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GLACIAL LAKE HISTORY, SOUTHERN INTERIOR PLATEAU, BRITISH COLUMBIA

(Report, 3 figures and 1 table)

Robert J. Fulton

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CONTENTS

Illustrations

ABSTRACT

Like most major drainage basins of the Interior Plateau of southern British Columbia, the Nicola, Thompson, Shuswap and North Okanagan basins contained glacial lakes during the ice retreat that followed the Fraser Glaciation climax.

The Nicola Basin was occupied by three glacial lakes: glacial Lake Quilchena which drained south, followed by glacial Lake Hamilton which drained east, and, finally, glacial Lake Merritt which drained north.

The Thompson Basin contained glacial Lake Thompson and glacial Lake Deadman, both of which drained to the east. In the course of their history, these lakes stood at various levels that were controlled by the retreat of ice from a series of valleys leading to the Okanagan Valley.

The North Okanagan Basin was occupied by one main lake: glacial Lake Penticton. During the early deglaciation period, however, a small lake, separated by ice from the main lake, occupied the Coldstream Creek valley. All stages of glacial Lake Penticton drained south, the level of each being controlled by dams of ice or debris and by isostatic tilting.

Two major glacial lakes formed in the Shuswap Basin: glacial Lake Thompson which was continuous with a glacial lake in the Thompson Basin, and glacial Lake Shuswap, several stages of which were continuous with glacial Lake Penticton in the North Okanagan Basin. Both these lakes drained into the Okanagan Valley.

Deglaciation of the Interior Plateau was well advanced by 9,750 B. P. , and by 8,900 B. P. all ice had melted and the glacial lakes had been drained.

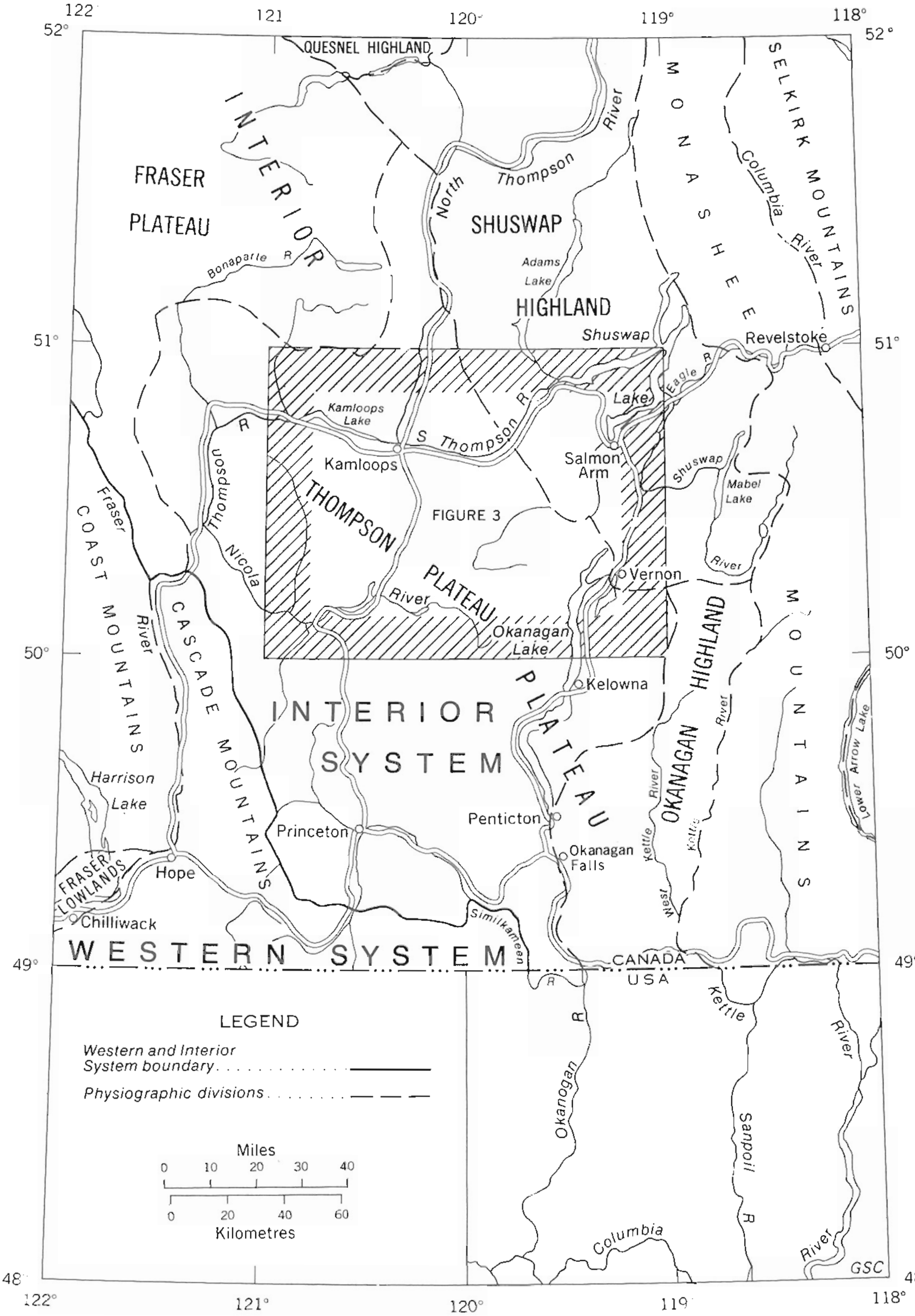

Figure 1. Southern Interior Plateau, British Columbia, showing the area where studies of glacial lake history were made.

