Middle Eocene sedimentary and volcanic infilling of an evolving supradetachment basin: White Lake Basin, south-central British Columbia

Jason D. McClaughry and David R. Gaylord

Abstract: The middle Eocene White Lake and Skaha formations in the White Lake Basin, British Columbia record the sedimentary and volcanic infilling of a supradetachment basin that developed during the latter stages of Shuswap metamorphic core complex exhumation. The 1.1-km-thick White Lake Formation is characterized by volcanogenic sediment gravity flow, fluvial, and sheetflood facies interbedded with volcanic deposits. Facies relations suggest White Lake strata accumulated on coalesced, west-sloping alluvial fans that drained an active volcanic center. The overlying 0.3-km-thick Skaha Formation records increased tectonism and mass-wasting. Pervasively shattered Skaha avalanche, slide, and sheetflood deposits accumulated on alluvial fans, shed from hanging-wall and footwall sources exposed along the Okanagan Valley fault. Clast compositions of the White Lake and Skaha formations record alluvial and tectonic stripping that locally eliminated hanging-wall blocks. Mylonite clasts in upper Skaha beds imply significant Okanagan Valley fault footwall uplift during the middle Eocene and syntectonic erosion of the Shuswap metamorphic core complex. The syntectonic sedimentary record preserved within the White Lake Basin elucidates the relations and timing between core complex exhumation and extensional tectonism in this region. The White Lake and Skaha formations are the apparent age equivalent of the Klondike Mountain Formation of northern Washington (USA.). White Lake Basin strata, however, are more complexly interstratified, post-depositionally disrupted, and contain a more complete record of core complex unroofing. Variations in the spatial distributions and textural and compositional character of middle Eocene strata in this area underscore the need to exercise care when developing regional-scale sedimentary–tectonic–volcanic models.

Résumé : Les formations de White Lake et de Skaha dans le bassin du lac White, en Colombie-Britannique, témoignent du remplissage sédimentaire et volcanique d'un bassin de supra-détachement qui s'est développé durant les derniers étages de l'exhumation du complexe à noyau métamorphique de Shuswap. La Formation de White Lake, d'une épaisseur de 1,1 km, est caractérisée par des faciès d'écoulement gravitaire, de sédiments volcanogéniques, fluvial et de nappe d'inondation, interstratifiés avec des dépôts volcaniques. Les relations entre les faciès suggèrent que les strates de White Lake se soient accumulées sur des deltas alluvionnaires combinés, à pente vers l'ouest, qui drainaient un centre volcanique actif. La Formation de Skaha, d'une épaisseur de 0,3 km et qui recouvre la Formation de White Lake, enregistre un tectonisme croissant et des mouvements de masse. Des dépôts d'avalanche, de glissement et de nappe d'inondation, complètement brisés, de la Formation de Skaha se sont accumulés sur les deltas alluvionnaires; ils proviennent d'épontes supérieures et inférieures affleurant le long de la faille de la vallée de l'Okanagan. Les compositions des clastes des formations de White Lake et de Skaha témoignent du décapage alluvial et tectonique qui a localement éliminé les blocs de l'éponte supérieure. Des clastes mylonitiques dans les lits supérieurs de la Formation de Skaha impliquent un relèvement significatif de l'éponte inférieure de la faille de la vallée de l'Okanagan au cours de l'Éocène moyen et l'érosion syntectonique du complexe à noyau métamorphique de Shuswap. La séquence sédimentaire syntectonique préservée dans le bassin du lac White jette de la lumière sur les relations entre l'exhumation du complexe à noyau et le tectonisme d'extension dans cette région ainsi que sur la synchronisation de ces événements. Les formations de White Lake et de Skaha seraient d'un âge apparent équivalent à la formation de Klondike Mountain du nord de l'état de Washington (É.-U.). Toutefois, l'interstratification des strates du bassin du lac White est plus complexe; ces strates ont été déformées après leur déposition et elles présentent des évidences plus complètes du retrait du toit du complexe à noyau. Les variations dans les distributions spatiales et les caractéristiques de texture et de composition des strates de l'Éocène moyen dans cette région soulignent le besoin d'agir avec prudence lors du développement de modèles sédimentaires–tectoniques–volcaniques à l'échelle régionale.

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Introduction

Extensional basins that are temporally and spatially associated with metamorphic core complexes often contain informative sedimentary and stratigraphic records of core complex unroofing. The White Lake Basin in south-central British Columbia contains a detailed record of middle Eocene synextensional sedimentation and volcanism that accompanied exhumation of the Shuswap metamorphic core complex, a composite of several, northerly elongate, metamorphic domes partly or entirely bounded by outward-dipping Eocene detachment faults (Brown and Carr 1990; Johnson and Brown 1996). The Shuswap complex is a highly extended region of high- to low-grade metamorphic rocks and middle Eocene volcanic and sedimentary strata that has been the focus of numerous geologic investigations (Church 1973; Fox et al. 1976; Armstrong 1982; Coney and Harms 1984; Templeman-Kluit and Parkinson 1986; Brown and Journeay 1987; Parrish et al. 1988; Fox and Rinehart 1988; Bardoux and Mareschal 1994; Cook 1995). Of these investigations only Church (1973) examined fundamental aspects of the stratigraphy and volcanology of the White Lake Basin, and even then many of the details regarding the interrelations among sedimentation, volcanism, and tectonism have remained obscure. By contrast, detailed sedimentary and stratigraphic investigations of Oligocene–Miocene strata from the USA. southern Cordillera have yielded significant insight into the character, timing, and interrelations among basin formation, infilling, and core complex exhumation in that region (Miller and John 1988; Beratan 1991; Fedo and Miller 1992; Fillmore et al. 1994; Friedman and Burbank 1995; Beratan and Nielson 1996; Fillmore and Walker 1996; Friedman et al. 1996).

