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Late Glacial History and Surficial Deposits

of the

OKANAGAN VALLEY, BRITISH COLUMBIA

by
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As a result of many requests for copies, Bulletin No. 46, originally printed in 1962, is being reprinted for your convenience.

The text is unchanged from the original; no attempt has been made to update it. Due to technical problems, the maps in the pocket, which were in colour in the original bulletin, are in black and white in the reprints.

AUTHOR'S NOTE:

The caption for Plate XX refers to Glacier Peak in the State of Washington. Since 1962 extensive work has been done on post-glacial ash falls in British Columbia. The volcanic ash shown in this photograph may have come from one of three ash falls: Bridge River in British Columbia, 2,500 years BP; St. Helens Y in the State of Washington, 3,200 years BP; or Mount Mazama (Crater Lake) in the State of Oregon, 6,700 years BP.

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INTRODUCTION

The field work on which this report is based was originally undertaken at the request of the Department of Agriculture in order to assess the possibilities of obtaining groundwater to supplement surface waters for irrigation in the Okanagan Valley. The first season of field work established the general principles governing the occurrence of groundwater, but additional work was done during two succeeding seasons in order to outline more clearly the late Pleistocene history of the Okanagan Valley. Pleistocene studies provide basic data for the evaluation of groundwater resources, furnish information useful in engineering studies involving unconsolidated deposits, and directly aid pedological studies of agricultural and forest soils.

This report presents an account of the late glacial history of the Okanagan Valley, when the last remnant of the Pleistocene ice-sheet wasted away and disappeared. During this time most of the unconsolidated deposits in the valley bottom accumulated and many minor topographic features were formed. It is hoped that future detailed studies of unconsolidated deposits in any part of the valley, whether for groundwater, engineering, or agricultural purposes, may be guided by the general outline of events and processes given here. The results of such studies, particularly of drilling, could be used to modify and amplify the observations and conclusions of this report.

The main body of the report deals with six map-areas showing the distribution of late glacial features, and each map-area is accompanied by a description of each feature and an interpretation of its significance in relation to other features in the same map-area. Because of special topographic conditions, the succession of events and glacial features are particularly well developed and clearly seen in the vicinity of Summerland, and this map, Map-area III, is supplemented by four additional maps which show the development of a variety of features at successive stages during the melting of the Okanagan ice lobe. These maps (III and IIIA–IIID) and the accompanying descriptive sections may profitably be studied first, although they illustrate features some of which were developed later than features of Map-areas I and II and earlier than features of Map-areas IV, V, and VI. The Summerland maps provide a clearer picture than do other maps of the relationship of various landforms and unconsolidated deposits to the Okanagan ice lobe, and illustrate better the mechanism of their formation.

Within each map-area a fairly straightforward succession of events took place as the ice surface melted down. In addition, there was a general progression of events from south to north. The features of Map-area I were in general formed before those of Map-area II, and those of II prior to those of III, and so on.

The primary purpose of the maps in this report is to provide a framework around which a discussion of the sequence of events and mechanisms of deposition can be developed. If the significance of an individual map unit is to be assessed in terms of a practical problem of groundwater, engineering, or agricultural soils, it will be necessary for the reader to have an understanding of the late glacial events and the mechanisms of deposition, which can only be obtained from a study of the text. It is hoped that a general understanding of this report will enable specific features, that are not discussed in detail, to be fitted into the framework of late Pleistocene history, and will aid their interpretation in terms of whatever problem is under consideration.

In order that the average reader may derive benefit from this report, the section containing detailed map descriptions is prefaced by an outline of current glacial knowledge and a discussion of terms. This report describes the first extended study of the Pleistocene in the interior of British Columbia, and consequently there is extremely little published information generally available. General information on Pleistocene history and glacial geology is found in texts and papers in geological libraries. Since much of this information is not readily available to the general reader, it is hoped that the outline of current glacial knowledge and discussion of terms will make the subsequent sections more understandable.

The third section attempts to gather the detail into a co-ordinated account of Okanagan Pleistocene history and to outline the progression of events during the wasting of the glacial lobe that filled the valley. The data of the six map-areas are correlated and synthesized in terms of process, form, and material.

The concluding section discusses the significance of certain features found in the Okanagan and elsewhere in the surrounding region. Finally, a short analysis is made of the relationship between Okanagan glaciation and that of other parts of British Columbia and the Pacific Northwest.

In preparing Figures 1 and 2 it has been necessary to omit some contour detail from the standard topographic maps in order to illustrate the geology to advantage. The reader is advised to provide himself with these standard maps, published at the same scale of 1 inch to 2 miles, in order to relate the geology to local land-forms and to the region as a whole. The maps are four in number: 82 L/NW—Salmon Arm; 82 L/SW—Vernon; 82 E/NW—Kelowna; 82 E/SW—Penticton. They are priced at 25 cents per copy, plus Provincial 5 per cent tax. Address: Director of Surveys and Mapping Branch, Attention Geographic Division, Department of Lands and Forests, Victoria, B.C.

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GLACIATION IN BRITISH COLUMBIA

The geological events described in this report took place during a very late stage of the earth's geological history. This was the Pleistocene epoch, commonly known as the glacial period, because it was characterized by the spread of glaciers over much of the continental areas of the north and south temperate zones. The time span of the Pleistocene is perhaps a million years, which is only a fraction of 1 per cent of the time span represented by the bedrock of the Okanagan Valley. The late stage of the Pleistocene epoch, during which the events described in this report occurred, probably covered only a few thousand years. This report, therefore, deals with only an infinitesimal part of geological time, the time during which the glaciers waned and disappeared and many of the surficial deposits of the Okanagan Valley were formed.

The idea that glaciers were once much more extensive than they are to-day was first postulated by European geologists about 1825. The idea gradually gained acceptance, particularly among those who were able to view the effects of present-day glaciers at close range. In Great Britain a period of marine submergence had been postulated to account for the distribution of unconsolidated deposits, and even after the acceptance of the idea of extensive glaciation, many British geologists felt that floating icebergs were responsible for the form and distribution of many unconsolidated deposits. This was the "glacial drift" theory, and its influence can be seen in the writings of some early North American geologists. However, the concept that the present time (the Recent epoch) closely follows a period during which glaciers were greatly expanded and ice covered most of the northern part of North America was well accepted by the time the first geologists began their studies in British Columbia. G. M. Dawson, working for the Geological Survey of Canada, explored and described the geology of large areas of British Columbia during the years 1875 to 1890. Although Dawson was somewhat influenced by the theory of widespread marine submergence, his extensive observations and writings on the physiography and glaciation of British Columbia have formed a sound background for studies by the geologists who have followed him.

In the years since the fact of extensive glaciation became generally accepted, many theories have been advanced to account for it. So far, no theory has proved entirely acceptable, partly because of the lack of basic data. However, it is well known that present-day glaciers are limited to mountainous areas of high precipitation where the amount of snow accumulated during the winter exceeds the amount of snow that melts during the summer. Each year's unmelted snow is converted to ice, which flows to lower elevations where summer melting exceeds winter snowfall. Existing glaciers would advance if a climatic change were to result in either an increase in the amount of snowfall during the winter or a decrease in the amount of melting during the summer.

Whatever may have been the ultimate cause, a climatic change involving increased winter precipitation and decreased summer melting must have preceded the onset of any glacial period. No doubt the ice of the glaciers themselves modified the climate as they advanced. With an increasing rate of accumulation of the ice, the glaciers continued to push out from the mountainous regions into areas of greater summer melting until a balance was reached between the melting of a glacier in its terminal zone and the accumulation of snow in the snowfields at its source. Ultimately a large part of the land became covered and an ice-cap was formed. The end of each ice age was brought about by some world-wide climatic change that reduced the amount of winter precipitation and increased the rate of summer melting.

The most extensive glaciers and icefields in British Columbia are found to-day in the Coast Mountains, an area of notably high precipitation. Less extensive glaciers and icefields are found in the Columbia Mountains and the Rocky Mountains. The distribution of present-day glaciers and icefields is shown on the Glacial Map in the Resources Atlas and on the Glacial Map of Canada,* and also on the latest edition of the wall map of British Columbia (scale 1:1,000,000). Undoubtedly these present-day icefields were the gathering grounds from which glaciers advanced to the maximum positions reached during the Pleistocene epoch. Mathews† has postulated a sequence of glacial stages through which an advancing glacier would pass as it developed from a local mountain glacier into an ice-sheet of continental proportions that completely buried the underlying topography. In a mountainous region such as British Columbia this sequence would differ substantially from the sequence through which a continental glacier would develop in an area of low relief such as northeastern Canada.

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* *See* bibliography.

† Mathews, W. H., and Davis, N. F. G.: Four Phases of Glaciation with Illustrations from Southwestern British Columbia, *Journal of Geology,* Vol. 52 (1944), pp. 403–413.

Much of the terminology and many of the concepts of the mechanisms by which certain features are formed have been developed by geologists working in relatively flat areas, and consequently are not strictly applicable to mountainous regions such as British Columbia. For example, there are implications in the use of the terms " active " and " stagnant " ice. In areas of low relief glacial ice becomes stagnant when its thickness is reduced to a hundred feet or so. It then breaks up into isolated blocks of ice, in which plastic flow of the ice does not take place. In a deep basin-shaped trough like the Okanagan Valley, on the other hand, an ice lobe fed by distant snowfields becomes stagnant when the surface of the ice has no gradient. This may be the result of a climatic change which effectively cuts off the flow of ice to the southern parts of the lobe. Stagnation of portions of the ice lobe may occur even though the ice is still 500 to 1,000 feet thick and is still capable of local plastic flow.

In this discussion, stagnation of the ice lobe is inferred where there is evidence that it had insufficient gradient to produce kame terraces and meltwater channels (*see* Glossary, p. 46) with a significant down-valley slope. There could still be minor plastic flow of ice within the lobe itself. Active ice movement is inferred where evidences of meltwater channels and kame terraces clearly indicate a significant down-valley slope to the ice-lobe surface.

Studies in Europe and eastern North America indicate that the Pleistocene epoch was marked by not one, but several advances and retreats of the continental glaciers. Major glacial periods were separated by interglacial periods, when the climate was as warm as or warmer than it is at present. Although studies are not sufficiently complete to prove a western sequence of glacial advances and retreats contemporaneous with those of eastern North America and Europe, it is nevertheless felt that the Pleistocene in British Columbia was marked by a similar series of climatic fluctuations. The last glacial stage in eastern North America is known as the Wisconsin, and the last maximum advance of glacial ice in British Columbia is generally correlated with the Wisconsin stage, chiefly on the basis of the similar degree of weathering of the deposits left by the respective glaciers. At the maximum of Wisconsin glaciation in British Columbia, the border of the ice-sheet stood beyond the present boundaries of the Province. On the west, the glacial ice discharging through the fiords of the Coastal Mountains terminated in a floating piedmont ice-sheet off the west coast of British Columbia. On the north the ice extended beyond the Yukon border, and on the east the Cordilleran ice pushed beyond the Rocky Mountains to meet the Keewatin ice-sheet advancing from the east. On the south, the ice-sheet pushed into the State of Washington to about the forty-eighth parallel, where the ice boundary has been mapped in some detail. The elevation of the surface of the ice-sheet which covered British Columbia is not known with any degree of certainty, but it is believed to have been at an elevation of at least 8,000 feet.* The actual thickness of the ice would vary tremendously with the underlying topography.

After the maximum stage of Wisconsin glaciation had been reached, the climate again changed, and the glaciers began to retreat and melt away. Detailed studies in eastern North America and in Europe indicate that the retreat of the Wisconsin ice-sheet was not a continuous process, but was interrupted at various times by climatic changes which produced a readvance of the ice front. It seems probable that the climatic changes were continent-wide and produced similar fluctuations in Wisconsin glaciers in British Columbia, although these minor fluctuations have not been clearly recognized. This may be because only a few detailed studies have been made as yet, or it may be because the Wisconsin glaciers in this

* *See* contours drawn on Glacial Map of Canada and Glacial Map in the British Columbia Resources Atlas.

mountainous terrain reacted differently to the climatic fluctuations than did the Wisconsin glaciers in eastern North America.

The evidence to date in British Columbia seems to indicate that, following maximum advance of the glaciers, there was a rapid and extreme change in climate. As a result, the Wisconsin ice-sheet in British Columbia seems to have wasted away by down-melting rather than by a retreat of the ice terminus along a well-defined front. As a result of this down-melting, except in areas of high precipitation, ground at higher elevations became ice-free before ground at lower elevations. In most parts the last active ice was in tongues in the main valleys, and finally even these became stagnant and disappeared.

The late glacial record in the Okanagan Valley is essentially the record of the wasting away of a tongue of glacial ice which was confined to the valley while the adjacent uplands were ice-free. The sequence of events is probably similar to that in other major valleys of British Columbia. This report therefore could serve as a guide to the interpretation of glacial features beyond the limits of the Okanagan Valley.

PHYSIOGRAPHY OF THE OKANAGAN VALLEY

The Okanagan Valley is a major valley in the Interior Plateau of British Columbia and the Columbia Plateau of north central Washington. It trends generally north-south between the Columbia River near the forty-eighth parallel and Shuswap Lake in British Columbia just south of the fifty-first parallel.

The main trench in British Columbia is occupied by Okanagan Lake and Okanagan River, which drain south to join the Columbia River at Brewster. From a few miles south of Peachland almost to the International Boundary a narrow discontinuous valley lies west of and parallel to the main trench and contains sections of several small streams and a few minor lakes. Between Kelowna and the north end of Okanagan Lake a few miles north of Vernon, a well-developed valley lies east of and parallel to the main trench and is occupied by Kalamalka and Wood Lakes. The segment of the trench which diverges most from the general north-south trend is that between Peachland and Kelowna. It trends northeast-southwest and is positioned almost as though to mark the offset of two formerly continuous parallel valleys. The known bedrock structures (*see* Kettle River, West Half, geological map) do not provide an obvious explanation for this curious pattern of the present major topographic features.

From Vernon to the International Boundary the Okanagan Valley consists of the main trench and parallel valleys, cut deeply into the general surface of the Interior Plateau. Minor tributary streams flow from the plateau surface in narrow valleys on steep gradients. At Vernon the Okanagan Valley is joined from the east by a major east-west valley, the Coldstream Valley. South of Vernon no major valley joins the Okanagan in Canada, and the watershed divides are abnormally close to the main valley for such a major valley system. North of Vernon the plateau is dissected by a network of valleys which are extensions of the arms of Shuswap Lake.

In general the valley bottom ranges in width from 2 to 10 miles and in elevation from 900 feet above sea-level at Osoyoos Lake to about 1,800 feet west of Enderby. The elevation of the underlying bedrock trench is unknown, but Okanagan Lake (elevation, 1,123 feet) is 760 feet deep at its deepest, and beneath the lake bottom lies an unknown thickness of unconsolidated sediment. A test well drilled in the Okanagan Valley north of Armstrong, starting at an elevation of approximately 1,220 feet, passed through slightly more than 1,300 feet of unconsolidated and unweathered sediments, apparently Pleistocene deposits, before bedrock was reached.

The present Okanagan Valley is connected to mountainous areas to the north and east by the Coldstream Valley and the deep narrow trenches occupied by arms of Shuswap Lake. The pre-glacial Okanagan Valley was in such a position that during a succession of glacial stages it provided an important passageway for glacial ice flowing away from centres of accumulation in the Monashee Mountains. During the onset of a glacial period, glacial ice did not accumulate on the relatively low watershed of the Okanagan Valley. Instead the valley provided a channel through which glacial ice pushed to the Columbia plateau to the south.

Whatever the original form of the Okanagan Valley and its relation to bedrock structure, its present form is the result of intensive glacial erosion during the Pleistocene. The valley was so situated that it provided a channel through which ice escaped from major mountainous centres of accumulation to lower elevations.

MAP SYMBOLS AND TERMS

The accompanying maps show the distribution of the various sorts of unconsolidated materials and the minor topographic features formed during the time of recession and final dissolution of the Okanagan glacier lobe. Most but not all were formed in consequence of the vast quantities of meltwater that poured from the ice. Each coloured map unit shows the distribution of the various glacial and post-glacial features, and indicates to some extent the process and environment of their formation.

Standard terms are used, and if there is perhaps a slight departure from common usage, it is hoped that the context makes the meaning clear.

The choice of units for Pleistocene geological mapping presents many difficulties and is usually a compromise between conflicting purposes to be served by the map. The units used in mapping bedrock in the Okanagan Valley* are lithologic units (granite, basalt, limestone, conglomerate, etc.) and time-stratigraphic units (Carboniferous, Triassic, Jurassic, etc.), but similar divisions are not suitable for a report on glacial geology. Post-glacial time is short and contains few distinctive marker events, so that a subdivision based on time would not be possible. The only purely lithologic units which might be used would be grain-size divisions —sand, gravel, silt, etc.—but variations in texture resulting from deposition in the glacial environment are so great that only part of the story would be told.

List of Map Units

Age	No.	Deposits
Recent	1	Okanagan River floodplain.
	2	Alluvial fans, deltas, and associated gullies and stream channels.
	3	Beaches, spits, and dunes.
Late Glacial	4	River channels and stream-cut terraces.
	5	Raised alluvial fans, terraces, and deltas.
Stage of Glacial Retreat	6	Outwash terraces.
	7	Kettled outwash.
	8	Glacial lake sediments.
Stage of Glacial Occupation	9	Moraine ridges.
	10	Kame terraces and meltwater channels.
Glacial Advance and Earlier	11	Mixed unconsolidated deposits.

The map units adopted for the present report have a loose time-stratigraphic connotation. They are grouped under Recent, Late Glacial, Stage of Glacial Retreat, Stage of Glacial Occupation, and Glacial Advance. Within the Recent group

* Kettle Valley sheet, East Half, *Geol. Surv., Canada,* Map 538A, 1940; Vernon sheet, *Geol. Surv., Canada,* Map 1059A, 1960.

are units which are forming now and have been formed within recent time under climatic conditions essentially similar to those of the present day. Late Glacial contains units formed under climatic and hydrologic conditions distinctly different from the present, although deposition did not take place in contact with glacial ice. Units grouped under Stage of Glacial Retreat were formed in contact with or near stagnant glacial ice. Units grouped under Stage of Glacial Occupation were formed in contact with glacial ice which was still active and was characterized by definite down-valley and cross-valley slopes. The oldest unit belongs to the stage of Glacial Advance and Earlier.

The sequence of events seems to show a continuous down-melting and retreat of glacial ice, possibly interrupted by temporary halts but not by any extensive readvance. The climate appears to have continuously moderated. Accordingly, at any one section of the Okanagan Valley there is indicated a progression from Stage of Glacial Occupation, through Stage of Glacial Retreat and Late Glacial to Recent, and a succession of deposits and events from older to younger. However, at any one time there was a difference in glacial environment from south to north along the valley. Units of the Stage of Glacial Occupation at the north end of the valley may be contemporaneous with Glacial Retreat, Late Glacial, and even Recent units farther south. Accordingly, these major groupings contain implications both of time and of spatial association with the glacial ice. This dual implication is partly the result of the fact that the glacial ice was extended along a narrow, deep north-south valley from its source, and that during the last stages of Wisconsin glaciation there was a marked regular climatic variation from south to north. Even at present there is a very considerable change in the climatic environment of the valley from south to north (*see* for instance discussion of climate in soils report of Kelley and Spilsbury).

