THE ORIGIN OF PEACE RIVER CANYON, BRITISH COLUMBIA.[1]

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ABSTRACT. Peace River has cut a deep canyon 17 miles long where it leaves the foothills east of the Rocky Mountains. Evidence is presented to show that in pre-glacial times Peace River flowed through the gap between Portage and Bullhead Mountains, while Johnson Creek was cutting the Lower Canyon. During Pleistocene time a glacier occupied Peace valley and deposited a terminal moraine in the gap. As the ice retreated a lake was formed back of the morainal dam. The water level was raised sufficiently to permit flow over a saddle on the west side of Bullhead Mountain and excavation of the Upper Canyon.

INTRODUCTION.

PEACE River flows eastward across the Rocky Mountains and the bordering foothills in northeastern British Columbia and continues through northern Alberta to join Slave River, part of the Mackenzie drainage to the Arctic Ocean. Where the Peace leaves the foothills it races through Peace River Canyon, an impressive horseshoe gorge some 17 miles long with steep rock walls 200 to 700 feet high. The eastern end of the Canyon is about three miles above the village of Hudson Hope.

During the summer of 1942 the writers mapped an extensive area in the vicinity of the canyon for the Geological Survey of Canada, and obtained information bearing upon the history of this part of Peace River and the causes of the excavation of the canyon.

PREVIOUS EXPLORATION.

The waters in the upper part of the canyon attain such velocity and "boil" with such turbulence that navigation within it is a suicidal venture. During the 150 years that the river is known to have been used as a route across the mountains, travellers ascending the river have been forced to disembark at Hudson Hope and make a 12-mile portage to the quieter waters above the canyon. The first published descriptions of Peace River Canyon are contained in Alexander Mackenzie's journal of his voyage from Fort Chipewyan to the Pacific Ocean in 1793 (1). Mackenzie describes so accurately the cliffs and

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other features along the canyon as to enable one to trace readily his passage along its lower reaches to the point where he was forced to abandon the river and cut a portage along the rugged, western slopes of Bullhead Mountain. This lone prominence rises nearly 4,660 feet above sea level in the arc of the canyon. Mackenzie gives a vivid description of the fury of the waters in the Upper Canyon:

> "It was really awful to behold with what infinite force the water drives against one side and with what impetuous strength it is repelled to the other; it then falls back, as it were, into a more strait but rugged passage over which it is tossed in high, foaming, half formed billows as far as the eye could follow it" (2).

In 1872 Captain W. F. Butler travelled up the Peace on his way to the Pacific coast. In his book "The Wild Northland" (3) he has conveyed more of his impressions of the scenery near the canyon and of the roar of the waters than data of scientific interest.

In 1875 A. R. C. Selwyn, Director of the Geological Survey of Canada, made a fairly accurate topographic map of Peace River and gave the first descriptions of the geology (4). Selwyn did not investigate the superficial deposits other than to mention the terraces along the river.

More recently F. H. McLearn of the Geological Survey of Canada made detailed investigations of the geology and coal deposits. McLearn's publications (5) deal largely with stratigraphy and paleontology, but contain considerable information about the evolution of the present drainage pattern. The writers are indebted to Doctor McLearn for much pertinent data and for critical reading of the manuscript.

PEACE RIVER VALLEY ABOVE THE CANYON.

Peace River flows across the Rockies and the foothills in an easterly direction at right angles to the structural trend of the bedrock. The river averages 800 to 1,000 feet wide, flowing swiftly over many rapids and riffles with little meandering. The mean gradient between Finlay Forks at the head of the river and the canyon is slightly more than three feet per mile.

The valley is a mile or more wide, and has the typical U-shaped cross-section of valleys scoured by glacial action. The valley bottom is flat and covered by a thick mantle of unconsolidated deposits. The lower valley sides rise steplike in

a series of terraces. Steep rock walls rise above the terraces to form isolated peaks as much as 2,000 feet above the water level. The terraces extend along both sides of the river for many miles above the canyon. They are poorly developed on the south side of the river, but are particularly prominent on the western slopes of Butler Ridge where three, and locally five, benches with steep faces rise like a flight of broad stairs to a height of 550 feet above the river or about 2,300 feet above sea level. During a reconnaissance trip up Peace River it was noted that the terraces extend fairly continuously to the mouth of the Ottertail (Nabische) river, some 45 miles above the canyon. The impression was gained that upstream the terraces gradually approach river level. Without precise elevations, however, it could not be determined whether the terraces are horizontal or reflect some slight regional tilting.