The primary purposes of this paper are to (1) determine the depositional history of middle Eocene sedimentary and volcanic strata in the White Lake Basin and (2) use that history as the basis for reconstructing the tectonic evolution of the basin. Infilling of the White Lake Basin proceeded in a manner, consistent with that identified for Oligocene–Miocene supradetachment basins in the southwestern USA. (e.g., Beratan 1991; Fillmore and Walker 1996; Friedman et al. 1996). Detailed sedimentary and stratigraphic analyses supported by revisions to field mapping of Church (1973) indicate that the White Lake and Skaha formations were deposited in an asymmetric half-graben and evolving supradetachment basin during the latter stages of Shuswap complex exhumation. Sedimentary and volcanic strata deposited within this basin accumulated locally on alluvial fans that were influenced by tectonism, volcanism, and the humid-temperate middle Eocene climate. The depositional history presented for the White Lake and Skaha formations is one of only a few such reconstructions that document relations between synextensional basin fill and metamorphic core complex exhumation in this part of the North American Cordillera.

Tectonic setting

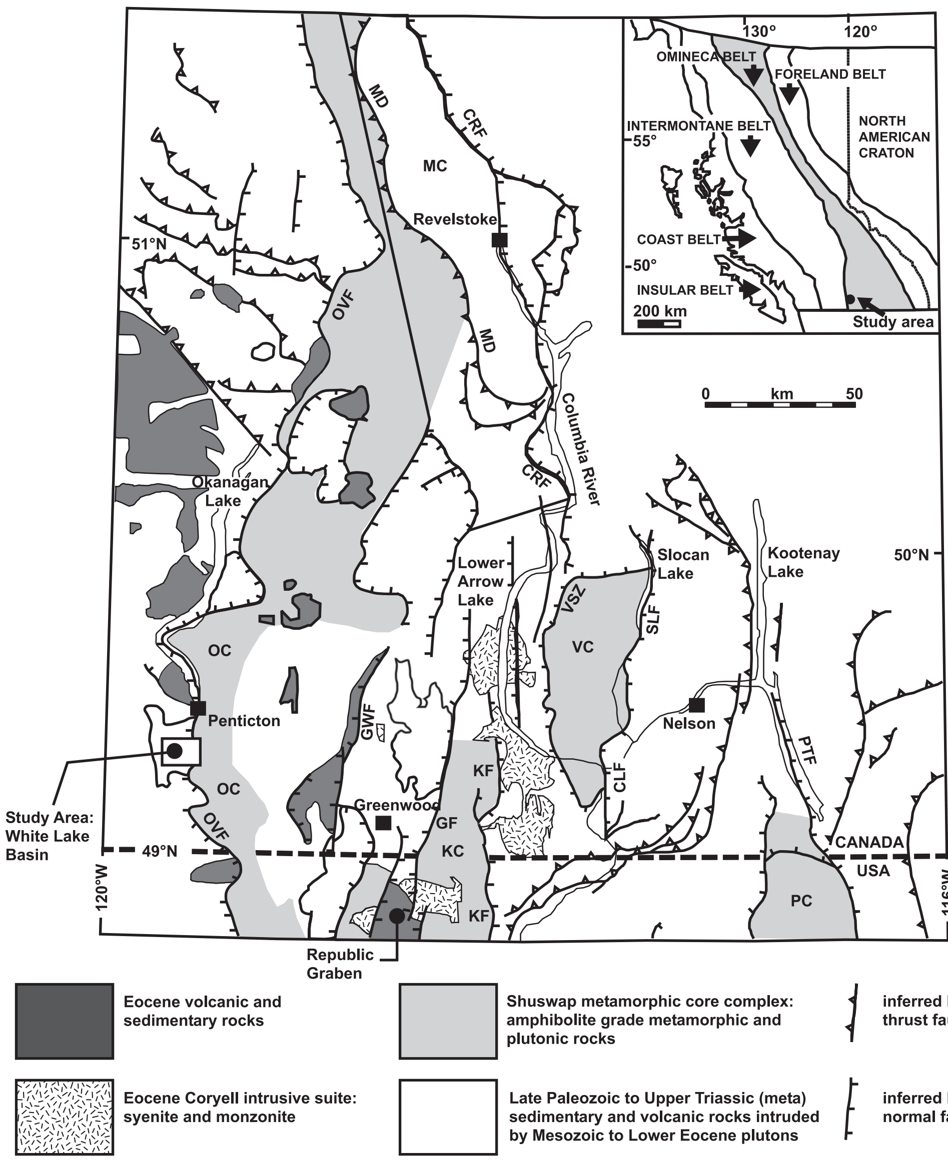
The White Lake Basin is an 11 km by 6 km east–west-trending extensional basin located on the western margin of the Okanagan dome of the Shuswap metamorphic core complex and the Omineca crystalline belt in south-central British Columbia (Fig. 1). Exhumation of mid-crustal metamorphic rocks of the Shuswap complex developed as Early Jurassic to Late Cretaceous – Paleocene compression evolved into rapid (59–48 Ma) late Paleocene to Eocene ESE–WNW-directed extension across the southern Omineca belt (Monger et al. 1982; Parrish et al. 1988; Carr 1992; Bardoux and Mareschal 1994; Wingate and Irving 1994). Extension of the Omineca belt in the southern Canadian Cordillera proceeded along a system of north–south-trending detachment faults and shear zones and has been attributed to a number of mechanisms, including (1) thermal weakening of the crust by magmatic pulses following late Cretaceous compression (Armstrong 1982; Coney and Harms 1984; Sonder et al. 1987), (2) gravitational collapse of overthickened, unstable crustal welts along lithospheric delaminations (Ranalli et al. 1989), (3) transtensional stress generated by oblique and decelerating subduction of the Kula and Farallon plates (Price 1979; Price et al. 1981; Price and Carmichael 1986; Harms and Price 1992), and (4) back-arc spreading (Ewing 1981; Davis and Lewis 1984; Lewis et al. 1988) facilitated by slab-window development and asthenospheric mantle upwellings (Thorkelson and Taylor 1989). Extensional basin formation and arc magmatism in the Pacific Northwest during the middle Eocene coincided with extension and exhumation of the Shuswap metamorphic domal culminations (as used in this paper) or individual metamorphic core complexes cited elsewhere (Holder et al. 1990; Suydam and Gaylord 1997; Gaylord et al. 2001).

