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Abstract

The sedimentology of the Tertiary White Lake Formation of the Okanagan Valley of southern British Columbia has never been seriously studied, and is currently poorly-understood. For this preliminary study, three long outcrops were described in detail to provide an initial view of these strata. Aside from minor hydrocarbon and coal exploration in the 20th C, little is known of the resource potential or groundwater potential, and these strata must be viewed as frontier prospects. However, the occurrences are located in an area of quickly increasing population and water use, near important markets. The currently fault-bounded Okanagan Basin is narrow and elongate, geologically complex and the potential is poorly constrained. A relatively high regional geothermal gradient, abundant sandstone/conglomerate potential reservoir/aquifer facies and the location near populous markets suggest significant potential. Facies observed in outcrop include 1) volcanic breccia debris flow conglomerate, 2) high energy braided fluvial conglomerate to pebbly sandstone, 3) fluvial sandstone, 4) pedogenically-altered overbank sandy siltstone, 5) pond/marsh carbonaceous mudstone, and 6) lahar sandflow deposits. Facies 2 and 3 represent potential hydrocarbon reservoir/groundwater aquifer facies. Further progress in analysis and understanding will require concerted geological and geophysical field work, and several stratigraphic test wells.

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Introduction

Within the interior of British Columbia are a number of fault-bounded basins, first identified by G.M. Dawson (1879), which contain nonmarine sedimentary and volcanic rocks of Tertiary age, and some coal. These basins are generally geographically small, geologically complex, represent only erosional remnants of their original extent, and have received little detailed study. Their conventional petroleum, coal-bed methane, uranium and aquifer potential are currently very poorly constrained, but additional examination and exploration may lead the way to new concepts and exploitation models (Hamblin, 2008). In addition, in a region of increasing wine production, the concept of "terroir", and its effect on wine quality (see Taylor et al., 2002), may make knowledge of the complex bedrock characteristics more important to that endeavour in future.

Most of the basins formed as extensional grabens controlled by north- or northwest-trending master faults during a phase of regional right-lateral shear as the Pacific Plate moved northward past the Cordillera. Whereas Tertiary volcanic sequences are important in many of these basins, sedimentary fill sequences are of early Eocene-early Oligocene age and can be quite thick (hundreds to thousands of metres). A variety of nonmarine lithologies, primarily clastic and volcaniclastic, are present. The White Lake Formation is a clastic succession present in several erosionally-limited outcrop areas in the Okanagan Valley. This valley is 250 km long (from 48° to 51° N), lying along the north-south-trending Okanagan Valley fault ("shear zone"), flanked to the east by the Okanagan Highlands/Omineca Crystalline Belt (1800 m a.s.l.), and to the west by the Thompson Plateau/Intermontane Belt (1300 m a.s.l.) (Eyles et al., 1991) (Fig. 1). Okanagan Lake (surface elevation about 338 m a.s.l.) and thick Quaternary deposits occupy a glacially-over-deepened and structurally-controlled bedrock basin, with the bedrock floor about 650 m below sea level (Eyles et al., 1991) (Fig. 1).

Outcrops Studied

Strata of the White Lake Formation were studied and described in detail in three long surface outcrops in the Okanagan Valley: one from each of the three main outcrop areas (Fig. 2). The roadcut on Highway 97 at the Glenrosa Road interchange near Kelowna (Fig. 3) is 164 m thick. The roadcut on Highway 97 at Sumac Ridge Winery in Summerland (Fig. 4) is 178 m thick. The roadcut along White Lake Road near the Dominion Astrophysical Observatory southwest of Okanagan Falls (Fig. 5) is 225 m thick. These outcrops present a wide geographic extent and reasonable variety of depositional facies with which to suggest a few preliminary interpretations. Future work may add more examples.

Regional Geological Setting

Prior to the evolution of the present Cordillera, the western Canadian continental margin was a westward-facing passive margin and the site of miogeoclinal accumulation of primarily Late Paleozoic carbonates and clastics (Porter et al., 1982; Stockmal et al., 1993). During the Jurassic-Paleocene, the Pacific Plate continuously subducted beneath Ancestral North America, periodically suturing a tectonic collage of island arcs and exotic allocthonous terranes onto the craton in the process (Porter et al., 1982; Monger, 1989; Gabrielse and Yorath, 1991; Roed et al., 1995). This was a period of tectonic accretion, thrust compression, telescoping to the east, and uplift and erosion, when little sediment accumulation occurred. Consequently, the exotic terranes, the telescoped miogeocline, and Mesozoic intrusions and volcanics represent the bulk of the Cordilleran Belt of British Columbia, and constitute the deformed basement rocks to the Tertiary basins. However, during Cenozoic time, the gravitationally-unstable crustal welt mass spread laterally down to the west along the previous weaknesses (Okanagan Fault, low-angle normal fault and brittle shear zone) originally imparted by thrusting, reversing the former compression and resulting in crustal extension, accompanied by magmatism, intermediate volcanism and nonmarine sedimentation (Coney and Harms, 1984; Parrish et al., 1988; Roed et al., 1995; Constenius, 1996).