The terraces are carved in unconsolidated deposits, largely of till, laminated clays and sands and silts. The till either rests directly on the bedrock valley floor or upon intervening stream gravels. It has a light buff color and contains rock fragments derived from sedimentary formations outcropping in the region and igneous rock from sources west of the Rockies. No material characteristic of Keewatin glacial deposits such as occur on the plains far to the east was observed. In lower Dunlevy creek valley and at water's edge along the northeast side of Peace River between the creek mouth and the canyon one hundred feet or more of laminated clays overlie the till. These clays have very uniform parallel bedding. Alternating beds are light gray and dark bluish gray and are one-half inch to two inches thick. Certain beds near the top are nearly six inches thick. Portions of the clay section appear to be varves formed by seasonal deposition in a lake. The clays grade upward into silts and very fine grained sands. These latter deposits are light gray to buff and have well developed parallel bedding. Up the Peace from Dunlevy Creek and in valleys of Gething and Johnson Creek the varved clays are absent and the silts and sands either rest upon till or upon intervening stream gravels. The pebbles within the gravels do not generally exceed three-quarters of an inch in diameter. The sands and silts are also interpreted as lacustrine deposits. The reason for the change from clay to silt and fine sand deposition in the lake is not immediately apparent. The lake is considered to have formed as glaciers occupying upper Peace and Gething valleys

gradually melted. While the lake was small and few streams fed débris into it the lake deposits were derived largely from material carried in the water in suspension. As the ice wasted further and more streams entered it coarser elastics are presumed to have been brought in and deposited over the clays.

PEACE RIVER CANYON.

Just west of Butler Ridge Peace River swings southward to the head of the canyon. (Fig. 1.) For the purpose of description it is convenient to regard the narrow gorge skirting the west and southwest sides of Bullhead Mountain as the Upper Canyon. The steep walled valley extending east from the mouth of Johnson Creek to within three miles of Hudson Hope will be referred to as the Lower Canyon.

The river narrows sharply at the head of the Upper Canyon from a width of 1,000 feet to less than 250 feet. The waters, activated by the restriction and a greatly increased gradient race wildly for eight miles between vertical rock walls 200 to 300 feet high and 500 to 800 feet apart. Above the canyon rim the sides continue to rise at steep angles to the western flanks of Bullhead Mountain and the hills southwest of the gorge. The downcutting of the canyon has been so rapid that tributary streams have failed to keep pace and either fall over the rim or reach the river level in a series of steep cataracts. Near the mouth of Johnson Creek both the river and its valley widen appreciably only to narrow again within three-quarters of a mile as the waters enter the Lower Canyon. For the next eight miles the river flows east-northeasterly between steep walls of black shales rising without break to benches 600 to 700 feet above the water just east of Bullhead Mountain but gradually decreasing in height as Hudson Hope is approached. The river in this part of its course averages 900 feet wide. Its flow is rapid, but turbulent only where sandstone beds within the shales cross the river and form rapids. The river has a low water elevation of 1,700 feet above sea level at the head of the canyon and an elevation of 1,490 feet just above Hudson Hope. Within this distance of 17½ miles it drops 210 feet with an average gradient of 12 feet per mile. Actually the gradient in Upper Canyon is about 18 feet per mile and about five feet per mile in Lower Canyon.