The White Lake Basin developed in response to extension along the Okanagan Valley fault system (OVF), a set of shallow, west dipping (15°–20°), approximately north–south-trending, 1–2-km-thick, brittle–ductile detachment faults that accommodated 60–90 km of top-to-the-west displacement during the Eocene (Templeman-Kluit and Parkinson 1986; Parrish et al. 1988; Bardoux and Mareschal 1994; Johnson and Brown 1996) (Fig. 1). Bedrock geology across the OVF is distinctive, with sillimanite-grade, lower plate rocks of the Shuswap complex preserved on the east and greenschist facies to variably undeformed strata of the upper plate exposed on the west (Templeman-Kluit and Parkinson 1986; Templeman-Kluit 1989).

The lower plate (footwall) of the OVF consists of paragneiss and deformed Mesozoic granitic rocks that make up the Shuswap complex (Parrish et al. 1988; Templeman-Kluit 1989) (Fig. 2). Core complex rocks grade upward into a broad shear zone characterized by layers of amphibolite–granodiorite gneiss, fine-grained mylonitic gneiss, augen gneiss, mylonite, and chloritized microbreccia near the top (Templeman-Kluit and Parkinson 1986). Synkinematic indicators within the shear zone and lower plate of the OVF indicate that top-to-the-west motion occurred between 51 ± 1 and 49.9 ± 1.6–2.1 Ma (U–Pb zircon) (Parrish et al. 1988). Truncation of the middle Eocene Coryell syenite (51.7 ± 0.5 Ma) and older rocks of the lower plate by the OVF suggests that initial displacement along these structures began between 51 and 52 Ma (Carr et al. 1987; Parrish et al. 1988). Younger age limits for fault displacement along the OVF are not well established.

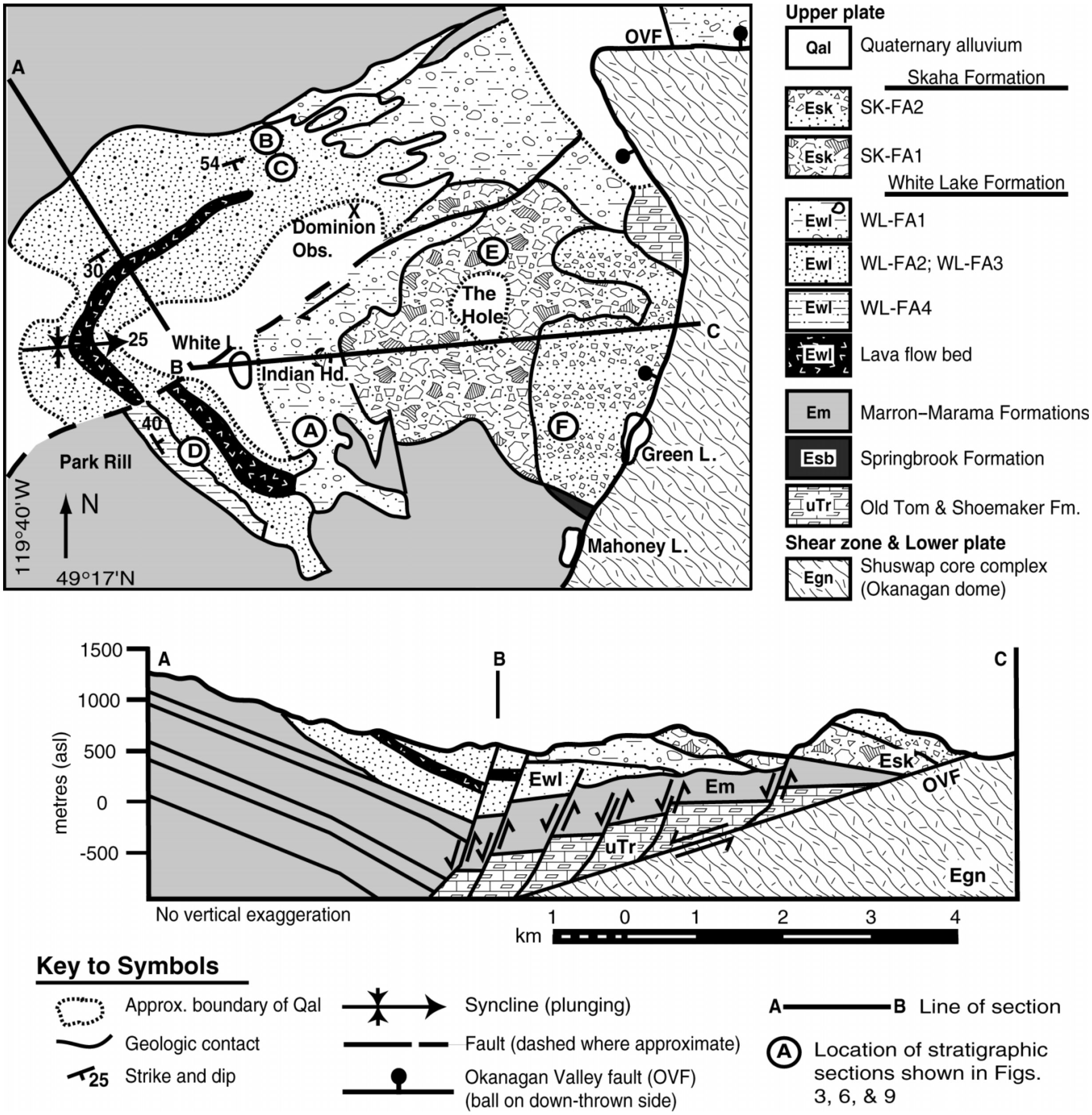
The upper plate (hanging wall) of the OVF in the White Lake Basin consists of synextensional, stratified Tertiary rocks that rest unconfomably upon greenschist facies, late Paleozoic to Upper Triassic metamorphic strata (Shoemaker and Old

Fig. 1. Simplified tectonic map showing the distribution of regional geologic and tectonic elements of the southern Omineca Belt (after Wingate and Irving 1994). Inset shows the relationship of the Omineca belt to other morpho-tectonic belts of the Canadian Cordillera. Domal culminations of the Shuswap metamorphic core complex: Okanagan complex (OC); Monashee complex (MC); Valhalla complex (VC); Kettle complex (KC); Priest River complex (PC). Major tectonic structures: Monashee Decollment (MD); Columbia River Fault (CRF); Okanagan Valley Fault (OVF); Purcell Trench Fault (PTF); Slocan Lake Fault (SLF); Champion Lakes Fault (CLF); Valkyr Shear Zone (VSZ); Kettle River Fault (KF); Granby Fault (GF); and Greenwood Fault (GWF). Teeth on faults indicate the upper plate of faults.