The Recent, Late Glacial, Glacial Retreat, and Glacial Occupation deposits of the present map are subdivided on the general basis of the depositional mechanisms and environment, as interpreted from the texture of the deposits and their minor topographic form. In order to clarify the significance of these various depositional units, they are discussed in the following brief notes.

Recent

1. *Okanagan River Floodplain.*—Three segments of Okanagan River floodplain are mapped: between Okanagan and Skaha Lakes, between Skaha and Vaseux Lakes, and between Vaseux and Osoyoos Lakes. The recent floodplain deposits consist of sand, silt, and swamp deposits. The segments between Skaha Lake and Osoyoos Lake consist of the channel of Okanagan River that was cut by large flows of meltwater in late glacial time. The present Okanagan River is underfit (undersized) in this older channel. It meanders across the floodplain deposits, which have been deposited in the channel to an unknown depth.

2. *Alluvial Fans and Deltas, and Associated Gullies and Stream Channels.*—These are the erosional and depositional features of the present-day streams. They are classified as Recent where the stream is graded to the present base level and where the deposits seem to be in keeping with the present runoff characteristics of the streams. Information from drilling might permit many of these features to be further subdivided. Although they are mapped as a single unit, the distinction between depositional features (alluvial fans and deltas) and dominantly erosional features (stream channels and gullies) should be readily apparent. The texture of these deposits varies within wide limits, from fine silty sand to coarse bouldery gravel.

3. *Beaches, Spits, and Dunes.*—Minor, recently formed deposits resulting from the reworking of older deposits by wind and wave action are relatively unimportant features, and only in a few places are large enough to form mappable units.

Swamp and bog deposits are forming in many poorly drained locations but have not been mapped separately. The distribution of peat deposits is shown on the Agricultural Soils map. Dating of these deposits by radiocarbon or other means may be very useful in studying the development of recent alluvial fans and deltas.

Late Glacial

4. *River Terraces and Channels.*—These are mapped between Vaseux Lake and Osoyoos Lake, between Enderby and Okanagan Lake, and a short segment in Marron Valley. They are dominantly erosional in character and consist of a thin veneer of river deposits on top of the earlier deposits in which the channels and terraces have been cut. These features mark the courses of former streams carrying large flows of glacial meltwater. In contrast to the meltwater channels of unit 10, the channels were cut at some distance from the glacial ice. The areas mapped in this unit are not contemporaneous. The channels were abandoned because the supply of meltwater diminished, or because the drainage pattern changed.

5. *Raised Alluvial Fans and Deltas.*—These are constructional features similar to Recent alluvial fans and deltas but were built by streams graded to a base level higher than at present. Lowering of the base level, whether Okanagan Lake or tributary streams, resulted in downcutting and partial erosion of fans and deltas by the streams that built them. Although similar in form and texture to many deposits mapped as glacial outwash, the raised alluvial fans and deltas are distinguished by the fact that the streams which built them were fed from normal precipitation and not by meltwater flowing from the ice lobe in the Okanagan Valley. Probably the climate and the intensity of erosion were both different when these alluvial fans and deltas were built, but no direct comparison with the present has been made.

Stage of Glacial Retreat

6. *Outwash Terraces.*—Outwash terraces consist of stratified drift* ranging in texture from fine sand to coarse gravel. The drift was deposited by meltwater streams fed by the melting ice of the main Okanagan lobe. The source of the water and the fluctuations characteristic of a meltwater source distinguish these deposits from alluvial fans and deltas. Topographically, outwash terraces may be very similar to alluvial fans and deltas and consist of terraces along the main valley, and floodplain and braided stream-channel deposits in the side valleys.

Outwash is defined as " stratified drift that is built beyond the glacier itself," and the outwash stream is therefore graded to a local or regional base level that is not controlled by the actual glacier. Outwash terraces thus differ from kame terraces, which are built in contact with the ice. The significance of outwash terraces is that they reflect down-valley conditions, including the level of glacial lakes, whereas kame terraces and ice contact features reflect the level of the ice in the area where they occur. In practice the distinction between the outwash terraces and kame terraces is not easy to maintain because they are in fact gradational into each other.

7. *Kettled Outwash.*—Kettled outwash consists largely of stream-deposited sand and gravel, but it may include some silt and clay deposited in local ponds. The material was deposited over and around stagnant blocks of glacial ice which subsequently melted away and left kettle holes. The collapse of the sediments

* Glacial drift is all rock material in transport by glacier ice or deposited from meltwater streams or in meltwater lakes. It is a broader term than till, which it includes. Till is not stratified.

over the melting ice produced the distinctive topography. In the Okanagan Valley most of the deposits in areas of kettled topography appear to be water deposited, although in some glaciated regions kettled topography may be developed in thick deposits of ablation moraine. The kettled outwash may be a part of either terraced outwash deposits or of kame-terrace deposits. Its significance is in the fact that it indicates the presence of stagnant ice at the time of deposition. In some places it indicates that the sediments were deposited close to the ice front; in others it may reflect topography which permitted stagnant blocks of ice to persist long after the melting of the main mass of ice. Kettled outwash is frequently associated with kames and eskers.

8. *Glacial-lake Sediments.*—Extensive proglacial lakes formed as the Okanagan ice lobe melted, and in them thick deposits of sand, silt, and clay accumulated. These deposits have been mapped wherever they are sufficiently thick and distinctive to form mappable units. The mapping represents the present distribution of the sediments and not the full extent of the glacial lakes. The distribution of the sediments is a result of various factors of sedimentation and of preservation of the sediments as the lakes were drained. The lakes themselves should be marked by shoreline features, but, as only a few recognizable beaches were formed, the extent of the lakes in which the various glacial-lake sediments were deposited is undetermined. Glacial-lake sediments are the only deposits with such a limited range of textures and distinctive sedimentary features that they may be recognized in limited exposures without reference to their topographic expression.

Stage of Glacial Occupation

9. *Moraine Ridges.*—These are constructional features consisting of ridges of sorted or unsorted material deposited at the edge of the ice lobe. Because of the special topographic situation in the Okanagan Valley, no true terminal moraines were formed, and the moraine ridges could probably be classified as lateral moraines. These moraine ridges mark the edge of the glacial ice at a time when it was active, and the ice surface probably rose fairly steeply from the line along which the moraine was built. In most cases there are no sections which show the internal structure of the moraine, but if deposited where the ice ended in standing water, the ridge might consist of stratified drift.

10. *Kame Terraces and Meltwater Channels.*—Kame terraces consist of stratified drift deposited by meltwater streams flowing along the edge of the ice. They are distinguished by their terraced form from the moraine ridges. They are distinguished from outwash terraces by the fact that the gradient of the meltwater stream was controlled by the adjacent ice rather than by some other factor farther down the valley. Kame terraces are commonly flanked by kettled outwash where the kame-terrace deposits were spread over adjacent stagnant ice.

Meltwater channels are the recognizable channels of meltwater streams that flowed along the edge of the ice lobe. They are preserved as distinctive dry channels contouring the slope of the valley wall. They are the channel correlatives of the kame deposits, often originating or terminating in kame terraces. In some instances the channels have been eroded in unconsolidated deposits or bedrock along the valley wall. In other instances the meltwater streams merely occupied pre-existing linear depressions which have been only slightly modified. Many linear depressions were not occupied by meltwater streams, and only those which clearly were once glacial meltwater channels are mapped as such. The location and gradient of meltwater channels give considerable information on the position, thickness, and slope of the ice tongue at the time the channels were occupied, and permit some correlation between ice contact features and outwash deposits and glacial lakes down valley.

Glacial Advance and Earlier

11. *Mixed Unconsolidated Deposits.*—This unit consists largely of ridges of advance glacial outwash and in some cases earlier deposits, mantled with till and thin glacial and post-glacial deposits, that are so thin that they do not obscure the topographic form of the earlier deposits. The mapped areas are interpreted on the basis of limited exposures and of topographic form. They characteristically are areas of deep unconsolidated material thinly mantled by later deposits.

DETAILED DESCRIPTIONS OF GLACIAL FEATURES

The following discussion refers to six map-areas. These are subdivisions of Figures 1 and 2 that were made in the original mapping and are retained for ease of reference.

Map-area I, Osoyoos-Oliver (Figure 1)

The maximum thickness attained by Wisconsin glacial ice cannot be determined by features in the vicinity of the Okanagan Valley itself. The best information* indicates that the upper surface of the ice in the southern Okanagan was at an elevation of at least 7,000 feet. As the ice melted back from its maximum elevation, the features which record the earliest indicated stages of retreat in the vicinity of the south end of the valley are a series of meltwater channels on the east side of the valley at elevations ranging from 2,800 feet to 3,500 feet, a mile or two north of the forty-ninth parallel. These channels carried glacial meltwater along the valley wall and apparently discharged into a lake basin in the valley of Nine Mile Creek. The lake was blocked just south of the forty-ninth parallel by the ice lobe which remained in the main Okanagan Valley.

As the ice melted down from this level, it became apparently more or less stagnant, with a surface that was essentially horizontal or had only a slight southerly gradient. Consequently the meltwater flowed in channels on top of the ice rather than along the edge of the lobe where it would be frequently diverted to channels along the valley wall. Between Oliver and the forty-ninth parallel there are trough-like depressions along the valley wall or behind spurs and ridges that could have carried meltwater, but show no sign of having done so.

Just north of Spotted Lake, west of the north end of Osoyoos Lake at an elevation of 2,000 feet, a small area of outwash marks the terminus of a minor meltwater stream, but the deposits are of limited extent and thickness, and the channel leading to them does not appear to have carried a large volume of water. The valley parallel to the main Okanagan trench on the east side, in which the Indian village of Inkaneep is situated, does not show signs of having carried as large a stream of meltwater as would be expected if the ice tongue in the main valley had an appreciable down-valley slope. Two meltwater channels shown on Map-area I may have carried water south and southwest from the Wolfcub Creek valley when the valley outlet was blocked by ice. At about the same time, kame terraces were built along the margin of the ice in the middle section of Wolfcub Creek (*see* Plate V), and at a slightly later stage silts were deposited in a lake ponded in Wolfcub Creek valley. A narrow north-south valley about 2 miles west of the main Okanagan Valley, extending from just south of Myers Flat to near

* *See* Glacial Map of Canada and Glacial Map in British Columbia Resources Atlas.

Fairview, would almost certainly have carried meltwater if the ice lobe in the Okanagan Valley had a down-valley slope of 50 feet per mile when the surface of the ice opposite Park Rill stood at an elevation between 1,600 and 2,000 feet. The fact that there are in this lateral valley no deposits or freshly cut channels which might have carried meltwater indicates that at this stage the ice lobe in the Okanagan Valley south of McIntyre Bluff was stagnant and did not have an appreciable down-valley slope or a convex cross-valley profile.

The stagnation of the ice lobe at this stage marks the end of active ice movement in the valley south of Oliver. It is not known how far north of Oliver the ice lobe stagnated, but it probably continued to be active in the northern half of the valley at least.

East of Oliver two areas of terminal moraine appear to mark a period of reactivation of the ice lobe as far south as Oliver. These moraines are at an elevation of about 1,500 feet, and apparently the stagnant ice lobe had melted down to this level when it was reactivated by ice flowing down the valley from the north. The interpretation of these features is based only on their topography and the texture of material in them at the surface, combined with the presence of several meltwater channels which mark the diversion of meltwater drainage from Wolfcub Creek along the valley east of the more southerly of the two areas of morainal ridges. Deposition from these meltwater channels probably contributed to outwash which was built south over stagnant ice in the valley in which Inkaneep Indian village is located.

Following this reactivation of the ice lobe north of Oliver, the general downmelting and progressive northerly stagnation of the ice lobe recommenced, and apparently continued without any marked interruption. As the ice surface became lower, ponds formed along the ice margin and rapidly coalesced over the stagnant ice. The resultant lake filled the valley south of Oliver, and is referred to as Lake Oliver. Into it were deposited glacial-lake silts very similar in a general character to the silts deposited later in the vicinity of Penticton and Summerland. The silts deposited in Lake Oliver were subsequently covered by sandy and gravelly outwash brought down from the melting ice lobe farther north in the Okanagan Valley, and the silts are now exposed only in road cuts and gullies. Typical exposures can be seen in the following localities: In a landslide that occurred in 1954(?) on the east side of Osoyoos Lake at the forty-ninth parallel (*see* Plates VI and VII); in gullies and road cuts along the lower part of Inkaneep Creek; in a road cut on Highway No. 97 about three-quarters of a mile south of the north end of Osoyoos Lake. Other exposures of silts and sandy silts which are probably deposits of Lake Oliver may be seen along the road west of Oliver and in the east bank of the Okanagan River half a mile south of Oliver. Numerous other exposures in gullies and shallow cuts indicate the extent of the silts.

Lake Oliver, into which the silts were deposited, was not a stable feature with a constant water level and fixed outlines. It originated as ponds along the side of the stagnant ice at the south end of the valley, spread across the valley, and extended north as the surface of the ice melted down. The lake extended south across the forty-ninth parallel, and the outlet which controlled the changing lake level is not at present known. Probably the lake level was controlled by deep outwash deposits which filled the Okanagan and Columbia River valleys in front of the glacial ice, and the lake level fell as the outlet was lowered by down-cutting of the river channels through these outwash deposits. Differential uplift of the lake basin in response to the removal of the load of glacial ice, a form of isostatic adjustment, was a further factor in lowering the lake level.

The upper limit of the main mass of the silts in the vicinity of Osoyoos and Oliver appears to be about 1,200 feet, although this probably does not represent the uppermost level of the lake surface.

These lacustrine deposits are mainly grey-white silts and are horizontally stratified. The strata range in thickness from a fraction of an inch to 6 inches, and contain some layers of fine sand. In general they grade from silt at the south end of the valley to silty sand and fine and coarse sand north of Oliver. The exposure on the east bank of the Okanagan River half a mile south of Oliver shows a similar gradation, from silty clay at the bottom to silty sand which is overlain by interbedded outwash sands and gravels. In some exposures the silty sands show features which superficially resemble ripple marks and cross-bedding, but which, because of the regularity of the pattern developed, are thought to be the result of compaction of the loosely deposited material.

As the lake level was lowered by down-cutting of the outlet and by isostatic adjustment, extensive sandy and gravelly outwash was deposited on top of the glacial-lake sediments and the stagnant masses of ice buried in them (*see* Plate XVIII). The contact between the glacial-lake sediments and the overlying outwash is not well exposed. It is not clear whether the deposits represent a normal sequence of events in which, as the lake drained, meltwater streams deposited outwash over the newly exposed lake bottom, or whether the outwash should be correlated with renewed glacial erosion brought about by a return to a more severe climate. Extensive kettled areas of outwash deposits lying on the glacial-lake sediments are attributed to the melting of stagnant ice blocks buried in the silts on the lake bottom, and although the time needed to melt well-insulated ice blocks cannot be reliably estimated, it is clear that no very long time interval elapsed between the draining of the lake and the deposition of the outwash deposits.

Most of the outwash terraces lie between elevations of 1,350 feet and 1,100 feet and represent deposition from streams flowing down the main Okanagan Valley. At the north end of the valley in which Inkaneep village is located, the outwash terrace at an elevation of 1,400 to 1,450 feet appears to be related to meltwater channels east of the more southerly morainal ridge. An area of outwash at an elevation of 1,400 feet 2 miles northeast of Oliver was probably deposited by a meltwater stream at the downstream end of a channel through which Vaseux Creek was diverted. An outwash area north and south of Park Rill at an elevation of about 1,400 feet is probably the result of deposition from a meltwater stream which followed the present course of Park Rill and is described in connection with Map-area II. These three outwash terraces were probably deposited slightly earlier than the outwash terraces at lower elevations.

At approximately the same time that streams of meltwater were building the outwash terraces along the valley, tributary streams were building alluvial fans from the sides of the valley onto the outwash and glacial-lake deposits. Prominent alluvial fans were built on the west side of Okanagan Valley a few miles south of Oliver by Testalinden, Tinhorn, Hester, and Reed Creeks. At about the same time Inkaneep Creek built the prominent fan on which Inkaneep village is situated. The alluvial fan remnant of Vaseux Creek was built at about the same time or possibly a little later.

As the ice lobe melted farther to the north, deposition of outwash terraces ceased, and the large volumes of meltwater flowing down the valley began to cut into and erode the outwash terraces to form a group of river-cut terraces at elevations between 1,100 and 960 feet. These terraces are represented now by discontinuous remnants which have a somewhat flatter gradient than the present floodplain of the Okanagan River. A few kettled areas of these river terraces indicate that remnants of stagnant ice still remained buried in the outwash deposits, but not all the closed depressions on the terraces are kettles. Gallagher Lake and Mud Lake north of Oliver occupy depressions in a stream channel partially blocked by alluvial fans.

During the final melting of ice in the Okanagan Valley, a meltwater stream flowed at approximately the present level of the Okanagan River and carved a channel from one-half to three-quarters of a mile in width. This channel is much too large for the present flow of the Okanagan River. On Map-area I the floodplain of the ancestral river extends from the north end of Osoyoos Lake north to the fan of Vaseux Creek, and being for the most part only a few feet above river level is frequently flooded during the spring runoff. For 2 or 3 miles north of Osoyoos Lake the floodplain consists of swamps and sloughs formed by cutoff meanders, and this section may have been formed by the filling of the northward extension of Osoyoos Lake with silt and sand brought down by the former river.

As the meltwater streams cut down through the outwash deposits to the present level of the Okanagan River, the tributary streams eroded the earlier alluvial fans that had been built onto the outwash terraces, and built new alluvial fans graded to the present base level. Haynes, Inkaneep, Testalinden, Hester, Wolfcub, Park Rill, and Vaseux Creeks have all built prominent alluvial fans. The time at which these alluvial fans were built is not readily determined, but Testalinden and Vaseux Creeks appear to have added to their fans within historic times. The valley of Wolfcub Creek, between 1,500 and 2,000 feet elevation, has been largely cleared of glacial deposits, including a deposit of glacial-lake silt of which only small remnants are left, and the bottom of this part of the valley consists of alluvial fans and swamps. This erosion and deposition may have occurred much earlier than the deposition of alluvial fans at the present level of the Okanagan River and Osoyoos Lake. Just east of Oliver, Wolfcub Creek has built a fan which blocked one channel of the late glacial Okanagan River, and Tugulnuit Lake now occupies this segment of the channel while the present Okanagan River flows in the other channel.

Osoyoos Lake appears to occupy a depression formed by the melting of an extensive segment of the stagnant ice lobe. When meltwater ceased to flow south in the Okanagan Valley, Nine Mile Creek built a fan across the valley south of the forty-ninth parallel, and the construction of this fan may have raised the level of Osoyoos Lake in post-glacial time. At the north edge of Map-area I, Vaseux Creek has built a fan completely across the late glacial meltwater channel and Vaseux Lake is impounded behind this fan.

Map-area II, Vaseux Lake-Penticton (Figure 1)

In the western part of Map-area II, a mile or so south of Highway No. 3, Twin Lakes occupy two large kettle holes. These kettle holes and the pitted outwash surrounding them appear to represent the earliest extensive deposits in this map-area that are related to the last retreat of ice. The kettled outwash lies at an elevation of approximately 2,675 feet, and at the time it was deposited the glacial ice had melted down until it remained as a lobe that filled the Okanagan Valley and minor tributary valleys such as Marron Valley and the White Lake basin to an elevation of approximately 2,700 feet. At this stage, water flowing from the melting ice was discharged west into the Similkameen Valley through the meltwater channel which now contains Yellow Lake, and through another channel southwest of Twin Lakes.