Till and fluvioglacial deposits occur at several points along

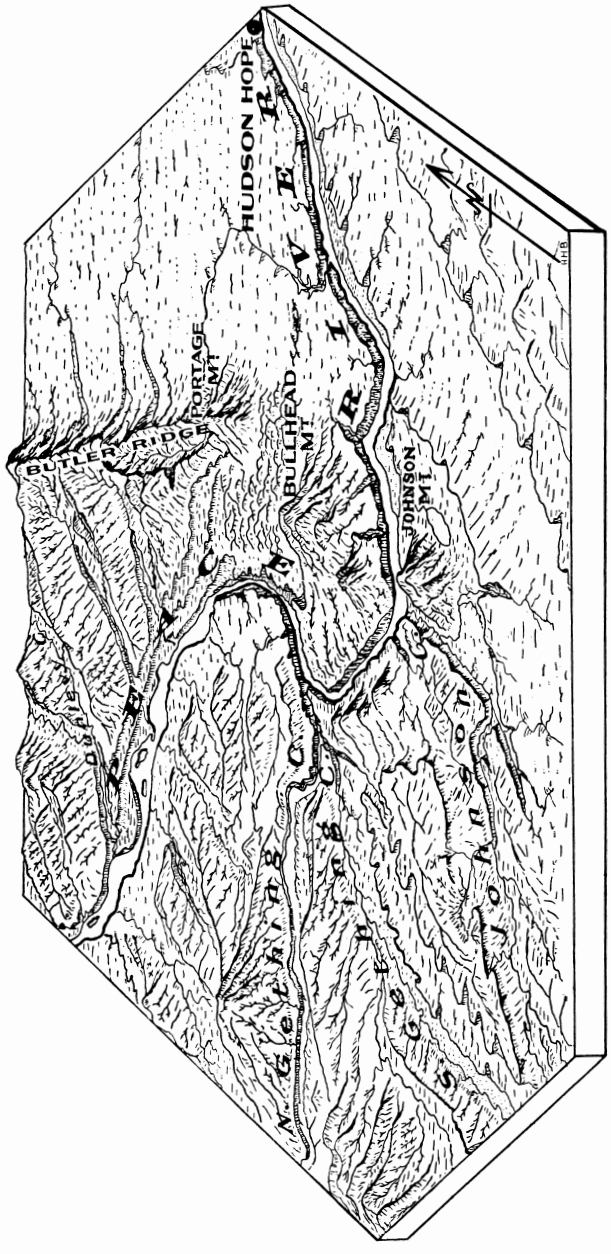

Fig. 1. Block diagram of Peace River Canyon Region, British Columbia. Scale approximately 4 miles to one inch.

the north side of Lower Canyon and are particularly well developed between one and three miles below the mouth of Johnson Creek. No unconsolidated deposits other than small patches of recent stream gravels were observed in the Upper Canyon.

Certain physiographic features away from the canyon are of interest as they shed light upon its geomorphic history. The most notable is the wind gap some two miles wide, separating Bullhead and Portage Mountains. The entire bottom of the gap has a very irregular topography with many deep undrained depressions and other features characteristic of terminal moraine. The eastern margin of the moraine extends a little beyond the gap over the broad sand plain north of the river and east of Butler Ridge. This sand plain extends 20 miles or more north of the river and a much greater distance to the east from Butler Ridge. The surface of the plain is in general flat but with many shallow undrained depressions, low ridges and for the most part a poorly developed drainage. Cross sections of the deposits show a hundred feet or more of very fine sand and silts with well developed parallel bedding and little cross bedding. A few thin layers of fine gravel were observed. The deposits are considered to be of lacustrine origin.

The major branches of both Gething and Johnson Creeks flow through narrow valleys carved in till overlain by sands and silts similar to those in Peace Valley above the canyon. These deposits, in turn, fill or partially fill broad, straight valleys with somewhat dissected but fairly continuous rock walls some distance from the present stream channels. In the immediate vicinity of Peace River these streams flow through deep, steep-sided, rock canyons, with much higher gradients than in the upper stretches.

INTERPRETATION OF OBSERVATIONS.

The following deductions regarding the changes in the course of Peace River during and since Pleistocene time are based upon field observations and detailed study of the vertical aerial photographs of the region.

Pre-glacial Peace River—There can be little doubt that the Peace Valley west of Dunlevy Creek existed in pre-glacial time essentially as at present. Undoubtedly it was enlarged greatly during the glacial period by a valley glacier, but hanging val-