The beginning of extension (~52 Ma; Middle Eocene) was roughly coincident with changes in plate motion in the northeast Pacific, reducing the horizontal compressive stress, and allowing the warm, tectonically-overthickened crust to collapse in extensional tectonic failure, superimposing widespread Eocene extension (i.e. “unthrusting”) on the pre-existing Mesozoic compressional features (Templeman-Kluit and Parkinson, 1986; Parrish, et al., 1988; Constenius, 1996). Extensional basin formation (along several separate trends) was partly concurrent with formation of metamorphic core complexes and regional magmatism, part of a manifestation of late Paleogene gravitational collapse and breakup of the entire Cordillera (Constenius, 1996). The end of the main period of extension (~42 Ma; Late Eocene) coincided in time with the major bend in the Hawaiian-Emperor seamount chain (Parrish, et al., 1988).

The record of the Tertiary volcanism and sedimentation is fragmentary, confined to the small, preserved fault-bounded basins of the central and eastern Cordillera (Porter et al., 1982; Parrish et al., 1988). The rapidly extruded volcanics are dated as 52 + 2 Ma, and paleopoles suggest this part of the Cordillera was in its present position and orientation relative to cratonic North America at this time (Bardoux and Irving, 1989). The nature of small and isolated, strike-slip/rapid subsidence basins is that many characteristics are unique to that basin, but some features are common to all. Most of these fault-controlled basins enclose successions of primarily Eocene-Oligocene age, which are thick compared to the size of the basin due to rapid subsidence rates, and consist of nonmarine, primarily fluvial/lacustrine sequences of conglomerate, sandstone, mudstone and coal, with variable associated volcanics (Hamblin, 2008). Both local facies changes and complex folding and faulting are common, although deformation is mild compared to that of the underlying basement rocks (Bardoux, 1985). The presence of contemporaneous volcanism suggests relatively high geothermal gradients. The thick successions are regionally overlain by flat-lying Miocene Plateau Basalts, which cover extensive portions of the interior of British Columbia, obscuring underlying stratigraphy and structure. The Eocene was a period of general climatic warmth compared to today (with little or no glacial ice), when crocodilians and coniferous forests thrived at 75° N paleolatitude, despite the winter darkness of these high latitudes.

Therefore, in the eastern Intermontane Belt/western Omineca Belt region (Okanagan Valley), the general geological setting is one of a basement of Late Paleozoic/Mesozoic metavolcanics and metasediments on the west side of the Okanagan Valley (Thompson Plateau), and of a basement of metamorphic/plutonic complexes (Shuswap/Okanagan Highlands) on the east side of the Valley, separated by a low-angle shear zone (Okanagan Fault) which dips westward under the lake (Bardoux, 1985; Templeman-Kluit and Parkinson, 1986; Parrish et al., 1988; Eyles et al., 1991). A series of now-disconnected small sedimentary basins include, from south to north: White Lake, Summerland, Kelowna, and Vernon, which may simply represent the erosional remnants of a once-more-continuous depositional system (Church, 1973; Templeman-Kluit and Parkinson, 1986). A general succession, common to all, is evident, consisting of intermediate volcanics (Marron/Marama formations) conformably overlain by coarse and fine clastics of fluvial-lacustrine nature (with minor coal) (White Lake Formation), all unconformably overlain by Miocene Plateau Basalt.