An extensive area of terraced outwash at an elevation of 2,600 feet on both sides of Marron Valley just north of Aeneas Lake seems to mark the next stage in the melting of the ice. The sands and gravels of this terrace are deposited over sands and silts which appear to be lacustrine deposits and may indicate that this part of Marron Valley* became free of ice between the times of deposition of the Twin Lakes outwash and this terraced outwash, and contained a glacial lake which was dammed between ice farther north in Marron Valley and a tongue of ice extending westward from the Okanagan ice lobe near Kaleden. A very faint beach line may mark the level of this lake on the east side of Marron Valley. During the stage when the outwash terraces just north of Aeneas Lake were being deposited, meltwater continued to drain westward into the Similkameen Valley by way of the Yellow Lake channel, although the meltwater channel southwest of Twin Lakes had probably been abandoned. At the same time, the meltwater channel now occupied by Brent Lake and Farleigh Lake was carrying meltwater which built kame terraces along the west side of Marron Valley south of the outlet of this channel. The highest kame terrace is at an elevation slightly above 2,700 feet.

As long as the ice tongue extending west from the main Okanagan lobe in the vicinity of Kaleden stood higher than 2,500 feet near the south end of Marron Lake, the meltwater in this vicinity flowed to the west through the Yellow Lake channel and into the Similkameen Valley. Evidently the ice occupying the Similkameen Valley was not so thick as the ice lobe in the Okanagan, and the meltwater flowed south in the Similkameen Valley to join the Okanagan drainage beyond the front of the Okanagan ice. At this time a small lake was formed between the Kaleden ice tongue and the spillway into the Yellow Lake channel, and thin silt deposits were laid down in this area. The Brent Lake-Farleigh Lake meltwater channel continued to carry water, which built outwash over and around stagnant ice in Marron Valley and eroded terraces in the higher outwash materials previously deposited in the vicinity of Aeneas Lake.

When the Kaleden ice tongue melted down still farther, the Yellow Lake meltwater channel was abandoned and meltwater from Marron Valley began to flow south and east through a channel now occupied by Kitley Lake, and thence by channels now occupied by Kearns Creek and Park Rill to the Okanagan Valley in front of the ice lobe. The outwash terrace at 1,400 feet elevation, adjacent to Park Rill about 2 miles north of Oliver, marks the base level controlling drainage in the Okanagan Valley south of the ice at this stage. During the time when this Kearns Creek-Park Rill meltwater channel was carrying meltwater, several areas of outwash were deposited along its route. An outwash terrace east of Marron Lake at an elevation of 2,200 feet was probably deposited earlier than the outwash terrace west of Marron Lake at an elevation of 2,000 feet which was deposited shortly before the meltwater abandoned the Kearns Creek-Park Rill channel. A large deposit of terraced outwash was deposited in the White Lake basin north of White Lake, and extensive outwash was deposited in the area along Park Rill and Kearns Creek known as Myers Flat. In the vicinity of Myers Flat there appear to be two main terrace levels, one about 50 feet higher than the other, but it is not possible to correlate these two terraces with features farther north along Kearns Creek.

During the time when the Kearns Creek-Park Rill channel carried meltwater, the main ice lobe filled the Okanagan Valley possibly to or a little south of McIntyre Bluff. As long as the surface of the ice opposite McIntyre Bluff stood higher than 1,700 feet, the drainage of Vaseux Creek was diverted south through a meltwater channel to an area of outwash adjacent to Wolfcub Creek (described in the section on Map-area I), and at the same or a slightly earlier time the drainage of Shuttleworth Creek was diverted into the same meltwater channel. In addition to the meltwater channels, morainal ridges at an elevation of about 1,900 feet east of Vaseux Lake mark this stage. Later stages, while the Kearns Creek-Park Rill chan-

* Marron Valley, following local usage, is considered to extend from Marron Creek past the fork of Shingle and Shatford Creeks, west of Niggertoe Mountain, and to cross the valley of Trout Creek at Faulder.

nel still carried meltwater, are marked in the Okanagan Valley by kame terraces at 1,500 and 1,600 feet on either side of the valley near Vaseux Lake.

Further melting so lowered the ice surface in the area west of Kaleden that meltwater coming down Marron Valley no longer flowed into the Kearns Creek-Park Rill channel but began to flow eastward, at first on top of the ice but later in a deep channel eroded in bedrock and glacial deposits along the present course of Marron Creek. This channel ends in an extensive outwash area (*see* Plate IX) on the west side of Skaha Lake just north of Okanagan Falls and is referred to as the Marron Creek channel. At about this time the part of the ice lobe in the Okanagan Valley between Okanagan Falls and McIntyre Bluff was relatively thin and became stagnant. Over this stagnant ice, outwash was deposited by meltwater coming both from the Marron Creek channel and from the active ice front which must have stood somewhere near the south end of Skaha Lake. Remnants of the terraced surface of this valley train indicate that it filled the valley to an elevation of 1,400 feet or possibly higher. As the blocks of stagnant ice melted away, the outwash deposits slumped and collapsed to form the extensive areas of kettled topography south of Okanagan Falls. Road cuts along the highway south of Okanagan Falls show that this kettled outwash consists of contorted sands and silts which evidently were deposited in ponds on top of the stagnating ice. These are overlain by outwash sands and gravels, also contorted and slumped, which evidently were deposited from streams flowing away from the ice front.

A striking feature of the kettled area on the west side of the valley north of Vaseux Lake is the concentration of erratic boulders lying on the surface of the outwash gravel. These boulders vary in size from a foot to 5 or 6 feet in diameter and consist almost exclusively of granitic and gneissic rock types. Boulders of the White Lake sediments and the Marron volcanics are conspicuously absent (*see* Geological Survey of Canada Map 627A, Okanagan Falls, for the distribution of various rock types in this area). The boulders appear to be concentrated toward the western edge of the kettled area along the Okanagan River channel and to be less frequent in the eastern part of the area. In places along the western edge of the area above the Okanagan River, these erratic boulders form a continuous layer on top of the outwash gravels. The mechanism by which the erratic boulders were transported and deposited is not clear, but this area of outwash containing stagnant blocks of ice evidently formed for a time the spillway of the glacial Lake Penticton, and the erratic boulders may have been ice rafted from the areas of gneissic and granitic rocks farther north in the valley and deposited when the ice rafts stranded at the outlet of the lake.

Meltwater was carried from the outlet of the Brent Lake-Farleigh Lake channel south along Marron Valley in a channel cut in the outwash terraces and kettled outwash as far as Marron Lake and then east in the narrow rock-walled Marron Creek channel to an extensive area of outwash at an elevation of approximately 1,450 feet northwest of Kaleden. For a time a glacial lake at the junction of Shatford and Shingle Creeks drained south through the Marron Creek channel. This lake was blocked by an ice tongue extending up Shingle Creek from the Okanagan lobe, and remnants of silt deposits of the lake are exposed in steep banks near the junction of Shatford and Shingle Creeks. Meltwater flowing along the western edge of the main ice lobe in the Okanagan Valley built kame terraces north and west of Kaleden, and some of this meltwater was diverted to the west along a short channel to join the Marron Creek channel about 2 miles west of Kaleden.

Further melting of the ice lobe in the Okanagan Valley brought about the abandonment of the Marron Creek channel and at about the same time the development of the initial stages of glacial Lake Penticton.

Marron Valley channel was probably abandoned when the ice tongue extending up Shingle Creek from the Okanagan lobe melted down to permit the draining of the glacial lake at the junction of Shingle Creek and Shatford Creek. This would have occurred when the ice surface at the mouth of Shingle Creek had melted down to an elevation of about 2,000 feet, and meltwater that flowed south along Marron Valley would instead flow eastward to the Okanagan Valley through the valley of Shingle Creek below its junction with Shatford Creek. At about the same time, however, as described in the section on Map-area III, meltwater from ice at the north end of Marron Valley began to follow the course of Trout Creek and was diverted into the Trout Creek-Penticton channel, which joined the main Okanagan Valley on the west bench at Penticton. When this occurred the ice in the Okanagan Valley at the mouth of Shingle Creek had melted down to between 1,800 and 1,900 feet. The drainage coming down the Shingle Creek valley was then no longer fed by meltwater from the melting Okanagan lobe but was derived from the watershed of Shingle Creek and its tributaries. No doubt the climate was more severe than at present, due to proximity of the Okanagan ice lobe, and the runoff from the Shingle Creek watershed was higher than at a later period when the ice lobe had receded to the north.

At about the time the Marron Creek channel was abandoned by meltwater streams, the Okanagan ice lobe began to stagnate at the south end of Skaha Lake, and as the ice melted down stagnation of the lobe extended north past the present site of Penticton. As the ice stagnated, ponds formed on top of the ice and these coalesced to form the initial stage of glacial Lake Penticton. Glacial silts were deposited in this lake and remnants of these deposits form discontinuous terraces along the border of Skaha Lake up to elevations of about 1,350 feet in the vicinity of Kaleden. The lake level was controlled by the outlet stream which flowed across the outwash deposits and buried blocks of stagnant ice that filled the valley from Okanagan Falls to McIntyre to an elevation of about 1,400 feet. The level of the outlet was lowered to the present level of Skaha Lake as the river flowing from Lake Penticton cut down through these deposits and as the ice blocks within them melted and allowed the outwash gravels to settle.

While the meltwater discharging from the Trout Creek-Penticton channel was building kame terraces and later depositing outwash sands and gravels along the western margin of the ice lobe, similar features were being built along the eastern side of the valley in conjunction with deposits from Penticton and Ellis Creeks. When the surface of the Okanagan lobe stood above about 2,100 feet at Penticton, meltwater flowing along the east side of the ice lobe was diverted east through channels north of Mount Campbell into the valley of Penticton Creek, and this meltwater, combined with the drainage of Penticton Creek, built outwash terraces along the east side of the Okanagan Valley east of Penticton. As the level of the ice fell, the meltwater flowed between the edge of the ice lobe and the valley wall and built kame terraces along the west slope of Mount Campbell. With further down-melting of the ice lobe, the ice became stagnant in the vicinity of Penticton, and glacial Lake Penticton was extended northward over the stagnating ice lobe. The Trout Creek-Penticton channel was abandoned when the level of the ice fell below about 1,500 feet, which was approximately the level at which glacial Lake Penticton extended over the stagnant ice lobe in the vicinity of Penticton. The glacial-lake silts which are so prominent a feature of this part of the Okanagan Valley were deposited in this lake, and the maximum elevation of the silts in the vicinity of Penticton is approximately 1,500 feet. The discrepancy between the apparent maximum elevation of the lake at Penticton and the elevation of the outwash south of Okanagan Falls that served as a control on the lake is due to differential uplift of the Okanagan Valley as a result of the removal of the ice load.

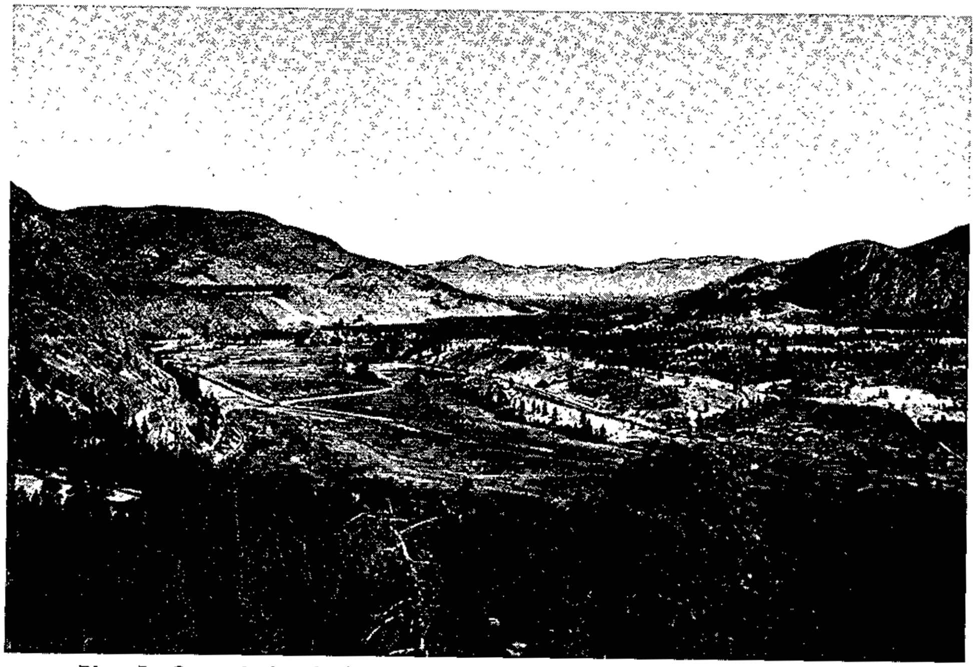

Plate I. General view looking north over Okanagan Falls toward Skaha Lake. An area of kettled outwash which formed the dam impounding the early stage of Lake Penticton can be seen at the right of the photograph. Terraced outwash deposited by a melt-water stream flowing from Marron Valley is visible in the middle distance at the left. The present Okanagan River meanders in a large channel cut by water flowing from Lake Penticton. This channel has been partially blocked by the fan of Shuttleworth Creek.

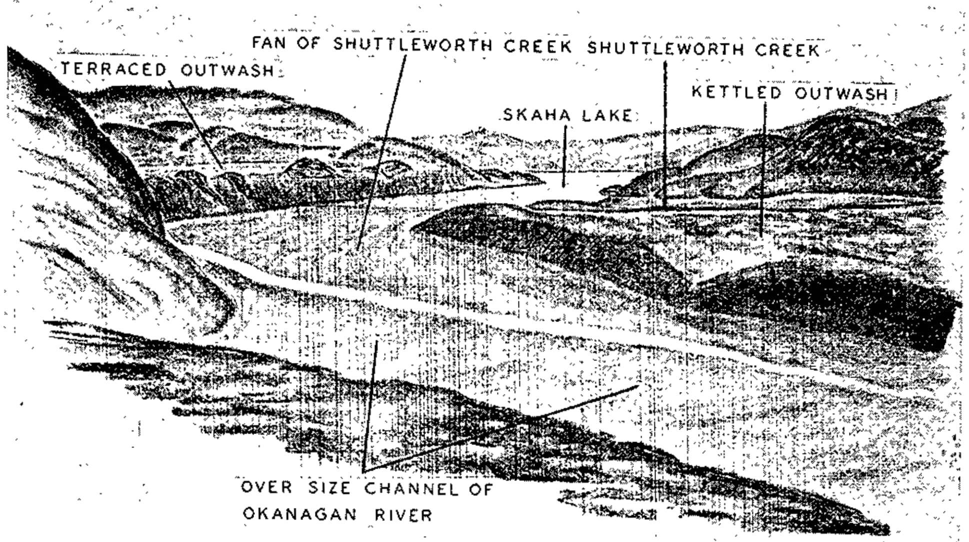

Plate II. Sketch accentuating the glacial features in the photograph above.

The large volumes of meltwater which flowed into Lake Penticton from the melting ice were discharged to the south through a channel cut into the outwash south of Okanagan Falls. It is not known how rapidly this channel was excavated and the lake level consequently lowered, but Penticton, Shingle, Ellis, and Shuttleworth Creeks built alluvial fans graded to a lake level intermediate between the levels of the highest lake and the present one. The Okanagan channel continued to carry a much larger volume of water than it does to-day for some time after the channel was cut to approximately its present level. It is possible that it was excavated somewhat below its present level during this stage. When the Okanagan channel no longer carried a large volume of meltwater, it was partially blocked by the extensive fan, built by Shuttleworth Creek, on which the settlement of Okanagan Falls is situated. The present Okanagan River here flows at the west side of the valley across a narrow rock ledge which, until the recent construction of the Okanagan Falls dam for the purpose of flood control, acted as the control on the level of Skaha Lake. Accordingly, the present level of Skaha Lake may be a few feet higher than the level of the last stage of Lake Penticton, but evidence is lacking on this point.

After the flow of water in the Okanagan channel decreased, Vaseux Creek built an extensive fan across the valley which partially blocked the meltwater channel. Vaseux Lake was formed in post-glacial time by this blocking of the channel by the fan of Vaseux Creek.

Penticton, Ellis, and Shingle Creeks have built alluvial fans graded to the present lake level, and these fans are sufficiently extensive to coalesce and divide the formerly continuous lake into the two lakes Okanagan and Skaha. The present Okanagan River follows a sinuous course between the fronts of the fans from Okanagan to Skaha Lakes, and it carries sand brought down by Shingle and Ellis Creeks to Skaha Lake, where wave action distributes the sand along a broad beach extending across the north end of Skaha Lake. In the time that this process has been going on, the accretion of sand on the Skaha Lake beach has been sufficient to extend the beach more than a mile into the lake. The succession of beaches is a conspicuous feature on aerial photographs of the north end of Skaha Lake.

Map-area III, Summerland-Peachland (Figure 1)

Glacial features in the vicinity of Summerland mark various stages in the retreat of the latest ice lobe to occupy the Okanagan Valley. The earliest feature seems to be an area of kettled outwash at an elevation of about 4,000 feet, on the divide between the headwaters of Deschamps Creek and Liddell Creek. At the time this body of kettled outwash was deposited, the Wisconsin ice-sheet had melted down from its maximum thickness, and in the vicinity of Summerland was a mass of ice filling the Okanagan trench to an elevation of about 4,000 feet. The ice probably increased in surface elevation toward the north and may have been somewhat thicker along the axis of the valley than along the edges. Drainage along the ice margin deposited outwash over and among stagnant ice blocks in the flat area at the head of Deschamps Creek. It is difficult to correlate this outwash with outwash which was being deposited contemporaneously farther south because the meltwater flowed south in part at least on top of ice which filled the valleys of Deschamps and Shingle Creeks.

As the ice surface lowered, the meltwater flowing along the margin of the glacial lobe occupied a succession of channels incised on the west wall of Marron Valley south of Trout Creek. These channels remain as narrow steep-sided gullies in bedrock and glacial till, contouring the west wall of the valley (*see* Plate XI). Most are dry at present or carry small ephemeral drainage. The steep-sided freshly excavated character of the gullies indicates that they carried meltwater drainage during the melting of the last Okanagan glacier, although it is possible that some were originally cut by meltwater during the advance or retreat of an earlier glacier and merely re-excavated during the retreat of the last ice tongue. It is not known from the present study whether or not prominent meltwater channels were cut in bedrock during a temporary halt in the down wasting or whether they were excavated rapidly along structurally weak zones while the ice surface was being continuously lowered. The short sections of meltwater channel cut in glacial till or other unconsolidated deposits could be excavated very rapidly, and probably have no significance as indicators of a temporary halt in the glacial retreat.

The meltwater channel which now contains Brent Lake and Farleigh Lake was occupied by meltwater at this time, and its relationship to features shown on Map-area II (Fig. 1, in pocket) permits some interpretation of the time relationships of deposition in the two map-areas.