leys as much as 700 feet up on the sides of Peace Valley attest the existence of a well developed drainage prior to glaciation. How the Peace developed a course across the entire belt of the Rocky Mountains, and whether it was antecedent to the Rockies or not are questions beyond the scope of this paper. The pre-glacial Peace is considered to have crossed Butler Ridge approximately in line with its course to the west, possibly with some monoclinal shifting down the noses of southerly plunging anticlinal structures forming Butler Ridge, and to have cut the deep valley of the present wind gap between Portage and Bullhead Mountains. That this gap was occupied by a large stream is indicated by well developed pot holes high up on the southern slopes of Portage Mountain. Pre-glacial Gething Creek flowed into the Peace somewhere near the center of the Gap. Remnants of the old Gething channel are traceable in a northeasterly direction across the northwest corner of Bullhead Mountain some 200 to 300 feet above the present water level in the canyon below. This channel has about the same elevation as the present Gething Creek at the point where it commences to cut into bedrock before entering the canyon. Both the ancestral Peace and Gething Creek were prevented from following their present course by a massive rock barrier forming a saddle between Bullhead Mountain and the hills southwest of the present canyon. A cross section of the saddle normal to the canyon suggests that the top of it was 2,400 to 2,500 feet above sea level. The course of the pre-glacial Peace eastward from Portage Gap is not known, because the entire area is covered by a thick blanket of silts and sands. A test hole sunk on the sand plain about five miles due east of the north end of Bullhead Mountain is reported to have penetrated more than 100 feet of sands and gravels without reaching bedrock. It is possible that the river joined the present valley somewhere in the vicinity of Hudson Hope.

Pre-glacial Johnson Creek is considered to have flowed through the broad valley immediately east of Johnson Mountain, and thence followed essentially the course of the present Lower Canyon. Remains of old bedrock channels replete with sizeable potholes are observable well up on the canyon sides. At a later time Johnson Creek was diverted from the segment east of Johnson Mountain and followed its present valley along the west side of the latter. Such divergence could have been brought about by headward erosion and final piracy by a tribu-

tary to the Lower Canyon segment of Johnson Creek. That this divergence was completed before the Glacial period is evidenced by the occurrence of till in Johnson Creek near its present mouth. It would appear then that practically all the Lower Canyon was in existence prior to the final advance of Pleistocene glaciation.

The strata forming the upper part of the saddle between Bullhead and the mountains to the west are largely shales, carbonaceous shales, and coal seams, striking in the direction of the lower section of the Upper Canyon. These strata are appreciably less resistant to erosion than the massive quartzites forming the lower part of the saddle, through which the Upper Canyon has been carved. It is probable that the saddle was reduced somewhat in height by a tributary stream working headward from Johnson Creek. The known position of the ancestral Gething Creek definitely precludes the existence of any easterly drainage across the saddle at this time.

Peace River during the Glacial Period—As temperatures lowered in the Cordilleran region at the start of the Ice Age, glaciers formed in upper Peace River Valley and in the valleys of Gething Creek and Johnson Creek. The glaciers moved eastward, scouring extensively to form straight valleys with characteristic U-shaped cross-sections. Judging from the height of the lips of the hanging valleys along the Peace, the ice in the main valley must have been at least 600 to 700 feet thick. At its maximum eastward advance the Peace Valley glacier occupied the Portage Gap where it built up an impressive terminal moraine. It is probable that the Gething Valley glacier coalesced with the Peace Valley glacier along approximately the lines of the former drainage.

The maximum advance of the Johnson Creek glacier is not known. The existence of kame deposits and till in the Lower Canyon northeast of Johnson Mountain indicates that the ice occupies at least the western part of the canyon. It is probable that the glacier extended around both the west and east sides of Johnson Mountain, but evidence of its existence in the valley east of the mountain has not been found, beyond the U-shape of the valley.

As the valley glaciers began to retreat they left behind thick deposits of till in the valleys they had occupied. Further evidence of the wasting ice is observable on the surface of the moraine in the Gap. It is marked by many deep, undrained

depressions formed as isolated blocks of ice, trapped in the moraine, gradually melted and disappeared. Water, flowing from the melting ice in the gap, gathered to form a small stream flowing eastward. Segments of its channel are clearly visible on the ground and its course is readily traceable for several miles on aerial photographs. It should be emphasized that this channel does not mark the course of the pre-glacial Peace River as it is entirely excavated in unconsolidated deposits. The test hole mentioned previously demonstrates that the pre-glacial Peace channel was more than 100 feet below the level of this channel.