Previous Work

Although a number of workers have studied the tectonic and structural evolution of the Cordillera, few have paid attention to the White Lake Formation itself. Dawson (1879) first noted the presence of Tertiary-aged coal-bearing strata in the valleys of south-central B.C. Camsell (1913) first examined the White Lake Coal Basin for its coal potential, and described a 600 m section along Kearns Creek (near the White Lake roadcut section of this study) of tuffaceous sandstone, shale, conglomerate and thin coal. Bostock (1941) mapped the Tertiary volcanic and sedimentary deposits of the southern Okanagan area and first named the White Lake Formation. Ward (1964) in his BSc thesis, studied the petrography of these same strata in a 600 m, non-vertical core (true thickness estimated as 363 m) drilled near the Observatory, which represented the lower 2/3 of the Formation. This was followed by the PhD study of Church (1973) of the geology of the entire White Lake Basin, particularly the White Lake Formation, wherein he mapped, defined and described the Tertiary volcanic and sedimentary units present. All these studies focussed exclusively on the geology of the outcrop area at the southern end of the valley. Templeman-Kluit (1989) compiled a regional-scale map which depicted White Lake Formation strata as present in two additional areas: Kelowna and Summerland (also noted by Church, 1980). The three outcrops measured for this present study represent all three of these known areas. The publication of Roed et al. (1995), primarily for popular consumption, summarized most of what is known of the geology of the White Lake Formation and other units exposed in the Okanagan Valley.

The White Lake Formation

Camsell (1913) identified a 600 m sedimentary succession unconformably underlain by Tertiary volcanic flows, and bearing minor coals and plant fossils of suggested Oligocene age, in a small synclinal basin around White Lake. He described 1) the lower 1/3 as mostly grey and black shale with minor sandstone and minor coal, 2) the middle 1/3 as grey sandstone with minor shale, and 3) the upper 1/3 as primarily tuffaceous sandstone, coarser to the west and finer to the east, suggesting depositional transport from west to east. Bostock (1941) mapped the Tertiary rocks of the White Lake Basin, named and described the White Lake Formation, and placed this unit in the still-recognized succession of a lower sedimentary Springbrook Formation, medial Marron Formation of intermediate volcanic flows, overlain by the White Lake, which in turn is overlain by another volcanic unit. Church (1982) proposed a new stratigraphic nomenclature for the Tertiary rocks of the Okanagan Valley: the

2500 m thick Penticton Group (ranging 48.4 to 53.1 MA ± 1.8 Ma), resting unconformably on basement and unconformably overlain by Miocene Plateau Basalts. In ascending order, the 6 contained formations are Springbrook (conglomerate and breccia), Marron (andesitic and trachytic flows), Marama (dacitic and andesitic flows), White Lake (fluvial sandstone and lacustrine siltstone with minor volcanics), and Skaha (breccias and fanglomerate) (Church, 1982). None of these publications provided formal definitions or designated type sections for the Penticton Group, or the White Lake Formation.

Much more detailed information on the lithology and petrography of the lower two-thirds of the White Lake Formation was presented by Ward (1964), based on study of a long core drilled in the White Lake Basin. He divided the 363 m of core into an overall fining-upward sequence of lower coarse sandstones and lithic tuffs with minor mudstone overlain by upper black mudstone with minor coarse sandstone and coaly beds.

Based on thin section study, he described the sandstones as light grey, rounded, fine to very coarse grained with graded bedding and a composition consisting of 79% volcanic fragments, 9% carbonate replacements of feldspar, 6% feldspar and traces of chlorite, mudstone clasts and biotite (Ward, 1964). Conglomerates were described as concentrated into horizons, with sub-rounded pebbles up to 2 cm, and consisting of 56% volcanic fragments, 25% carbonaceous matrix, 9% mudstone clasts, 6% sandstone clasts, 4% feldspar and trace biotite (Ward, 1964). Dark to light grey siltstones, present only in the lower half of the core, have the composition 58% volcanic fragments, 16% mudstone clasts, 12% carbonate, 9% feldspar, and 2% biotite (Ward, 1964).

Whereas there are no detailed studies of the White Lake Formation in the more northern (Kelowna and Summerland) outcrop areas, the most comprehensive study of the Tertiary geology of the White Lake Basin, including the White Lake Formation, is that of Church (1973). He identified an eastward-dipping Eocene succession, up to 3600 m thick, resting unconformably on older rocks, and with 5 main subdivisions. In ascending order these are: Springbrook Formation discontinuous basal conglomerate up to 200 m thick; Marron Formation trachytic and andesitic lavas up to 1700 m thick; Marama formation rhyodacitic lavas up to 300 m thick; White Lake Formation sandstones, conglomerates, mudstones and minor volcanics up to 1100 m thick; Skaha Formation slide breccias and conglomerate up to 300 m thick. He described the Eocene?/Oligocene? White Lake sedimentary unit as one of great diversity of lithologies, deposited on the deeply eroded surface of the underlying volcanics, with most sediment derived from those volcanics, and with lenses of pyroclastic rocks throughout (Church, 1973). Sandstones are grey, medium to coarse grained, with abundant volcanic rock fragments set in an argillaceous matrix, thick bedded and with trough cross beds (Church, 1973). Dark grey mudstones are common but poorly exposed, thin bedded, commonly carbonaceous, with abundant plant debris, including *Metasequoia* (Church, 1973). The facies depicted on the measured sections and described in the next paragraphs attest to the range and assortment of lithologies present. According to Church (1973) volcanic rocks are more common in the White Lake Formation toward the east, and toward the top of the unit. The measured section included in the current study from Church's study area, on White Lake Road, represents approximately the lower one-third of the formation.