When the ice surface had melted down to an elevation of approximately 2,600 feet at Faulder in Trout Creek valley, meltwater drainage was flowing south on the floor of Marron Valley, depositing a mantle of terraced outwash between Trout Creek and the junction of Shingle Creek and Marron Valley. The conditions at this time were those shown on Map-area IIIA, Figure 3. Ice filled the north end of Marron Valley, and meltwater from this ice flowed south along the valley, depositing outwash over stagnant ice which partly filled the valley. As the stagnant ice melted, the outwash developed the present kettled topography. Outwash was also deposited over a mass of stagnant ice which lay just east of the rocky knoll which divides Marron Valley at its junction with Trout Creek valley. As this ice melted, a small glacial lake was formed in which silts and fine sands were deposited. The glacial-lake silts cover an area of about one-half square mile, but their depth is unknown.

Also at the time represented by Map-area IIIA, ice filled the valley of Eneas Creek (locally known as Garnet Valley) to an elevation of more than 2,500 feet and diverted meltwater through a small north-south valley northeast of Faulder. This meltwater built extensive kame terraces up to elevations of 2,600 feet along the north side of the ice tongue occupying Trout Creek valley. At the stage shown by Map-area IIIA, this meltwater flowed west along the north side of the ice tongue, joined the meltwater coming from the north, and flowed south along Marron Valley. As the level of the ice in Trout Creek valley at Faulder fell below 2,500 feet, the meltwater abandoned its route south through Marron Valley and began to flow east along the south side of the ice in Trout Creek valley, and to excavate or re-excavate the canyon of Trout Creek west of Mount Conkle.* At this time the group of kame terraces along the north side of Trout Creek valley was completed and a series of kame terraces was built as far as the beginning of the canyon on the south side of the valley.

Map-area IIIB illustrates the situation when the ice surface had melted down farther, and the lobe of still plastic ice extended only as far west as the Summerland reservoir at the west end of Prairie Valley. At this stage the valley of Eneas Creek was still filled with ice to an elevation of more than 2,400 feet, and meltwater flowed south along the northern part of Marron Valley till it joined the waters of Trout Creek coming from the west near Faulder; it then flowed east along the present route of Trout Creek. Immediately south of Giants Head, ice of the main Okanagan Valley lobe extended west up the lower part of Trout Creek and diverted the meltwater coming down Trout Creek south through a narrow sinuous canyon

* In pre-glacial times Trout Creek probably flowed east and northeast to join the Okanagan drainage near the present settlement of Summerland. It was probably diverted to its present course as a result of the blocking of its original channel during the glacial period, but it is not certain when the initial diversion took place. It certainly occurred earlier than the final retreat of the latest Okanagan glacier.

which joins the main Okanagan trench on the bench immediately west of Penticton. This meltwater channel (referred to subsequently as the Trout Creek-Penticton diversion) permits some correlation to be made between features on this map and those on Map-area II (Fig. 1).

At the north end of the Trout Creek-Penticton diversion, meltwater was ponded against the Okanagan ice lobe and a series of deltas was built into this ponded water, the most extensive of which lies at an elevation of about 1,950 feet. The main terrace is composed of sands and gravels, but along its northeastern edge there is an accumulation of glacial-like silts deposited in a pond which was evidently never completely filled by the coarser outwash materials carried down Trout Creek. After the 1,950-foot terrace was built, the level at which the meltwater entered the Trout Creek-Penticton diversion fell, and several terraces at lower elevations down to about 1,800 feet were cut in the deposits of the 1,950-foot terrace. Several of these are shown on Plate X. The changes in the level at which the meltwater entered the Trout Creek-Penticton diversion may have been controlled by down-cutting of the diversion canyon itself, or they may have been controlled by changes in elevation of the ice or lake at the downstream end of the diversion at Penticton. Such changes are indicated by a series of terraces at the Penticton end of the diversion, but they cannot confidently be correlated with individual terraces at the upstream end.

After the pond at the upstream end of the Trout Creek-Penticton diversion fell below an elevation of 1,800 feet, the diversion was abandoned and meltwater coming down Trout Creek flowed east, approximately along the present course of Trout Creek, to join the meltwater drainage along and over the ice in the Okanagan Valley.

After the Trout Creek-Penticton diversion had been abandoned, cones of coarse talus built by falls of rock from the steep canyon walls filled the canyon to depths of a hundred or more feet in places. Accordingly, the elevation at which water flowed through this diversion cannot be determined from the canyon itself, but only from the terraces at the upstream and downstream ends of the canyon.

On Map-area IIIB, Shingle Creek is shown as flowing east and northeast to join the Trout Creek drainage near the point where the canyon makes a sharp bend from south to east. It is clear that at some time Shingle Creek followed this course and built a large alluvial fan across Marron Valley. The present relatively minor drainage along this route has been able to cut only a small steep gully to reach the bottom of the canyon, and it is therefore presumed that when the drainage of Shingle Creek followed this route, the water level in Trout Creek was near the top of the canyon and the two streams joined accordantly. This could have occurred at any time until Trout Creek began to deeply excavate its canyon at about the stage represented by Map-area IIID, so that the time at which the alluvial fan was built is not precisely determined. After the fan had been built, Shingle Creek changed its course and began to flow south along Marron Valley to follow the course it now occupies. Possibly during flood stages water is still discharged from Shingle Creek to Trout Creek along its old route, and undoubtedly a substantial amount of water finds its way by underground seepage through the alluvial fan to the old channel and thence to Trout Creek.

Two additional short sections of meltwater channel also appear on Map-area IIIB. They represent brief diversions of meltwater across ridges from the surface of the ice and are marked by small local deposits of outwash sands and gravels at the ends of the channels. It is clear that these channels carried meltwater at about this stage, but they are only of very local significance.

Following the stage represented by Map-area IIIB, the ice lobe in the Okanagan Valley continued to melt down, and the tongue of ice which pushed west up Prairie Valley stagnated and melted back from its position near the present West Summerland reservoir, leaving a series of steep-sided ridges a hundred feet or more high across the valley just east of the point where Trout Creek turns sharply south into its canyon. The balancing reservoir for the West Summerland domestic water system occupies a depression between two of these ridges, which appear clearly on vertical airphotos of the region.

By the time conditions represented by Map-area IIIC had been established, the ice lobe in the vicinity of Summerland was confined to the main Okanagan Valley now occupied by Okanagan Lake. Eneas Creek valley was largely free of ice except at the north end in the vicinity of Garnet Lake, where a tongue of ice from the north and east partially controlled the flow of meltwater streams. The main meltwater flow had abandoned its course down Marron Valley and now followed the valley of Eneas Creek and built a delta into a temporary lake ponded in the area of West Summerland. At an early stage this lake spilled south through the gap west of Giants Head, through which the Kettle Valley railway now passes, and the outflow joined the Trout Creek drainage and flowed south along and across the ice in the Okanagan Valley. The outlet of this glacial lake appears to have been about at the present West Summerland railway station at an elevation of 1,725 feet, and the highest delta terrace at the entrance of the Eneas Creek meltwater into the local glacial lake is at approximately this elevation (*see* Plates III and IV). It is therefore clear that the Trout Creek-Penticton diversion had been abandoned (at 1,800 feet elevation) before the Eneas Creek valley became an important meltwater channel.

As the ice in the Okanagan Valley melted down still farther, this local glacial lake was drained along a channel between the east side of Giants Head and the ice in the Okanagan Valley. At this stage, which is intermediate between the stage illustrated by Map-area IIIC and that illustrated by Map-area IIID, the meltwater discharging from the Eneas Creek valley built a kame terrace along the east side of Giants Head at an elevation of about 1,600 feet. This kame terrace is kettled on its eastern edge due to collapse of the deposits over stagnant ice blocks, and to the north and east it was probably continuous with the intermediate terrace shown in Plate IV, and a similar terrace immediately to the south of the present settlement of West Summerland.

The final stage of the Eneas Creek meltwater channel is shown on Map-area IIID. The main ice lobe had melted down to an elevation of 1,500 feet or less and had stagnated so that it no longer forced the meltwater drainage along the edge of the Okanagan Valley. The meltwater which was still being deflected into the Eneas Creek valley by active ice in the neighbourhood of Peachland now discharged freely to the east into an early stage of Lake Penticton bordering and possibly partly covering the stagnant ice in the Okanagan Valley. The meltwater eroded the intermediate terrace to cut the lowest terrace shown in Plate IV and deposited fine silt in the lake bordering the ice lobe in the Okanagan Valley. Before the level of Lake Penticton fell much below 1,550 feet elevation, the discharge of meltwater down the Eneas Creek valley ceased, indicating that while the lake level stood at about 1,500 feet at Summerland, the ice lobe in the vicinity of Peachland had melted down to about 2,500 feet, the level at which it ceased to divert meltwater into the Eneas Creek valley.

After the stage illustrated by Map-area IIID, the level of Lake Penticton fell steadily, with apparently only a few short pauses, to the present level of Okanagan Lake. Eneas Creek has cut only a relatively narrow gully in the terrace left by the last meltwater stream which discharged down Eneas Creek valley. Trout Creek,

Plate III. General view looking north across orchards of West Summerland toward meltwater channel now occupied by Eneas Creek. Terraces built by the meltwater stream mark drainage levels as the ice lobe in the Okanagan Valley (to the right of the picture) melted down.

Plate IV. Sketch accentuating the glacial features in the photograph above.

with a larger drainage area and considerable flow, built alluvial fans into Lake Penticton on top of the glacial-lake silts at successively lower levels, and, since Okanagan Lake reached its present level, has built a large delta extending almost a mile into the lake.

At the stage illustrated by Map-area IIIc a small lake apparently formed in the north end of Marron Valley, probably occupying a depression left by the melting of stagnant ice which had previously filled Marron Valley. Into this lake, Darke Creek, flowing from Darke Lake, built an alluvial fan. Subsequently this temporary lake was drained and alluvial deposits spread over the lacustrine sediments.

Map-area III, Figure 1, shows the distribution of the various features as they appear to-day in the Summerland area. The foregoing discussion describes the sequence of events which led to their formation. Because of the exceptional conditions of topography, the evidence of the sequence of events is less ambiguous than it is in most other parts of the Okanagan Valley.

Map-area IV, Peachland-Ellison Lake (Figure 2)

Kelowna Area

As the ice melted down from the maximum level reached during the Wisconsin glaciation, the surface of the interior plateau at elevations of 4,000 feet and higher became ice-free, while an extensive lobe of ice still filled the Okanagan Valley. This lobe of ice continued to be nourished by icefields to the north and northeast, and local tongues extended laterally from it up several of the larger tributary valleys, including the valley of Mission Creek.

The ice lobe filled the Okanagan Valley and the parallel valley on the east which contains Ellison Lake, Wood Lake, and Kalamalka Lake. Meltwater, combined with streams draining the plateau, flowed along the margin of the ice lobe, eroding temporary channels and depositing gravels and sands, sometimes on the edge of the ice and sometimes in ponds blocked in the tributary valleys by the ice. Segments of these channels (*see* Plate XII) can be recognized on the valley wall east of Rutland up to elevations of 3,500 feet, where the steep slope of the valley wall begins to flatten to the undulating surface of the plateau. About a mile east of Black Knight Mountain near Prather Creek, several well-developed terraces at elevations between 3,000 and 3,500 feet mark the discharge of meltwater streams into a temporary lake ponded in the valley of Mission Creek by the ice lobe in the Okanagan Valley. Drainage from a series of such ponds in the valley of Mission Creek found its way across the terminus of the tongue of ice which pushed into Mission Creek valley from the main Okanagan lobe, along the steep valley wall below the grade of the Kettle Valley railway south of Kelowna, and finally into the main Okanagan trench through a series of canyon-like channels on the west flank of Okanagan Mountain. Two of the more prominent canyon-like channels are now occupied by minor streams (*see* Plate XIII). Because of the discontinuous nature of the channels carrying meltwater at this stage, it is impossible to correlate them along their courses down the valley so as to obtain some estimate of the slope on the surface of the ice lobe which occupied the Okanagan trench.

On Map-area IV an area of meltwater channels and kame terraces is shown extending along the east wall of Okanagan Valley from Rutland north to the point where Kelowna (Mill) Creek enters the valley. This area is marked by a complex network of meltwater channels similar to that illustrated in Plate XII. These channels mark the courses of meltwater flowing from the surface of the ice, or into local ponds held in embayments in the valley wall by the ice in the valley.

When the ice surface was at an elevation somewhat above 2,000 feet, east of Rutland, meltwater was diverted through a series of channels which lie in the trough between Mine Hill and Black Knight Mountain, and flowed under and around the stagnant terminus of the ice tongue that extended up Mission Creek from the main Okanagan lobe, building a complex of kames, eskers, and kettled outwash just southwest of Black Knight Mountain (*see* Plate XIV). Similarly the valley wall east of Winfield is cut by a complex group of meltwater channels which terminate in a group of kames and eskers on the west side of Clark Creek (south edge of Map-area V).

At approximately the same time the ice in the main part of the valley south of Rutland stood high enough to divert the drainage from Mission Creek, Hydraulic Creek, and Klo Creek west from their present courses along the front of the ice. Deposits from these creeks, combined with outwash from the ice, built a series of morainal ridges between the ice front and the steep valley wall to the south. These morainal ridges were cut by local channels, at the western ends of which kettled outwash was deposited. In places, depressions in the kettled outwash held local ponds in which silts accumulated, but for the most part the outwash consists of sand and gravel. A prominent channel begins at a terrace on the west side of Klo Creek about a mile south of its junction with Mission Creek and extends to the west for about 2½ miles before it disappears in an area of kettled outwash. This channel probably carried the flow of Mission Creek for a time, and was abandoned when the ice had melted down sufficiently to allow Mission Creek to cut a channel to the north, approximately along its present course. As Mission Creek began to flow north along its present course, it at first was diverted westward by the ice, and built an uneven outwash terrace at elevations between 1,500 and 1,600 feet, a short distance to the east of East Kelowna. By the time deposition of this outwash terrace was completed, the ice had become essentially stagnant, and the course of Mission Creek was no longer directly influenced by it.

Bellevue (Sawmill) Creek flows into Okanagan Lake at Okanagan Mission, and while the surface of the ice lobe in the Okanagan Valley was at an elevation of 1,500 feet or higher, Bellevue Creek was diverted to the south and west in the same manner as Mission Creek. Along the valley wall south and west of Bellevue Creek, kame terraces, outwash terraces, kettled outwash, and meltwater channels formed as the ice lobe melted down and became stagnant at this point.

From the foregoing it can be seen that along the east wall of the valley, from Ellison Lake south past Okanagan Mission, kame terraces, meltwater channels, moraine ridges, kame and esker complexes, and kettled outwash record the succession of drainage changes that occurred as the ice lobe which occupied the Okanagan Valley melted down and became stagnant. These features are complex, and in the present study no attempt is made to formulate in detail the succession of events.

The meltwater channels along the east side of the valley near Rutland have a gradient of approximately 25 feet per mile, as determined by altimeter along several of the more continuous channels. The channels terminate at various elevations, but none continues below an elevation of about 1,550 feet. This is approximately the elevation of the first outwash terrace built by Mission Creek after it abandoned the channels through which it had been diverted by the ice. Also, 1,550 feet is approximately the maximum elevation of the extensive glacial-lake silts which occur northeast of Kelowna. It is thus apparent that the surface of the ice lobe became essentially flat (and the ice stagnant) when it had melted down to an elevation of about 1,550 feet. At this elevation, lakes formed first along the edge of the ice but subsequently covered the front of the ice lobe and extended completely across the Okanagan Valley as Lake Penticton.

The stagnation of the ice lobe in the valley between Winfield and Oyama (Map-area V) is marked by extensive deposits of sandy outwash along the east side of Wood Lake up to elevations of about 1,700 feet and by gravelly outwash on the ridge separating the valley of Wood Lake and Ellison Lake from the main Okanagan trench. The lacustrine deposits in this area range in texture from silts to medium and coarse sand and are intermixed with sand and gravel outwash so that it is difficult to determine precisely the upper limit of glacial-lake deposits. A small area of outwash west of Winfield lies at the end of a short meltwater channel and has the topographic form and internal structure of a delta. The surface of this outwash is at an elevation of 1,600 feet and probably marks the elevation of one of the early lakes which formed along the edge of the stagnating ice lobe.

In the vicinity of Kelowna, glacial-lake silts and alluvial fans built by streams tributary to the Okanagan record the succession of events as the surface of Lake Penticton fell to the present lake level. The time involved in the lowering of the lake from its initial level at about 1,500 feet elevation to the present level of 1,123 has not been determined, but it may have been relatively short. Only Mission Creek, the largest of the streams in the area, was able to build two extensive alluvial fans which seem to record two temporary halts in the lowering of the lake level.

The highest of these alluvial fans is the area locally known as the East Kelowna Bench, on which the settlement of East Kelowna is situated. This is a typical fan-shaped area sloping down from 1,550 feet near its apex to 1,400 feet at its margins. It has subsequently been dissected by Mission Creek flowing at lower elevations, the largest remnant being at East Kelowna and a similar though smaller remnant on the east side of Mission Creek. The two parts of this alluvial fan are shown on Map-area IV, and Figure 4 is a diagrammatic section through the fan along the line A-A′.

At the surface of the East Kelowna Bench, 10 to 20 feet of coarse bouldery gravel is stratified parallel to the surface of the bench and represents sub-aerial stream deposits of Mission Creek. Foreset beds of a delta built into Lake Penticton underlie the coarse gravel and consist of sand and gravel, becoming more sandy at depth and at greater distances from the apex of the delta. The sandy foreset beds grade into varved silts and clays deposited in deeper water. At the front of the delta these varved silts are contorted by slumping over melting blocks of ice in the lake. As the level of Lake Penticton fell, Mission Creek cut down through the East Kelowna Bench, exposing till under the foreset sands and gravels. At one place the till is seen to overlie silts and river gravels which are probably sediments of Mission Creek laid down before the glacier which deposited the till overrode the area. In the course of cutting down to its present level, Mission Creek built a fan at an intermediate level, part of which was deposited on contorted silts at the west side of the East Kelowna Bench.

The second or intermediate fan of Mission Creek is named the Rutland fan, and three remnants of it are shown on Map-area IV. The largest remnant, the sub-aerial part of the fan, is a terraced area on which the settlement of Rutland is situated. The other two remnants lie farther west and consist of sand with some silt and clay layers and are the remnants of the deltaic part of the fan. These two deltaic remnants are marked by numerous well-developed kettles, good examples of which can be seen on the golf course, in the Bankhead district, and in an area between Mission Creek on the west and East Kelowna. The level at which the lake stood when the Rutland fan was being built is not exactly determined, but it was probably between 1,250 and 1,300 feet and more likely was nearer to 1,300 feet.

