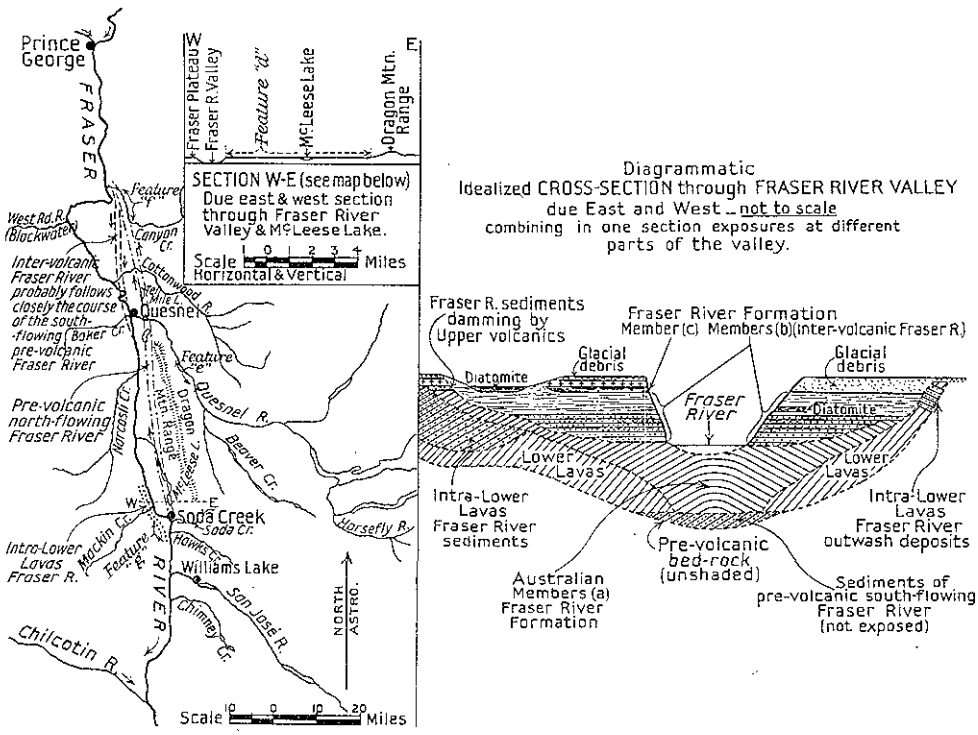

Fig. 1. Sketch-map showing former channels of Fraser River, and diagrammatic cross-section.

closed by a number of large exposures that the drainage history may be summarized thus:-

(1) In Eocene or earlier time, between Soda Creek and Quesnel, eruption of the Lower Lavas caused extensive damming. Locally, lava filled the valley to a depth of 1,200 feet or more, and the effects of damming were evident probably far north of Quesnel. Large and noteworthy remaining remnants of these dams through which or past which the river now flows, are those in the vicinity of the mouth of Narcosli Creek, and the narrow gorge of the river between Marguerite and Soda Creek.

(2) As a result of damming caused by this volcanism, basins were formed in which the basal members of the Fraser River formation were laid down. These sediments must, therefore, be of unquestionable fresh-water origin.

(3) On field evidence the Fraser River formation is subdivided thus:-

(a) Australian members, basal members. These comprise the now tilted lignite coal measures, well exposed near Australian although there are many outcrops at other points.

(b) Well-sorted imbricated gravel and overlying sediments of the inter-volcanic Fraser River.

(c) Diatomite deposits, uppermost member.

Between (a) and (b) there is angular unconformity. The attitude of members (b) and (c) is horizontal or only slightly inclined.

(4) Exposures at the Big Bend of the Fraser River, 10 miles north of Quesnel, demonstrate that after the deposition of members (a), these members were tilted, and slightly folded, and that drainage over them was restored by the inter-volcanic Fraser River. This river finally reached lacustrine conditions, and the numerous deposits of diatomite were formed in river-made lakes.

(5) It is proved, however, by an exposure on the left bank of Baker Creek immediately below the Fraser Plateau on Pre-emption Lot 8651,* that subsequent to the formation of the diatomite deposits, which are overlain at some points by the Upper Volcanics, the Fraser River was dammed by these volcanics.

(6) One mile south of Australian Creek on the east side of the river, the Australian members of the Fraser River formation are exposed at water-level and overlain by basalt of the Upper Volcanics, the thickness of which varies from a few feet to 40 feet. The unusual topographic position of the basalt demonstrates that the river-valley had been again incised to this depth at this point in Miocene (?) time.

(7) The existence of the Lower Lavas, and the Fraser River formation within the present Fraser River valley proves that this valley had been incised to great depth prior to the Eocene by which time therefore the capture of any northerly-flowing river must have been effected, and a southerly flow established.

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*Quesnel Sheet, Map No. 3G shows all pre-emption lots mentioned and may be obtained on application to the Department of Lands, Victoria, British Columbia.

Topography.

After flowing north-westerly within the Rocky Mountain Trench in its upper reaches, the Fraser River makes a great bend to enter the Interior Plateaux and thereafter to flow almost due south from the confluence with the Nechako River at Prince George. From Prince George to Macalister it flows within a wide valley of mature relief incised in the densely-timbered Fraser Plateau, whereas just south of Macalister the valley closes in abruptly and the river enters a narrow gorge, which becomes progressively deeper down-stream reaching a depth of 1,500 feet near Chimney Creek, and deeper still farther down-stream. Although north of Macalister there are several canyons, or gorges, these are merely incisions in the bottom of a wide valley, the subdued relief of which is unobscured by the canyons. The further curious fact is also evident inasmuch as north of the confluence of the Chilcotin River, the direction of flow of all major tributaries, the San Jose River, Hawks (Deep) Creek, Quesnel, Cottonwood, Willow and Bowron Rivers on the east, and of the Nazko, West Road (Blackwater) and Chilako Rivers on the west, is opposed to that of a southerly-flowing parent stream. (See Fig. 2.) It is also a point of interest that the drainage-pattern of western tributaries is dendritic, whereas that of eastern tributaries is of trellis-type, indicating absence and presence of structural control respectively.

Another significant topographic feature (Feature "d", Fig. 1) is the great bench averaging about 5 miles in width for a distance of 50 miles, with a central depression which flanks the east or left bank of the Fraser River between Ten Mile Lake and Soda Creek. The height above the Fraser River varies from about 700 feet at Ten Mile Lake to 1155 feet at the intermediate point of Alix Lake and, to 1808 feet just north of Soda Creek. This central depression is occupied by Ten Mile, Dragon, Eveline, Alix, Cuisson and McLeese lakes and much meadow farm-land and other smaller lakes. A length of at least 30 miles, north of Soda Creek, stands out as a distinct physiographic unit, because hereabouts its western cliff-like edge drops off sharply to form the east rim of the Fraser River Valley. Farther north the western edge is not as steep. It will be noted that it slopes downwards to the north and not to the south. The elevation of its floor is 3,175 feet just north of Soda Creek, 2,622 feet at Alix Lake, 2,300 feet at Ten Mile Lake. In the vicinity of Dragon Lake, the elevation is 2,025 feet, but hereabouts the flood waters of the Quesnel River have at different times effected considerable erosion. Southerly the bench is terminated abruptly immediately north of Soda Creek where the river makes a sharp