Tom formations) and Mesozoic to Cenozoic granitic rocks (Fig. 2). The Eocene Springbrook and Marron formations are the oldest synextensional deposits in the basin. These strata occur as isolated hanging-wall remnants, scattered across the Okanagan Highlands in southern British Columbia (Templeman-Kluit 1989). The Springbrook Formation is the oldest Tertiary unit in the White Lake Basin; it consists of 80–110 m of polymict breccia that grades eastward to sand-rich conglomerate and sandstone (Rittenhouse-Mitchell 1997). Marron strata unconformably overlie the Springbrook Formation and consist of an ~2-km-thick succession of high-K, calc-alkaline volcanic rocks. Marron Formation lava flow beds are succeeded upward by rhyodacite and rhyolite of the Marama Formation. Cooling ages for volcanic rocks of the Marron and Marama formations range from 48.4 Ma (whole rock) to 53.1 Ma (K/Ar-biotite) (Church 1973, 1985). The middle Eocene White Lake and Skaha formations record the youngest Eocene deposits preserved in the White Lake Basin. Volcanogenic sedimentary and volcanic rocks of the 1.1-km-thick White Lake Formation overlie the Marron and Marama formations with angular unconformity and are exposed as patch-like outliers west of the OVF (e.g., near Penticton, Summerland, and Kelowna) (Church 1985). The 0.3-km-thick Skaha Formation overlies the White Lake Formation with angular unconformity (Church 1973) and consists of pervasively shattered, megaclast-rich breccia and stratified, boulder-

Fig. 2. Generalized geologic map and cross-section (A–B–C) of the White Lake Basin highlighting facies associations distributions of the White Lake and Skaha formations (after Church 1973). asl, above sea level.



rich conglomerate. Exposures of the Skaha Formation are restricted to the White Lake Basin. These upper plate strata have been deformed into an east–west-trending syncline with an east-plunging (25°) hinge-line surface trace. The syncline has been cut by pervasive normal and reverse faults that are mechanically and temporally linked to the OVF shear zone (Fig. 2) (Templeman-Kluit and Parkinson 1986).

Sedimentology

Twenty-five stratigraphic sections ranging in thickness from 8 to 143m were measured within the White Lake and Skaha formations. The general lack of continuous exposure and extensive burial beneath glacial drift precluded bed by bed correlation; however sedimentary, stratigraphic, and map features were sufficiently distinct to reconstruct general facies relations (Fig. 2). Eighteen facies were grouped into six facies associations, each representing different depositional environments (Table 1). Although the original geometries of the White Lake and Skaha formations in the White Lake Basin are obscure, the internal characteristics of deposits have much in common with alluvial fans dominated by sediment gravity flow (e.g., debris flow, rock avalanche, rock slide facies) and tractional fluid flow deposits (e.g., sheetflood, ephemeral stream facies) (Blair and McPherson 1994).

White Lake Formation

The White Lake Formation is characterized by a 1.1-km-thick, coarsening-upward succession of volcanogenic sediment gravity flow, fluvial, and sheetflood deposits and lava

Table 1. Sedimentary facies of the White Lake and Skaha formations, White Lake Basin, B.C.

Facies	Lithofacies character	Sedimentary structures	Interpretation
Gma	Conglomerate, boulders–cobbles, clast-supported poorly sorted, subrounded clasts	Massive to locally stratified, normally graded, weak clast imbrication	Hyperconcentrated flood flow deposits
Gmb	Conglomerate, pebble–sand, clast-supported, moderately sorted, prolate spheroid clasts	Massive to stratified, coarsening-upward beds, clast imbrication, sand lenses, & clast clusters	Fluvial gravel bar deposits
Gms	Conglomerate–breccia, boulders–pebbles, matrix-supported, poorly sorted, subrounded clasts	Massive, coarse-tail inversely & normally graded, slump folds, sandtone lenses	Debris flow deposits
Gba	Breccia, boulders, clast-supported, poorly sorted, angular clasts	Massive, jigsaw & crackle breccia	Rock avalanche deposits
Gbb	Breccia, megablocks up to 600 m, jointed	Crackle breccia, comminuted slip surfaces	Rock slide deposits
St	Sandstone, medium- to coarse-grained	Trough cross-stratification, pebble stringers	Sinuous crested dune deposits
Sp	Sandstone, medium- to coarse-grained	Planar cross-stratification, pebble stringers	Transverse or linguoid bar deposits
Sh	Sandstone, medium- to coarse-grained	Horizontal stratification, pebble stringers	Shallow planar bed flow deposits
Sma	Sandstone, coarse-grained, poorly sorted	Massive to stratified, normally graded	Sediment gravity-flow deposits
Smb	Sandstone, medium- to coarse-grained, moderately sorted, subrounded pebble clasts	Massive to cross-stratified, fining-upward beds, pebble lenses and clusters	Fluvial channel bar deposits
Se	Sandstone, fine- to coarse-grained, moderately sorted, locally pebbly	Massive to horizontal-stratified, scoured lower contacts, fining-upward beds	Minor channels or scours, deposits of waning floods
Ss	Sandstone, fine- to coarse-grained, angular to subrounded pebble to boulder intraclasts	Massive to horizontal-stratified, inversely graded, pebble lenses and clast clusters	Minor channels or scours, deposits of waning floods
Sl	Sandstone, coarse-grained, moderately sorted	Massive to cross-stratified, normally graded	Crevasse splay deposits
Fla	Siltstone, interstratified sandstone	Horizontal & ripple cross-laminations	Sheetflood deposits
Flb	Siltstone, interstratified sandstone and shale	Horizontal & ripple cross-laminations	Overbank deposits
C	Coal	Fissile, convolute beds	Paludal deposits
Ta	Ash, angular lithic and crystal fragments	Massive, convolute beds	Air-fall tephra deposits
Tr	Tuffaceous siltstone–shale	Horizontal and ripple cross-laminations	Reworked tephra deposits