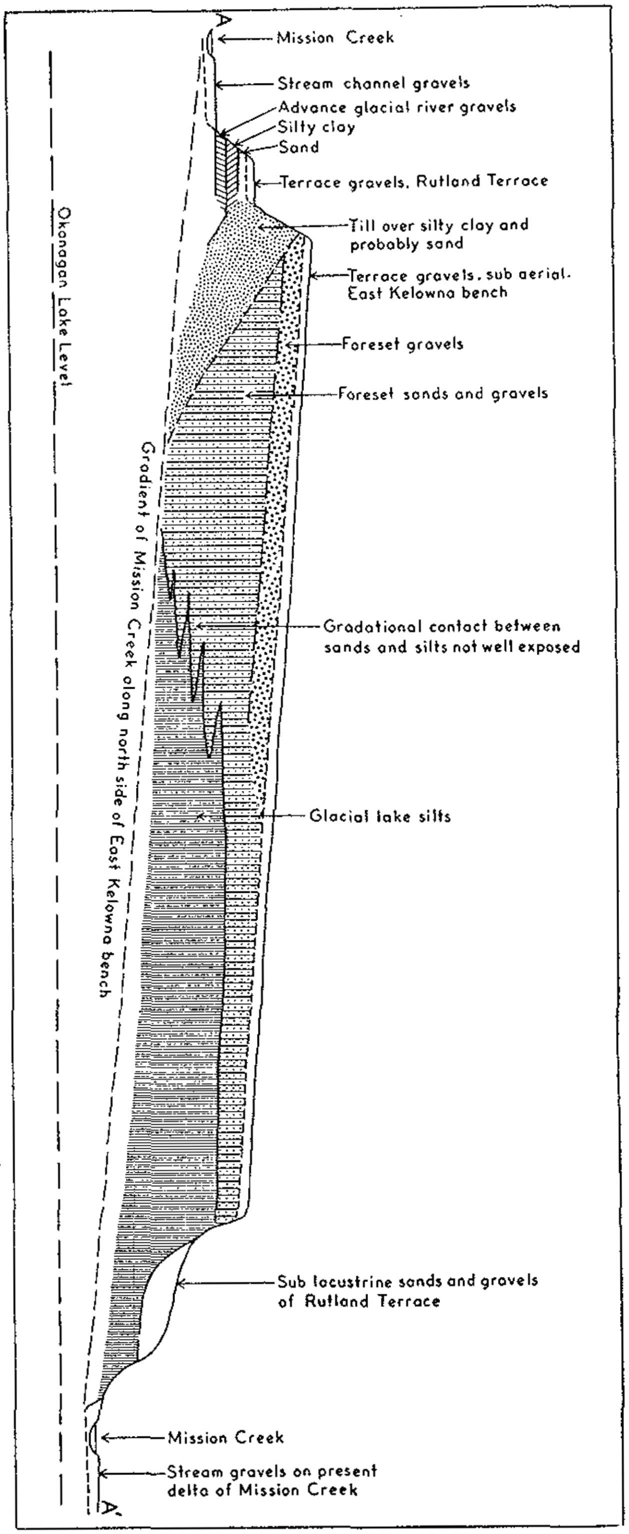

Figure 4. Section across East Kelowna Bench along line A-A', Map-area IV. Alluvial fan of Mission Creek built at the edge of Lake Penticton.

The correlation of this fan with features to the north is noted on page 42 in the section discussing the succession of events throughout the whole Okanagan Valley.

As the lake fell from the level at which the Rutland fan was built, Mission Creek together with Kelowna Creek eroded a large part of the Rutland fan and the glacial-lake silts on which it was built, and redeposited them in Okanagan Lake to form the extensive delta which is the site of the city of Kelowna.

Bellevue Creek, partly by erosion and partly by deposition, formed a similar series of alluvial fans as it flowed into the lake at successively lower levels. The present alluvial fans of Scotty Creek, Kelowna Creek, and Vernon Creek (Map-area V) are graded to approximately the same level as the Rutland fan of Mission Creek, and so cannot be distinguished from the fans that these creeks built at the time of the Rutland fan. On the south side of Kelowna Creek where it enters the Okanagan Valley, there is a small remnant of a fan at an elevation of 1,475 feet which might be correlated with the East Kelowna fan of Mission Creek. Alluvial-fan remnants which flank Vernon Creek and are graded to a base level of approximately 1,500 feet may possibly have been built at about the same time.

While the ice lobe was sufficiently thick to force the drainage of meltwater along the sides of the main valley, it ponded lakes in the tributary valleys. In the valley of Mission Creek, thick deposits of silt were laid down near the mouth of Hydraulic Creek. Subsequently these silts were eroded and partially buried under deposits of Mission Creek as it cut down to its present level. Locally small lakes formed in depressions in areas of kettled outwash, and in them small bodies of glacial silts accumulated. By far the largest part of the glacial-lake silts in the Kelowna area, however, was deposited in glacial Lake Penticton, which formed at an elevation of about 1,500 feet, first along the margins of the ice lobe and then entirely covering the stagnating ice. The largest area of varved silts is in the Glenmore Valley north-east of Kelowna, but other extensive areas occur in the valley north of Rutland and along the front of the bench south and west of East Kelowna. Alluvial deposits of local creeks overlie these glacial-lake silts in many places.

Materials Deposited Prior to the Last Advance of Ice in the Kelowna Area.— When Mission Creek cut its channel down to the present level through the moraine ridges and later deposits in the region of the East Kelowna Bench, it exposed sections of deposits which were formed prior to the last major advance of the glaciers.

At the point where Mission Creek turns to the west to flow along the front of the East Kelowna Bench, basal till is exposed underlying the foreset sands and gravels of the bench. In a small exposure, till rests on sandy silt, which in turn is underlain by well-washed river gravels. On the west bank of Mission Creek, nearly 2 miles upstream, no till is exposed but it is thought that silty clay and river gravel are the same as those exposed farther downstream and that the till was eroded by Mission Creek as it deposited the coarse terrace gravels. The firmly packed character of the sand overlying the silty clay suggests that it too is a pre-till deposit. These relationships are shown in section on Figure 4, and it is believed that the river gravel was deposited by Mission Creek prior to the advance of the glacier which deposited the till. The silts and sands may have been deposited in a backwater or in a lake ponded against the front of the advancing ice.

A quarter of a mile or less upstream from the same bridge, a section exposed by Mission Creek shows a complex inter-stratification of basal till, stratified sand, and outwash gravels. Other sections on Mission Creek upstream toward the mouth of Klo Creek show deposits of river gravels, stratified sands, and basal till. In some of the sections these materials are seen to be resting on poorly lithified sediments which are somewhat contorted and may be part of the Tertiary succession in this area. No layers of vegetation were seen in the deposits along Mission Creek to indicate that the pre-till deposits were laid down under interglacial conditions. The deposits are believed to have been deposited by Mission Creek under varying conditions as the glacier advanced down the Okanagan Valley.

On Bellevue Creek, sections are exposed showing extensive deposits which were laid down before the advance of the latest ice-sheet. A little more than a mile east of the mouth of the creek a thick gravel deposit is exposed on the north side of the creek. This is horizontally stratified, well-washed, and well-rounded medium to fine gravel which appears to be a sub-aerial deposit of an aggrading stream. It is well compacted though not conspicuously cemented, and is being worked as a commercial gravel pit in several faces, 30 or more feet high (*see* Plate XV), which show little tendency to slough. The top of the deposit is not clearly exposed, but the character of the deposit and its similarity to one overlain by till farther north along Okanagan Lake suggest that this gravel was deposited as outwash before the latest advance of ice through the Okanagan Valley.

In the space of half a mile east of this gravel deposit, exposures reveal a thickness of 75 feet or more of grey-white faintly stratified silt, very similar in general appearance to the Penticton silts. This silt underlies the gravels exposed to the west, however, and must have been deposited before the last advance of ice and cannot be correlated with the deposits of Lake Penticton. The bottom of the silts is not extensively exposed, but they appear to rest on a thin layer of till which is in turn underlain by stratified gravels and sands. No deposits of vegetation or other organic matter were seen in these exposures to suggest that they were deposited under interglacial conditions, and in general the deposits are fresh and unweathered.

Westbank Area

On the west side of the lake the same sequence of events occurred as the ice lobe melted down and stagnated and the glacial lake fell by successive levels until the present level of Okanagan Lake was reached. However, because of the different nature of the topography in the Westbank area, glacial features were developed of somewhat different character to those of the Kelowna area.

Except at higher elevations, the west side of the Okanagan Valley on Map-area IV is in general steeper and covered by less overburden than the east side in the vicinity of Rutland. For this reason, meltwater apparently flowed on top of the ice rather than in channels cut in the valley wall, as was the case on the east side. Just north of the map-area the middle part of Bald Range Creek flows in a prominent channel parallel to the Okanagan Valley at an elevation of approximately 3,000 feet. Another prominent channel paralleling the valley at an elevation of 2,000 feet carried meltwater and the diverted drainage of Lambly (Bear) Creek when the ice surface stood a little higher than 2,000 feet. Between the time when the ice surface was too low to divert meltwater into the channel of Bald Range Creek and the time when the ice surface opposite Lambly Creek had melted down to a height somewhat above 2,000 feet, the meltwater must have flowed largely on the surface of the ice. This situation contrasts with that on the valley wall east of Rutland, where a succession of meltwater channel segments at vertical intervals of 50 to 100 feet mark the downward progression of the ice surface from 3,500 to 1,550 feet.

While the ice surface in the Okanagan Valley stood at elevations above 2,000 feet opposite the mouth of Lambly Creek, the flow from this creek plus meltwater from the ice lobe was diverted through Rose Valley, a narrow steep-sided valley which parallels the lake. When the meltwater was first diverted through Rose Valley, ice filled the depression extending from Westside to Westbank past Mount Boucherie, and the meltwater flowing between that ice and the steep valley wall built a series of kame terraces along the valley wall from elevations of about 2,000 feet down to elevations of about 1,650 feet. Shannon Lake occupies what is probably a large kettle in one of the lowest of these kame terraces. In later stages, but before the Rose Valley diversion was abandoned, the meltwater from this channel, instead of flowing southwestward along the present channel of McDougall Creek, turned abruptly southeast and built an outwash terrace into Lake Boucherie (*see* below).

When the ice lobe filled the Okanagan Valley to an elevation of 2,500 feet at Westbank, the drainage of Powers Creek, combined with meltwater flowing along the edge of the ice from the north, was diverted to the south through two meltwater channels which now carry the relatively minor streams of Law Creek and Drought Creek. As the level of the ice fell below that at which water could be diverted into the Drought Creek channel, at about 2,400 feet, the drainage flowed on top of the ice for a time and then began to flow through the narrow channel which Highway No. 97 follows about a mile south of the Powers Creek bridge. This channel is at an elevation of about 1,625 feet.

As the ice lobe melted down from the level of the Drought Creek meltwater channel to that of the 1,625-foot channel, the ice filling the depression northwest of Mount Boucherie became stagnant. The ice in the Okanagan trench, however, blocked the depression north and south of Mount Boucherie, and a glacial lake (referred to as Lake Boucherie) was formed. The level of Lake Boucherie was controlled by the spillway through the 1,625-foot channel at an elevation of about 1,650 feet, or possibly for a time slightly higher. Powers Creek built an extensive fan at an elevation of 1,675 feet into Lake Boucherie, and glacial silts were deposited both north and south of Mount Boucherie. This lake remained as a separate entity with a level controlled by the level of the 1,625-foot channel. That channel, which initially may have been higher than 1,625 feet, existed until the main ice lobe in the Okanagan Valley melted down to permit drainage across the surface of the ice, and the channel was abandoned. At an elevation of about 1,500 feet, as indicated by features on the east side of the valley, the ice lobe became stagnant and Lake Boucherie merged with Lake Penticton, which filled the Okanagan Valley and covered the stagnant ice. Therefore, the Lake Penticton silts probably include all those exposed at the surface in the Westbank area below an elevation of 1,500 feet, and only those exposed at the surface above this elevation can be referred to the earlier and smaller lake.

As the lake level fell from 1,500 feet to the present level of Okanagan Lake, Powers Creek and McDougall Creek eroded the deltas they had built into Lake Boucherie and redeposited the sands and gravels of the deltas into Lake Penticton at successively lower levels. Evidently these creeks were not supplied with extensive loads of debris with which to built their deltas. The pauses in the lowering of Lake Penticton at 1,400 and 1,300 feet, indicated by the extensive fans of Mission Creek, are marked only by small deltas on Powers Creek and by no recognizable features on McDougall Creek. Both creeks have built deltas into the present Okanagan Lake, and McDougall Creek has built a much larger one than Powers Creek, because Powers Creek is confined in rock canyons in several places and has been unable to rework the sands and gravels deposited during the late stages of glaciation.

Trepanier Creek, from a point somewhat above the junction of Silver Creek, flows in a flat-bottomed valley with gentle to moderate gradient and steep rock walls mantled with fairly coarse granitic drift. The valley is floored with terraced outwash containing coarse granitic detritus, including boulders so large as to suggest that it was transported from the west by a glacial tongue coming down Trepanier Creek. Apparently the area at the head of Trepanier Creek supported a local highland glacier. There may also have been late local glaciers at the head of Peachland and Greata Creeks. The terraces of Trepanier Creek may be in part kame terraces built along the edge of the late local glacier and in part outwash terraces cut in these earlier deposits. At the junction with the Okanagan Valley the terraces of Trepanier Creek merge with kame terraces along the lake south of Westbank. The highest kame terrace is at about 1,800 feet. Lower terraces were formed as ice and lake level fell. Trepanier Creek, however, has been diverted to the south side of the valley and cut a bedrock channel which has permitted only partial excavation of the glacial fill. Much of the valley of Trepanier Creek is covered with coarse bouldery material unsuitable for agriculture, but in places abandoned stream channels have been filled with finer-textured material, including alluvial-fan deposits from the valley walls.

Map-area V, Winfield-Swan Lake (Figure 2)

Map-area VI, Swan Lake-Enderby (Figure 2)

The glacial deposits and topographic features of the Okanagan and Coldstream Valleys shown in Map-areas V and VI are largely related to stagnation of the Okanagan ice lobe and to successive stages of glacial Lake Penticton.

Areas of kame terraces and minor meltwater channels along the valley wall east of Vernon mark the stage at which the ice lobe diverted meltwater along the valley wall. The channels do not extend below about 1,750 feet, and it was probably at this level that the ice lobe became stagnant and ponds formed on the surface and along the edge of the ice lobe. This was the initial stage of Lake Penticton in this area, although the lake already existed farther south in the valley. Lake Penticton formed a continuous sheet of water extending from north of Vernon to Okanagan Falls. The fact that there is a difference in elevation between features which mark the lake levels at the north and south ends of the valley is accounted for by post-glacial uplift which was greater at the north end of the valley.

About 2 miles east of Lavington an area of ridged moraine whose upper surface stands at an elevation of about 2,000 feet seems to mark the diversion of meltwater and drainage of Duteau Creek along the front of an ice lobe which extended down Coldstream Valley from the east. These two features, the kame-terrace meltwater channel areas and the ridged moraine, are the main features of Map-area V which record the ice lobes in these valleys during the stage of retreat of the ice before it became stagnant.

In the Coldstream Valley about a mile east of Coldstream railway siding, outwash terraces between elevations of 1,650 and 1,750 feet were deposited from meltwater streams that drained west in Coldstream Valley into Lake Penticton at its higher stages. As the level of Lake Penticton subsequently fell, streams continued to flow west in Coldstream Valley and eroded the earlier outwash terraces, building thin deltaic deposits of sand and gravel into the lake on top of the glacial-lake sediments. At about this time extensive alluvial fans were built from the walls of the valley onto the valley floor, obscuring the evidence of meltwater streams and burying outwash terraces. Most of the fans appear to be stable at present, but some, across which permanent streams flow, have been extended in late post-glacial time. Coldstream Creek, for example, has built an alluvial fan across the valley a mile east of Lavington, and this fan has diverted drainage in Coldstream Valley east of it into the Shuswap River.

As the level of Lake Penticton fell, Coldstream Creek extended its channel west toward the present Kalamalka Lake, cutting into and depositing thin alluvium on the glacial-lake sediments. When the level of Lake Penticton in the vicinity of Vernon fell to about 1,400 feet, the chain of Kalamalka, Wood, and Ellison Lakes formed a single body of water separated from the main body of Lake Penticton.

Outflow from these lakes began to cut the channel of Vernon Creek between Kalamalka Lake and the arm of Okanagan Lake at Okanagan Landing. B.X. Creek, just north of Vernon, built a series of alluvial fans into Lake Penticton at successively lower levels. One of the more prominent of these, at about 1,490 feet, seems to mark a temporary pause in the decline of the lake level that is also marked by a very faint beach line at the north end of Kalamalka Lake. As the level of Lake Penticton dropped farther, B.X. Creek built an extensive alluvial fan over the glacial-lake deposits.

At the north end of Okanagan Lake an extensive sandy delta was built over stagnant ice blocks in Lake Penticton by meltwater streams flowing southeast from the Salmon River valley through the valley containing Spallumcheen and Round Lakes. When the ice buried in the outwash deposits melted, large kettles were formed, several of which now contain small lakes. Terraced outwash and meltwater channels indicate that large streams of meltwater flowed through this valley until the level of Lake Penticton had fallen to between 1,400 and 1,500 feet.

At about the same time another meltwater channel carried meltwater from the Salmon River valley near Glenemma east and northeast into Lake Penticton north of Armstrong. This channel was apparently abandoned before the more southerly one as its outlet terminates in glacial-lake deposits at about 1,650 feet elevation. These deposits consist of silts and sands and are the highest extensive glacial-lake deposits in the area mapped. They indicate that the level of glacial Lake Penticton north of Armstrong was at 1,700 feet or higher when it first formed with stagnation of the ice lobe.

Silts were deposited in the lake as the level fell. In parts of the former lake basin, particularly at higher elevations, the silts merely mantle the pre-existing deposits without obscuring the topography, but in many of the lower parts of the basin the silt deposit is so thick that it hides the underlying irregularities and forms a gently undulating plain of lacustrine silts and clays.

When the level of Lake Penticton had fallen to between 30 and 50 feet above the present level of Okanagan Lake, its outlines nearly coincided with those of the present lake, and the glacial-lake deposits were exposed from Okanagan Lake north to Enderby. At this stage the Shuswap River and probably the drainage of Shuswap Lake flowed south into the Okanagan system, cutting a prominent channel in the glacial-lake sediments from near Enderby to the north end of Okanagan Lake. The abandonment of this channel and the diversion of the Shuswap drainage into the South Thompson, together with the lowering of the lake to the present level, mark the close of glaciation in the Okanagan Valley area.

Finally, Fortune Creek built an alluvial fan into the Enderby-Okanagan channel, and from this fan drainage including Fortune Creek flows north to the Shuswap while Deep Creek flows south to the Okanagan. Vernon, Equesis, Naswhito, Whiteman, and other creeks built alluvial fans into Okanagan Lake, extending and concealing fans which were initiated during the late stages of Lake Penticton.

Glacial Material Deposited Prior to the Last Advance of Ice in the Okanagan Valley

On Map-area V several areas contain deposits of glacial advance or earlier. These are areas of deep drift, only a small part of which is the result of late glacial and post-glacial deposition. In some good exposures it is seen that the deposits were laid down prior to the last advance of ice and that their topographic expression has not been subsequently changed. The late glacial and post-glacial materials are merely a thin veneer on the earlier deposits. In other cases no adequate exposures have been seen, and the character of the deposit is merely inferred from the topographic expression. The covering late glacial and post-glacial materials are usually thin outwash, glacial-lake deposits, or local fan deposits, and notes on the map indicate the character of the late glacial veneer.

A prominent ridge extends partly across the Coldstream Valley east of Lavington at an elevation of approximately 2,100 feet. In a gully cut by overflow from an irrigation ditch, outwash sand and gravel overlain by till is exposed. Surface material on the ridge is sandy gravelly outwash. The shape and position of this ridge suggest that it may be part of a terminal moraine or consist of down-valley outwash built in front of a glacier advancing west down Coldstream Valley. Indistinct terraces on the northwesterly slope of the ridge suggest that before being overridden by the advancing ice, it was breached and terraced by meltwater. Other somewhat elongate ridges on the north side of the valley may also be advance glacial outwash deposits whose outline has been rounded and smoothed by overriding ice.