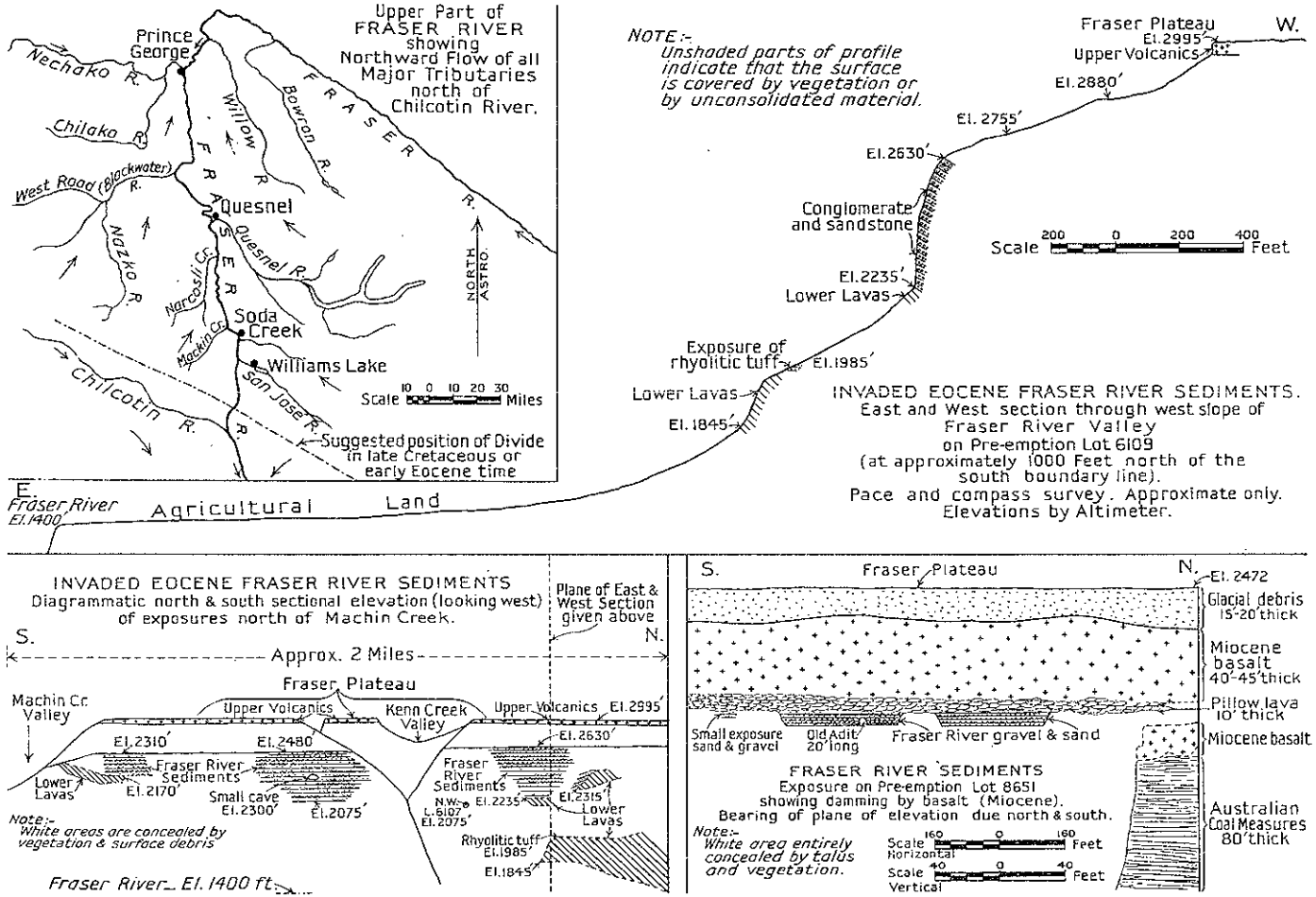


Fig. 2. Map of upper part of Fraser River, and sections of former channels of Fraser River.

bend easterly, its southern edge forming a rock bluff many hundreds of feet in height. From Quesnel southerly the bench is terminated on the east by a range of mountains, which may for convenience be called the Dragon Mountain Range because Dragon Mountain is the most northerly point of this range, which separates the Fraser River Valley from the Quesnel River and Beaver Creek Valleys.

On the east side of the mountain range mentioned, in the Quesnel River Valley, a similar smaller bench (Feature "e", Fig. 1) flanks the west or left bank of the Quesnel River at elevation 2,590 feet or 600 feet above the Quesnel River.

Another striking feature is the large size of the northerly-trending part of Canyon Creek Valley (Feature "f", Fig. 1) situated in line with and some distance north of the bench described.

The foregoing topographic features strongly suggest stream piracy. It therefore seems probable that in late Cretaceous or early Eocene time, there was a divide north of the mouth of the Chilcotin River, from which the drainage was northerly into the Peace River, while south of the divide the drainage was southerly as at present. The large bench mentioned with its central depression, sloping downwards to the north, is quite likely an erosion remnant of this northerly-flowing river, which may have originally flowed northerly by way of McLeese, Cuisson, Dragon and Ten Mile Lakes, and the northerly-trending part of Canyon Creek Valley.

Further, it seems evident that piracy was chiefly accomplished by a tributary of the Chilcotin River which eroded northerly in much the same valley as that now occupied by the Fraser River in this region and, finally, accomplished a reversal of flow in the Fraser River Valley. To a lesser extent and in the same way, the Clearwater River, a tributary of the North Thompson, probably cut off eastern tributary drainage.

The evidence very strongly supports the view of stream-piracy as outlined, and it is highly probable that such piracy took place before the volcanism expressed by the Lower Lavas, because the occurrences of the latter, within that part of the river examined, are without exception of the valley-fill type in a deeply-incised valley. Such early deep incision must have been due to diastrophic movement, and if there was a still earlier drainage to the north then existent as indicated, its reversal would certainly have been effected by this deep incision.

Another large bench (Feature "g", Fig. 1) flanks the

west or right bank of the Fraser River, 400 feet above river-level, immediately south of Soda Creek.

The depth of the gorges occupied by tributaries prior to their junction with the Fraser River, is noteworthy. The San Jose River and Williams Lake Creek now occupy the same large valley, which trends south-easterly from its junction with the Fraser River Valley for a distance of at least 50 miles (see Fig. 1). This valley, near its junction with the Fraser River Valley, is but little inferior in size to the latter, and both in this region are gorge-like. Up-stream the gorge-like character of the San Jose Valley gives place to one of more mature relief. Deposits of diatomite near the east end of Williams Lake bear witness to the age of this valley, and its size, suggests that prior to the piracy of its headwaters, it was occupied by a much larger stream of water than at present. Hawks Creek (formerly named Deep Creek), occupies for many miles near its mouth, a deeply-incised valley which at its confluence with the Fraser River becomes a deep gorge. Soda Creek is also contained in a deep gorge at its confluence with the Fraser River, and the depth of rock cut by it up-stream is obviously considerable. The upper parts of the valley are largely drift-filled, and the waters of the creek are so super-charged with lime that it has been unable to move the glacial material owing to the rapid rate at which calcareous tufa is deposited within its bed but a short distance from its mouth, causing constant choking of new channels. The Quesnel River, at the point where its flow changes from north-westerly to westerly, and finally south-westerly is contained in a rock-canyon 2 miles long, called the Big Canyon. Down-stream for a further 3 miles the river occupies a deep gorge in which rock-outcrops are obscured. Within the Big Canyon tightly-compacted residual gravel overlies rock-benches which flank both sides of the river at heights varying from 10 to 30 feet above river-level. This gravel within the canyon is immediately overlain by soil and dense vegetation, except above the north wall where it is overlain by glacial materials. Exposures here show that this gorge, the depth of which approaches 700 feet, is of pre-glacial age, and the canyon incised in its bottom is post-glacial. This river was evidently compelled to deviate from a structurally-controlled valley by a parent stream rapidly deepening its bed. A depression in the plateau, trending north-westerly towards Ten Mile Lake at the head of the canyon and continuous with the up-stream part of its valley, suggests the position of the earlier valley occupied by this river.

Narcosli and Baker Creeks are both contained in large and deep scenic gorges, immediately before entering the Fraser

River Valley.

The Cottonwood River in its down-stream part is also contained in a deeply-incised valley. (Refer to Annual Report, Minister of Mines, British Columbia, 1936, pages C17 to C28).