GLACIAL LAKE HISTORY, SOUTHERN INTERIOR PLATEAU, BRITISH COLUMBIA

INTRODUCTION

This report is based on observations made during mapping of the surficial geology of the Nicola-Vernon area (50°-51° N, 119°-121° W) in the Interior Plateau of south-central British Columbia (Fig. 1), and is concerned with the history of glacial lakes that occupied the four basins here referred to as the Nicola, Thompson, Shuswap and North Okanagan basins (Fig. 2). Mathews (1944) discussed the glacial lakes of the Nicola and Thompson basins and Nasmith (1962) outlined the late glacial history of the North Okanagan Basin. The present report is in agreement with the general framework of glacial and postglacial history as outlined by these authors but adds many details. Addition of the glacial lake history of the Shuswap Basin makes it possible here to correlate the histories of the areas discussed by Mathews and Nasmith.

Physiographic Setting

The area discussed in this report occupies the northern half of the Thompson Plateau and the southwest quarter of the Shuswap Highland (Holland, 1964). Figure 1 shows that these two physiographic subdivisions lie in the southwest corner of the Interior Plateau of the Interior System as delineated by Bostock (1948). The study area consists of rolling uplands separated by steep-walled, flat-floored valleys. Maximum altitude of individual uplands varies from 4,000 to 7,000 feet asl, with the valley floors from 3,000 to 5,000 feet below the level of adjacent uplands. At present, the north half and the southwest quarter of the Nicola-Vernon area are part of the Fraser drainage system whereas the southeast quarter drains into the Columbia River by way of the Okanagan River.

Fraser Glaciation

During the last glaciation, named the Fraser Glaciation by Armstrong et al. (1965), the entire area was covered by ice that flowed generally south-southeast. Deglaciation was mainly by downwasting, with the uplands emerging through the ice while tongues remained in the valleys. This completely disrupted the drainage pattern, causing large glacial lakes, ponded by stagnant ice tongues and active ice lobes, to develop in the major valleys, and small glacial lakes to form in many upland valleys and marginal to the ice.

The exact chronology of deglaciation and glacial lake development in the Nicola-Vernon area is known only within certain limits. Each available radiocarbon date bearing on the chronology is a limiting minimum for certain events, but none of

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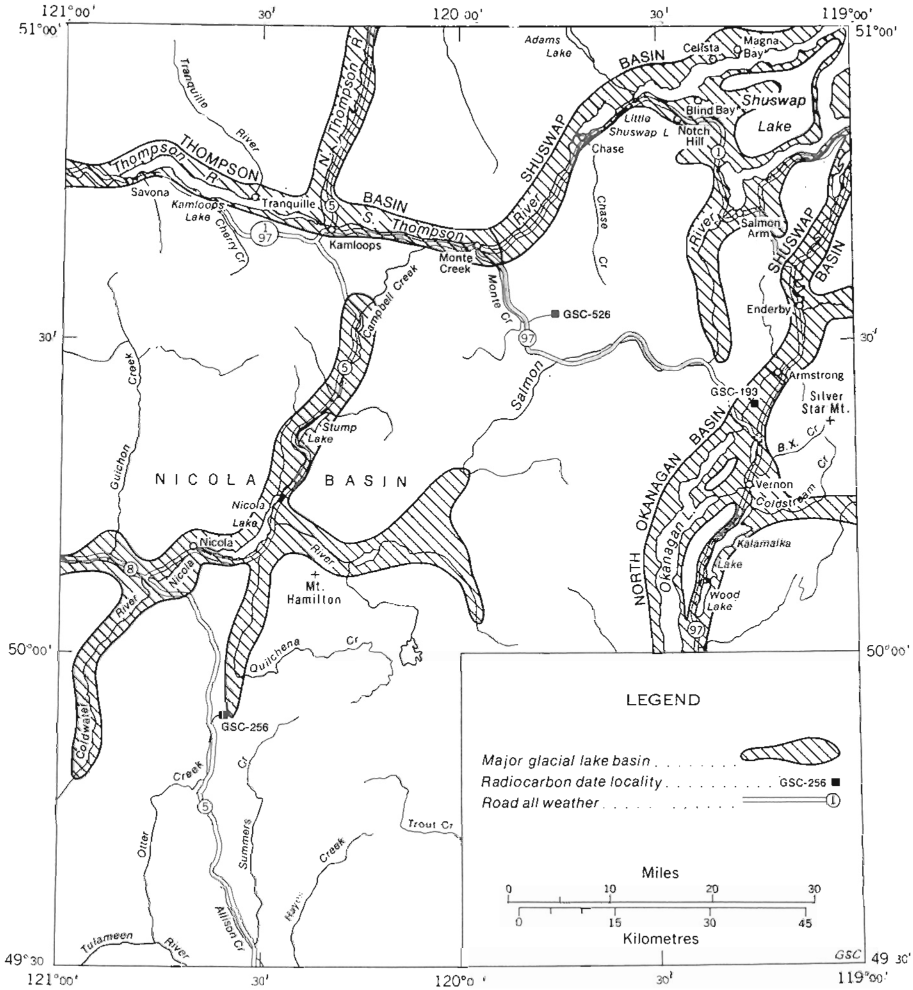

Figure 2. Location of glacial lakes in relation to present drainage.

the dates define specific lake stages. The oldest date, 9,750 ± 170 (GSC-526, Lowdon et al., 1967), was obtained from a sample of fibrous organic material mixed with clay, taken from a glacial lake outlet channel at an altitude of about 3,000 feet in Paxton Creek valley (Fig. 2). This date indicates that, prior to 9,750 years B. P., the uplands above 3,000 feet had been deglaciated, a small glacial lake had formed and been drained, and vegetation was established. The youngest radiocarbon date pertinent to the glacial lake history of the area is 8,900 ± 150 B. P. (GSC-193, Dyck et al., 1965) for organic silt in the bottom of the Otter Lake spillway which connects the Shuswap and North Okanagan basins (Fig. 2). This date indicates that the area was ice free, all glacial lakes were drained, and modern drainage was established prior to 8,900 years B. P.