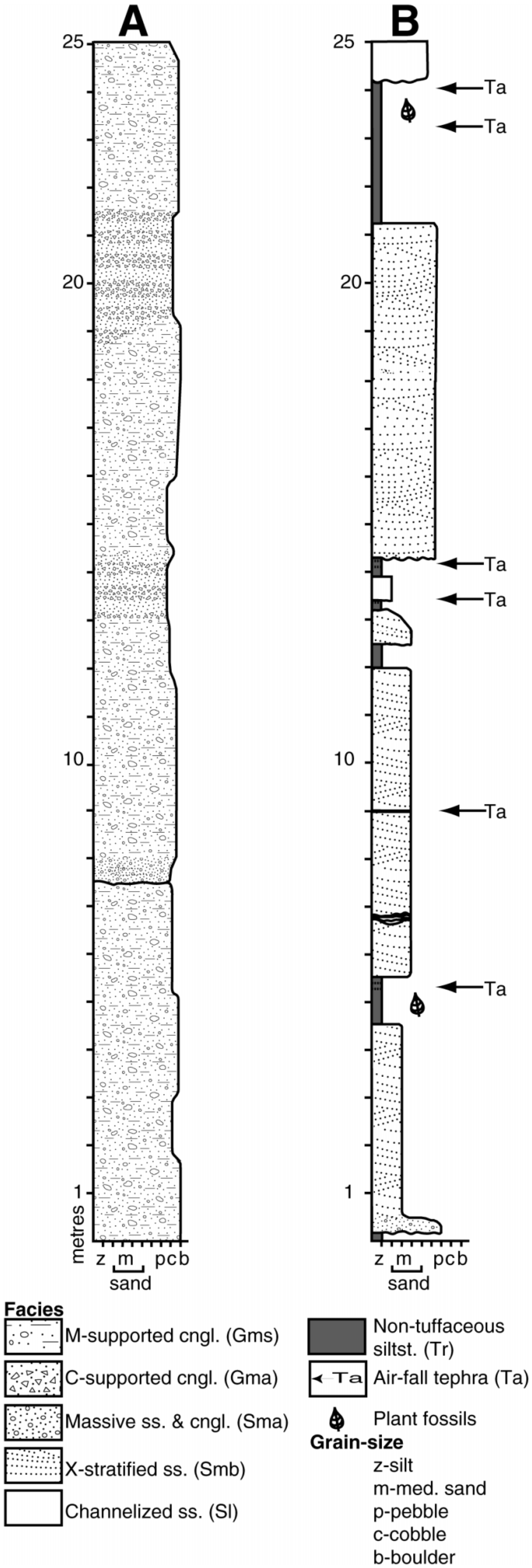


Fig. 3. Representative, partial 25-m-thick columnar stratigraphic sections of the White Lake Formation. (A) Sediment gravity flow-dominated deposits (WL-FA1) (Total section thickness = 128 m), (B) Fluvial channel deposits (WL-FA2) (Total section thickness = 143 m). Locations of stratigraphic sections are shown in Fig. 2. cngl., conglomerate; ss, sandstone; siltst., siltstone; C-, clast-; M-, matrix-; X-, cross-.

beds that accumulated during an active volcanic episode. Strata of the White Lake Formation were initially named and described by Bostock (1941) and subsequently divided into lower, middle, and upper members by Church (1973). The Lower and Middle members consist of interfingered sedimentary and volcanic deposits; the Upper Member consists mainly of sediment gravity flow deposits, lava beds, and tuff. Four sedimentary facies associations are recognized in the White Lake Formation: (1) sediment gravity flow-dominated deposits (WL-FA1), (2) fluvial channel deposits (WL-FA2), (3) fluvial overbank and paludal deposits (WL-FA3), and (4) sheetflood deposits (WL-FA4) (Fig. 2).

White Lake sedimentary clasts consist of abundant rhyodacite, hypocrystalline andesite, and anorthoclase rhomb porphyries, derived from the Marron and Marama formations, and lower greenschist-facies metachert derived from the Shoemaker Formation. Minor amounts of detrital quartz and granite are also present. Stratigraphically, the lower half of White Lake Formation is dominated by rhyodacite clasts derived from the Marama Formation. Clast composition in the upper half of the White Lake Formation consists mostly of hypocrystalline andesite and anorthoclase rhomb porphyry, reflecting deep erosion into the oldest units of the Marron Formation. Incision into the oldest units of the Marron Formation, implied by drastic thickness changes in Marron and Marama rocks across the Dominion Observatory fault, may indicate significant topographic relief during deposition of the White Lake Formation, relief likely linked to normal faulting (Fig. 2).

White Lake facies association 1 (WL-FA1) — sediment gravity flow-dominated deposits

Description

WL-FA1 consists primarily of single- and multistory depositional units of matrix-supported breccia and conglomerate (Gms), with subordinate clast-supported conglomerate (Gma), and clast-supported breccia (Gba) facies (Fig. 3A). Sedimentary deposits are interstratified with relatively thin (<16-m-thick) massive, high-K, calc-alkaline latite to trachydacite lava flow beds and tuff.