On the east shore of Kalamalka Lake about a mile north of Oyama, there is a prominent terrace with the typical form of a delta (*see* Plate XIX). This delta lies at the downstream end of a deep rock canyon cut parallel to the east shore of Kalamalka Lake. Meltwater that was diverted from an ice tongue at an elevation of more than 1,900 feet cut this canyon and deposited its load in an ice-marginal lake some 300 feet lower down. This means that the southerly slope of the ice was not less than 150 feet per mile, a slope much steeper than that of the ice tongue in late glacial time, as indicated by other features. It is consequently believed that most of the material in this delta was deposited at the time of advance of glaciers down the valley. No cuts or other exposures were found that would indicate the character of the unconsolidated deposits of which the delta is built.

A subdued terrace extending from Vernon south to the north end of Kalamalka Lake and southwest to Okanagan Landing is seen in numerous exposures to consist of sandy and gravelly outwash. In an exposure on the steep slope east of the Vernon Army Camp, varved silts of glacial Lake Penticton are separated from the underlying well-washed sands and gravels by a foot or two of coarse angular gravel, which is possibly ablation moraine, and about a foot of fine gravel in a silty matrix, which is possibly basal till (*see* Plate XVI). This terrace, which extends up to about 1,700 feet elevation, is believed to consist of outwash sands and gravels which were eroded by meltwater before being overridden by advancing ice. The terrace is largely mantled by varved silts of glacial Lake Penticton, but in places the underlying gravels have been exposed.

The indistinctly terraced area on the east side of Swan Lake extending south to B.X. Creek probably also consists in part of advance glacial outwash which was eroded by meltwater and subsequently overridden by ice.

About 3 miles south of Armstrong on the east side of the valley there is an indistinct terrace with a surface elevation of about 1,700 feet. Gravel pits excavated along the west front of this terrace reveal advance outwash sands and gravels. Exposures are, however, inadequate to show the exact relationship of the gravels to overlying materials. Creeks flowing from the steep valley wall have extensively gullied the terrace and built fans onto the glacial-lake sediments west of the terrace. The gullying was probably begun before the draining of glacial Lake Penticton, and lake deposits immediately west of this terrace probably contain lenses of sand and gravel.

About 3 miles north of Armstrong the plain of deep lacustrine silts is bordered by an area of irregular rolling topography through which Deep Creek has cut a deep channel. The general appearance of this area suggests that, although many rock outcrops occur, much of it is underlain by a considerable depth of drift which is mantled by relatively thin glacial-lake sediments and scattered deposits of outwash.

Exposures are inadequate to reveal much of the character of the materials underlying the surficial deposits, but the irregular ridged topography suggests that a terminal moraine was deposited in front of an ice tongue pushing south from the region of Salmon Arm. Within this area, exposures in road cuts and gravel pits just west of Deep Creek (*see* note on Map-area VI) show a series of beds of sands and medium gravel dipping south with moderate dips, suggesting the foreset beds of a delta. These sands and gravels are truncated and overlain by other gravels, which in turn are cut by a channel containing sand and gravel (*see* Plate XVII). The first two mentioned units are weathered and poorly indurated and are clearly earlier than the advance outwash gravels exposed elsewhere. The channel deposits of sand and gravel are not weathered, but since they have no local topographic expression, they probably were deposited prior to the last advance of ice, although no glacial till was recognized in the exposures.

Terraces with a surface elevation of 1,500 to 1,700 feet flank Equesis, Naswhito, and Whiteman Creeks, flowing into Okanagan Lake on the west side. Although the surfaces of these terraces have been modified by erosion and by the deposition of alluvial fans at the time that these creeks flowed onto the Okanagan ice lobe and into Lake Penticton, it is thought that the bulk of the material in the terraces was deposited prior to the last advance of the ice.

During the course of this survey no wood or other organic remains were collected from the sands and gravels which are thought to have been deposited prior to the last advance of ice. A report by a local road foreman of fossil teeth or ivory being found in a gravel deposit being worked on B.X. Creek could not be confirmed.

LATE PLEISTOCENE EVENTS IN THE OKANAGAN VALLEY

Within the area of this report relatively few features were produced during the last maximum advance of glacial ice. Some unconsolidated materials exposed on Mission Creek near Kelowna (Map-area IV) and in various places around Vernon (Map-area V) and north of Armstrong (Map-area VI) were deposited prior to the last advance, but they provide very little information regarding the advancing ice itself. Ideas regarding conditions prior to the late stages of glacial retreat are therefore inferred from topography, climatic conditions, and concepts of the mechanisms and ultimate causes of glacial retreats and advances. Probably the gathering grounds of the ice tongue which pushed down the Okanagan Valley were in the Monashee Mountains north and east of the Okanagan Valley. None of the valleys tributary to the main Okanagan Valley south of Coldstream Valley have a strongly glaciated aspect, and it seems evident that the adjacent plateau and highlands made no contribution of ice to the glacier which was pushing down the valley during the initial stages of glacial advance. As the ice advanced and thickened, it completely filled the valley and was joined by streams of ice flowing southeast across the interior plateau from the Coast Mountains. By this time local accumulations of ice may have formed on the plateau and highlands adjacent to the Okanagan Valley. As a result of the modification of climate by the increasing accumulation of ice, these areas now became gathering grounds of the main ice-sheet that moved south and southeast to the Columbia plateau south of the forty-ninth parallel.

In the Okanagan Valley no features can be found which record the position of the ice at the stage of its maximum advance. Daly, in his study of the geology of the forty-ninth parallel, inferred from observations on mountains east and west of the Okanagan Valley that at its maximum the elevation of the ice surface over the Okanagan Valley near the border was approximately 7,200 feet. The ice over the axis of the valley was thus about 6,300 feet thick. South of the forty-ninth parallel in the State of Washington, terminal moraines marking the greatest extent of the Okanagan ice lobe occur near Coulee City, approximately 90 miles south of the border. At the stage of maximum glacial advance, therefore, the Okanagan Valley and the adjacent highlands and plateau north of the forty-ninth parallel were completely buried beneath an ice-sheet which moved south and southeast, more or less independently of the underlying topography.

After the maximum accumulation of ice had been reached, a climatic change occurred which brought about a decline and a retreat of the ice from its maximum position. Whether this climatic change resulted in a lessening of precipitation in the areas of ice accumulation or in an increase in the rate of melting is not known. The effect, however, was to cause a lowering of the ice surface and stagnation and retreat of the ice front.

No well-defined moraines are reported north of the terminal moraine near Coulee City, and it appears that retreat of the main ice front was accomplished largely by down-melting and stagnation of the ice mass as a whole, with no clearly defined halts or readvances. The down-melting of the ice surface ultimately left the plateau and highland areas ice-free, and when the remaining glacial ice was confined to the valleys the surface area of the melting ice was greatly reduced. It seems likely that the effective withdrawal of the ice may have proceeded much more rapidly in the early stages of retreat than in the later stages because the sharp reduction of the ablation area may have been sufficient to bring down-melting into temporary equilibrium with ice accumulation. In other words, although the change to a milder climate may have been continuous, the rate of disappearance of the ice may not. When the ice was confined to the Okanagan Valley, there were times when a sharp reduction of surface area could have brought about such a decrease in the rate of melting that melting was in temporary equilibrium with ice accumulation. Consequently a halt in the recession of the ice could have occurred that did not represent a reversal or halt in the rate of climatic change.

The earliest features which can be related to ice retreat in the Okanagan Valley are several meltwater channels between elevations of 2,800 and 3,700 feet east of Osoyoos Lake and a mile or two north of the forty-ninth parallel. These channels mark the stage when the ice was confined to the Okanagan Valley at the forty-ninth parallel and the ice surface was reduced by melting from the upper to the lower elevation. Meltwater flowing along the edge of the ice lobe was diverted through these channels eastward into a temporary lake ponded in the valley of Nine Mile Creek, which enters the Okanagan Valley a few miles south of the forty-ninth parallel.

As the surface of the ice continued to melt down, it apparently had a flat cross-valley profile so that meltwater flowed on top of the ice instead of along the edge of the ice or in minor valleys parallel to the main valley. If the ice lobe had had a convex cross profile and an appreciable down-valley slope, meltwater would have been readily diverted into several minor valleys south of Oliver, but only one of these shows signs of meltwater activity in spite of the fact that all are favourably situated for diversion. From this evidence it is inferred that the ice lobe became essentially stagnant* and was not reactivated south of Oliver, whereas to the north of Oliver it was. This period of rapid melting of the ice prior to a slight readvance is probably represented farther north by kettled outwash surrounding Twin Lakes, by kettled outwash at the head of Deschamps Creek west of Summerland, and at the south end of the valley by the initial stages of Lake Oliver.

Whereas the numerous minor valleys and notches paralleling the main valley south of Oliver show little or no evidence of meltwater deposits, similar features to the north show abundant evidence that they were occupied for short or long periods

* *See* note *re* use of this term on page 9.

by meltwater flowing along the edge of the ice lobe. From this it is inferred that north of McIntyre Bluff the ice lobe had a convex cross profile and appreciable down-valley slope, in contrast to the stagnant ice lobe south of Oliver. This convex cross profile and down-valley slope is believed to indicate renewed activity of the ice lobe due to a temporary climatic change. It is also possible that the reduction of ablation area as the ice lobe melted down and the resistance to ice flow offered by the narrow section of the valley at McIntyre Bluff may have been factors which contributed to the change in character of the Okanagan ice lobe at Oliver.

The southern limit of this temporary readvance of the Okanagan ice lobe may be marked by one or other of the morainal ridges on the east side of the Okanagan Valley north of Oliver. Farther north, meltwater was diverted westward into the Similkameen Valley through the Yellow Lake channel, and at the entrance to this channel carved a terrace in the kettled outwash deposits which extend south toward Twin Lakes. At this same time, ice filled Marron Valley north of Eneas Lake and meltwater, including the drainage of Trout Creek, flowed in meltwater channels along the west side of Marron Valley, through the Brent Lake-Farleigh Lake channel, and deposited terraced outwash near Eneas Lake. Some of this terraced outwash lies on lacustrine sands and silts, suggesting that prior to this minor readvance lakes and ponds had formed in Marron Valley adjacent to the down-melting ice lobe.

No features were recognized which clarify the relationship of the Okanagan ice lobe with Lake Oliver at about this time. Probably the ice lobe terminated in the waters of the lake. The sediments of Lake Oliver are overlain by sand and gravel outwash (*see* Plates VII and XVIII), and it seems likely that the outwash dates from the period of ice retreat following the readvance.

Following this minor readvance of the ice, the down-melting and retreat of the Okanagan ice lobe was resumed. All features of the Okanagan Valley appear to record that the subsequent decay of the ice lobe was continuous, uninterrupted by halts or readvances within the limits of the area covered by this study.

As the ice melted down, the Yellow Lake meltwater channel was abandoned. The Kearns Creek-Park Rill channel carried meltwater parallel to the main Okanagan lobe south as far as the outwash terrace adjacent to Park Rill north of Oliver. The ice level west of Kaleden was high enough to divert meltwater coming south from the Brent Lake-Farleigh Lake channel into Kearns Creek. The McIntyre diversion may have been abandoned by this time, and outwash from the terminus of the ice was probably being deposited down valley over the sediments of Lake Oliver.

Further melting of the Okanagan lobe resulted in abandonment of the Kearns Creek-Park Rill meltwater channel. Meltwater then flowed along the present course of Marron Creek and built an extensive outwash terrace where it joined the Okanagan Valley near Okanagan Falls (*see* Plates I, II, and IX). The ice tongue between Okanagan Falls and McIntyre Bluff stagnated at about this time and an outwash train was built down the valley over the stagnant ice and over the sediments of Lake Oliver. At about the same time, ice in Marron Valley had stagnated as far north as Trout Creek. The Brent Lake-Farleigh Lake channel was abandoned and a temporary lake was formed at the junction of Shingle Creek and Shatford Creek, in which deposits of glacial-lake silts accumulated. The ice lobe in the Okanagan Valley was sufficiently thick as far south as Skaha Lake to cause meltwater to flow along the borders of the ice and build scattered kame terraces, which to-day can be seen along both sides of Skaha Lake.

With continued melting of the Okanagan lobe, Lake Penticton came into being. Ponds first formed along the border of the ice, but these rapidly coalesced to form a body of water that filled the basin of Skaha Lake. The level of this early stage of Lake Penticton was governed by the massive plug of outwash and stagnant ice that blocked the Okanagan Valley from near Okanagan Falls south to McIntyre Bluff. At this initial stage of Lake Penticton the ice in Marron Valley stagnated as far north as the terminus of Marron Valley near Garnet Lake. For a short time, meltwater may have flowed south in Marron Valley as far as Shingle Creek and then flowed east to the Okanagan Valley at Penticton, but if this episode occurred at all, it must have been brief. About the time Lake Penticton was initiated, meltwater followed the present course of Trout Creek and then flowed south through the Trout Creek-Penticton diversion, and where this channel joined the main Okanagan Valley, the meltwater built kame terraces and later outwash terraces along the valley wall west of Penticton. At this time the Okanagan ice lobe opposite Summerland extended west and terminated against the ridged moraine near the West Summerland reservoir.

Melting of the main ice lobe continued, with the result that the Trout Creek-Penticton diversion was abandoned and Trout Creek came to follow approximately its present course. Lake Penticton extended north past Penticton over the stagnant ice, and at about this time the down-cutting of the outlet of Lake Penticton must have been initiated. Meltwater abandoned Marron Valley north of Trout Creek and began to follow the course of Eneas Creek and to build a series of terraces into a lake ponded in the area of West Summerland (*see* Plates III and IV). Farther north in the Okanagan Valley, meltwater channels at about 2,500 feet elevation may have been carrying, as well as meltwater, the drainage of Powers Creek southwest toward Peachland. On the east side of the lake, the Wild Horse Canyon channel may have been carrying meltwater, and some of the meltwater channels east of Rutland may date from this stage. Exact correlation between the Summerland area and the Westbank-Kelowna area is difficult because of the discontinuity of features from one area to the other; the features just described may in fact be somewhat later than the Eneas Creek meltwater drainage.

As the Okanagan lobe continued to melt, the Eneas Creek meltwater channel was abandoned and Lake Penticton extended north over the stagnant terminus of the ice lobe, probably to the vicinity of Peachland. At about this time the ridged moraine was being built against the ice terminus at East Kelowna, and Mission Creek and Bellevue Creek were diverted to the southwest along the valley wall. In the Westbank area, kame terraces were being built along the west wall of the valley, and these in turn gave way to the local Lake Boucherie ponded between the ice and valley wall. Lake Boucherie drained south through a meltwater channel now followed by the highway south of Powers Creek. Powers Creek built a prominent terrace into Lake Boucherie at an elevation of about 1,700 feet.

Shortly after the construction of this terrace by Powers Creek, the ice lobe stagnated to the north of Kelowna and Lake Penticton extended north to cover the stagnant ice. By this time the surface of the ice lobe probably had only a slight southward slope and soon the whole Okanagan lobe stagnated within the report area. The meltwater channels and kame terraces in the vicinity of Winfield and farther north near Vernon are not readily correlated with the features farther south, but they probably were formed at this late stage. Probably the ridged moraine in the Coldstream Valley east of Lavington was built against the terminus of active ice at about this time.

With stagnation of the ice in the Okanagan Valley, Lake Penticton extended to north of Enderby. By this time the outlet of Lake Penticton at Okanagan Falls must have been lowered to near its present level as a result of melting of the stagnant ice buried in the outwash plug south of Okanagan Falls and through erosion of the outwash by outflow from Lake Penticton.

Features in the vicinity of Vernon and Armstrong that appear to mark the level of Lake Penticton when the Okanagan lobe first stagnated are: The outwash terrace delta near Coldstream at an elevation of 1,650 to 1,750 feet; the sandy delta of Grandview flats, and the meltwater channel leading to it from the Salmon River valley at an elevation of about 1,650 feet; meltwater channels northwest of Armstrong which terminate at about 1,675 feet and seem to mark an early stage of Lake Penticton in this area. The thick silt deposits in the north end of the Okanagan Valley mark deposition in Lake Penticton at this stage.

At this stage Lake Penticton reached its greatest extent, from Okanagan Falls north along the Okanagan Valley to beyond Enderby, possibly including much of Shuswap Lake and perhaps continuous with glacial lakes in the Thompson River valley. There is a difference in elevation between features which mark the apparent lake surface at the north end of the Okanagan Valley and the outlet at Okanagan Falls, that is largely due to a later upwarping of the north end of the valley relative to the south. There is little record of succeeding stages of Lake Penticton as the north end of the valley was uplifted and the lake was reduced in size.

Faint beach lines at the north end of Kalamalka Lake, near Oyama, and along the shores of Okanagan Lake appear to mark a temporary halt in the lowering of the level of Lake Penticton. The stage marked by these faint beaches may be correlated with the deposition of the Rutland terrace of Mission Creek near Kelowna, which was built into Lake Penticton when the lake level at Kelowna stood at about 1,300 feet. Other alluvial fans of creeks farther south may date from this and later stages of Lake Penticton, but are not readily correlated with each other because of the uncertain factor of warping. A beach line at an elevation of 1,390 feet is recognized at the north end of Kalamalka Lake. About 8 miles to the south, what is believed to be the same beach near Oyama is seen at an elevation of 1,360 feet (*see* Plate XIX), indicating that the former water plane has been tilted up to the north at a slope of about 3.5 feet per mile.

The drainage of the Shuswap River, Shuswap Lake, and possibly much of the lake system occupying the South Thompson Valley was probably to the south through Lake Penticton during much of the late glacial stage, but no well-defined channel existed until the level of Lake Penticton fell and the glacial-lake silts were exposed. A prominent channel was then cut south from near Enderby to the north end of Okanagan Lake in the glacial-lake sediments when the level of Lake Penticton stood only 50 feet or so above the present level of Okanagan Lake near Vernon.

The abandonment of this meltwater channel and the diversion of the Shuswap drainage to the Thompson and Fraser Rivers may be regarded as marking the end of late glacial time in the Okanagan Valley. Near Armstrong, Fortune Creek built into this abandoned channel an alluvial fan which now forms the divide between Okanagan drainage to the Columbia River and Shuswap drainage to the Fraser River. The reduction in the flow of water through the Okanagan River channel south of Skaha Lake permitted tributary streams such as Shuttleworth and McIntyre Creeks to build alluvial fans across the channel along which the undersized Okanagan River meandered.

In the interval since Okanagan Lake reached its present level and drainage was established in its present pattern, the chief changes have been by stream erosion, the formation of deltas and alluvial fans, and the accumulation of peat and swamp deposits in poorly drained localities. The post-glacial advance of the delta of Mission and Kelowna Creeks at Kelowna and of the combined alluvial fans and beach deposits in the vicinity of Penticton are clearly recognizable in aerial photographs.

Flash floods have added to the alluvial fans of Testalinden Creek and Tinhorn Creek in historic times. Landslides have occurred on steep slopes along the lakes, and the resultant debris has been reworked by wave action into spits at present lake level. These and other post-glacial events have not been studied in detail and are difficult to correlate from one part of the valley to another.