Description of Lake History-Ice Retreat Diagrams

Figures 3A to 3J show lake development and ice retreat in the Nicola-Vernon area, the shape of the ice margin having been determined from the position of meltwater channels and ice marginal deposits. Ice tongues are shown as stagnant where flow, in a regional sense, is thought to have ceased but where the ice was still thick enough to retain plasticity and minor local flow. Ice shown as dead is considered too thin to be plastic or to maintain a surface gradient. Ice marginal drainage features, such as meltwater channels and kame terraces, form in valleys occupied by stagnant ice. Englacial or subglacial features such as eskers and kames form in valleys still occupied by dead ice. Density of control data varies from one valley to the next so the accuracy of positioning the ice margin varies from one part of the area to another. Where data are scarce or lacking, ice margins were drawn with gradients obtained from topographically similar areas which had sufficient control. Correlation of the ice margins in one valley with those in the next is based largely on common drainage events (see Fulton, 1967). The general approach used in constructing the lake history-ice retreat diagrams is best illustrated by the following discussion of the data and reasoning used in constructing Figure 3F.

Flow from Salmon River valley into North Okanagan Basin west of Armstrong built a delta at the level of the Grandview Flats stage of glacial Lake Penticton. Operation of this outlet channel controlled the level of Niskonlith stage of glacial Lake Thompson so that this lake stage, in the Shuswap-Thompson Basins, correlates, in part at least, with the Grandview Flats stage of glacial Lake Penticton in North Okanagan Basin. For water to flow through the outlet channel west of Armstrong, an ice dam would have had to block the south end of Salmon River valley at Round Lake. Lacustrine deposits in Salmon River valley indicate that ponding occurred, but as these deposits contain disrupted structures and occur as prisms along the valley walls, they would seem to have been laid down in narrow channels on either side of an ice tongue. The ice dam at Round Lake was, therefore, apparently connected to the main body of ice in Salmon Arm by a narrow ice tongue. Kettled lacustrine deposits between Tappen and Blind Bay indicate that ice was buried in this area. Lack of similar deposits on the shore of Blind Bay and east of Tappen indicate that, at this time, ice tongues occupied both arms of the present Shuswap Lake. Kettled lacustrine deposits in the South Thompson River valley south of Little Shuswap Lake show that ice was submerged there below the glacial lake level. Ice occupied the entire valley bottom east of modern Little Shuswap Lake, however, as the kettled lacustrine deposits end abruptly at this lake's outlet. In the Thompson Valley at this time, ice lay at the mouth of Deadman River, for kame terraces in this area are built to the level of the Niskonlith stage of glacial Lake Thompson. Niskonlith stage shorelines are well developed throughout the Kamloops Lake basin, suggesting it was free of ice. They cannot, however, be traced west of the mouth of Deadman River, suggesting that the valley was occupied by ice west of this point. Extent of the lakes and position of the ice tongues in other valleys were determined by a similar process of deduction.

GLACIAL LAKE HISTORIES

Many lakes formed and were drained during deglaciation of the Nicola-Vernon area. Lack of evidence makes it impossible to show all the small lakes that formed in upland areas but several are shown in Figures 3A to 3E. It is possible, however, to construct a detailed history of the major glacial lakes that occupied the main valleys because they left abundant lake deposits, deltas and shoreline features. As the major glacial lakes formed relatively independently of each other, it has been feasible to trace the lake history of each of the four main drainage basins separately.

Nicola Basin

The Nicola Basin includes parts of the valleys of the Nicola River, Stumplake Creek, Quilchena Creek and Coldwater River (see Fig. 2). Glacial lake development in this basin is well documented because:

- outlet levels were controlled by stream divides rather than by ice as was the case with many lakes in the other basins,

- lake levels were stable enough for shore features to develop,

- shore features occur largely in presently unforested parts of the area.

Mathews (1944) named the three successive lakes which occupied the basin Quilchena, Hamilton and Merritt. He described the extent of the lakes, designated their outlets and showed the approximate position of the ice front during the development of each lake. The present report differs from Mathews only in minor detail.

Glacial Lake Quilchena (Figs. 3A and 3B)

Glacial Lake Quilchena, named after Quilchena Creek, was the first major lake to form in the Nicola Basin. It overflowed south into Otter Creek (see Fig. 2) through an outlet with a present elevation of 3,300 feet. The water plane was probably about 25 feet higher than this but its elevation is difficult to determine because the lake was largely marginal to ice, so that most contemporary deposits are in part ice contact, and shore features are developed in only a few places. It is not known when the lake began or how long it lasted, but it is known that the outlet was abandoned by 9,320 ± 160 B. P. (GSC-256, Dyck et al., 1965) as this radiocarbon date was obtained for basal peat in a bog that formed in the outlet channel (Fig. 2).