Matrix-supported breccia and conglomerate beds range from 1.5–16-m-thick, contain poorly sorted, angular to subrounded gravel clasts (maximum diameter = 1.5 m) are massive (unstratified), and are ungraded to coarse-tail normally and inversely graded (Fig. 4). Gravel clasts are supported by a fine- to coarse-grained, crystal-lithic sand-rich matrix. Clast-supported conglomerate beds are 1.5–6 m thick and consist of weakly stratified, normally graded breccia and conglomerate in gradational contact with matrix-supported facies. Clast-supported breccia facies consist of pervasively fractured, boulder- and megaclast-rich gravel that forms a single 5–10-m-thick depositional unit near the topographically

Fig. 4. Boulder-rich debris flow deposit in WL-FA1 exposed in the eastern White Lake Basin.

prominent Indian Head point (Fig. 2). Brecciated gravel clasts (maximum diameter > 2.5 m) are surrounded by a poorly sorted, clay- to sand-sized rock "flour" matrix.

Near the OVF and in bluffs near White Lake, matrix-supported conglomerate beds crop out in multistory, coarse-grained units that are interbedded with facies Gma, Gba, Fla, and lava flow and tuff beds (Figs. 2, 3A). West and north of White Lake, matrix-supported gravel beds crop out as single depositional units intercalated with fluvial deposits of WL-FA2 and WL-FA3; clast-supported conglomerate and breccia are absent. Western, matrix-supported deposits decrease in bed thickness (<3 m) and mean clast size (maximum diameter = 0.6 m) and have a higher percentage of matrix support than eastern outcrops. Intercalated lava flow and tuff beds also decrease in thickness and frequency west of the OVF.

Interpretation

The distribution and character of sedimentary facies and volcanic interbeds indicate that WL-FA1 accumulated in proximal to medial reaches of a sediment gravity flow-dominated alluvial fan complex near an active volcanic center. The massive (unstratified), coarse-tail normally and inversely graded, poorly sorted, and bi-modally distributed nature of the matrix-supported conglomerate (Gms) is compatible with rapid deposition from non-cohesive volcanogenic debris flows (Vallance 2000). Weakly stratified, normally graded, clast-supported conglomerate (Gma) deposits are attributed to deposition from water-rich debris flows and hyper-concentrated flood flows. The gradational relations between the matrix- and clast-supported conglomerate likely reflects the fluctuating stages of debris flow transport and deposition (cf. Nemec and Steel 1984). The pervasively fractured nature and angularity of clasts, jigsaw breccia fabric, and compositional uniformity between matrix and clasts in facies Gba is consistent with deposition from volcanic debris avalanches (Smith and Lowe 1991). Volcaniclastic successions of similar character to WL-FA1 are common to volcanic terranes and have been interpreted as the products of debris flows and debris avalanches (Smith and Lowe 1991; Smith 1991). Textural gradation from the coarse-grained breccia and conglomerate of the eastern basin margin to the finer grained conglomerate of the west-central basin, as well as the decreased frequency of lava and tuff beds west of the OVF are evidence that sedimentary and volcanic rocks were derived from source areas located east of the White Lake Basin. Additionally, the Coryell intrusive suite, exposed on the east near Greenwood, British Columbia has been interpreted as the source feeder to volcanic flow rocks in the White Lake Basin (Fig. 2) (Church 1973; Templeman-Kluit and Parkinson 1986).

White Lake facies association 2 (WL-FA2) — fluvial channel deposits

Description

WL-FA2 consists of clast-supported conglomerate (Gmb), cross-stratified to massive conglomerate and sandstone (Smb), trough cross-stratified sandstone (St), planar cross-stratified sandstone (Sp), and horizontal-stratified sandstone (Sh) facies. Gravel clasts in WL-FA2 are dominantly pebble-sized, well-rounded, prolate spheroids. WL-FA2 deposits are exposed in the west-central basin, interfinger with coarse-grained gravel beds of WL-FA1 to the east, and are interbedded with deposits of WL-FA3 and WL-FA4 to the west (Figs. 2, 3B).

Clast-supported conglomerate beds range from 1–3 m thick, coarsen upward, contain poorly sorted imbricated clasts, and have scour-filled bases. These beds grade laterally and vertically to planar cross-stratified sandstone that locally contains pebble-rich lenses and clast-supported clusters of pebbles. Cross-stratified to massive sandstone beds range from 0.25–7.25 m thick and consist of moderately sorted, medium- to coarse-grained sandstone that generally has scoured lower contacts (Fig. 5A). These scoured contacts are filled by cross-stratified, pebble-rich deposits that contain sand-rich lenses and clast clusters; the basal pebble-rich deposits grade upward to horizontally stratified sandstone that is capped by horizontally laminated to ripple cross-laminated siltstone. Trough cross-strata, planar cross-strata, and horizontal strata consist of 1–3-m-thick, stacked and laterally overlapping beds of locally pebble-rich sandstone. Interstratified silt–clay strata are rare within WL-FA2.

Interpretation

The poorly sorted lithologic character and laterally discontinuous nature of WL-FA2 deposits suggests accumulation of conglomerate and sandstone within ephemeral stream channels in medial to distal regions of alluvial fans. Coarsening upward, clast-supported, well-rounded, gravel-rich facies (Gmb) are interpreted as channel bars that migrated within