Many palynological samples collected during field work for this report yielded abundant organic matter, especially pollen, spores, woody detritus and exinous material, but most of it was so badly degraded and poorly preserved that very little was identifiable (White, 2003). A few samples are dateable as Late Paleocene to Eocene, most likely the latter, and Thermal Alteration Index was ranked as 2 to 3 (high immature to mature oil window) (White, 2003).

Facies Observed in Outcrops

Matrix-Supported Pebble to Boulder Conglomerate

Thick units of grey, massive, unbedded, unsorted matrix-supported pebble to boulder conglomerate represent a very prominent and distinctive facies in these outcrops of the White Lake Formation. They form beds up to 11 m thick, and typically have scoured bases, with erosional topography up to 2 m. Subangular to subrounded clasts (primarily volcanic rock fragments), with a wide range of grain sizes up to 100 cm in diameter, float in an unsorted matrix of pebbly coarse sandstone to granulestone (also primarily volcanic rock fragments) with chaotic textures. Sedimentary structures are rare, although a few instances of lenses of sorted sandstone and broad, shallow troughy planes are evident. Large carbonized wood fragments are common, and tree branches, roots and entire broken *in situ* tree stumps occur. There is a tendency for this facies to be most prominent in lower to middle portions of all the exposures of White Lake Formation.

These beds are interpreted to represent massive debris flow/volcanic breccia deposits, associated with volcanic eruptions in the waning stages of the Tertiary volcanic episode represented by the thick, underlying Marron Formation. They are interpreted as the high energy agglomerate flows on the flanks of the volcanic vents and edifices which must have marked the landscape.

Clast-Supported Pebble Conglomerate to Pebbly Coarse Sandstone

The most common facies in the White Lake is thin to thick beds of grey, moderately- to well-sorted, clast-supported, pebbly coarse sandstone to conglomerate. Beds range 20 to 400 cm, typically have scoured bases with modest erosional topography, and fine-upward. They are often capped by finer grained facies in an overall fining-upward succession several metres thick. Subangular to subrounded clasts (primarily volcanic rock fragments, with some resedimented sandstone clasts) up to 30 cm in diameter are set in a matrix of medium to coarse sandstone to granulestone. Trough cross bedding is common, pebble imbrication, horizontal lamination and ripple cross lamination occur, and siltstone rip-ups, wood fragments, roots and tree stumps are present. This facies is well illustrated in the Hwy 97 Sumac Ridge and lower part of the White Lake Rd sections (Figs. 4, 5).

This facies appears to represent water-lain deposition by high-energy, braided fluvial systems, associated with the volcanic vents and structures present in the area. These streams likely reworked the ubiquitous debris flow deposits which were present in the landscape.

Fine to Coarse Sandstone

Grey to greenish grey, fine to coarse grained, well sorted sandstone occurs in erosionally-based beds up to 3 m thick. Many beds have lags of pebbles, large wood fragments and siltstone rip-ups, floating pebbles or lenses of pebbly sandstone. Most beds display some fining-upward, and are associated with, or interbedded with, finer grained facies. Trough cross bedding and ripple cross lamination are common, horizontal lamination and convolute lamination are present, and many beds are penetrated by preserved roots. Several contain large, upright, preserved, *in situ* tree stumps and root systems of *Metasequoia*. There is a tendency for this facies to be more prominent in the middle to upper portions of the exposures of the White Lake Formation.

This facies is interpreted to represent sandy, primarily braided, fluvial deposition through the terrigenous landscape developing in this region as volcanism waned. Most paleocurrent indicators are derived from trough cross bedding in this facies, and suggest predominant flow toward the southern hemisphere.