Glacial Lake Hamilton (Fig. 3C)

Glacial Lake Hamilton, the second major glacial lake in the Nicola Basin, formed when ice retreat in the Salmon River valley permitted eastward drainage. Type locality of shore features of this lake is on the north slope of Mt. Hamilton, southeast of the present Nicola Lake. The outlet at Index Lake, east of Chapperon Lake, has a present elevation 3,050 feet, with shorelines near the outlet indicating a water plane about 20 feet higher. Prior to incision of the Index Lake outlet, water flowed from the lake through a second channel at Rush Lake. Shore features twenty-five feet above the main level of glacial Lake Hamilton developed during the simultaneous operation of these two outlets. There is no information on the exact age or duration of glacial Lake Hamilton but the degree of shore feature development suggests it existed longer than glacial Lake Quilchena.

Glacial Lake Merritt (Figs. 3D to 3G)

Glacial Lake Merritt formed when ice retreated from Campbell Creek valley permitting drainage north to the South Thompson Valley at Barnhart Vale. Type locality of shoreline features is the west-sloping side of Nicola River valley east of Merritt. The lake level was controlled by a bedrock threshold, at a present elevation of 2,550 feet, between Napier and Stump lakes. This glacial lake existed until ice retreat from the lower Nicola River valley established the present drainage of the Nicola Basin. Precise dates are lacking, but well developed shore features and the presence of delta terraces at the mouths of many small valleys suggest that Lake Merritt had the longest duration of all glacial lakes in the Vernon-Nicola area.

Lake deposition in the Nicola Basin

Most parts of the floor of the Nicola Basin are covered with less than ten feet of varved silt. Lacustrine deposition was minor as little silt and clay were carried into the glacial lakes. Glaciolacustrine deposits have two main sources: debris incorporated within the ice and debris eroded from basal till by meltwater. The first source was not effective in the Nicola Basin as the ice was relatively clean – inferred from the scarcity of glaciofluvial and ablation deposits. The second source supplied little material as, by the time the lakes came into existence, the ice had shrunk to the dimensions of a valley tongue and, as much of the ice margin actually lay inside the limits of the glacial lakes, little or no meltwater erosion could take place.

Thick lake deposits are found, however, in the Quilchena Creek valley and in the area east of Merritt. Quilchena Creek valley was deglaciated while ice still remained on the adjacent uplands and, consequently, meltwater from the uplands carried large quantities of silt into the lake basin. Glacial lakes formed in the Merritt area after deglaciation of the adjacent uplands but, even so, large quantities of silt were carried into the area from wasting ice in Guichon Creek valley (Figs. 3C and 3D).

Isostatic Tilting

Shore features of glacial Lake Quilchena are too poorly developed to permit reconstruction of the water plane. Altimeter observations on the strandlines of glacial lakes Hamilton and Merritt show that the water planes of these lakes have been deformed into shallow curves with the amount of deformation increasing toward the north. Tilting of the Lake Hamilton shoreline is on a N 77° E isobase and increases from 4 feet per mile down to the south at the southern edge of the basin, to 25 feet per mile farther north. The Lake Merritt shoreline has been deformed on a N 63° E isobase, with tilting varying from 3 feet per mile to 16 feet per mile down to the south.

Thompson Basin

The Thompson Basin includes the valleys of North Thompson River, South Thompson River and Thompson River (Fig. 2). A number of difficulties are encountered in determining the limits of the glacial lakes that occupied this basin. High-level lakes were largely ice marginal and thus left little evidence of their existence. Lower-level lakes produced abundant shorelines and delta terraces that can be correlated throughout the basin, but it is difficult to determine their outlets as the lake levels were controlled by retreating ice and isostatic tilting in valleys thirty or forty miles away. The only radiocarbon date pertinent to glacial lake history of the Thompson Basin is the Otter Lake Spillway date of 8,900 ± 150 (GSC-193, Dyck et al., 1965) (Fig. 2) which is minimal for drainage of all glacial lakes from the Thompson Basin.

Mathews (1944) presented the first definitive outline of the glacial lake history of the Thompson Basin and referred to each stage as a level of glacial Lake Thompson e.g. 1,600-foot stage. Names are substituted for levels in this report in order to eliminate confusion caused by isostatic warping of former water planes.

Glacial Lake Thompson – High-level stages

The first glacial lakes in the Thompson Basin formed on the north side of divides in the valleys of Chase and Monte Creeks (Fig. 3C) with the meltwater flowing southward into tributaries of Salmon River. Ice retreat from Turtle Valley between Chase Creek and Chum Lake, and from the valley containing Phillips and Skimikin lakes, allowed meltwater to flow into the Shuswap Basin northeast of Salmon Arm. Within the ice-filled Shuswap Basin the water may have flowed across the ice into the Okanagan Valley north of Gardom Lake or followed the ice margin south, entering Okanagan Valley west of Armstrong (Fig. 3D).

Glacial Lake Thompson – South Thompson stage (Fig. 3D)

This stage of glacial Lake Thompson is named after the South Thompson River valley in which the lake developed between ice tongues receding west and northeast. The level of the South Thompson stage was controlled at first by ice marginal drainage and later by the divide (present elevation about 1,900 feet), between Chase Creek and Turtle Valley. When the terminus of the ice tongue receding west in the South Thompson River valley stood between the mouths of Monte and Campbell creeks, the lake level was about 1,800 feet (South Thompson I Fig. 3D), and by the time the ice had receded to Kamloops, the lake level had fallen below 1,750 feet (South Thompson II Fig. 3E). The drop in level may have been due to isostatic rebound of the basin relative to the outlet or to drainage through ice marginal outlets lower than the Chase Creek-Turtle Valley divide.