One feature of the Fraser River Valley, applying only to that part south of Quesnel, is the occurrence of frequent and extensive rampart-like rock-exposures, which cap both valley-rims forming the floor of the Fraser Plateau. Because the lower valley-slopes are frequently obscured with vegetation and the plateau and lower valley-slopes are densely timbered, the boldness with which these outcrops stand out on the sky-line, is accentuated. North of the mouth of Baker Creek this feature no longer exists, and the valley-rims, unfeatured by rock-exposures, slope gradually down to river-level, near which they are terraced, for a distance of about 6 miles. Farther up-stream, 10 miles north of Quesnel, in the vicinity of the Big Bend which is composed of two hairpin bends, the character of the rims changes abruptly. Conglomerate of the Fraser River formation overlain by clay, sand, silt, and diatomite capped by basalt and finally by boulder-clay, rises almost sheer from the river to the plateau, on the west side at this point 760 feet above the river. On the east side of the river, the order of succession of strata is much the same save that the slope is more gradual, and no basalt is present. It is apparent that the lava-cap forming the floor of the plateau has been the means of averting serious slides, and, where it is not present, as on the east side of the Big Bend for instance in the region of the Big Slide, extensive sloughing may result. Fortunately the well-lithified conglomerate at river-level limits a movement which would otherwise be even more serious. Up-stream from the Big Bend, the valley-slopes again become less sharp, and about 1 mile above the junction of the Cottonwood River sediments of the Cache Creek series appear in both banks of the river. These rocks gradually rise to form the steep walls of the Cottonwood Canyon, the height of which approaches 375 feet at the head of the canyon, at the mouth of Whittier Creek.

The Fraser River and all its tributaries are at present in a state of active rejuvenation, similar to the condition exemplified by the Peace River and its tributaries. It is apparent that a race for capture is in progress between these two large pirate rivers. The most southerly drainage of the Peace River at Summit Lake is within a few miles of Tay Creek a tributary of the Fraser River, and diastrophic movement might throw the balance in favour of one river or the other.

It is also evident that the active rejuvenation of the Fraser River persists to its headwaters where it is likely to capture the headwaters of the Miette River (in Alberta) in a comparatively short space of geologic time.

Glacial Geology.

During the Pleistocene period, the Fraser River Valley and tributary valleys received large amounts of glacial debris, and the many terraced gravel benches indicate the various levels occupied by post-glacial streams in cutting down through this accumulation. From the commercial point of view, the concentrations of placer-gold accompanied, at some points, by the platinum group of metals, that resulted from this resorting process are important at present, as are recent concentrations on the many river-bars. The present annual recovery from this source, from Chimney Creek up-stream, amounts to many thousands of dollars, and forms a major contribution to the total output of placer-gold. The present examination was not however concerned with the study of glacial geology save indirectly as, in that part of the river examined, it was apparent that glaciation had not obscured the Tertiary history The distribution of erratics within the Beaver Creek Valley and the Quesnel River Valley down-stream from the junction of the latter indicates a north-westerly movement of an ice-tongue, which is an interesting and curious fact. Within Beaver Creek Valley numerous erratics of micaceous rocks were observed, which are cut by the upper reaches of the Horsefly River. On the bench immediately east of the river just north of Soda Creek an erratic of micaceous schist was found 1,800 feet above the river. Most striking was a large erratic about 12 feet by 8 feet by 6 feet, perched on top of the north wall of the Big Canyon of the Quesnel River that had obviously originated from Dragon Mountain Range. It seems likely that this local north-westerly distribution of drift is to be attributed to a large tongue of ice moving down from the high mountains at the upper reaches of the Horsefly River along the Horsefly River, Beaver Creek and lower part of the Quesnel River Valleys.

Bed-rock Geology.

The rocks exposed within the Fraser River Valley between Chimney Creek and the Cottonwood Canyon consist of chiefly sediments of the Cache Creek series of Carboniferous age; the Lower Lavas of Eocene or earlier age; the Fraser River formation; and the Upper Volcanics of Miocene(?)age. These volcanic rocks of two different ages also occur in the Horsefly area, and are discussed on pages C20 and C21 of the Annual Report,

Minister of Mines, 1938. The respective ages assigned to them in this report are based upon the findings of Cockfield in Summary Report, 1931, Part A, Geological Survey, Canada, pages 58 to 65, and upon those of Walker in Summary Report, 1932, Part A 1, Geological Survey, Canada, pages 84 and 85, and also upon paleontological evidence as cited in the Annual Report, Minister of Mines, British Columbia, 1938.

In addition, there are numerous large exposures of stratified breccias, tuffs and waterlain sediments, varying from coarse conglomerates to silt intercalated with the Lower Lavas. These exposures of Eocene or earlier Fraser River sediments differ markedly from those of the Fraser River formation, in that they are much more perfectly lithified; the constituent pebbles or grains are much more angular; and they are either invaded or overlain and underlain by the Lower Lavas.

The Upper Volcanics consist of fresh-looking, flat-lying or gently-inclined olivine basalt, black in colour, usually vesicular, and frequently exhibiting columnar structure.

The Lower Lavas are prevailingly less basic, have been disturbed to a much greater extent, evince a greater degree of metamorphism, and also frequently exhibit columnar structure. Although some of these lavas approach the composition of andesite, the rarity of siliceous Tertiary lavas in the Cariboo district is well known and appears strange in view of the great thickness of acid tuff beds in the Horsefly area. Attention to this fact is drawn by Louise Stevens Stevenson in a paper "Rhyodacite from the Tranquille Plateau, British Columbia," presented to the Mineralogical Society of America, December 29, 1938. The most acid lava of this age, discovered during the present examination, is an outcrop of greyish-white vesicular quartz-latite (tridymite-latite) on the west bank of a small southerly-flowing creek which enters the Fraser River on the east side just north-west of Soda Creek. This creek has incised a deep gorge close to the boundary line between Pre-emption Lots 5086 and 5087, and exposed on its east bank some limestone of the Cache Creek series, and on its west bank latite. In this region the Provincial highway passes close to the base of a large cliff-like rock-exposure 1,300 feet in height which extends west of this creek. The eastern part of this exposure consists of strata of latite and pumice with intercalated beds of fine-grained white tuff, sandstone and coarse tuffaceous material. The sandstone beds are presumed to be Eocene or earlier Fraser River sediments. The tuff beds strike north 63 degrees east and dip south-eastward at 65 degrees. Owing to the precipitous nature of the exposure, closely approaching 600 feet in vertical height,

close examination can only be made of the upper part of this large exposure.

Beds of white tuff are also exposed north of Kenn Creek on the west side of and 585 feet above the Fraser River in close proximity to the Lower Lavas but the contact is obscured.

With regard to exposures of Eocene or earlier Fraser River sediments: These remarkable deposits doubtless owe their origin to the fact that they were formed during the final stages of volcanism after the main diastrophic movement of this period when restoration of flow of the Fraser River had been effected. In some it is difficult to distinguish between breccias or tuffs and waterlain sediments, as the latter are not only overlain and underlain by flow-rocks but some exposures are invaded by the lavas or contain granulated lava distributed through them. Others are faulted, the displacement amounting only to a few feet and faults are filled with dykes or chalcedony. All such exposures are well-lithified. The presence of much driftwood completely replaced by aragonite sometimes unmistakably reveals the true identity of a deposit, which would otherwise perhaps be deemed to consist of breccias. In some, the identity of the intercalated sediments is sufficiently obvious and the angle of inclination of such strata did not exceed 30 degrees save in one instance; and in most cases was considerably less than this. This fact suggests that they cannot have been involved in the tectonic movement that produced the steep dips which in main characterize the contact planes of the Lower Lavas, a movement which the pre-existent bed-rock gravel of the pre-volcanic south-flowing Fraser River could hardly have escaped. It is known that although a great thickness of lava was erupted during this period there was also much volcanism of an explosive character in the later stages. It, therefore, seems entirely reasonable to suppose that the river of this period, which is termed the intra-Lower Lavas Fraser River, would be conveying much volcanic ejectamenta in addition to its normal stream-load. It seems likely that the large deposits of coarse, angular, sub-angular, and rounded pebbles exposed on the west side of the river north of Mackin Creek, which are not actually overlain by the Lower Lavas, express restoration of a large stream of water to which the name intra-Lower Lavas Fraser River seems appropriate. The dykes and sills and minor faults in these deposits express the final stages of the volcanism of the Lower Lavas subsequent to the formation of the sediments. On the other hand, exposures of fine sediments and associated stratified breccias already described are probably the outwash deposits of the intra-Lower Lavas Fraser River. Their invari-

ably high topographic position indicates the height to which the waters were caused to rise owing to damming by lava.