Sandy Siltstone to Very Fine Sandstone

A common accessory facies comprises greenish grey to grey to buff, moderately sorted, siltstone to fine grained sandstone, typically sandy siltstone to very fine grained sandstone. Most characteristic are the macro-textures: uniform, massive, rubbly, blocky and fractured. Mudstone partings, carbonaceous streaks and thin medium to coarse grained (even pebbly in some sections) sandstone beds or lenses are common. Bed thickness ranges up to 2 m (generally < 1 m), bed boundaries may be sharp or gradational, and beds may fine-upward, coarsen-upward, or show no trend. Wood fragments and roots are typically abundant. This facies is particularly well-illustrated in the White Lake Road section (Fig. 5), but also occur in the other two sections.

These units are interpreted to represent pedogenically-altered fluvial floodplain overbank fine grained deposits, associated with the braided fluvial deposits. The pedogenic features suggest there were significant periods of subaerial exposure and non-deposition on the floodplains of this region.

Carbonaceous Siltstone to Mudstone

Dark grey to black, carbonaceous mudstone, silty mudstone and siltstone occur in beds up to 2 m thick in all three measured sections, but are most common in the White Lake Rd section (Fig. 5). Some are thinly laminated, whereas others appear massive. Coaly streaks, beds and lenses are common, and a few have thin pale grey ash beds preserved. Large wood fragments and roots are common. Many occurrences include thin interbeds of fine to coarse grained sandstone.

These fine grained deposits are interpreted as the result of sedimentation in minor, relatively short-lived marshes and ponds on the subaerial fluvial floodplain.

Massive Tuffaceous Argillaceous Sandstone

In the middle portion of the Hwy 97 Glenrosa Rd section (Fig. 3), several thin to thick beds of pale grey to greenish grey tuffaceous sandstone are evident. These range from 20 to 200 cm thick, have sharp, commonly erosional bases, and are medium to coarse grained sandstone. They are poorly sorted, massive and typically contain floating, angular volcanic clasts up to cobble size. The upper surfaces may be rooted.

These beds are interpreted to represent lahar sandflow deposits of resedimented volcaniclastic material, associated with the debris flow conglomerates on the flanks of volcanic structures.

Resource Potential

Hydrocarbons

Very little modern hydrocarbon exploration has been conducted in the Tertiary Intermontane basins of southern B.C. (Hannigan et al., 1993). In 1930, the Okanagan Oil and Gas Company of Kelowna spudded a well on the south side of Mission Creek (in the vicinity of the current Scenic Canyon Regional Park), drilling through faulted White Lake Formation strata to a depth of about 1000 m into the underlying Monashee Gneiss. Although greeted with much fanfare at the time, no commercial hydrocarbons were ever produced (Cairnes, 1932; Roed et al, 1995).

Because no commercial hydrocarbons have ever been produced from the White Lake, the presence and quality of source and reservoir rocks is somewhat speculative. Coal ranks at surface are relatively low, but are very depth dependant, and general geothermal gradients are relatively high due to the influence of ubiquitous associated volcanic and igneous intrusive activity (Ryan, 2001). Maturation level is likely greater in the deeper, central parts of each outcrop area.

The White Lake Formation includes a thick sedimentary succession of nonmarine mudstones and sandstones. Little is known of the geometries, extents, or reservoir qualities, but the limited size of the preserved basins themselves suggests relatively small traps and reservoirs. Most of the deposits are poorly sorted, or fine grained, but the clast-supported conglomerate to pebbly coarse sandstone facies and the fine to coarse sandstone facies (both representing braided fluvial deposition) may have preserved primary porosity and permeability. There is currently no information, from either surface outcrops or subsurface wells, regarding porosity and permeability. Potential reservoirs in the White

Lake Formation could be trapped by internal structural and stratigraphic discontinuities. In this deformed tectonic setting, structural traps could be expected, both of fault and fold origin In addition, interbedding of multiple facies tracts suggests the possibility for stratigraphic traps associated with the pinchout of fluvial channel sandstone bodies into adjacent lacustrine and floodplain mudstone facies which could provide seals.

For the White Lake Formation of the Okanagan Valley, the simple lack of knowledge and understanding of the geology, and the present lack of known commercial hydrocarbon accumulations, places these basins into a rank frontier category, where informed speculation is necessary. However, the presence of carbonaceous material, thin coal seams and organic-rich mudstone (potential source) facies, fluvial sandstone (potential reservoir) facies, moderate thermal maturity, abundant structural and stratigraphic trap possibilities, and the lack of concerted exploration efforts in the past are all positive factors suggesting that some untapped potential exists. The geographic limits to the outcrop/subcrop areas, lack of regional seals, poor to modest surface outcrops, and the rarity of subsurface data are significant limiting negative factors. However, the general characteristics and location in a near-market area are encouraging, although discovery of large accumulations is less certain.