The uplands north, south and west of Kamloops were being deglaciated at this time. Meltwater from these areas was funnelled into glacial Lake Thompson, depositing voluminous quantities of silt and filling the valley south of Kamloops to an elevation of about 1,650 feet. Deposition of this silt, originally named "White Silts" (Dawson, 1879) but more recently referred to as South Thompson silt, is discussed in Fulton, 1965.

Glacial Lake Thompson – Niskonlith stage (Fig. 3F)

The level of glacial Lake Thompson fell as downwasting of ice in the Shuswap Basin permitted flow through the Notch Hill area northwest of Salmon Arm. Water levels in both the Thompson and Shuswap basins were controlled by divides separating them from the Okanagan Valley north of Gardom Lake and west of Armstrong. Flow over these divides, whose present elevations are about 1,700 feet, stabilized the water level and permitted shore features and delta terraces to develop in the Thompson Basin.

Type locality for shore features of this stage is the west side of South Thompson River valley near Niskonlith Lake. At its maximum, the lake at this stage extended into the Shuswap Basin as an ice marginal lake (see section on Shuswap Basin, glacial Lake Thompson - Niskonlith stage), occupied the North Thompson River valley north of Kamloops and extended west to ice that still occupied the Thompson River valley from the mouth of Deadman River west (Fig. 3F). A six-foot per mile isostatic adjustment on a N 58° E isobase has tilted the Niskonlith stage water-plane down to the east so that the present altitude of shore features varies from a minimum of 1,635 feet east of Niskonlith Lake to a maximum of 1,800 feet at the mouth of Deadman River.

Glacial Lake Deadman

Glacial Lake Thompson ended when the water level fell low enough to expose the South Thompson silt east of Kamloops. From this time on, lakes in the Thompson Basin were separated from those in the Shuswap Basin. The lake left in the Thompson Basin by this development is known as glacial Lake Deadman after the Deadman River at the west end of Kamloops Lake. Lake Deadman overflowed east through a channel cut into the South Thompson silt and graded to the water level of Shuswap Basin.

Glacial Lake Deadman – Tranquille stage (Fig. 3G)

Tranquille, the highest documented stage of glacial Lake Deadman, formed when the Thompson Basin outlet was temporarily stabilized at an altitude of about 1,400 feet. The type locality is at the mouth of Tranquille River, about eight miles west of Kamloops. The lake, at this stage extended west beyond the map-area at least to the mouth of the Nicola River and an unknown distance north of the area of study along the North Thompson River valley. Deltaic deposits and buried ice at the mouth of Deadman River separated the part of the lake west of the map-area from that in the present Kamloops Lake basin and the North Thompson River valley. Tranquille stage shore features have been tilted about three feet per mile down to the east on a N 58° E isobase so that their present altitude varies from 1,405 feet at Tranquille to 1,465 feet at the Deadman River. The supply of lacustrine material during this stage was minimal as all adjacent uplands had been deglaciated.

Glacial Lake Deadman – Durand stage (Fig. 3H)

The Durand stage of glacial Lake Deadman marked the lowest, eastward-draining lake to occupy the Thompson Basin. The type locality for this stage is located at the mouth of Durand Creek, near the west end of Kamloops Lake. Stabilization of the water plane at an altitude of 1,230 feet occurred when the outlet channel cut in the South Thompson silt became graded to the level of glacial Lake Shuswap - Tappen stage i.e., 1,220-foot elevation. This stage of glacial Lake Deadman extended north beyond the study area in the North Thompson River valley, and west of the mouth of the Nicola River in the Thompson Valley. Deltaic deposits built across the Thompson Valley at the mouths of the Deadman River and the Bonaparte River (northwest of the map-area), separated the western arm of the lake into two basins (Sanger and Fulton, in preparation). Isostatic tilting of the Durand stage water-plane was not great enough to be detected by an aneroid altimeter survey of shore features. This stage of glacial Lake Deadman must, therefore, have occurred after the period of major isostatic adjustment.

Kamloops Lake – Cherry Creek stage (Fig. 3J)

This lake level is considered as a high stage of present day Kamloops Lake rather than a low stage of glacial Lake Deadman. The type locality is at the mouth of

Cherry Creek on the south side of Kamloops Lake. This stage formed as the present westward drainage became established following deglaciation of the Fraser Valley. After the westward drainage was initiated, headward erosion quickly captured and drained each lake basin in the Thompson Valley west of the Deadman River delta. Kamloops Lake - Cherry Creek stage remained east of Deadman River delta, but westward drainage lowered the water level 60 feet from that of the preceding Durand stage of Lake Deadman, to an elevation of 1,160 feet.

Development of present Thompson Valley drainage

Headward erosion upstream from Kamloops Lake in the South Thompson River valley, cut through the South Thompson silt and captured the waters of Shuswap Basin from the Okanagan - Columbia River drainage. This extra flow into the Thompson River probably initiated the phase of downcutting that lowered Kamloops Lake 40 feet from the Cherry Creek stage to its present level.

