

**POST-GLACIAL HISTORY and GEOMORPHIC DEVELOPMENT  
of the SOUTH OKANAGAN VALLEY, BRITISH COLUMBIA<sup>1</sup>**

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**INTRODUCTION**

Post-glacial loosely refers to an interval of time when all glacial ice disappeared to the present moment. This encompasses about 13,000 years or so, but nobody knows when **all** the ice actually melted. Clearly, remnant giant blocks of ice, now occupied by the major lakes of the valley, persisted for many years and were contemporaneous with the existence of Glacial Lake Penticton. The latter is a lake that formed in the valley stretching from a morainal dam near Okanagan Falls north to at least Enderby. A similar lake formed in the Thompson River Valley. If geomorphic development of the valley was that simple, and could be explained by events occurring in a mere 13,000 years, then this would be a short field trip indeed!

The geomorphic development of the valley, like anything of value, took a long time, and it's a long story, mostly involving geologic events that are almost impossible to imagine, difficult to believe and hard to prove. Nevertheless, it is a story that rivals the most imaginative science fiction known to man.

At our first stop (see map) there will be a summary of how all the bedrock was deposited or formed, and what happened to it up until the glaciation of the Pleistocene Epoch commenced (recently tagged at 1.65 million years ago by the Geological Survey of Canada, but more than 2.0 million years by others). This summary will start with the Monashee Gneiss Complex, the most common rock in Naramata. Some geologists think that these rocks represent the original cratonic rocks at the edge of the North American continent, and are dated at two billion years old (incidentally, the oldest rocks in BC). They are metamorphic; that is, they have been changed by heat and pressure at certain periods of time, and have been deeply buried at least once. Also, large bodies of granite have intruded them first during the Jurassic-Cretaceous Periods, then again during the Tertiary Period. The rocks as a group form the central crystalline core of British Columbia and extend northward to near Jasper National Park. About the only general item important for this field trip is that this central core has been more or less on the rise and subject to erosion throughout most of geologic history.

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<sup>1</sup> Much of the geologic framework or background for this field trip is contained in a 1995 publication of a book entitled "Geology of the Kelowna Area and Origin of the Okanagan Valley, British Columbia", published by the Kelowna Geology Committee. A new edition is being planned. Funds for this project are being solicited from private and public entities, and any and all donations would be greatly appreciated.

Skipping quickly to the Jurassic Period (and for the sake of simplicity excluding the kaleidoscope of events in the Paleozoic Era and part of the Mesozoic Era), the entire world began to break up with continents splitting and drifting...plate tectonics is the term. During this time western British Columbia was engulfed by a huge slice of volcanic and sedimentary rock that originated in the Pacific Ocean. **This rock slice is known as Quesnellia Terrane and it was obducted (or thrust over) onto the rock at the surface...incredible as it sounds!** MAY HAVE TO MODIFY THIS BUSINESS0. Much of this Quesnellia rock in the Okanagan has been eroded. Meanwhile, lower portions of the Pacific Ocean crust were subducted (injected deeply below the continent). These rocks melted, mixed with water, and like balloons rising in the air, they punched through all other rock...these are the Coast Range Intrusives, but numerous dikes, plutons and batholiths of these granitic intrusive rocks occur in the Okanagan. These events are mountain building geologic events and affected large regions of the Cordillera of North and South America.

Then an even stranger event happened. Presumably sometime in late Cretaceous or early Tertiary, perhaps near the time that the dinosaurs disappeared from the Earth, the Okanagan Valley was split by a great fault. All of the rocks to the west slid off the central rising crystalline core of the Monashee Gneiss. They slid 100 kilometers in an unusual process known as Continental Extension. This is a net real estate gain! Many deep cracks and rift valleys developed in central BC and Washington State at this time so that during the Eocene (40 to 50 million years ago), explosive volcanic eruptions occurred in many places in the Okanagan, and flooded vast regions of central and northern BC.

#### STOP ONE: MUNSON HILL. A PANORAMIC VIEWPOINT.

There are many examples of these early Tertiary volcanics in Kelowna, Summerland, Peachland, Kaleden, Keremeous, and White Lake, but only one solitary reminder near Naramata and Penticton...Munson Hill.