Coal

Coal seams of the southern Intermontane Basins invite some commercial interest due to coal-bed methane potential. Tertiary coals of southern B.C. tend to have lower rank and higher vitrinite contents than Cretaceous coals, and should generate thermogenic methane at lower temperatures and have better adsorption characteristics (Ryan, 2001). However, seams in the White Lake Formation of Okanagan Valley are too thin and too uncommon to be prospective (Camsell, 1913; Church, 1973).

Minerals

Church (1980) identified a possible uranium play in the thick ash flow deposits of the underlying Marama Formation volcanics in the Summerland outlier. He also suggested the possibility that uranium could be re-mobilized from these strata into secondary deposits hosted in the carbonaceous mudstones and thin coals of the associated White Lake Formation (Church, 1980).

Groundwater

The hydrology of the Okanagan Valley is highly variable in time and space, and due to its geographic location in the rain shadow of the Coast Mountains, is susceptible to drought (Turner et al., 2006). The human population of the Valley is expected to increase from about 300,000 to about 500,000 over the next few decades and the consequent increase in human demand for water, coupled with the original high agricultural demand and the needs of the natural wetlands/lakes/rivers are expected to stress the future water supply in this region (Turner et al., 2006). The economy and culture, both current and historical, have always relied heavily on the most important resource in this region: water. Much of this resource is derived from snowmelt from the Highlands and groundwater flow into the lakes and rivers (Turner et al., 2006). Although unconsolidated Quaternary deposits represent the most important aquifers and have received some study to date, potential bedrock aquifers such as the White Lake Formation may prove to be significant in future, and are as yet poorly-understood.

Terroir

Few vineyards are underlain by White Lake Formation bedrock, but several appear to produce excellent Rieslings, although local climate (in an elongate north-south-oriented valley) and local soils (thick glacially-mixed deposits that may not reflect underlying bedrock) are also clearly important factors in wine provenance (Taylor et al., 2002). Most currently-productive vines have been in the ground for only 20-30 years (Taylor et al., 2002), and so their root systems may not yet be tapping into the bedrock. Some wines may more be closely influenced by, and reflect, the bedrock characteristics in future vintages.

Conclusion

Geological understanding of the Tertiary strata in the intermontane basins of the southern Cordillera, including the White Lake Formation, is low. Concerted collection of basic geological and geophysical field data, including outcrop work, seismic and drilling of a few stratigraphic test holes would greatly improve the potential for modern stratigraphic and structural basin analysis and significantly improve our understanding and assessment of the White Lake Formation and its resource potential. In future, analysis of groundwater potential and vineyard terroir may prove to be the most important bedrock studies.

In particular, analysis of facies, stratigraphic architecture, lateral predictability of reservoir/aquifer geometry, reservoir/aquifer quality, characterization of rocks and thermal history, seismic analysis of structural trends and modelling of basin formation would be most valuable in encouraging much more focussed analysis. Deep stratigraphic tests drilled in each outcrop area would be of vital importance in establishing the three-dimensional geological framework upon which to base hydrocarbon, mineral and groundwater analysis. This could yield a surge in understanding from a region of expanding population and economic impact. Past geological efforts have clearly not fully evaluated the possibilities.

Figure Captions

1. A. Simplified general geological setting of Okanagan Valley (modified from Roed et al., 1995). B. Simplified cross section of Okanagan Valley (symbols as in Figure 2) (modified from Roed et al., 1995).
2. A. Simplified geology of field area, with outcrop areas of White Lake Formation (modified from Taylor et al., 2002). B. Simplified geological column for Okanagan Valley (simplified from Roed et al., 1995).
3. Highway 97/Glenrosa Road measured section.
4. Highway 97/Sumac Ridge measured section.
5. White Lake Road measured section.