North Okanagan Basin

The North Okanagan Basin of this paper includes the part of Okanagan Valley between the 50th parallel and Armstrong, and the valleys containing Swan Lake, Kalamalka Lake and Coldstream Creek (Fig. 2).

Nasmith (1962) discussed the late glacial history of the Okanagan Valley and applied the name 'Lake Penticton' to the glacial lake that occupied the Okanagan Basin. In this report glacial Lake Penticton is defined in terms of stages based on evidence from the North Okanagan Basin.

Nasmith ascribed the high levels of glacial Lake Penticton to differential isostatic tilting and to dams of glacial deposit and stagnant ice in the Okanagan Falls - McIntyre Bluff area (Fig. 2). This combination of controls appears to have produced a gradually falling lake level with only a few short periods of stability.

Glacial Lakes Coldstream I and II (Figs. 3A and 3B)

The earliest lakes in the North Okanagan Basin developed in the Coldstream Valley. At first, water ponded in Coldstream Valley drained southwest along the ice margin into the ice-filled Kalamalka Lake valley, the lake level falling steadily as the ice margin retreated downslope (glacial Lake Coldstream I, Fig. 3A). During final stages of Coldstream Lake, the outlet flow became entrenched into a single channel with a present threshold altitude of about 1,800 feet (see glacial Lake Coldstream II, Fig. 3B). Ice must have remained in the Kalamalka Lake valley at this time as, otherwise, the outlet flow would not have been diverted into a lateral channel. Continued retreat opened lower ice marginal channels, lowering the level of glacial Lake Coldstream II, first to 1,690 feet elevation and, later, to 1,660 feet. Complete ice retreat from the Kalamalka Lake valley permitted the lake in the Coldstream Valley to become part of glacial Lake Penticton.

Glacial Lake Penticton – Long Lake stage (Figs. 3C and 3D)

Long Lake is the local name used when referring to both Kalamalka and Wood lakes. The Long Lake stage of glacial Lake Penticton developed as ice receded from Kalamalka Lake valley (Fig. 3C). Ice remained in the present Okanagan Lake basin at this time but a channel between Vernon and Armstrong allowed Long Lake stage to enter the Okanagan Valley north of Okanagan Lake basin (Fig. 3D). Delta terraces indicate that the Long Lake stage water level was between 1,600 and 1,700 feet. Large quantities of silt from areas of active glacier wastage to the north and west, were deposited in the Armstrong area.

Glacial Lake Penticton – Grandview Flats stage (Figs. 3E and 3F)

The Grandview Flats stage began when glacial Lake Penticton occupied the eastern arm of the North Okanagan Basin. At the beginning of this stage, ice probably remained in the lake basin as, otherwise, silt entering the lake at Armstrong would have been carried south to fill the basin of the present Okanagan Lake. However, this ice had apparently withdrawn to the valley centre (Fig. 3E), as normal, non-glacial delta terraces were deposited at the level of this glacial lake stage. As the ice retreated, glacial Lake Penticton – Grandview Flats stage expanded to occupy the entire North Okanagan Basin. The present altitude of these lake-shore features in the North Okanagan Basin is about 1,600 feet. Heavy sedimentation continued during this stage of glacial Lake Penticton, with silt-laden meltwater entering the basin from the north and west. Lack of well documented water-planes for this and the Long Lake stages may indicate that the lake level was steadily falling in response to differential isostatic tilting. Unfortunately, too little data is available on the Grandview Flats stage water level to permit measurement of isostatic tilting.

Glacial Lake Penticton – B. X. stage (Fig. 3G)

This is the best documented of all glacial Lake Penticton stages in the North Okanagan Basin. Delta terraces were constructed at the mouths of most streams and weak shorelines were developed locally (Nasmith, 1962, pp. 36 and 42). The particular delta terrace used to define this stage is on B. X. Creek north of Vernon. The present altitude of B. X. stage terraces here is about 1,400 feet, indicating a 200-foot water-level drop from the Grandview Flats stage. This lowering of the lake level may have resulted from the melting of buried ice at Okanagan Falls (Nasmith, 1962, p. 21). The temporary lake level stability which permitted development of B. X. stage shore features may have occurred because removal of a sufficient volume of water to permit a 200-foot-drop in level over the entire lake caused the outlet end of the Okanagan Basin to rise isostatically as rapidly as the recently deglaciated northern end. During the B. X. stage, glacial Lake Penticton extended east into Shuswap River valley, north into the Mara Lake basin and probably extended into the present Shuswap Lake Basin and the Eagle River valley. Unfortunately, information permitting correlation between the Shuswap and Okanagan basins has not yet been found.

Glacial Lake Penticton – O'Keefe stage (Fig. 3H)

Lack of shore features below an altitude of 1,400 feet in the North Okanagan Basin suggests a steady falling of lake levels. This apparent gradual change of lake level was probably due to isostatic uplift of the north end of the basin relative to the south. Nasmith (1962, p. 42) reports 3.5 feet per mile tilting of the B. X. stage shoreline down towards the south. This tilting is great enough to account for the glacial lake level at Vernon apparently falling from 1,400 feet to 1,175 feet elevation with the level of the Lake Penticton outlet remaining unchanged. Differential tilting eventually led to emergence of part of the lake floor south of Armstrong and final separation of the lakes in the North Okanagan Basin from those in the Shuswap Basin. The water level fell steadily until it stood at an elevation of 1,160 feet – the level of the lowest or O'Keefe stage of glacial Lake Penticton, named after a siding on the C. N. R. north of Okanagan Lake. At this time isostatic readjustment was virtually complete and the outlet at Okanagan Falls was stabilized.