Erosion immediately set to work on the ragged volcanic landscape, because, after all, rainfall was in the order of 400 inches per year, and BC and the rest of Canada were still quite a way south in tropical latitudes (plate tectonics of course). A huge river system developed in the interior, eroding the landscape and depositing material in the rugged land, even burying some volcanic peaks in the process. These deposits are represented by the White Lake Formation today and include conglomerate, sandstone, siltstone and coal layers with a combined thickness of 1,000 meters in places. Numerous fossil plants have been recovered from these rocks, and there should be fossil fish and insects too in this formation which, by the way, records the first forest presence in the Okanagan. Spectacular outcrops of these rocks can be seen in the White Lake Valley, on both sides of the road at Summerland, and across the road from Gorman Brothers mill at Westbank, and in several places in Kelowna.

These rocks had no sooner consolidated when the eastern Cordillera began to develop during the Rocky Mountain Orogeny. It is by no means clear how or when, but the fact is that all of the Tertiary rocks were folded and faulted in the Okanagan during or

about this time. The sturdy “spine” of Monashee Gneiss however, appears to have been largely unaffected. But not completely since the Mission Creek Fault at Kelowna did shift this stubborn land mass to help form the great bend in Okanagan Lake.

The land kept rising in central BC and so did the Coast Range Mountains. Great fissures must have developed near the end of Tertiary time since extensive plateau basalts were formed over the Thompson Plateau and Okanagan Highland. The continued rise in land and accompanying climatic change, reversal of poles, wobbling of the Earth’s axis, and other unknowns, culminated in ice sheets and mountain glaciers in much of North America, and northern regions of the rest of the world. Four periods of glaciation are commonly or traditionally recognized but even more are suspected, each separated by warm “interglacial” intervals. Irrefutable evidence of two ice sheets and a major interglacial interval has been found in the Okanagan and in other parts of BC. An early glaciation dating to at least a million years is documented in Wells Grey Park...so there has been a lot of ice traversing the landscape, and every peak in the Okanagan.

Noteworthy with respect to glacial effects in the valley is that the bedrock below the lake has been gouged out by repeated glacial erosion to a depth –640 meters (2100 feet) Below Sea Level. Glacial and Post-glacial sediment overlying the bedrock is up to 750 meters (2460 feet) thick (Eyles, *et al*, 1990). The maximum depth of Lake Okanagan is off Whisky Island at 232 meters (762 feet), and the average elevation of the lake is 342 meters ( 1123 feet). It is estimated that sedimentation in the lake as a result of deglaciation totals about 90 cubic kilometres.

The effects of glaciation, deep fjord-like erosion of lake basin and river valleys, carving of meltwater channels, rounding of rugged landforms, scraping old soils, deposition of moraine of all types, and general scavenging of the land, cannot be underestimated. Many of the geomorphic affects of this will be observed during the field trip, but it is important to remember that the major geomorphic framework is clearly formed by the bedrock and its complex tectonic and paleogeomorphic history.

The last glacier that occupied the Okanagan is the Fraser Glacier, and specifically the “Okanagan Lobe”. This glacier advanced about 25,000 years ago, attaining its maximum thickness of two kilometers probably 18,000 years ago and had largely melted 13,000 years ago or about 11000BC. By about 10,000 years ago even remnant masses of ice in the valley had apparently all melted, which brings us to our second stop.

## STOP TWO: ARAWANA LATERAL MORAINE

The Arawana Lateral Moraine Complex is a series of bench-like terraces three to four kilometers long abutting the Naramata Highland from an elevation of 500 to 800 meters approximately. The numerous switchbacks up Arawana Road are an engineering attempt to surmount these spectacular geologic features. Here we can visualise a stagnating portion of the melting Fraser Glacier in the Okanagan Valley. The moraines are composed of glacial till, and outwash sand and gravel, much of it formed in contact with ice. When these moraines were formed, Glacial Lake Penticton still had not

originated. Meltwater was directed along the margins of the ice, escaping to the south via a complex and constantly changing series of channels.

In the adjacent upland, Naramata Creek Canyon was being severely attacked by tremendous deluges of meltwater as a result of melting of upland ice. Much of the material cut out of the canyon ended up on top of the ice of the stagnating glacier and along the sides of the glacier. Almost all of the great canyons of the Okanagan... Bellevue, Mission, Bear, and so on, were formed in this manner...with ice stagnated or at a still-stand at the "knick point". These are "hanging valleys". The implication of this will be realised when the present Naramata Creek valley is viewed near the village center.

### STOP THREE: VIEWPOINT, ARAWANA ROAD

Going back down the road, pretend that the ice that formed the moraines has now melted, but for some reason a lake has formed in the Okanagan Valley, and is lapping onto a shore right at this Stop. Apparently glacial material and ice blocked the normal southerly drainage, and as Nasmith (1962) determined, this happened at Okanagan Falls and Vaseux Lake. This caused the ponding of meltwater of the entire Okanagan watershed, and for a time, also meltwater from the Thompson and Shuswap valleys far to the north.