Lindgren in "The Tertiary Gravels of the Sierra Nevada of California," Professional Paper 73, published by Geological Survey, United States, 1911, calls attention to what appear to be similar stratified breccias observed in California. He states: "By far the greater part of the andesite occurs in the form of a tuffaceous breccia in numerous superimposed flows. These breccias must have issued from fissures near the summit of the range, and were either before their eruption or at the time of issue mixed with enormous quantities of water.. ...The derivation of the water and the exact mode of eruption are difficult to determine." A ready explanation of the origin of the water is afforded in the case of the Fraser River deposits.

The geographic distribution and topographic position of these rocks is significant and important. The rocks of the pre-volcanic Cache Creek series are those in which the Cottonwood Canyon is incised. Down-stream from the head of the Canyon, these rocks are exposed on both banks of the river for a distance of about 1 1/2 miles, and in them Baker Creek Canyon is incised. They next appear in the river-valley near Soda Creek and from this place the river has incised its deep gorge wholly in them as far as and below Chimney Creek. A small unnamed creek flowing southerly near the boundary line between Pre-emption Lots 5086 and 5087 from the high bench in this region, has incised a deep gorge which exposes on its east bank limestone of the Cache Creek series and on its west bank vesicular quartz-latite (tridymite-latite) intercalated with tuffs of the Lower Lavas and Eocene or earlier Fraser River sediments.

The Lower Lavas are typical valley-fill occurrences and are exposed on both sides of the river at a number of different points between Soda Creek and Macalister, the gorges of the river in this region being incised in them. Up-stream from Macalister, to and north of Windt Creek these lavas are exposed at a number of different points high on the valley-slope on the east side of the river, and on the west side of the river they form an individual unit named Castle Rock. North of this, up-stream on the west side of the river, they are very prominently exposed, and down-stream from the mouth of Narcosli Creek for some miles they rise sharply from the river to a height of many hundreds of feet. In them Narcosli Creek has incised a steep-walled gorge, the depth of which approaches 1,000 feet, and which constitutes one of the scenic spots of the neighbourhood. The most northerly exposure out-

crops on the west side and 200 feet above the river, at about 3 miles south of Quesnel. Although the occurrence of the Lower Lavas is typical valley-fill, they and their intercalated sediments extend at many points east of the river to the top of the valley-rim, where their cliff-like exposures occupy the normal topographic position of the Upper Volcanics. The Lower Lavas also form the western boundary of the large flat on the right bank of the Fraser River south of Soda Creek.

The Fraser River formation assigned by this examination to unquestionable fresh-water origin, is, on field evidence, subdivided thus:

(a) Australian members. This term is applied to the basal members, the well known lignite coal measures, the best exposures of which are in the Fraser River Valley, near Australian, although many others occur both north and south of this place. The commercial significance of the contained lignite coal seams has at different times attracted attention. (Refer to Geological Survey, Canada, Summary Report, Part A, 1931, pages 58 to 65 also to Annual Report, Minister of Mines, British Columbia, 1930, pages 170 to 172). These members have been gently folded, and angles of dip reach 20 to 30 degrees.

(b) Imbricated well-sorted gravel, with overlying interstratified beds of fine gravel, sand, silt, clay, lignite, and occasional tuff beds. Lignite seams reach a maximum observed thickness of 2 feet 3 inches. These beds are horizontal or nearly so.

(c) Diatomite deposits. These are the uppermost members overlying (b).

It is to be noted that there is a distinct angular unconformity between (a) and (b). In the case of the diatomite deposits, the slight dips observed are probably largely due to slumping. Although members (b) and (c) are composed of nearly horizontal strata, they are subdivided because members (b) clearly express the restoration of a southerly flowing river (as shown by the imbricated gravel), the inter-volcanic Fraser River, and its gradual reduction to lacustrine conditions. It is clear that the diatomite deposits were laid down in river-made lakes, and not in basins due to lava damming, because the diatomite deposits in several exposures are overlain by Miocene (?) basalt, which is in turn capped with glacial deposits. The complete succession of these strata, as above given, is clearly apparent from exposures at the Big Bend of the Fraser River 10 miles north of Quesnel. Here the angular unconformi-

ty between members (a) and (b) is well exposed at low stages of water.

Many exposures of the Australian members (a) occur adjacent to the Fraser River where, at a number of different points, they form the lower part of the valley-rims, and extend below river-level. They also occur at high elevations, for example on the left or west bank of Baker Creek below the Canyon at points several hundred feet above the Fraser River, and also in the valley of Australian Creek. In this section they are exposed continuously in the valley for half a mile or more up to elevation 2,162 feet (682 feet above the Fraser River at the mouth of this creek). This exposure is at least 2 miles from the Fraser River, proving the considerable thickness of the members and the size of the containing basin. In the Annual Report, Minister of Mines, British Columbia, 1930, on pages 170 to 172 on account of diamond-drilling carried out in the Australian coal measures is given. A map also shows the position of a drill-hole which was commenced in 1930 and carried to a depth of 1,090 feet in 1931 and, subsequently abandoned. An account of the findings is given in Geological Survey, Summary Report, 1931, Part A. The pre-volcanic Fraser River sediments or the Lower Lavas must underlie the Australian members (a), but it is not known if the drilling penetrated them. Several exposures demonstrate that these coal measures have been burnt or possibly baked at different points by overlying lava. Of these, the best known is "Red Hill" on the highway about half a mile south of Quesnel. No evidence, however, was found of intrusion of the Australian members or overlying members of the Fraser River formation by igneous bodies.

Large and continuous exposures of members (b) of this formation occur at and immediately above and below the Big Bend, 10 miles north of Quesnel.

Member (c) diatomite deposits are exposed on both sides of the Fraser River at the Big Bend, and at several other points near Quesnel. All such exposures are adjacent to the river. To the south, on the west side of the river, north of the Alexandria Ferry, on and adjacent to Pre-emption Lot 8015, diatomite deposits occur at a number of different points and occurrences are also reported in Narcosli Creek Valley. It will be noted these latter occurrences are from 2 to 4 miles west of the river. There is every reason to suppose that a large area in this region is underlain by diatomite. The normal topographic position of these deposits is 700 to 800 feet above the Fraser River, and low-lying individual deposits have possibly sloughed from their original position.

The Upper Volcanics almost always, but not invariably, occur at the top of the valley-rims on both sides of the Fraser River, and the rampart-like exposures averaging about 50 feet in height, and extending for considerable distances, are a feature of the landscape south of Quesnel. Such exposures do not occur far north of Quesnel. Owing to the extensive erosion which has taken place within the Fraser River Valley since this lava was erupted, valley-fill occurrences are likely to be rare. One such, however, exists at water-level on the east bank of the river about 1 mile below Australian Creek, where a maximum thickness of 40 feet of vesicular basalt directly overlies the Australian members of the Fraser River formation. The basalt is directly overlain by a varying thickness of silt, and at the up-stream end of the exposure, which occurs at a bend of the river, the Australian members are overlain by iron-stained river-gravel. This exposure very plainly indicates that an earlier channel of the river lies buried east of the river in this region.

At a number of different points the Miocene (?) basalt is overlain by a varying thickness of glacial material, up to an observed maximum of 25 feet. At other points, however, it is evident that glacial materials have been swept off by post-glacial waters, and little save soil and vegetation overlie this rock.

Although the normal topographic position of the Miocene (?) basalt is a valley-capping, in some instances it is apparent that erosion has removed it entirely, leaving in its place cliff-like exposures of invaded Eocene Fraser River sediments. For this reason a distant view is apt to convey a wrong impression of real identity.