One post-glacial feature which provides a distinctive time marker and thus could be useful in a variety of studies is a fall of volcanic ash which occurred in post-glacial time. This thin layer of ash can be recognized in many talus and alluvial deposits throughout the valley (*see* Plate XX), and is known to occur within many peat bogs. It was recognized in bottom sediments of Okanagan Lake in cores recovered from test drilling near Kelowna. It is believed to be in the same fall of ash as one that is known in eastern Washington and is correlated with ash occurring in peat bogs in the Puget Sound region. This fall of ash is believed to have come from an explosive outburst of Glacier Peak, a volcanic peak in the Cascade Mountains of central Washington, 100 to 200 miles southwest of the Okanagan Valley. Radio-carbon dating of peat underlying the ash layer in bogs in the vicinity of Seattle indicates that the Glacier Peak explosion occurred about 6,700 years ago.* This ash layer, where it can be found, is a useful marker horizon and furnishes a means of correlating such varied phenomena as delta-building, sediment accumulation, peat accumulation, and soil development. Since it probably lies within the time range of the earliest migrations of native populations, it might prove a useful marker in evaluating the oldest archæological sites.

RELATIONS TO BRITISH COLUMBIA GLACIATION

The Glacial Geology Map in the British Columbia Atlas of Resources (1956) and the Glacial Map of Canada (1958) record observations made throughout British Columbia of glacial striæ, meltwater channels, outwash deposits, and glacial-lake sediments. These observations show the trends of glacier movement away from centres of ice accumulation in the mountains onto the interior plateau and from the interior plateau southward across the forty-ninth parallel and northeastward into the Peace River area. The extent of the glacial-lake deposits shown on both maps indicates the importance of these features to-day. However, the observations are of necessity generalized and include scattered and unco-ordinated facts which can show little of the sequence of Pleistocene events.

Within a few areas more detailed studies have been made which reveal something of the complexity of Pleistocene history. In the Strait of Georgia area, which includes the lower Fraser Valley and southern Vancouver Island, the earliest studies of the Pleistocene deposits were published by Johnston and Clapp. More recently detailed studies have been published by Armstrong and Fyles. Mathews has published detailed studies of a glacial-lake sequence in the Merritt-Kamloops region as well as a preliminary study of unconsolidated deposits in the Peace River District of northeastern British Columbia. Armstrong has studied unconsolidated deposits in the Fort St. James map-area of central British Columbia. Of these four areas, the Georgia Strait area shows the longest sequence of glacial and interglacial deposition, although the other areas also show evidence of multiple glaciation. In all areas, however, the bulk of the evidence is of late glacial and post-glacial deposits which were laid down during the final retreat of the last ice-sheet. Thus, as in the Okanagan, the late glacial and post-glacial events are the most clearly recorded.

These four areas are widely separated, and the studies in them are of only a reconnaissance nature, so that it probably will be some time before sufficient information has been gathered to permit correlation of even late glacial events over the

* Reported in the bibliography.

whole Province. The following paragraphs therefore offer only a few speculative comments on the glaciation of British Columbia in general in relation to the glaciation of the Okanagan Valley.

The Pleistocene epoch in British Columbia, as in other parts of the world, was marked by periods of glaciation during which the Province was smothered under an ice-sheet, separated by intervening periods during which the glaciers receded and the climate was as warm as it is at present or warmer. Such a succession of glacial and interglacial periods is indicated by studies in the Strait of Georgia area and is to be inferred from knowledge of glacial history elsewhere in North America.

With the onset of each glacial period the ice began to accumulate in mountainous areas of high precipitation, first forming mountain valley glaciers and then spreading out to cover the adjacent plateau areas in the form of piedmont glaciers. During each glacial period the ice probably originated in the same mountainous areas that nourish glaciers to-day. Ice advanced onto the interior plateau from the Coast Mountains on the west, from the Skeena Mountains on the north, and from the Cariboo and Monashee Mountains on the east. The first ice to appear in the Okanagan Valley probably originated in the Monashee Mountains north and east of Mabel Lake, and formed valley glaciers that pushed south from Shuswap Lake and west along Coldstream Valley. While these glaciers were expanding, a similar and probably more rapid expansion of glaciers from the Coast Mountains was taking place. Ultimately, the coalescent piedmont glaciers on the eastern flank of the Coast Mountains covered the interior plateau and began to flow southward toward the forty-ninth parallel and northeastward toward the Rocky Mountains. Striations, drumlins, and grooves plotted on the Glacial Map of Canada and the Resources Map clearly show these and the other general trends of ice movement. By the time the ice moving east and south from the Coast Mountains reached the Okanagan Valley, glaciers from the Monashee Mountains probably completely filled the Okanagan Valley. The ice from the two sources coalesced and flowed southward across the forty-ninth parallel.

Deep glacial erosion of the Okanagan Valley was probably accomplished by the glacier originating in the Monashee Mountains before it had expanded to the stage where it coalesced with the Coast Range ice-sheet. Knowledge of the speed and mechanism of glacial erosion is limited, but it is reasonable to assume that erosion of the Okanagan Valley was accomplished by the ice that flowed rapidly through it as a valley glacier rather than by the later ice-sheet that covered the whole of southern British Columbia to an elevation of 7,000 feet or more. The whole question of glacial over-deepening and erosion is a complex one, and the interested reader could consult Flint and references contained in that text for further discussion. The position of a series of fiord-lake basins which now contain Kootenay Lake, Arrow Lakes, Okanagan Lake, Mabel Lake, Shuswap Lake, Adams Lake, Canim and Mahood Lakes, and Quesnel Lake relative to the Cariboo and Monashee Mountains is believed to be significant in considering the origin of the Okanagan Valley. All these fiord-lake basins are so situated as to have provided passageways for glacial ice flowing away from centres of ice accumulation in the mountains. It is believed that they owe their narrow deep straight form to intensive erosion by valley glaciers passing through them.

Evidence from deep drilling near Enderby in the Okanagan indicates that most of the glacial erosion had been accomplished before the last advance of Wisconsin ice through the Okanagan Valley. A well drilled in search of oil near Enderby passed through approximately 700 feet of silty clay, believed to be a glacial-lake deposit of Lake Penticton, and then through fine gravel and coarse sand containing a few fragments of wood to a depth of 1,350 feet. It is believed that this sand and gravel was deposited either in front of the last glacier to advance into the Okanagan Valley or possibly earlier. The Okanagan Valley had therefore been eroded to approximately its present depth and form by some earlier glacier. It is of interest to note that the bedrock floor of the Okanagan Valley at this point is slightly lower than present sea-level.

Late glacial time throughout British Columbia was marked by the formation of extensive glacial lakes in which silts and clays were deposited. The successive stages of ice retreat and the eskers, kames, and outwash deposits which mark these stages can often be correlated with changes in the level and extent of these lakes. Materials deposited in these lakes are known in the Peace River district, in the Prince George-Fort St. James region, and in the Merritt-Kamloops area. The best hope of correlating late glacial events throughout the Province appears to be in the study and correlation of these late glacial-lake systems and of their drainage systems.

Mathews has described a succession of late glacial lakes in the Merritt-Ashcroft-Kamloops region. These lakes, which he has named Lake Quilchena, Lake Hamilton, Lake Merritt, and Lake Thompson, were formed at the edge of the melting ice-sheet in much the same manner that Lake Penticton formed south of the melting ice lobe which occupied the Okanagan Valley. They appear to mark the time when the ice-sheet on the interior plateau separated into two piedmont ice-sheets, one fed by glaciers in the Coast Mountains and the other fed by glaciers in the Monashee Mountains.

Lake Thompson, the last glacial lake in the sequence described by Mathews, is marked by a prominent shoreline at 1,800 feet elevation in the vicinity of Kamloops. Mathews believed that the level of Lake Thompson at this stage was controlled by a spillway whose present elevation is 1,950 feet near Squilax. This stage of Lake Thompson would be approximately contemporaneous with the stage of Lake Penticton marked by lacustrine deposits north of Armstrong at an elevation of about 1,700 feet. Lake Quilchena and Lake Hamilton would then correlate with the earlier stages of Lake Penticton. A more precise correlation might be obtained from a study of glacial and late glacial features in the valley of the Salmon River, which appears to have been an outlet for Lake Hamilton.

In later stages Lake Thompson was probably continuous through the Shuswap basin with the final stages of Lake Penticton. Detailed studies of the development of the present Thompson River drainage from the late stages of Lake Thompson might explain the mechanism of the diversion of the Shuswap River, at Enderby, from the Okanagan to the Thompson drainage system.

No doubt the various late glacial lakes and meltwater channels that have been observed throughout British Columbia are roughly contemporaneous with the features of late glacial marine submergence on the Pacific coast of British Columbia, but much more detailed work will have to be done before the sequence of retreat of the last ice-sheet can be postulated with any confidence.

GLOSSARY

Ablation—is the combined processes of melting and evaporation by which glacial ice is destroyed.

Drift—is a general term to include all unconsolidated materials transported and deposited both directly and indirectly by glacier ice. The term originated before the concept of glaciation was established, when these deposits were thought to have " drifted " into place during a period of marine submergence.

Esker—is a long narrow ridge often resembling a railroad embankment composed of stratified drift.

Fan—is a sub-aerial deposit laid down by a stream where its gradient is suddenly reduced, as, for example, when it flows out of a steep tributary valley onto the flat bottom of the main valley. The deposit has the form of a segment of a flat cone; where it is built into a lake, the portion below water is a delta.

Foreset deposits—are stratified deposits with moderate to steep dips deposited on the front of a delta being built into a lake or other body of standing water.

Glacial lake—is a lake located in close proximity to a glacier. In many cases the glacier itself brought about the formation of the lake, and in all cases the glacier exerted a large influence on the environment and deposits of the lake.

Isostatic—refers to uplift and depression of the earth's crust in response to changes in the total load on the crust. In the case of glaciers the earth's crust was depressed under the load of ice and rebounded when the ice melted away.

Kame—is an ice-contact deposit with the topographic form of a steep-sided knoll or ridge.

Kame terrace—consists of stratified drift deposited between a glacier and the valley wall. After the melting of the glacier the deposit remains as a flat-topped terrace along the valley wall.

Kettle—is a depression that occurs in drift as a result of the melting away of a mass of ice which had been buried within the drift.

Lacustrine—means of a lake, and when modified by the term " glacio " it implies the existence of a glacial environment.

Meltwater—is water from melting glacial ice in distinction to water derived directly from precipitation as rain or snow.

Moraine—originally this word referred to ridge-like deposits of glacial debris, but its meaning has been extended to include deposits with a distinctive topographic form by direct action of the glacier ice.

Outwash—stratified drift that is built beyond the limits of the glacier by streams flowing from the melting ice.

Proglacial—refers to processes and features which are related to the glacier but are taking place or are located beyond the limits of the glacial ice.

Till—is a general term to distinguish non-sorted unstratified drift from stratified drift. It includes a wide variety of materials of glacial origin.

Valley train—is a long narrow body of outwash confined within a valley and deposited by meltwater flowing away from a glacier which occupies the upper portion of the valley.

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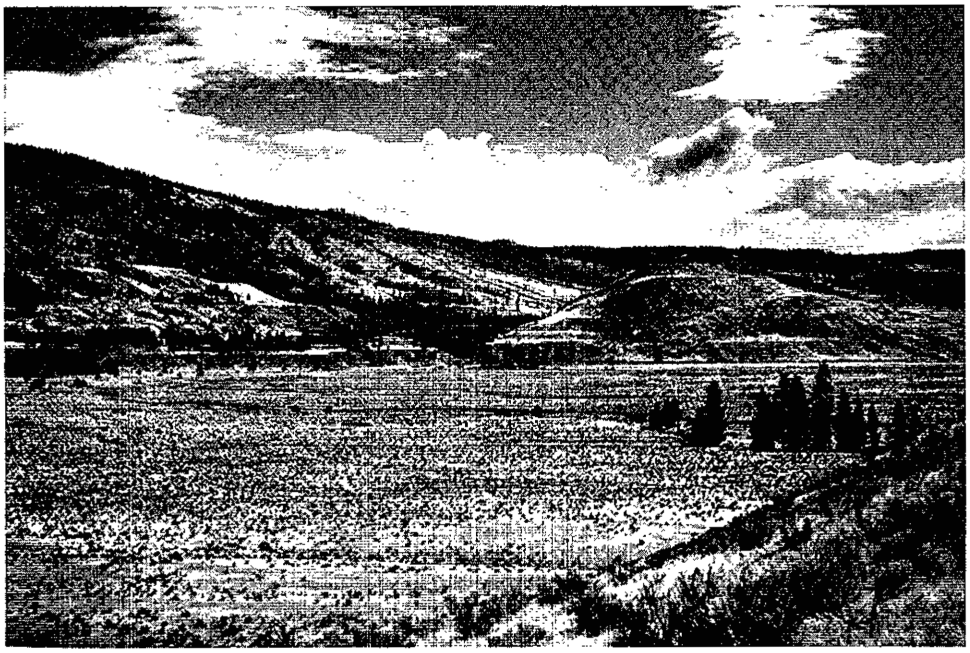

Plate V. General view eastward toward Wolfcub Creek, east of Oliver. Kame terraces along the valley wall were built when glacier ice diverted the flow of Wolfcub Creek south through meltwater channels. Outwash terrace in the foreground was deposited at downstream end of diversion channel of McIntyre Creek. Photograph taken from top of moraine ridge.

Plate VI. A landslide which occurred in glacial-lake silts on the shore of Osoyoos Lake. The silts were apparently saturated by excess irrigation water. The movement took place rapidly and was completed within a few minutes.

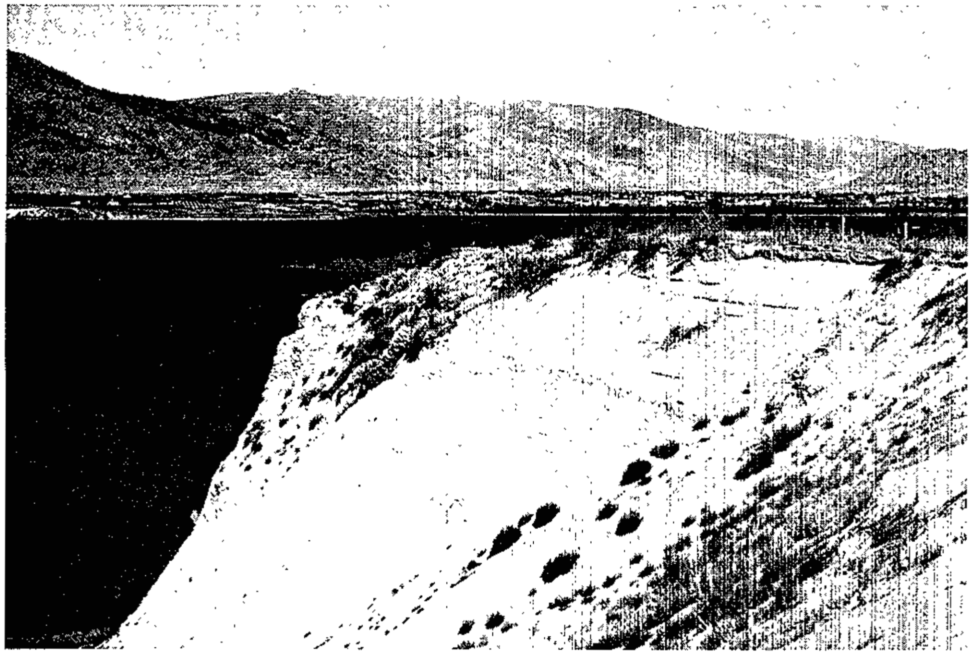

Plate VII. Silts of glacial Lake Oliver overlain by sandy outwash near Osoyoos.

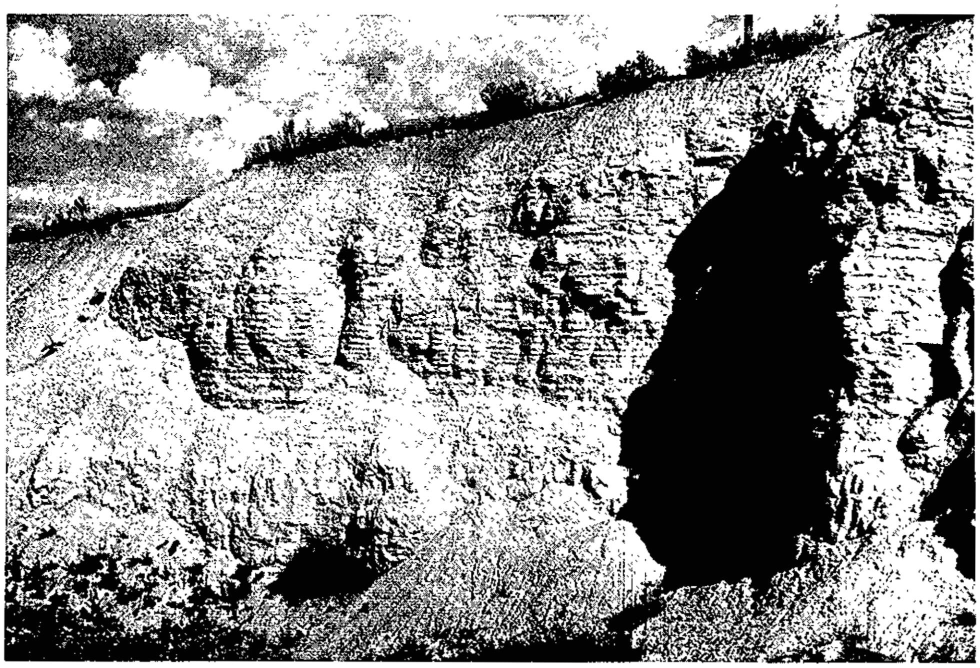

Plate VIII. Varved silts of glacial Lake Penticton exposed in a road cut near Vernon. These varved deposits are characteristic of the upper 30 feet of the deposits of Lake Penticton and overlie a more massive, thickly bedded silt.

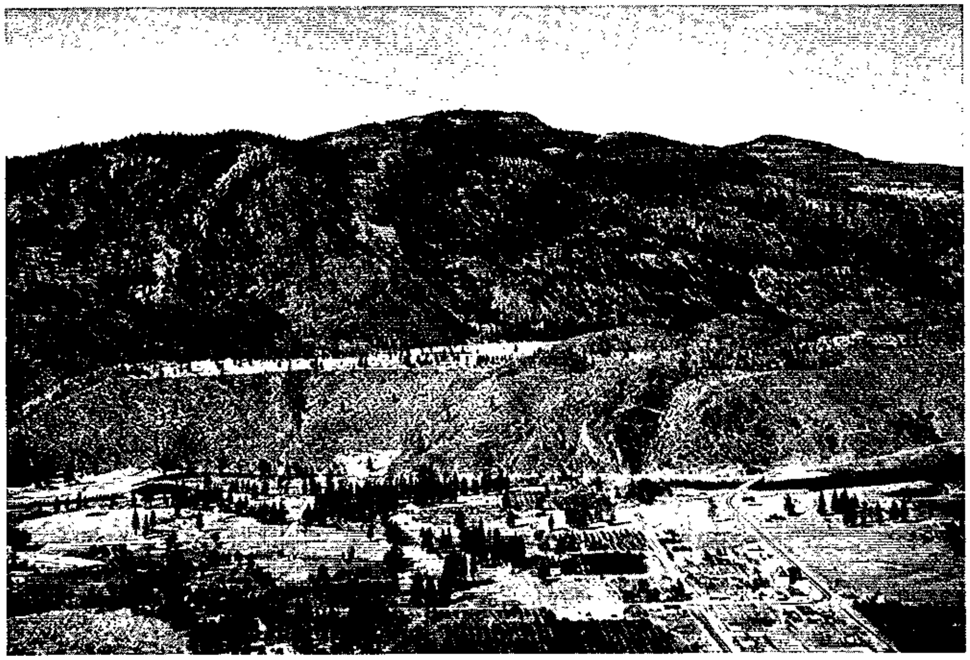

Plate IX. View westward across the settlement of Okanagan Falls. The terrace beyond the Okanagan River was built by meltwater which flowed down Marron Valley at an early stage of Lake Penticton. The fan of Shuttleworth Creek can be seen in the foreground (*see* Plates I and II).