If we could look out over this lake from this viewpoint, we would see a vast unfamiliar scene, a strong cold catabatic breeze would be blowing, and huge meltwater streams would be plunging into the lake at Summerland, along a high level of Naramata Creek and other places up and down the valley, and not a tree or blade of grass in sight. Here and there would be large icebergs drifting, and perhaps we could see portions of a central submerged core of the remnant glacier out in the lake some place. This is Glacial Lake Penticton.

This is good spot also to contemplate the inferred fluctuations in the Okanagan climate over the last 13,000 years as revealed by pollen and spore analysis in bogs, and microfossils in lake sediments. Dendrochronology of trees has also been employed quite reliably for the last 600 years of historic time.

There have been a number of climatic fluctuations, between warm and cold, dry and moist, in the last 13,000 years, and at least a half dozen minor glacial advances and retreats. This is an interval of time that includes the Holocene, and we live at the "end" of it. However, most recent work by paleobotanists suggest that climatic fluctuations generally have not been extreme. Alley in 1976 published his assessment of Holocene climate fluctuations from a bog deposit near the Kelowna airport. He meticulously recorded pollen and spore counts of various plants, indicators of precise environmental conditions, and others have done similar studies. The bog layers also contained layers of volcanic ash that can be dated and assigned to known eruptions, for example, the Crater Lake eruption in Oregon which deposited Mazama Ash all over the Okanagan 7600 years ago or so. Similar studies of marine life, sedimentation patterns and microfossils in

ocean basins, and glacier studies paint a similar spectrum of minor climate fluctuations. Over the last ten years or so, researchers at Okanagan University College and others have added considerable similar data specific to Okanagan climate change.

There appears to be a general consensus that there have only been three or four more or less distinct intervals of “global climate change” in the last 15,000 years, relevant to the Okanagan. The first of course was a major warming starting at least 15,000 years ago which served to largely melt the Fraser Glacier in two to three thousand years. Minor cirque and valley glacier advances, or re-advances, in the Cascade Mountains to the southwest indicate that there was some unevenness associated with the warming trend at about the time of an eruption of Glacier Peak about 13,000 years ago. Even Nasmith (1962) who first mapped the glacial deposits in the Okanagan suggests a stillstand or active ice at Penticton roughly near this time.

Early Holocene: The overall warm trend continued marked by melting of the ice dam at Okanagan Falls and drainage of Glacial Lake Penticton in at least two well defined stages (Figure --), related in part to spillage as a result of rebound. This occurred perhaps at about the 12000 year date and marked the beginning of the Holocene or Recent Epoch in which we live (officially documented beginning at 10,000 years ago). Although paleobotanists at Okanagan University College recognize an initial tundra and steppe cool interval at about this time (there were probably still large buried blocks of ice in the lakes of the valley), they record a passage to warm dry conditions for at least the next four thousand years. Summer temperatures are thought to have been warmer than present, but winters were more severe. Summer drought conditions are indicated through studies of saline lakes affected the Okanagan (Heinrichs, *et al*, 1999). They refer to this interval as Xerothermic. It was likely during this time that the numerous cross valley fans and raised deltas along the lake and valley began to form. Materials in these fans suggest debris torrents were not uncommon and stream flow somewhat substantially elevated compared to today. Examples of these include Fortune Creek fan in the north, Scotty and Mill Creek fans in Lake Country, Rutland fan, Bellevue fan, Mission and Mill Creek fans at Kelowna, Ellis, Penticton and Shingle Creek fans at Penticton and similar fans at Vaseux Lake. These fans influenced and deranged all previous drainage on the valley floor. Similarly, a number of deltas formed along Okanagan Lake, at Fintry, Bear Creek, and Trout Creek, for examples. These deltas are now raised, likely due to rebound after glacial ice disappeared.

Forests became established in this period although more open than present, and grasslands were more extensive than today. Fires maintained the open landscape balance.