Development of present drainage

Okanagan Lake is at present forty feet below the O'Keefe level of glacial Lake Penticton. Part of the drop in level was probably due to capture of the Shuswap Basin drainage by the Thompson-Fraser system (see above, Thompson Basin, Development of present Thompson Valley drainage). This piracy reduced the area of the Okanagan Basin drainage to three-tenths of its late-glacial extent. The rest of this 40-foot drop may have been due to downcutting of the outlet at Okanagan Falls and to limited tilting in response to residual isostatic imbalance.

Shuswap Basin

The Shuswap Basin is a sprawling multi-armed feature containing Mara Lake and the four arms of the present Shuswap Lake. Most of the basin is fiord-like, with steep, rock walls which retain little evidence of former glacial lakes. Most data pertaining to basin history came from the gently sloping area north of Celista on the north side of the main arm. Correlation of lake levels from delta terraces at the mouth of one creek to those at the mouth of the next, is hampered by the thick vegetation that hides whatever shore features may be present.

High-level stages

Ice in the Shuswap Basin downwasted to an elevation of 1,880 feet before major lakes formed. The lowest ice-contact, glaciofluvial deposits occur at this level. Widely scattered delta terraces between this lowest occurrence of ice contact deposits and the highest defined lake level, were deposited in ice-marginal lakes which probably drained over the ice into the Okanagan Valley north of Gardom Lake or west of Armstrong (Figs. 3D and 3E).

Glacial Lake Thompson – Niskonlith stage (Fig. 3F)

The Niskonlith stage of glacial Lake Thompson, already discussed (see Thompson Basin, Glacial Lake Thompson – Niskonlith stage), is the highest, defined lake level in the Shuswap Basin. Blocks of stagnant ice must have remained in the topographic saddle between Tappen and Blind Bay as Niskonlith stage deposits between the two main arms of Shuswap Lake are kettled. A lack of lacustrine deposits at the margins of the present lake basin, north and east of the kettled deposits, suggests that ice occupied the main arms of this basin at this time (Fig. 3F). Water drained from the lake through outlets north of Gardom Lake and west of Armstrong. The waterplane has been tilted six feet per mile, as is also the case for this stage in the Thompson Basin, but the tilting is down to the west on a N 10° W isobase in Shuswap Basin whereas it is down to the east on a N 58° E isobase in the Thompson Basin.

Glacial Lake Shuswap

The opening of a channel between the Salmon River valley and the Okanagan Valley at Round Lake, lowered the water level in the Thompson and Shuswap basins fifty feet, exposing the South Thompson silt east of Kamloops and thus ending the existence of glacial Lake Thompson (see also, Thompson Basin, Lake Deadman). The glacial lake which from then on occupied the Shuswap Basin east of the exposed silt is referred to as glacial Lake Shuswap. It drained into the Okanagan Valley, its level falling as lower outlets were opened and as isostatic rebound raised the Shuswap Basin relative to the Okanagan Valley. Several temporary stabilizations of the water level have been recognized and referred to as stages of this glacial lake.

Glacial Lake Shuswap – Rocky Point stage

The Rocky Point stage of glacial Lake Shuswap (not shown in the figures) drained into glacial Lake Penticton through the Round Lake outlet whose present altitude is about 1,600 feet. The type locality of this stage is a well-developed shoreline on the south side of South Thompson River valley about three miles east of Rocky Point. The water-plane in the Shuswap Basin has been tilted about three feet per mile down to the west on a N 10° W isobase. Shore features vary in altitude from 1,580 feet at Rocky Point in the South Thompson River valley to 1,665 feet at Ross Creek on the north side of the present Shuswap Lake.

Glacial Lake Shuswap – Intermediate and Magna Bay stages (Fig. 3G)

Ice recession in the Mara Lake basin and in the vicinity of Sinnemousun Narrows allowed direct flow from the Shuswap Basin into the North Okanagan Basin. The new outlet completely drained the continuous, ice marginal lake, leaving the Shuswap Basin occupied by a stagnant ice tongue which dammed lakes in several tributary valleys. One of the more stable, ice-dammed lakes, at an altitude of about 1,400 feet, occupied the South Thompson River valley west of Scotch Creek. It was this lake that provided the base level for the Tranquille stage of Lake Deadman (q.v.). Later in the basin history, the water was temporarily stabilized at an altitude of about 1,300 feet. This lake level is referred to as the Magna Bay stage of glacial Lake Shuswap and Magna Bay, on the north side of the present Shuswap Lake, is the type locality. As the Shuswap Basin was probably completely free of ice at this time, glacial Lake Shuswap would have been continuous with glacial Lake Penticton in the North Okanagan Basin.

Glacial Lake Shuswap – Tappen stage (Fig. 3H)

Lakes in the Shuswap and North Okanagan basins were continuous until differential tilting caused the lake bottom to emerge south of Armstrong (Fig. 3H). The emerging lake bottom sufficiently restricted flow from the Shuswap Basin into the North Okanagan Basin to stabilize the level of glacial Lake Shuswap at an altitude of 1,220 feet. This lake level is referred to as the Tappen stage, and its type locality is situated near Tappen on the north bay of Salmon Arm. The outlet of glacial Lake Shuswap, the Otter Lake spillway, was cut in soft, easily eroded silt, but the depth to which it could be lowered was limited to the level of water in the North Okanagan Basin.