As the ice wasted away in Peace Valley the melted waters accumulated to form a lake in the area between Dunlevy Creek and the head of the Upper Canyon. It was retained by the valley ice to the west, by the moraine in the Gap, and by the saddle west of Bullhead Mountain. At this stage waters were sufficiently quiescent to permit the deposition of the glacial lake clays on the Peace above the canyon and in Dunlevy Creek Valley. The impounded waters reached their maximum level of 2,500 to 2,600 feet above sea level, determined by the height of the morainic dam in the gap and the highest lake deposits on the valley sides. They are considered to have been raised sufficiently high to have found an outlet over the broad saddle on the western side of Bullhead Mountain, and the active downcutting of the Upper Canyon began. It is probable that in the early stages of the creation of the outlet, flow was small or even intermittent, but the gradient of the newly created stream was high, and downcutting would have been rapid from the start. During this stage the lake expanded greatly up the Peace and into Gething Creek as their valleys became freed of ice. Fine sands and silts blanket the till over extensive areas along the Peace and Gething Valleys and overlie the earlier lake clays in the vicinity of Dunlevy Creek.

The occurrence of similar sands and silts overlying till in Johnson Creek would indicate that a lake also existed in its valleys. There is evidence, however, suggesting that the history of this lake was somewhat different from that of the lake above the canyon. The Keewatin ice sheet is known to have existed in the plains region many miles to the east of the foothills, but its western extent is almost entirely unknown as yet. A broad, flat sandplain extends eastward from the eastern margin of the foothills both north and south of Peace River.

It is plausible that these deposits were laid down in an extensive pro-glacial lake existing between the Keewatin ice front and the foothills in Pleistocene time. That such a lake was in contact with the Keewatin ice is suggested by the occurrence of large isolated granitic and gneissic boulders, typical of those predominant in Keewatin drift, at several points along Lynx Creek, which flows into the Peace about four miles east of Hudson Hope. These boulders do not resemble the granitic types derived from regions west of the Rockies. Inasmuch as the boulders do not occur in till it is possible that they may have been ice rafted to their present positions. The occurrence of similar Keewatin type granitic boulders on lower Johnson Creek and tributary Coal Creek have led the writers to the conclusion that the lake postulated above extended as an arm up at least the lower part of Johnson Creek valley. Unfortunately the field mapping program did not permit more detailed investigation of the superficial deposits east of the foothills.

The Canyon in post-Pleistocene Time—The post-Pleistocene history of the canyon has been that of rapid downcutting with little or no widening of the channel. So rapid, indeed, has been the downcutting that tributary streams to both the Upper and Lower Canyons have been unable to keep pace, and enter the river discordantly, either plunging over high rock ledges as falls or descending over a series of falls and cataracts in narrow, steep-sided gorges. The process of excavating the canyon has not proceeded without interruption. Segments of channels now high on the sides of the Upper and Lower Canyon indicate that the river has changed its course locally from time to time. This is reflected in the many unpaired terraces along the river above the canyon, indicative of times when the hydraulic gradient was sufficiently low to permit meandering and for a time ascendancy of lateral planation over downcutting.

SUMMARY.

Evidence has been presented to show that Peace River Canyon has had a rather complex history. Lower Canyon was a part of Johnson Creek Valley in pre-glacial times, while Peace River flowed through Portage Gap. During Pleistocene time Peace River was deflected by the creation of a high morainic dam in the gap. As the glaciers occupying Peace and Gething Valleys melted a lake was formed. The impounded waters rose

sufficiently to permit flow over the crest of a saddle on the west side of Bullhead Mountain. The Upper Canyon segment of the Peace drainage thus created was excavated rapidly into a deep gorge, linking the course above the Gap with the Johnson drainage through the Lower Canyon. Excavation of both the Upper and the Lower Canyon has continued to the present time.

At several places along the canyon it would be possible to construct dams for the generation of hydro-electric power. One such site is at the head of the Upper Canyon. Careful investigation of the morainic dam in the gap should be made before development of this site is undertaken and the water in the fore bay raised appreciably. It is conceivable that if the waters were raised sufficiently to reach the moraine, seepages into the pre-glacial course of the Peace might develop particularly if gravels underlie the moraine covering the old channel. Despite the fact that the morainic dam once held back a large lake subsequent stream action and movement of groundwater may have affected the permeability of the deposits within local areas.

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