Middle Holocene: The next clearly recognized interval spans a time period from 8000 to 4000 years ago. It is referred to as the Middle Holocene by geologists and as the Mesothermic by paleobotanists. It is roughly dated by a cataclysmic eruption of Mount Mazama, now Crater Lake in Oregon, approximately 7600 years ago (5700BC). The Mazama ash is most concentrated in Washington, Oregon and southern British Columbia, but minute shards of the tephra have been obtained from as far away as the Greenland Ice Sheet (Zdanowicz, *et al*, 1999). This period marks the transition from hot dry summers

and severe winters to a climate not unlike what we have today, but perhaps somewhat cooler. To begin with open forest was most common in the uplands and grassland with antelope brush common in the valley apart from riparian cottonwood and related vegetation along streams. As moist conditions increased, forests expanded down slopes, and cooler conditions are recorded by a number of minor cirque and valley glacier advances six to seven thousand years ago during an early Neoglacial interval.

Late Holocene: During the last four thousand years the overall climate for the Okanagan Valley has changed little according to most paleobotanic experts. However, this is a period that includes an interval known as the Neoglacial, and witnessed the advance of several groups of alpine glaciers scattered throughout the Cordillera, starting about 3000 years ago to about 1000 years ago. Some of these advances include the Tiedmann Glacier and the Battle Mountain advance, for examples. It is logical to presume that the climate did change towards the cooler end during this period. Alley (1976) suggests these glacial fluctuations coincided with moister conditions in the bog chronology of Kelowna.

A slightly warmer and less moist interval is presumed to have occurred between the Neoglacial and the well documented Little Ice Age of the 18<sup>th</sup> Century. The historic Medieval Warm period happens to fall within part of this interval. Numerous recent dendrochronology studies for the last six hundred years, the period in which there is a high confidence level, also reflect conditions leading up to the Little Ice Age.

This Century

A somewhat different story has emerged for the last 100 years. Since the Little Ice Age, ending about 1900, there has been a gradual rise in average temperature of at least one degree Celsius to the present time in the Okanagan. All recent dendrochronology data and detailed climate records, one as close as Summerland (Figure--), support this trend, and some tree ring data indicate a slight acceleration starting at about 1950 (Figure--). Many experts have cited a greenhouse effect to at least part of this trend, and that it has anthropogenic roots. This is a controversial issue with opponents arguing that it could be a natural recovery from the Little Ice Age and/or a normal solar fluctuation. Perhaps it is a bit of everything, but paleobotanic evidence, which seems to be in abundance currently, does not record any exactly similar trends, apart from what had to be a major prolonged climate change that melted the Fraser Glacier. Average stream flow in some unlogged watersheds in the Okanagan suggest that precipitation, and runoff, has decreased slightly over the same general period.

LUNCH STOP: HILLSIDE WINERY

#### STOP FOUR: FRED RITCHIE STRANDBLINE

The Fred Ritchie strandline is a beach sand deposit formed at the maximum level of Glacial Lake Penticton, approximately 115 meters or 377 feet above the present level of Lake Okanagan. It is located near Nature Trust property north of the village center of Naramata. It is named here for Fred since without his guidance, the author would not know about it.

This beach deposit is one of very few in the Okanagan. Most seem to have been preserved in protected “coves” formed by adjacent bedrock hills. Deposits of Glacial Lake Penticton are never found above these high level beaches, therefore it is inferred that they represent the highest level of the lake. It is not known how long the lake persisted at this level, but as will be observed on the way to Stop Six, varved sediment occurs in the lake deposits, and these form on a yearly basis, one varve per year (see Plate 15 in the “book”, and count them yourself). The author has counted 65 varves in one section on KLO Road in Kelowna, and there appears to be over a hundred varves in a section on Vernon Creek that Nasmith illustrated. So the lake may have persisted for at least a hundred years, lots of time to form a well-sorted storm beach as demonstrated by this outcrop. However, the lake may have existed for much longer.

These beaches have a profound archeologic importance. If there was early migration into the Okanagan, 13,000 years ago, the most prospective place to search is near these beaches. Certainly there is a concentration of artifacts dating to perhaps as old as 4000 years, and several habitation sites adjacent to the beaches, but little exploration has been attempted. Many discoveries await future scientists. Quite a few pictographs or rock paintings and fire pits are known from this particular locality.

#### .STOP FIVE: MILL BAY VIA GULCH ROAD

Road cuts along Gulch Road reveal structures and features that allow further elucidation of the geomorphic changes that affected the basin of Glacial Lake Penticton. Normally in glacial lake deposits bedding planes are horizontal. Numerous outcrops along the road display inclined bedding and even displaced bedding (faults). Fractures and joints are plainly visible. The entire section appears to have been quite strongly disturbed.

There are two obvious potential causes of such disturbance. One is that these structures are tectonic in origin, and the result, for example, of tectonic disturbance caused by a large magnitude earthquake. It is well known that even in the last seventy years the Okanagan has suffered quite a few earthquakes, the largest centred northwest of Vernon at magnitude 4.5 Richter in 1936. Perhaps there has been a bigger one?