Exposures of Eocene or earlier Fraser River sediments. Exposures were examined at the following points:

(1) On the west side of the Fraser River, within a distance of about 2 miles north of Mackin Creek, are 3 adjacent exposures.

(2) On the east side of the Fraser River: (a) both north and south of Windt Creek, (b) 4.1 miles south of the point at which the highway crosses Australian Creek, (c) 12 miles south of the point at which the highway crosses Australian Creek. All these exposures lie near the top of the valley-rims and all are large and cliff-like, so that it is only the lowest parts of each that can be closely examined.

(1) Exposures to the north of Mackin Creek on the west

side of the Fraser River, on Pre-emption Lots 6106, 6107 and 6109.

These exposures are reached by crossing the river by Soda Creek ferry. A road passable for cars for a distance of 7.1 miles, switchbacks up the steep valley-slope from the north ferry-landing and thereafter parallels the Fraser River northwards as far as Mackin Creek. From this point a trail follows a flat about 125 feet above and flanking the river. The exposures are readily reached from this trail by climbing the steep valley-slope. Two of the three exposures lie between Mackin and Kenn Creeks, and one is north of the latter. The exposures, illustrated on Fig. 2, consist of conglomerate beds of angular, sub-angular and rounded pebbles and boulders varying in size from 3 inches up to 2 feet, and interstratified beds of sandstone underlain by the Lower Lavas. The pebbles and boulders in the conglomerate are composed almost entirely of the same rocks as those in which the channel is incised. These cliff-like exposures, some hundreds of feet in length individually, vary in height from 240 feet to 400 feet. The elevations of the tops vary from 910 feet to 1,230 feet above the Fraser River.

The most southerly and most northerly exposures are immediately underlain by the Lower Lavas. The base of the central exposure is concealed by talus and vegetation. The most southerly exposure is underlain by basalt and a green-coloured flow-rock similar to that exposed on the highway on the east side of the river opposite this point. In the most northerly exposure the underlying rock is basalt. The sediments show much evidence of minor faulting both normal and reverse, but no displacement of more than a few feet was observed. Some fault-planes are healed with serpentinized basic dykes, and at several different points sills of the same material, a few inches wide, invade the bedding-planes. The beds are well-lithified, strike due north and dip west at angles varying from a few degrees to 30 degrees in the case of the most northerly exposure. At the top of these exposures the terrain is at some points quite flat; at others, is occupied by a shallow depression, and elsewhere rises from 20 degrees to 30 degrees up to rampart-like exposures of the Upper Volcanics, which form the floor of the Fraser Plateau, the elevation of which is 2,995 feet, or about 350 feet above the top of the gravel-exposures.

At a point 330 feet below the base of the most northerly exposure, white volcanic tuff outcrops close to a large exposure of grey vesicular flow-rock, but vegetation and talus obscure the stratigraphic relationship.

It is clear that these exposures are of one and the same stream. The size and angular character of the gravel indicates very hurried sorting by a heavily-loaded rapid stream of water. In view of their size the exposures probably express a restoration of a major part of the flow of the river-waters during the eruption of the Lower Lavas and may be termed the intra-Lower Lavas Fraser River.

Exposures on the east side of the Fraser River. All these may be readily reached from the highway by ascending the valley-rim at the points indicated.

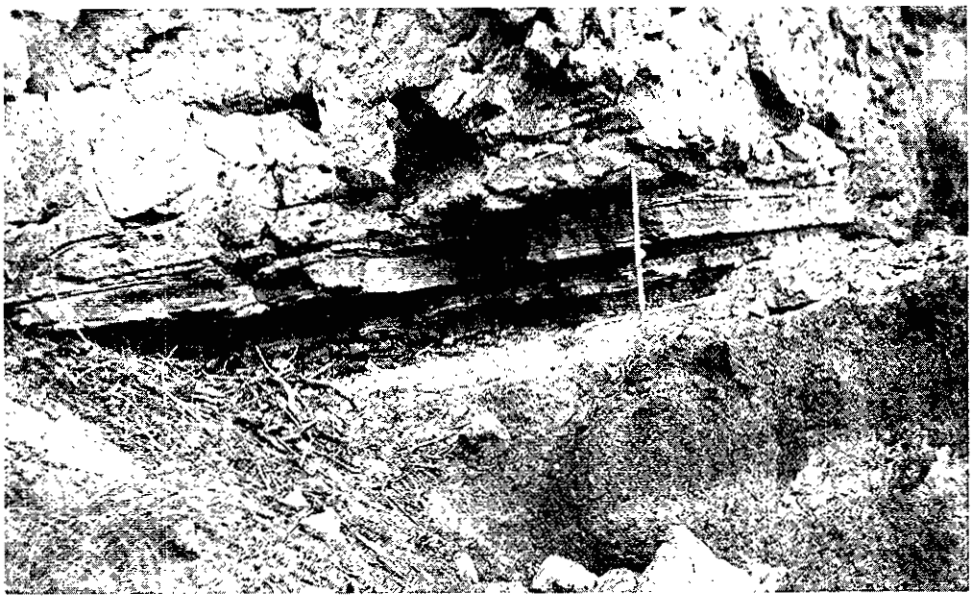
Exposures north and south of Windt Creek. Immediately below the Fraser Plateau, the elevation of which in this region varies from 2,600 to 2,700 feet, that is 1,133 feet to 1,233 feet above the Fraser River, are adjoining cliff-like rock-exposures, which are distributed over a distance of about 1 1/2 miles, north and south of Windt Creek. South of Windt Creek one exposure somewhat over 1,000 feet long and 135 feet high, consists of basaltic flows of the Lower Lavas with intercalated beds of silt, sandstone, and breccia. These are overlain by 20 feet of columnar basalt, and the latter is again overlain by breccia, which extends almost to the plateau-level. North of Windt Creek another large exposure exhibits columnar basalt of the Lower Lavas both overlying and underlying silt beds of a total thickness of 35 feet. The silt beds are intruded by vesicular dykes, and contain much granulated lava. The strike of the silt beds is north 8 degrees east, and their dip is 5 degrees south-eastward. These exposures indicate that the Lower Lavas extend in this region to the top of the valley-rim, and any once-existent rocks of the Upper Volcanics have been entirely eroded. These exposures are probably outwash deposits of the Eocene Fraser River, and exemplify the height to which the waters of the river rose as a result of the great height of the lava dams of this period.

Exposure 4.1 miles south of the highway-crossing of Australian Creek. Immediately below the Fraser Plateau high up on the east rim of the Fraser River Valley connected with the Plateau by a peninsula-like rock-remnant is a large and prominent knoll, the summit elevation of which is 2,437 feet. The base of the knoll is covered by a long talus slope and dense vegetation. The uppermost 60 feet are composed of well-lithified beds of sandstone, the individual grains of which are angular, sub-angular and rounded. These beds strike north 22 degrees west, and dip north-eastward at 5 degrees. This deposit is noteworthy for the large amount of driftwood therein, pieces ranging up to 6 inches in diameter. This driftwood

has been entirely changed to aragonite, replacement by this mineral being perfect. It was noted that a number of birds' nests had been built in deep holes in the exposure. At first it was extremely difficult to understand how sand-martins could peck deep holes in such a well-lithified rock until it was perceived that each nest represented the space formerly occupied by a piece of driftwood some inches in diameter. The birds apparently find it possible to peck their way into the comparatively soft aragonite. The elevation of the Fraser Plateau in this neighbourhood is about 170 feet above the top of this knoll. This exposure also appears to exemplify outwash deposits of the Eocene Fraser River caused to rise to a great height owing to lava damming of this period. In the rear of this knoll and to the south of it, at the edge of the Fraser Plateau, columnar basalt of the Lower Lavas is exposed.