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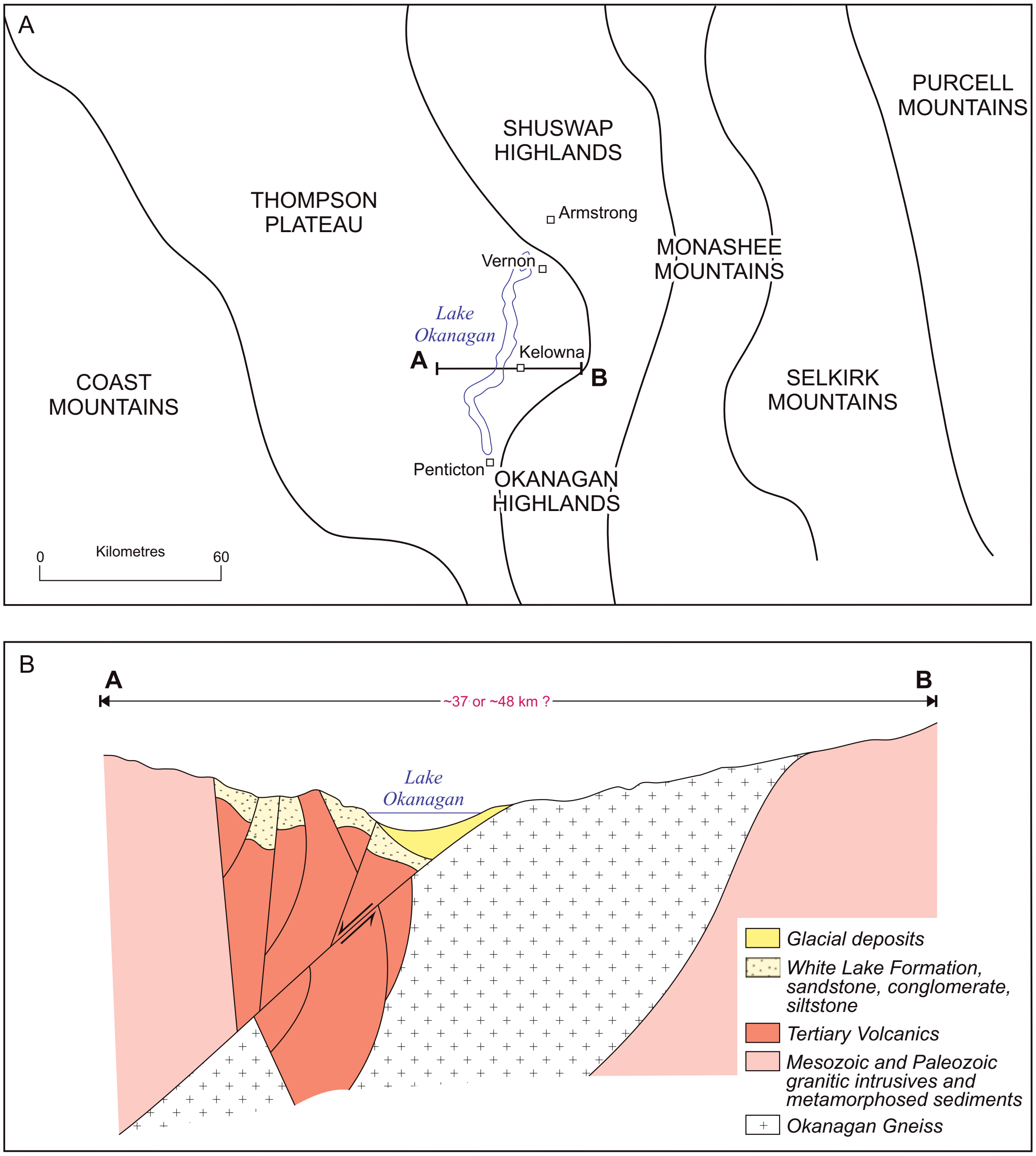

Figure 1. A. Simplified general geological setting of Okanagan Valley (modified from Roed et al., 1995).
B. Simplified cross section of Okanagan Valley (modified from Roed et al., 1995).