Glacial Lake Shuswap – Blind Bay stage (Fig. 3J)

Tilting continued to lower the water level at the north end of the North Okanagan Basin, exposing more valley floor north of the present end of Okanagan Lake. Erosion in the outlet channel from glacial Lake Shuswap kept pace with this uplift, lowering the level of that lake. Isostatic balance was established when glacial Lake Penticton stood at an elevation of 1,160 feet (see Glacial Lake Penticton – O'Keefe stage). The adjustment of the Otter Lake spillway down to this 1,160-foot level held the water level in the Shuswap Basin at 1,170 feet. The state of beach development and the size of delta terraces indicate that this, the Blind Bay stage of glacial Lake Shuswap, existed longer than any of the higher stages. The type locality for this stage lies on the south side of the main arm of the present Shuswap Lake. During this stage, the lake extended a few miles south of the town of Salmon Arm in Salmon Arm valley, a short distance south of Chase in the South Thompson River valley, about seven miles east of Sicamous in Eagle River valley, south to Enderby in Okanagan Valley, and about ten miles east of Enderby in Shuswap River valley.

Development of present drainage

During the Tappen stage of glacial Lake Shuswap, water from the Thompson Basin flowed into the Shuswap Basin. Prior to stabilization of the Shuswap lake level at 1,170 feet (Blind Bay stage) the Fraser River captured Thompson Basin drainage and, during the Blind Bay stage, headward erosion of the Fraser system in the South Thompson River valley tapped the Shuswap Basin. At first the South Thompson outlet probably functioned in conjunction with the Otter Lake spillway but, eventually, the additional flow in the Thompson system cut down the outlet of Kamloops Lake sufficiently to allow the South Thompson River to capture the entire outflow of the Shuswap Basin. Complete capture of the Shuswap Basin drainage caused further down-cutting of the Kamloops Lake outlet and lowered the base level of the South Thompson River. This, in turn, lowered the outlet of Lake Shuswap by about twenty feet. bringing the lake down to the level of the present Shuswap Lake.

At present, three lakes – Shuswap, Mara and Little Shuswap – occupy the Shuswap Basin. Mara Lake formed when Eagle River built a delta across the narrows at the mouth of Eagle River valley. Little Shuswap Lake was separated from the main lake basin when Adams River built a delta across the western end of the present Shuswap Lake basin at Squilax.

SUMMARY

The glacial lake development discussed in the text and depicted in Figures 3A to 3I is summarized in Table I.

TABLE I

Lake History Summary

Figure	Basin	Glacial Lake	Stage	Outlet	Outlet* Altitude (feet)	Lake** Level (feet)
3A	Nicola	Quilchena		Otter Creek	3,300	?
	North Okanagan	Coldstream	I	Ice Marginal	above 1,800	?
3B	Nicola	Quilchena		Otter Creek	3,300	?
	North Okanagan	Coldstream	II	E. side Kalamalka L.	Ca. 1,800	?
		Penticton	Long Lake	Okanagan Falls	unknown***	Ca. 1,650
3C	Nicola	Hamilton		Salmon River	3,050	3,075
	North Okanagan	Penticton	Long Lake	Okanagan Falls	unknown***	Ca. 1,650
3D	Thompson	Thompson	South Thompson I	Turtle Valley	Ca. 1,900	?
	Nicola	Merritt		Campbell Creek	2,550	2,445
	North Okanagan	Penticton	Long Lake	Okanagan Falls	unknown***	Ca. 1,650
3E	Thompson-Shuswap	Thompson	South Thompson II	Notch Hill	Ca. 1,750	1,750-1,650
	Nicola	Merritt		Campbell Creek	2,550	2,445
	North Okanagan	Penticton	Grandview Flats	Okanagan Falls	unknown***	1,600
3F	Thompson-Shuswap	Thompson	Niskonlith	Gardom Lake and Armstrong	1,700	1,635
	Nicola	Merritt		Campbell Creek	2,500	2,445
	North Okanagan	Penticton	Grandview Flats	Okanagan Falls	unknown***	1,600
3G	Thompson	Deadman	Tranquille	South Thompson Valley	Ca. 1,400	1,405
	Nicola	drained		Nicola River		
	North Okanagan	Penticton	B. X.	Okanagan Falls	unknown***	1,400
not	Shuswap	Shuswap	Rocky Point	Round Lake	1,600	1,580
figured	Shuswap	Shuswap	Magna Bay	Mara Lake	unknown	1,300
3H	Thompson	Deadman	Durand	South Thompson Valley	1,230	1,230
	Shuswap	Shuswap	Tappen	Otter Lake	1,220	1,220
	Nicola	drained				
	North Okanagan	Penticton	between stages	Okanagan Falls	-	-
3J	Thompson	Kamloops	Cherry Creek	Fraser River	1,160	1,160
	Shuswap	Shuswap	Blind Bay	Otter Lake	1,170	1,170
	Nicola	drained				
	North Okanagan	Penticton	O'Keefe	Okanagan Falls	1,160	1,160

* Altitude of outlet channel threshold.

** Water level in the area from which the stage name was derived.

*** The outlet of glacial Lake Penticton was at Okanagan Falls throughout the life of the lake. The change in level from one stage to the next was caused by melting of ice, removal of debris, down-cutting of the outlet channel, and isostatic tilting of the lake basin relative to the outlet (Nasmith, 1962). No correlation was made between the levels or stages of glacial Lake Penticton in the North Okanagan Basin and the level of the outlet at Okanagan Falls.

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