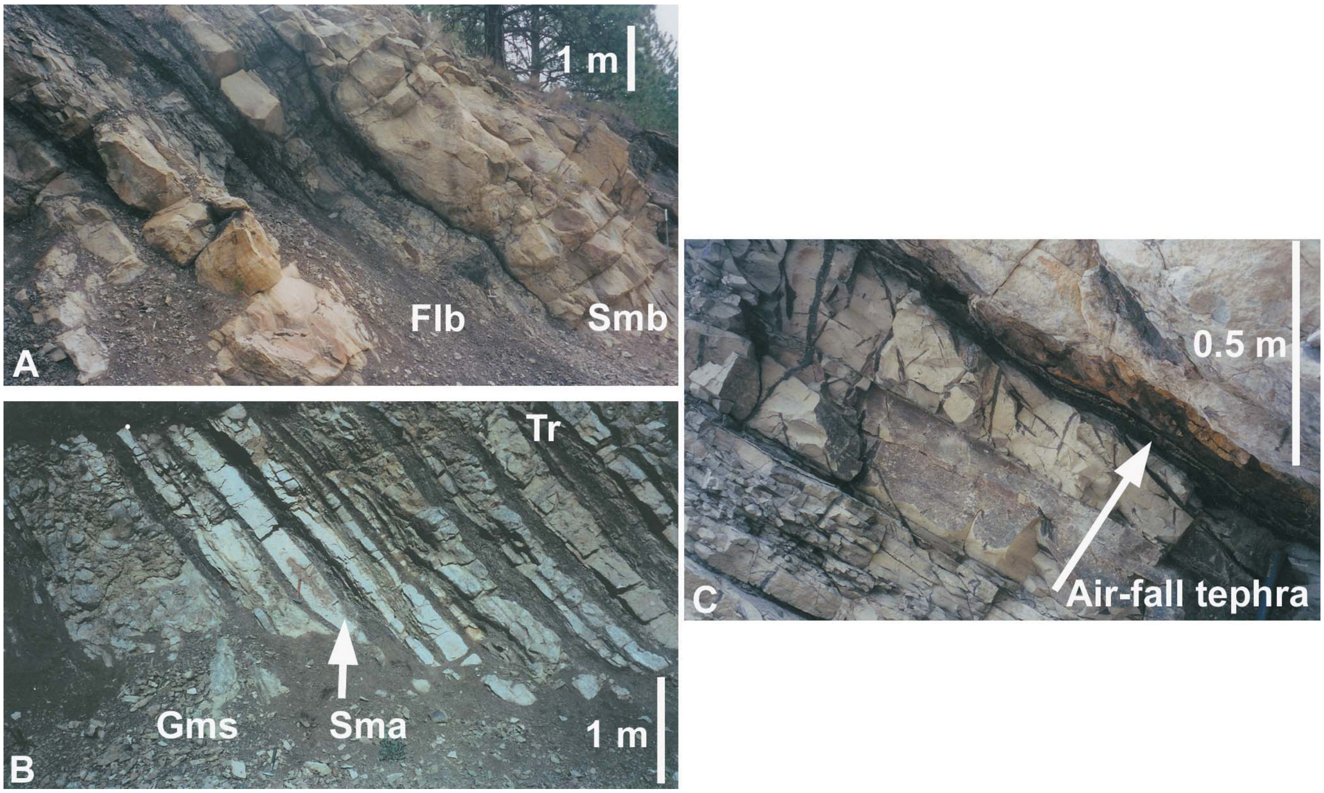


Fig. 5. Fluvial channel (WL-FA2) and overbank (WL-FA3) deposits. (A) Interbedded fluvial channel bar deposits and overbank deposits. (B) Interbedded overbank, sediment gravity flow, and debris flow deposits. (C) Overbank siltstone containing root traces. Siltstone is overlain by 0.10 m of interstratified coal and air-fall tephra. Stratigraphic-up is toward the top, right-hand corner of the photographs.

channels. The coarsening-upward textural trends of these bar deposits, as well as scour-filled bases are evidence for rapidly fluctuating flow strength during deposition (Eriksson and Simpson 1993). Fining-upward, massive and cross-stratified sandstone beds (Smb) are interpreted as vertical aggradation features within channels. Upward reduction in mean grain-size, dominance of cross-stratification, and capping beds of horizontally stratified sandstone indicate that water levels within channels steadily decreased to the point where upper flow regime conditions prevailed. Such transitions from lower to upper flow regime conditions have been linked elsewhere with deposition during the waning stages of flow or the gradual abandonment of channels during avulsions (Miall 1985). Stacked deposits of trough cross-strata (St), planar cross-strata (Sp), and horizontal strata (Sh) are interpreted as stream channel deposits. Lateral overlapping of distinctly different facies and limited overbank silt-clay beds suggests successive deposition and erosion episodes that arose from flashy, ephemeral discharge in broadly unconfined stream channels (Miall 1985).

White Lake facies association 3 (WL-FA3) — fluvial overbank and paludal deposits

Description

WL-FA3 is only exposed along the White Lake Road and consists of 0.05–10.25-m-thick laterally discontinuous successions of tuffaceous siltstone and shale (Tr) and non-tuffaceous siltstone (Flb) facies that are interbedded with WL-FA1 and WL-FA2 (Figs. 5B, 6C). Siltstone and shale strata contain interstratified <1-m-thick beds of massive, normally graded sandstone and pebble conglomerate (Sma), and cross-stratified, normally graded channelized sandstone facies (Sl). Beds of fissile coal (C) <0.5 m thick and crystal-rich tephra beds (Ta) <0.04 m thick also are intercalated with silt-rich facies in this association (Fig. 5C). Coal and tephra beds are typically interstratified with one another.

Coalified plant macrofossils are common in the siltstone-dominated facies of WL-FA3, while tree stumps and root traces are preserved in growth position (Fig. 5C). The macrofossils preserved in the White Lake Formation are similar to those in the middle Eocene Klondike Mountain Formation in the Republic Graben of northern Washington, USA., indicating a humid-temperate middle Eocene climate (Wolfe and Wehr 1987). Recovered White Lake macrofossils identified by Dr. W. Rember, University of Idaho, Moscow, Idaho are dominated by *Metasequoia* (dawn redwood), with lesser percentages of *Equisitites* (horsetail), *Pinus* (pine), *Platanus* (sycamore), *Bigoniacea dombeyopsis* (bigonia), *Cericidiphyllum* (katsura tree), *Acer* (maple), *Rosacea amelianchier* (serviceberry), *Populus* (poplar), *Alnus* (alder), and *Juglans* (walnut). *Comptonia* sp. is also recognized (Church 1973). Similar assemblages of intermixed hardwoods are identified from disturbed modern settings that are inundated by floods or volcanic activity (Myers 1996).