The other obvious potential cause is that the sediment became disturbed when underlying glacial ice melted, thus removing support, collapsing, and forming what is seen today. It is well known that many of the sediments comprising Glacial Lake Penticton were in fact deposited contemporaneously with remnant stagnant glacial ice

that persisted perhaps for hundreds of years in the lake basin. At one spot along the road, varved clay and silt are apparent

Joints, fractures and contorted bedding, to one degree or another, are common structures in Glacial Lake Penticton silt, but there has been neither an adequate study of these features, nor is there a consensus of a definitive origin.

#### STOP SIX: MILL BAY SILT BLUFF

The Mill Bay silt bluffs display typical features of the bulk of the sediments forming Glacial Lake Penticton sediments in this part of the valley. Horizontal to undulating bedding is visible, prominent fractures can be seen, and the peculiar ability of the silt to exist in near vertical walls is apparent.

All is not as calm as it appears, however. Numerous large silt flows and block failures have affected the picturesque bluffs of this part of the Okanagan. A good example of a failure is visible at this location (can you spot it?). Also, severe erosion of slopes has resulted from the addition of water, natural or otherwise, and other types of landslides have occurred. Finally, the silt deposits are susceptible in some places to the effects of “piping”. This is a peculiar form of erosion that is fundamentally caused by groundwater mobilising individual silt particles along fractures and joints (open spaces), accelerating to such a degree that cavities are formed, and in extreme cases erosion reaches to the surface with the formation of sinkholes and deep gullies. Few occur on the eastern side of the lake to the author’s knowledge, but there used to be plenty in the area of Sage Mesa, the last STOP.

#### STOP SEVEN: NARAMATA CREEK VALLEY, FIREHALL LOT

The object of this Stop is to compare the meagre erosion in this portion of the valley to that in the deep canyon of Naramata Creek several kilometers up stream. The tremendous erosion that carved the canyon had virtually no comparable affect on this portion of the stream. This proves that there had to be ice above on which all the debris from canyon erosion was deposited.

When Glacial Lake Penticton drained about 13,000 years ago, it did so with catastrophic fury in at least two stages. Released waters helped scour a great scabland in the State of Washington, and untold amounts of silt were removed from the bed of the lake and from flanking shorelines. All major gullies at low elevation were also formed at that time. In terms of our daily experience, driving or walking up and down the valley, this event has to be the most dramatic, because this event formed the spectacular silt bluffs and orchard-mantled terraces for which the Okanagan is famous.

The principal geomorphic process after the glacial lake drained was the development of alluvial fans and deltas, some stretching right across the valley as

exemplified by Ellison, Penticton and Shingle Creeks. The City of Penticton now straddles this landform, however, till is close to the surface in places so it is likely that the core of the city is likely formed by a recessional moraine, eroded during the release of the glacial lake

## STOP EIGHT: SAGE MESA SINKHOLES

Unmodified sink holes that are easily accessible do not exist in the Sage Mesa area of Penticton at the present time. Several existed at the northern end of Sage Mesa Road up until quite recently. Unfortunately for this trip, they have been infilled. However, their character can be inferred by viewing outcrops of the silt along a scenic drive through the subdivision.

The Sage Mesa sinkhole terrain has been the subject of many studies, some in-depth, and some short and specific, primarily by the consulting engineering industry. The concern is of great interest to local planning agencies since sinkhole terrain offers limited conditions or even dubious opportunities for construction of single family residences in most cases. Basically the problem is that if construction is on or near a former sinkhole, any addition of water in the vicinity may initiate failure of foundation material. Also, at times, land owners attempt to “reclaim” sinkholes, filling them with material which of course eventually disappears down the hole. Also, these features are hazards to anyone out walking, especially if they have been filled in with loose material.

Sinkhole erosion is one of the more unusual geomorphic processes in the south Okanagan, but also affects the similar Thompson silt near Barnhartville. Although, again, no one knows for sure when sinkhole development actually started, or whether or not there were distinct periods of accelerated activity, perhaps tied to one or more of the many climatic changes in the valley, or whether the phenomenon was largely due to hydraulic action when the glacial lake suddenly drained. Perhaps a gopher dug the first hole! That’s the burden of the scientist...you no sooner get an answer for one thing and then you are faced with the riddle of another. Fun! Anyway, that is the story on the main geomorphic events in the south Okanagan during the last 15,000 years.

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