Plate X. Terraces along the right bank of Trout Creek, south of Summerland, cut by meltwater which was diverted through the Trout Creek-Penticton diversion (*see* Map-area IIIB and text, p. 25).

Plate XI. Meltwater channel cut in till deposits which mantle the sides of Marron Valley.

Plate. XII. A channel cut in bedrock and till deposits by meltwater which flowed from the ice lobe onto the valley wall east of Rutland and back ontó the ice surface.

Plate XIII. General view looking northward across Okanagan Lake from highway near Summerland to Squally Point. A series of canyons indicated by the notched profile of the ridge carried meltwater streams when the lake was filled with the remnants of the Okanagan glacier.

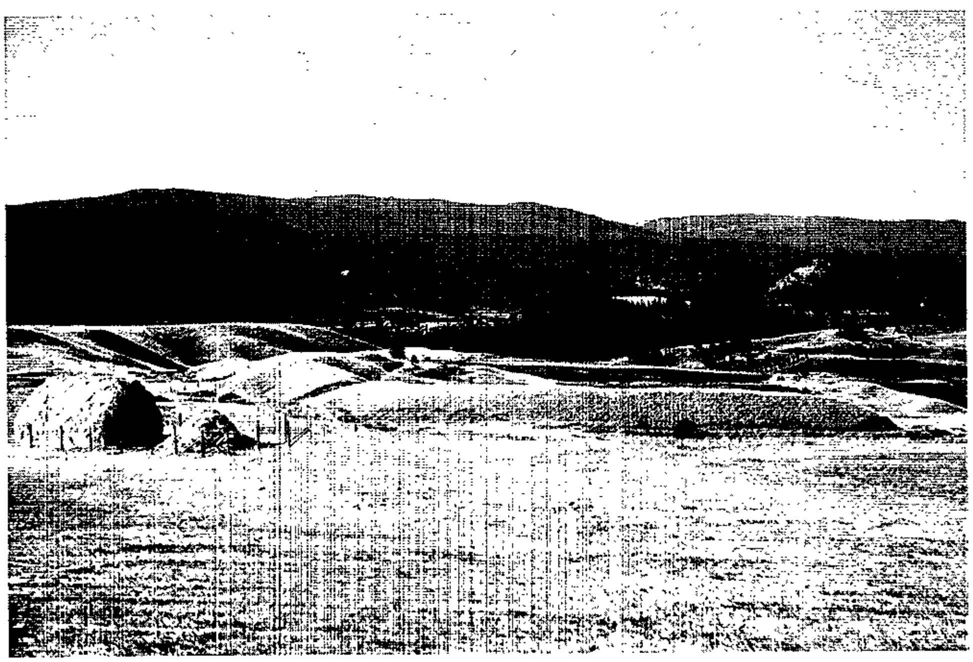

Plate XIV. An esker built by meltwater flowing under stagnant glacial ice near Mission Creek, south of Black Knight Mountain.

Plate XV. Compacted gravels exposed in a pit near Bellevue (Sawmill) Creek, south of Kelowna. These gravels were deposited as outwash before the last time that glacial ice advancing down the Okanagan Valley overrode this area. Elsewhere on Bellevue Creek these gravels overlie silts similar in character to glacial Lake Penticton silts but clearly of much earlier age.

Plate XVI. Varved silty clay of glacial Lake Penticton overlying gravelly sand outwash deposited before the last ice advance. Contact is marked by a thin layer of angular gravel, X-X, which may be ablation moraine, and a foot or so of fine gravel in a silty matrix, which may be basal till. Exposure in a gully adjacent to Vernon Creek, south of Vernon.

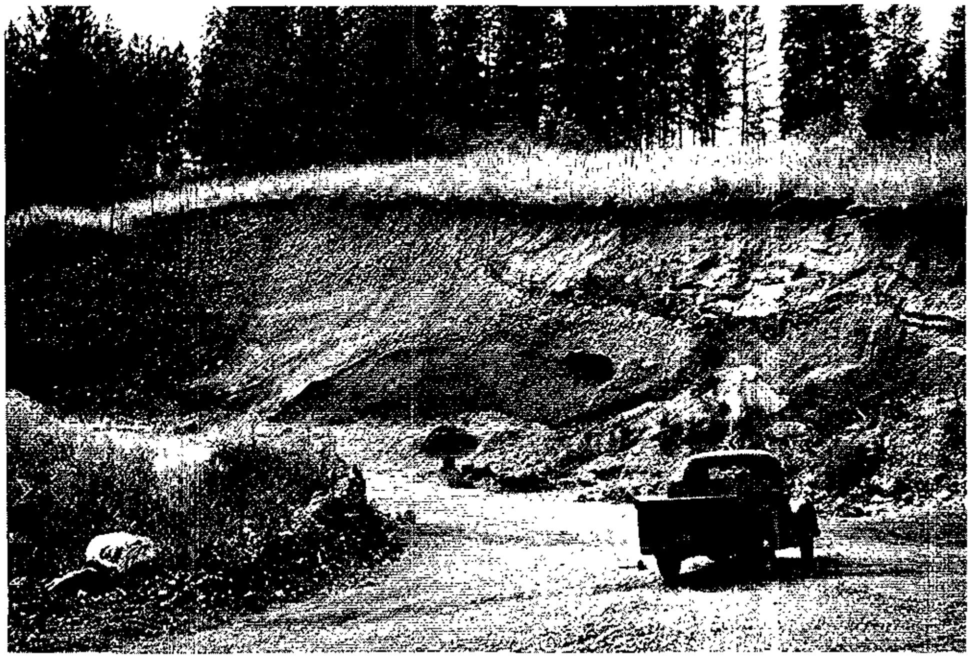

Plate XVII. Gravel pit west of Deep Creek (*see* note on Map-area VI and description on p. 38). The gravel-filled channel exposed above the truck has no surface expression in the adjoining field and so probably pre-dates the latest glaciation of this area, even though no basal till is exposed in the face of the pit.

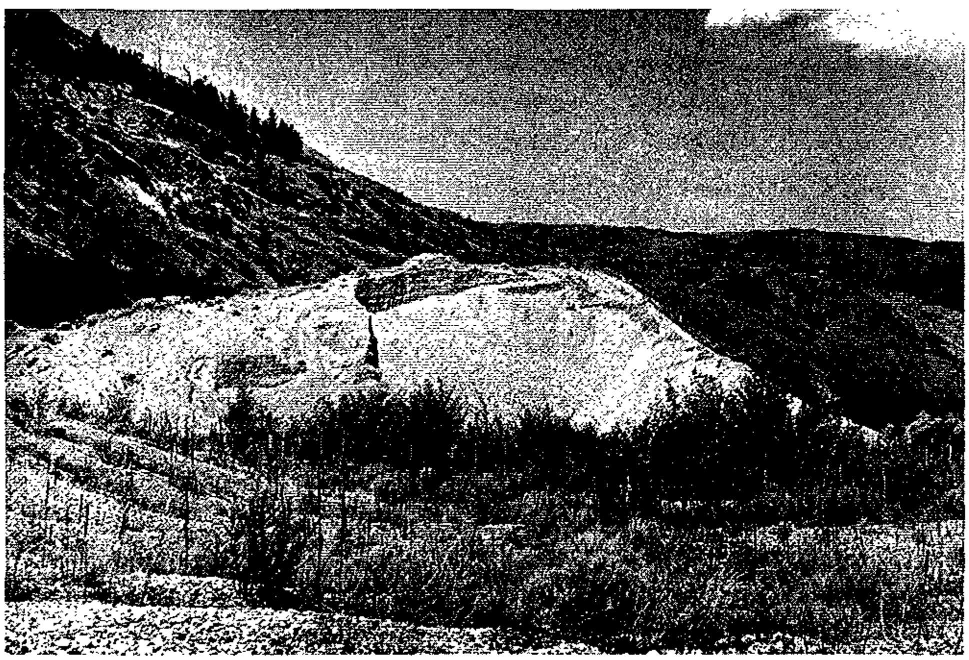

Plate XVIII. Gravel outwash exposed in a pit near Oliver. Topography and internal structure indicate that it is a river bar deposited from a meltwater stream flowing in the Okanagan River channel. Other outwash sands and gravels of this group are seen to rest on silts deposited in glacial Lake Oliver.

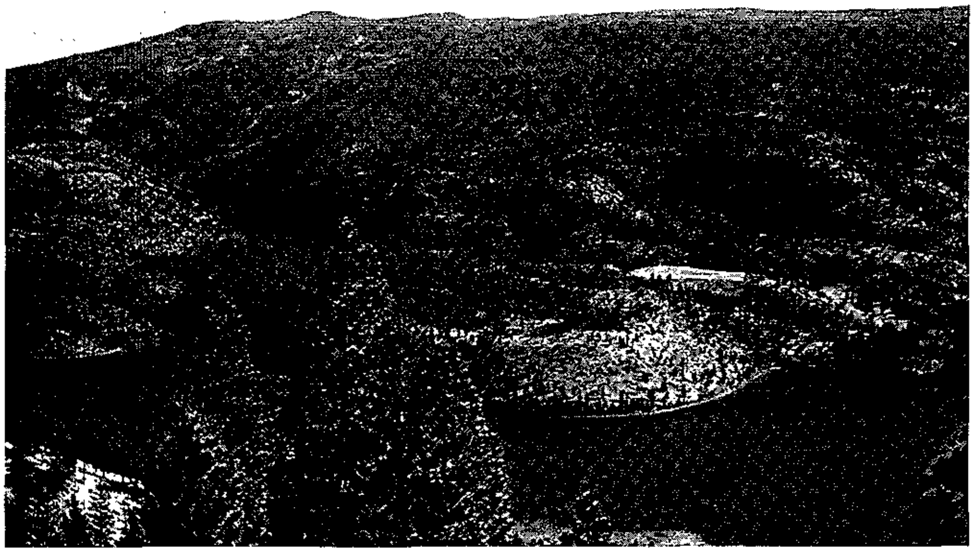

Plate XIX. Looking northeasterly across the south end of Kalamalka Lake toward a prominent raised delta at the downstream end of a meltwater channel parallel to the east side of the lake. Under favourable lighting conditions a faint shoreline can be seen along the steep front of this delta about 75 feet above lake level.

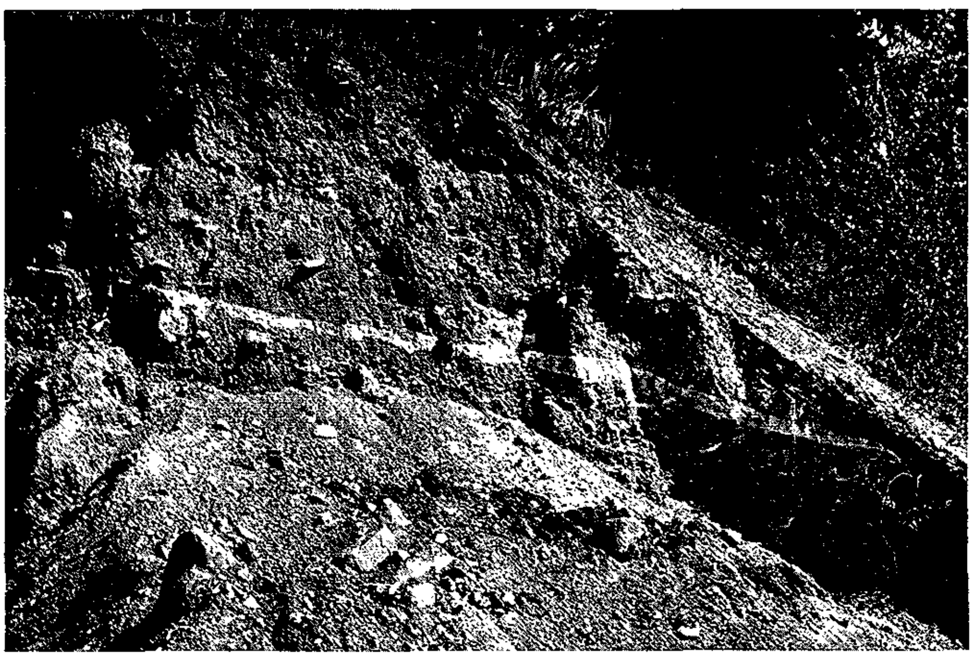

Plate XX. A layer of light-grey volcanic ash in a small gravel pit excavated in an alluvial fan near Lumby. The ash is considerably thicker here than elsewhere in the Okanagan Valley, having been washed into place by running water. This ash may have come from an explosion of Glacier Peak in the State of Washington, about 6,700 years ago.

To accompany B.C Department of Mines and Petroleum Resources Bulletin 46, 1962

FIGURE 1


119°30'
119°00'
50°30'
50°00'
NOTE
Within this limited area gravel pits and road cuts show weathered and somewhat indurated sands and gravels. They are clearly not part of the Wisconsin glacial deposits and may be earler Pleistocene or possibly late Tertiary gravels.
ENDERBY
ARMSTRONG
MT. SWANSON
MT. ROSE
Glenemma
Spallumcheen
Round L.
Otter L.
Goose L.
SWAN L.
MAP AREA VI
MAP AREA V
VERNON
Okanagan Landing
Lavington
Deep L.
KALAMALKA L.
Oyama
WOOD L.
Winfield
OKANAGAN LAKE
MAP AREA V
MAP AREA IV
NOTE
The terraces up Trepanier Creek are mapped as a raised alluvial terrace. The abundant granitic boulders, however, suggest that the material might be outwash from a local glacier nourished on the slopes of Mount Godfriedsen at the head of Trepanier Creek.
KELOWNA
MT. KNOX
MT. WORTH
Rutland
East Kelowna
MT. BOUCHERIE
MINE HILL
BLACK KNIGHT MTN
Okanagan Mission
McCall Lakes
Trepanier
SURFICIAL DEPOSITS
OF
LATE GLACIAL AND RECENT AGE
NORTHERN OKANAGAN VALLEY
by
Hugh Nasmith
LEGEND
RECENT
1 Okanagan River Floodplain
2 Alluvial fans, deltas, and associated gullies and stream channels
3 Beaches, spits, and dunes
LATE GLACIAL
4 River channels and stream-cut terraces
5 Raised alluvial fans, terraces, and deltas
STAGE OF GLACIAL RETREAT
6 Outwash terraces
7 Kettled outwash
8 Glacial lake sediments
STAGE OF GLACIAL OCCUPATION
9 Moraine ridges
10 Kame terraces and meltwater channels
Meltwater channels
GLACIAL ADVANCE AND EARLIER
11 Mixed unconsolidated deposits
Roads
Scale 1 0 1 2 3 Miles
Contour interval 500 feet
#46 2
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FIGURE 2

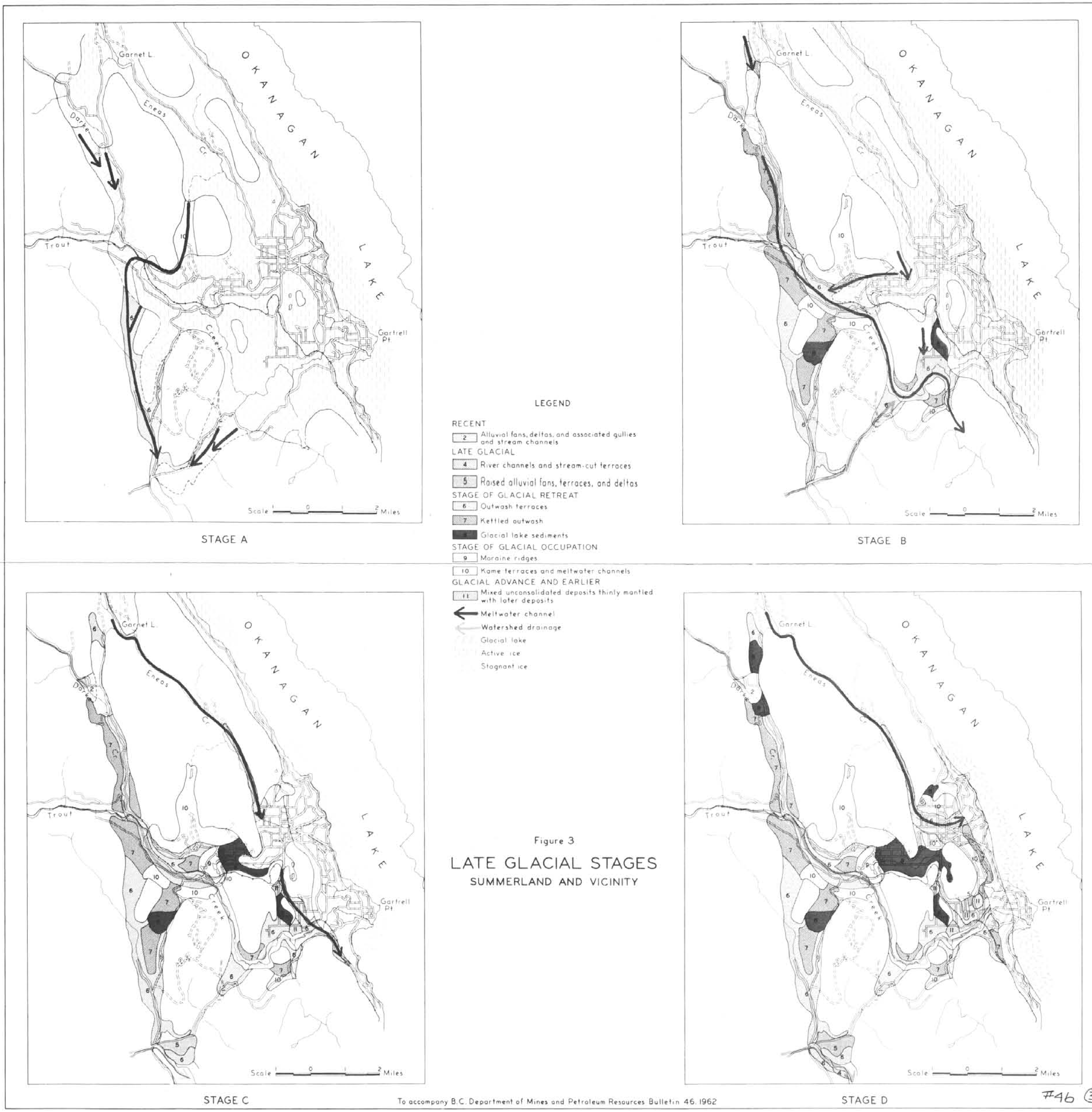

Figure 3

LATE GLACIAL STAGES

SUMMERLAND AND VICINITY

To accompany B.C. Department of Mines and Petroleum Resources Bulletin 46, 1962

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