Exposure 12 miles south of the highway-crossing of Australian Creek. This exposure is immediately below the top of the Fraser Plateau at the rear of the large bench on which a monument on the highway has been erected by the Historic Sites and Monuments Board. The elevation of the base of the exposure is 2,477 feet. At this level, a 90-foot width of stratified breccia, well-lithified waterlain silt, sand and clay beds, extends for a length of some hundreds of feet 200 feet below the Fraser Plateau. Basalt of the Lower Lavas which extends to the plateau overlies these. At the base of the exposure is a long talus slope through which basalt of the Lower Lavas emerges at elevation 2,247 feet.

Fraser River Formation. Exposures showing the three sub-divisions of this formation are situated on the west side of the Fraser River at the Big Bend, 10 miles north of Quesnel, although all do not appear in the one section. Extensive sloughing has taken place of recent years below the plateau in this region, but owing to the well-cemented character of the gravels of the inter-volcanic Fraser River, and the underlying inclined beds, sloughing is confined entirely to the overlying members. In Geological Survey, Canada, Memoir 118, 1920, pages 14 and 15, Reinecke gives a detailed account of sections then visible, from which it is clear that the diatomite deposits overlie the sands and clays which in turn overlie the gravel beds of the inter-volcanic Fraser River. At the time of examination on July 12th, it was apparent that the gravel beds which are horizontal or nearly so rest upon coarse grit beds containing well carbonized driftwood which strike north 58 degrees east and dip 30 degrees north-westward. The exposure of these inclined beds is about 75 feet long and of a maximum height of 20 feet. Directly overlying the inclined beds is 15 feet of coarse well-sorted cemented gravel, the imbrication of which indicates a



Outwash sediments of intra-Lower Lavas Fraser River in Lower Lavas.

Exposures of gravel of intra-Lower Lavas Fraser River, north of Mackin Creek.

Beds of inter-volcanic Fraser River, at Big Bend, showing differential weathering. Pinnacle about 150 feet high.

Beds of intra-Lower Lavas Fraser River, north of Mackin Creek.

southerly flow. Overlying the latter, is a thickness of upwards of 300 feet of gravel and sand beds well-lithified, which owing to differential weathering are pinnacled. One pinnacle, about 150 feet high, capped with ferruginous sandstone, is particularly striking, and a photograph of it appears in this report. The inclined beds mentioned are correlated with the Australian members (a) of the Fraser River formation. These exposures prove that the flow of the Fraser River was restored over the Australian members of the Fraser River formation in a southerly direction for a long period. Finally, lacustrine conditions were reached through the operation of those well known processes which function in the life history of rivers, and in river-made lakes (ox-bow, etc.), the diatomite deposits were laid down. These diatomite deposits are overlain by basalt of the Upper Volcanics, and the latter is overlain by boulder clay.

On the opposite side of the river at the Big Bend, at the southern end of the base of the Big Slide, just west of Pre-emption Lot 4382, well-sorted and well-lithified gravel of the inter-volcanic Fraser River rises vertically to a height of 20 feet above the river. Directly overlying the latter, in ascending order, are the following strata: 10 feet of compacted silt; 10 feet of green clay; 3 feet of white clay; a 6-inch lignite seam; 5 feet of white clay; a 6-inch lignite seam; 2 feet of white clay; a 2-foot 3-inch lignite seam; 2 feet of white clay; a 2-foot lignite seam; 4 feet of clay and soil. These strata are horizontal. The top of this section is obscured by vegetation, but up-stream, clays with small seams of lignite occur up to the base of the Big Slide at a height of 165 feet above the river. Coal-forming processes although probably commercially unimportant were therefore operative, subsequent to the formation of the Australian members of the Fraser River formation. Down-stream from the last-described exposure, just below the Big Bend on the east side of the river, is a large exposure of the upper members of the Fraser River formation which is described by Reinecke on page 15 of Geological Survey, Canada, Memoir 118, 1920. On Pre-emption Lot 6182, adjacent to the highway two individual masses of diatomite occur at a height of 335 feet above river-level. It is problematical whether these deposits are in place or not as this position is not normally occupied by diatomite.

Exposure of Fraser River Sediments Dammed by the Upper Volcanics. Rampart-like exposures of basalt of the Upper Volcanics, capped by glacial materials, form the floor of the Fraser Plateau, where it is deeply incised by Baker Creek. These exposures extend northwards into the Fraser River Valley on the left or west bank of this creek for about half a

mile. Near the point where the valleys of Baker Creek and Fraser River merge on Pre-emption Lot 8651, at a height of 922 feet above the Fraser River, 40 to 45 feet of basalt underlies 15 to 20 feet of glacial debris, and overlies an average width of 8 feet of well-washed sand, silt, and gravel. About 10 feet of pillow lava immediately overlies the sediments. The sediments are exposed, discontinuously for a total length of 500 feet, and the pillow lava extends beyond the sediments. Imbrication of the gravel indicates that a southerly-flowing stream was dammed by the lava. The sediments strike due north and dip 7 degrees west. An adit 20 feet long is run south 55 degrees west in the central part at the base of the exposure of sediments. The sediments are compacted but are not cemented. The steep valley-slope below this exposure is obscured by talus and vegetation, but north of the most northerly exposure of sediments, and somewhat below it, basalt overlies the Australian members of the Fraser River formation. These members are also exposed on both banks of Baker Creek on Pre-emption Lot 1228.

The above exposure lies due west of the channel exposed on the opposite bank of Baker Creek, described on pages C36 to C39 of the Annual Report, Minister of Mines, British Columbia, 1938.

Mining Operations concerned with the Fraser River Tertiary Drainage-system.

The only extensive operation is the Tertiary Mine. Other operations are: the Canyon Mine; those of F. Delong; and those of the Golden Province Mines Company. All of these are next described.

Tertiary Mine. This property consisting of 1 placer-mining lease owned by D. D. Fraser and J. McHardie of Quesnel, is at the lower end of the Cottonwood Canyon on the north side of the Fraser River, which flows but little south of east in this region.

The property is reached by a road 6.5 miles long, which branches from the Quesnel-Blackwater road at a point 9.6 miles from Quesnel. The road, passable for light cars with high clearance in dry weather, although there are several soft spots, crosses the Fraser Plateau in a northerly direction, then switchbacks down a steep gravel-bank at the edge of the plateau to a large flat 215 feet above the river. After crossing the latter the road descends a steep grade cut in rock to a boat-landing at the lower end of the Cottonwood Canyon opposite the mine-buildings, the river being crossed

by motor-boat.

At the junction of Whittier Creek, the Fraser River enters the Cottonwood Canyon. The length of this steep rock-walled canyon is about 1 mile; the depth, at its head, of about 375 feet, decreases down-stream, and the river emerges from it at the Tertiary Mine, although rock is exposed on both banks of the river for a further half a mile down-stream. Below the canyon on both sides of the river at varying heights above the latter, terraced benches mark the various levels occupied by the river in cutting through the glacial debris occupying its valley at the close of the Pleistocene period. On the south bank of the river, one bench, 215 feet above the river continues almost to the Big Bend. The entire region is well timbered.

The formation, in which the Tertiary Mine channel is wholly incised at the point of exposure, is argillite of the Cache Creek series. The Cottonwood Canyon is cut in quartzite, limestone and argillite of this series. This formation is also exposed on both banks of the river for a distance of about half a mile below the canyon. It is intruded by a stock of diorite of considerable size on the south side of the river near the head of the canyon and at this point diorite also outcrops on the north side of the river.

The type of placer occurrence is a buried channel of undoubted pre-glacial age, cut diagonally by the Fraser River and exposed on its north bank, at the lower end of the Cottonwood Canyon, about 600 yards below a south-westerly-flowing tributary locally named Killam Creek. The exposure is of particular informative value as the bed-rock, 25 feet above the Fraser River, both rims, and a thickness of 80 feet of channel-filling are clearly revealed. At 105 feet above the river the distance between rims is approximately 1,140 feet. The apparent continuation of this channel, down-stream, is exposed at the Canyon Mine on the opposite bank of the Fraser River about 1,240 feet in a down-stream direction, although the bed-rock of this channel is not here exposed.