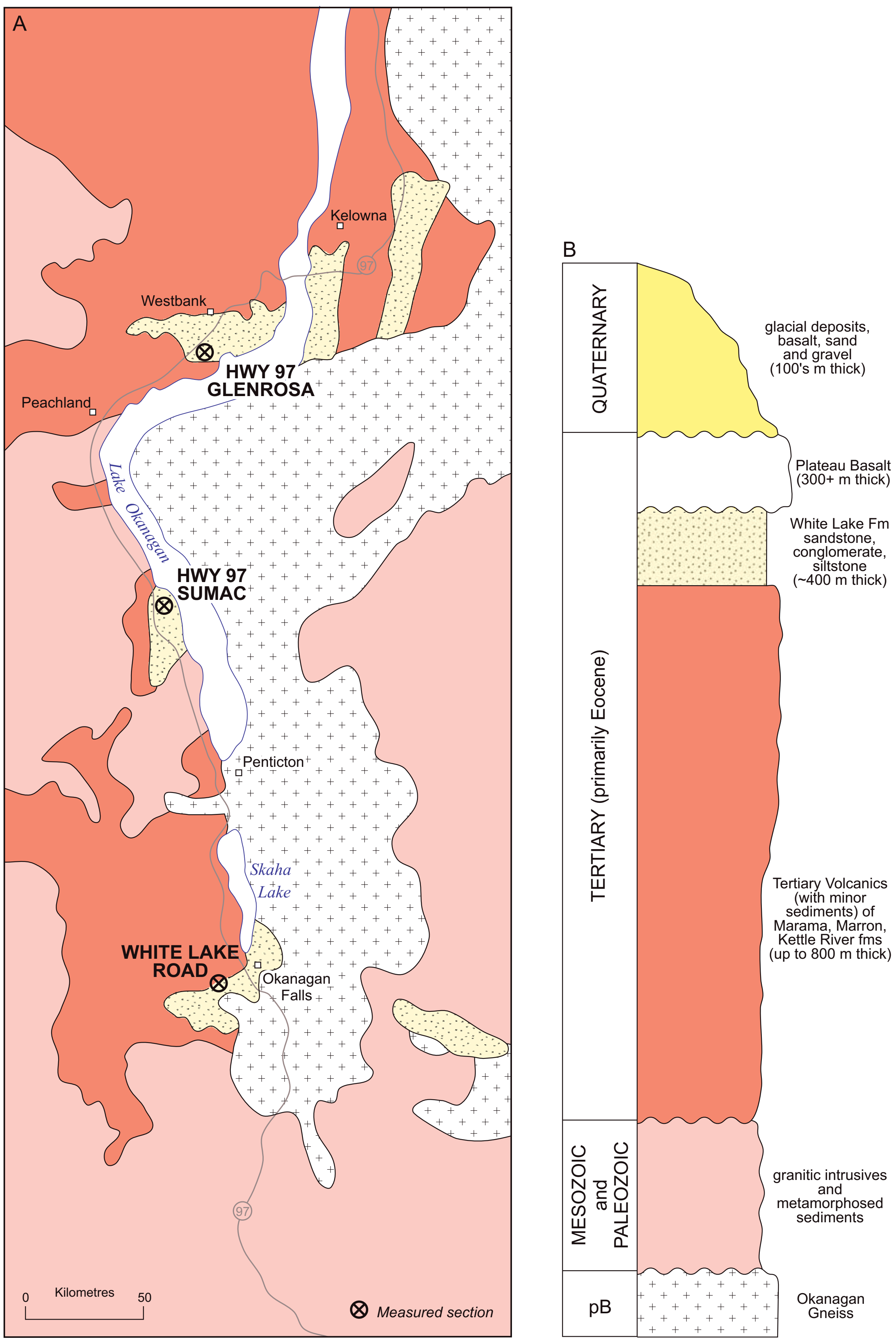

Figure 2. A. Simplified geology of field area, with outcrop areas of White Lake Formation (modified from Taylor et al., 2002).
B. Simplified geological column for Okanagan Valley (simplified from Roed et al., 1995)

Figure 3. Highway 97/Glenrosa Road Section
1.8 km north of Coquihalla Interchange, 1.5 km southwest of Westbank
White Lake Formation (strike 110°, dip 30°N)
82E/13 (Peachland) 095222; 49°49'30"N, 119°38'40"W
top of section: UTM Zone 11: 309 494E, 5 521 802N

Figure 4. Highway 97/Sumac Ridge Section
1.5 km north of Summerland
White Lake Formation (strike 15°, dip 40°SE)
82E/12 (Summerland) 065997; 49°37'20"N, 119°40'30"W
base of section: UTM Zone 11: 306 354E, 5 499 717N; top of section: UTM Zone 11: 306 505E, 5 499 496N

Figure 5. White Lake Road Section
1 km north of Dominion Radio Astrophysical Observatory
White Lake Formation (strike 45°, dip 50°SE)
82E/05 (Penticton) 090673; 49°19'50"N, 119°37'40"W
top of section: UTM Zone 11: 309 002E, 5 467 127N; base of section: UTM Zone 11: 308 832E, 5 467 408N