Values are confined almost entirely to a thickness of 6 feet of gravel immediately overlying bed-rock, and to cracks and crevices in the latter. The gold is stated to be fairly coarse with occasional nuggets. Recovery involves drift-mining methods, save that the bed-rock gravel is cemented, and no timber is required.

The earliest record of work on this property dates from about 1900 when a small amount of drifting and testing was

carried out by the late Senator Reid. In 1907, a man named Killam, a practical placer-miner, acquired the property, which then became known as the "Killam Gravel Mine," and he and his partner carried on small-scale drifting operations for about 10 years. They drifted about 650 feet up-stream in the exposed cemented gravel immediately overlying bed-rock. Mining was done in the winter and the cemented gravel stacked at the portal of the drift, thereby exposing it to the disintegrating action of general weathering and frost, so that it could be washed the following spring. It is reported that gold recovered by these operations amounted to about 1,000 ozs. In 1917 the property was acquired by the Tertiary Gravel Company of Chicago, and a compressed-air plant for mining with machine drills was installed and, also a mill consisting of jaw-crusher, ball-mill and Pearce amalgamator. The idea prompting mill construction being that only by crushing could the placer-gold be freed sufficiently to be recoverable by sluicing. The venture apparently did not prove a commercial success, and operations were suspended in 1922, when the present owners acquired the property. It was ascertained by them that if 60 per cent dynamite was used in mining, the gold was almost completely freed and recoverable by ordinary sluice-flume methods. Accordingly, they continued small-scale drift-mining until 1926 by which time a length of 1,250 feet of the channel had been mined from the surface inwards. At about this point, however, the workings broke through the cemented gravel into post-glacial gravel, which affording free percolation of surface waters rendered continuation of drifting impossible. It was, therefore, evident that part of the pre-glacial channel had been entirely eroded by post-glacial waters. The operators report that work was profitably carried on up to this point and a total of about 1,000 ounces of gold was recovered. Work was suspended in 1926.

On the assumption that the eroded part of the channel was of limited extent only, an option on the property was acquired in 1935 by the B. C. Development Company, Limited, of London, and in that and the following year a drive was continued up-stream by this company, in the south or right rim of the channel for a total distance of 625 feet. In addition, for safety, a drive was run 225 feet in the rim down-stream around earlier workings in the channel. As the eroded part of the channel proved more extensive than anticipated, ten Keystone-drill holes were bored to bed-rock in the deeply-incised valley of Killam Creek, which flows south-westerly over the westerly extremity of the underground workings, but operations were subsequently discontinued by this company. During the past two years, the owners have carried on small-scale testing and mining.

Surface Exposures. An excellent exposure of the channel is afforded where the Fraser River cuts it on the north bank of the river, as bed-rock, both rims, and a mostly virgin section of the channel-filling, 80 feet in thickness, can be seen. This exposure is about 600 yards down-stream from Killam Creek.

The two rims of the channel at a height of 105 feet above the river, were found by pacing to be 1,140 feet apart. Immediately east of the portal of the Killam drift, which followed the bed-rock gravels inward for about 650 feet, an old hydraulic pit reveals a section of the channel-filling, which flanks the river at this point, from bed-rock up to the top of a flat 105 feet above the river. Channel bed-rock was about 25 feet above river-level on the date of examination on July 8th. Bed-rock gravel and overlying sediments are horizontally stratified. About 20 feet of cemented poorly-sorted gravel rests on bed-rock. The gravel varies from the size of a pea to rounded boulders up to 2 feet in diameter. The average size of the sub-angular and rounded gravel is from 8 to 10 inches. Interstices are filled with sand. Many of the constituent pebbles of the bed-rock gravel consist of quartz, the prevalence of which is noteworthy. Other pebbles are composed of sediments of the Cache Creek series and diorite. Well-carbonized driftwood is also present in considerable amount. Much of the gold recovered was coarse, it is stated, some nuggets having adhering particles of quartz. Overlying this gravel-stratum is a thickness of 7 feet of fine gravel, immediately overlain by a seam of lignite a few inches wide, on which rests 12 feet of mainly clay. Overlying the latter is another small lignite seam, and above this 6 feet of fine gravel. Resting on this is another seam of lignite about 1 foot thick, which has been largely replaced by aragonite, and which contains numerous fine specimens of authigenetic pyrite. This stratum marks the end of the revealed Tertiary history as it is directly overlain by 35 feet of post-glacial gravel which extends to the surface, near which the gravel is coarsest. This exposure very clearly indicates that a stream, of large proportions and cutting power, flowed for a comparatively short time, and was then reduced to one of sluggish flow. Lacustrine conditions were finally reached, and again sluggish flow was restored for a short time to be again followed by an evidently lengthy lacustrine period, evidenced by the clay beds containing authigenetic pyrite and conversion of carbonized driftwood into aragonite. The binding material of the bed-rock gravel is not calcium carbonate which seems strange in view of the fact that there is limestone in the vicinity, and a large deposit of calcareous tufa has formed adjacent to the south or right rim-rock up-stream from the exposure. The bed-rock gravel exudes alum, a mineral which forms a white incrustation where the gravel is exposed to the air.

The underground workings within the channel indicate that the direction of flow in this region is south 37 degrees east, and the bed-rock gradient is 2.17 per cent.

Underground Workings. Killam and his partner drifted on bed-rock from the Fraser River following the channel up-stream for a distance of about 650 feet, and mined bed-rock gravel over a width of between 100 feet and 125 feet. No timber was necessary as the gravel is tightly-compacted or cemented. The later operators drove an adit 400 feet long through the south rim of the channel connecting with the face of Killam's drift and from this point continued drifting for a further 600 feet until the section eroded by post-glacial waters was reached. From this point a rock-drive was continued for 625 feet in the south rim-rock, by B. C. Development Company, Limited. For ventilation a vertical raise, 40 feet long, was driven to the surface in Killam Creek valley, at a point 250 feet from the end of the rock-drive.

Rock-outcrops are obscured by unconsolidated materials on Killam Creek, but McHardie Creek, a larger approximately parallel tributary of the Fraser River about 2 1/2 miles up-stream from Killam Creek, flows in a deep gorge ending 1 mile above its mouth. The gorge is mostly rock-walled, being incised in sediments of the Cache Creek series, but there is a gap in the rock-walls about a quarter of a mile long between points 1 1/2 miles and 1 3/4 miles above its mouth. A vertical shaft, now filled with water, was sunk to a stated depth of 100 feet in the centre of this gap, in 1927, by the present owners, as they deemed it likely that the up-stream continuation of the Tertiary Mine channel passes through this gap, and also that north, of this point, it swings north-eastward towards a point on Canyon Creek near the mouth of Terry Creek. It is understood, that the owners consider that the results of Keystone-drilling on Killam Creek coupled with the existence of this gap and information obtained from certain work done by them in 1929 on Canyon Creek near the mouth of Terry Creek, support this view.

Canyon Mine. This property is on the right bank of the Fraser River, and immediately down-stream from the boat-landing at the end of the road to the Tertiary Mine, and access to it is gained by the latter road. The property lies idle at present, and no information is available as to its early history. In 1932 S.R. Craft and associates carried out some prospecting, but subsequently discontinued operations.

The only known exposure at the property consists of a large buried channel, the exact proportions of which are somewhat obscured by vegetation, but both rim-rocks outcrop. This

channel has been cut diagonally by the Fraser River like the Tertiary Mine channel on the opposite bank, and there is every indication that it is the down-stream continuation of the latter. The bed-rock is, however, below river-level, but just how much cannot now be ascertained, as underground workings are flooded. In the central part of the exposure 8 feet above river-level, on July 6th, an incline had been run south 10 degrees east on a 15-degree slope in tightly-compacted gravel. Water was within 17 feet of the mouth of the working, but, it is stated the incline is 45 feet long and, from the end of it a winze is sunk a short distance, to a paystreak, but whether the latter is on bed-rock is not known. The fact that bed-rock lies below river-level, and, that the grade of bed-rock is unfavourable for drift-mining methods, has doubtless discouraged development of this property. The incline on this property lies south 23 degrees east of the portal of the main rim-rock adit of the Tertiary Mine, and the calculated horizontal distance between these two workings is 1,240 feet, so that as the average bed-rock grade of the Tertiary Mine channel is 2.17 per cent, within the distance mentioned down-stream it might be expected to be somewhat below the Fraser River.

Immediately above the Canyon Mine extensive benches terraced by post-glacial waters, flank the south or right bank of the Fraser River, at elevations between 70 feet to 215 feet above the river. The highest is very long extending to a point just above the Big Bend. Up-stream from the Canyon Mine, the benches extend immediately south of the Cottonwood Canyon, and some are underlain at shallow depth by rock. Some were worked by early miners, and subsequently, about 40 years ago, Cottonwood Alluvial Gold Mining Company, Limited, under the management of the late C. J. Seymour Baker, installed an hydraulic plant, bringing in water from Whittier Creek by ditch and flume-line at an elevation of 200 feet above the Fraser River, and piped off gravel overlying a rock-bench immediately up-stream from and adjacent to the Canyon Mine. A considerable yardage was hydraulicked in this region but the amount of gold recovered is not known.

Due to the intersection of the Tertiary Mine-Canyon Mine channel by the Fraser River, a concentration in the bed of the latter immediately below the point of intersection seems a logical anticipation.

Operations of F. Delong. On the north bank of the Fraser River, about 1 1/2 miles up-stream from the Cottonwood River, at the down-stream end of an exposure of rocks of the Cache Creek series on Pre-emption Lot 8608, F. Delong has

drifted 220 feet on a bearing north 10 degrees east 15 feet above river-level. For the first 160 feet the drift is on rock, thereafter bed-rock disappears and the drift-face is in compact silt and gravel. It is not known what values were discovered. At this point, a rock-bench about 200 feet wide, flanks this bank of the river at a height of 15 feet to 35 feet above the river, and is overlain by 15 feet of unconsolidated material. North of this bench, the rim of the Fraser River Valley rises sharply to a height of several hundred feet above the river. Distant 213 feet north 40 degrees west from the portal of the drift mentioned and 55 feet above the river, is another drift now caved, and distant 60 feet south 27 degrees east of this is a shaft, also caved. About 300 feet down-stream from the first-mentioned drift, J. McHardie drilled a hole to a depth of 200 feet from the top of the low-lying bench mentioned, 50 feet north of the river. He reports, that for the greater part of its length this hole passed through white clay, which at certain stages of water is stated to be visible in the bed of the river at this point. It is apparent that the workings just described are on the west rim of the southerly-flowing inter-volcanic Fraser River, the gravel and overlying sediments of which, are exposed a short distance down-stream at the Big Bend.

Re possible up-stream continuation of Tertiary Mine channel. Until further field-work has been carried out, it is impossible to express a definite opinion on this point, but certain facts are clear from exposures. The extensive exposures near the Big Bend prove the existence of the inter-volcanic Fraser River in this region. Exposures of the Cache Creek series on both sides of the Fraser River below the Tertiary Mine extending as far as the workings of Frank Delong, can only be the west rim of this channel. Further it is highly probable that the course of the inter-volcanic Fraser River closely follows that of the earlier pre-volcanic southerly-flowing Fraser River and is super-imposed upon it. Although no exposures of the Lower Lavas have been observed near the Fraser River north of Quesnel, and quite possibly never existed there, from the known height of damming by these lavas down-stream it is apparent that consequent basins would be likely to form at points many miles north of Quesnel. In these basins, the now-tilted Australian members (a) of the Fraser River formation were laid down. Hence, the diagnostic value of exposures of these beds, in delineating approximately the underlying pre-volcanic southerly-flowing Fraser River. Although detailed field-work has not yet been undertaken north of the Cottonwood River, from known rock-outcrops, and topography in this region it seems reasonable to assume that the up-stream course of these buried rivers must lie about due north of the mouth of the Cottonwood River. In this connec-

tion, the large north-trending valley now occupied by the lower part of Canyon Creek seems of particular significance and likely to be the containing valley of these ancient rivers. The Tertiary Mine channel certainly cannot be correlated with either of these. From the evidence secured to date, relationship between the Tertiary Mine channel and the one exposed on the east bank of Baker Creek, and the intra-Lower Lavas Fraser River, seems quite possible.

Golden Province Mines Company. This company was incorporated prior to the year 1899, apparently for the purpose of investigating the buried river-channel exposed in the right or east bank of Baker Creek, described on pages C36 to C39 of the Annual Report, Minister of Mines, British Columbia, 1938. Little is now known of this early mining effort beyond the fact that this company drove a rim-rock adit, known as "Law's Tunnel," in the left or west bank of Baker Creek, 50 feet above creek-level at elevation 1,707 feet. This working is now caved and cannot be examined. Above this on the steep valley-slope at elevation 2,097 feet are other old workings possibly undertaken by this company. A shaft now completely caved, at elevation 2,272 feet, in the talus slope below the Fraser Plateau, north of the old workings mentioned, may also have been sunk by this company.

Conclusion.

To sum up the evidence, direct and indirect, obtained in the course of this examination, the following Tertiary drainage-history of the Fraser River is indicated.

Supported by indirect but strong evidence, it may be postulated that a pre-volcanic Fraser River, flowed northerly in late Cretaceous time on the high bench west of Dragon Mountain Range. Immediately east of this range, the Quesnel River then, as now, flowed north-westerly in this region, but its junction with its parent stream was farther north than at present, possibly near Ten Mile Lake. South of the Chilcotin River, the Fraser River then, as now, flowed southerly.

The direction of flow, in this early northerly-flowing river-system, was reversed by the rapid headward erosion of a tributary of the Chilcotin River, which was caused by favourable diastrophic movement. Reversal of flow, was accomplished before the volcanism expressed by the Lower Lavas, because it is known that the latter filled an already deeply-entrenched valley to the west of the earlier northerly-flowing river-system in the region above described.

The flow of this pre-volcanic southerly-flowing Fraser

River was subsequently obstructed by the eruption of the Lower Lavas, more especially between Soda Creek and Quesnel. The height of the lava dams, in this part of the river, was likely felt far north of Quesnel, although, in the latter region, there is no evidence that actual eruption of the Lower Lavas took place.

The effect of damming was the formation of basins in the valley in which were deposited the Australian members (a) of the Fraser River formation.

Exposures on the west side of the Fraser River, more immediately north of Mackin Creek, represent the restoration of flow of the Fraser River towards the close of this period of volcanism and before its actual cessation. This restored river is named the intra-Lower Lavas Fraser River. Possibly the channel exposed on the east bank of Baker Creek expresses the up-stream continuation of that exposed near Mackin Creek, and with it the Tertiary Mine channel may be contemporaneous, but to date no direct evidence has been obtained on this last-mentioned point. Down-stream the intra-Lower Lavas Fraser River may have occupied the high bench described on the west side of the Fraser River south of Soda Creek.

Later than the intra-Lower Lavas Fraser River are numerous large exposures of sediments of the inter-volcanic Fraser River, which unconformably overlie the Australian members of the Fraser River formation. The sediments of the inter-volcanic Fraser River clearly express the sustained flow of a river uninterrupted by volcanism within the area of exposures, and its arrival at lacustrine conditions through the operation of those well known processes functioning in the life history of rivers.

The deposits of diatomite were formed in the river-made lakes of the inter-volcanic Fraser River and the normal topographic and stratigraphic position of this diatomite is at the top of the Fraser River formation. Certain exposures of diatomite are overlain by the Upper Volcanics.

Subsequent to the formation of diatomite, the described exposure on the west bank of Baker Creek proves that flow of the Fraser River was dammed by the Upper Volcanics.

The position of the successive channels occupied by the Fraser River in Tertiary time is approximately indicated on Fig. 1 accompanying this report.