Interpretation

The wide textural range of WL-FA3 facies, as well as the stratigraphic relation of these facies to WL-FA2 channel deposits, is evidence that the association accumulated primar-

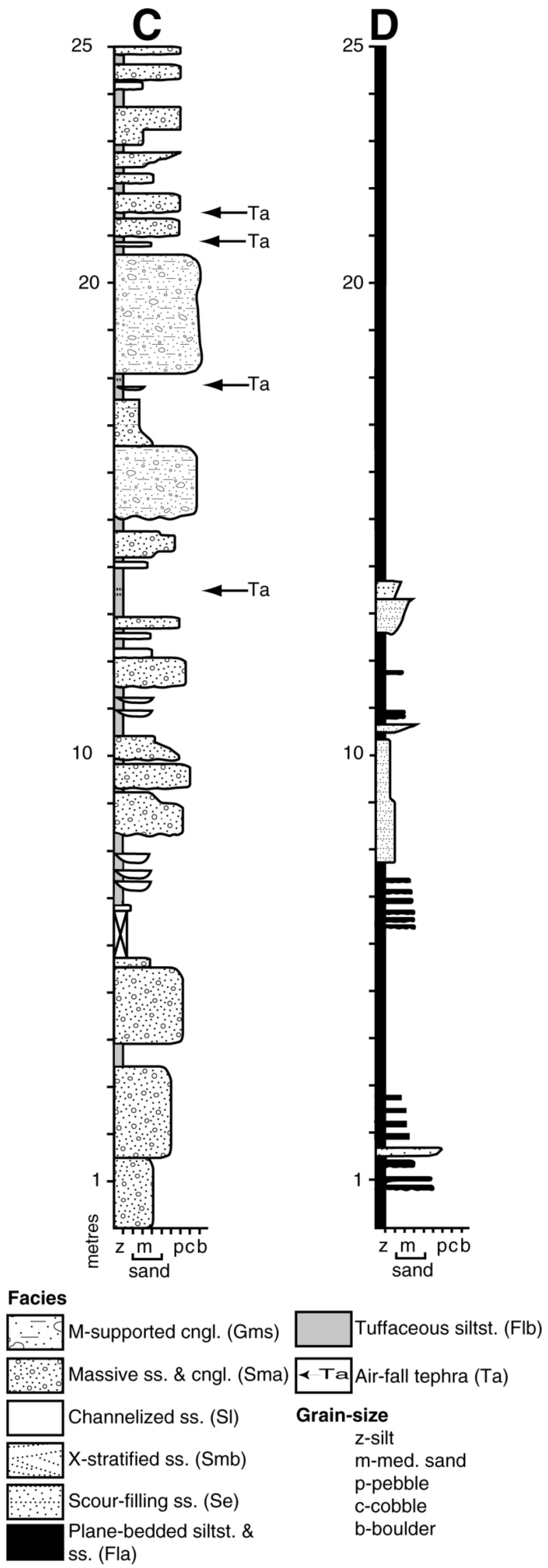


Fig. 6. Representative, partial 25-m-thick columnar stratigraphic sections of the White Lake Formation. (C) Fluvial overbank and paludal deposits (WL-FA3) (total section thickness = 143 m), (D) Sheetflood deposits (WL-FA4) (total section thickness = 32 m). Locations of stratigraphic sections are shown in Fig. 2. Abbreviations as in Fig. 3.

ily in overbank and paludal settings. Sedimentary deposits accumulated as sediment-charged stream flows (Tr, Flb), crevasse splays (Sl), and sediment gravity flows (Sma) deposited their loads during and after floods. Floral macrofossils, root traces, coal beds, and air-fall tephra preserved within this association indicate that much of the overbank was swampy and poorly drained. Shaly partings within fine-grained overbank deposits and coal beds are evidence that fine-grained clastic detritus periodically was introduced into these paludal areas. However, vegetation was sufficiently dense and persistent to survive episodic incursions of sediment and tephra. The common association of tephras with coal beds indicates that the tephras were buried relatively rapidly beneath organic matter, a process that promoted their exceptional preservation. The rapidly alternating, interstratified character of fluvial channel (WL-FA2) and overbank and paludal (WL-FA3) deposits indicates repeated episodes of overbank or channel avulsions that muted floodplain relief and helped minimize soil profile development.

White Lake facies association 4 (WL-FA4) — sheetflood deposits

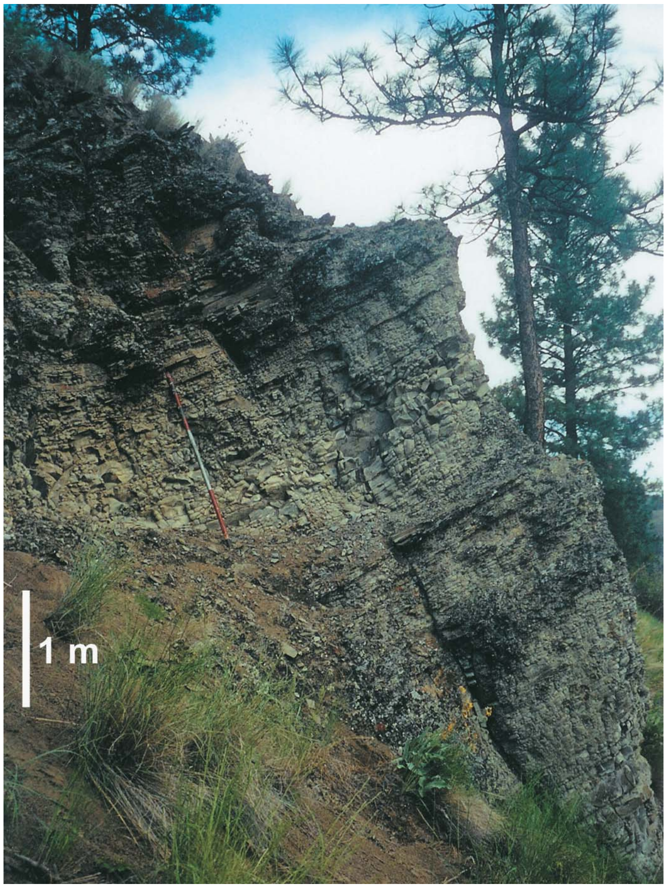
Description

WL-FA4 is exposed in the western White Lake Basin and consists of 0.1–16-m-thick successions of laterally persistent, plane-bedded siltstone (*Fla*) and sandstone (*Se*) facies (Figs. 6D, 7). Siltstone beds range from 0.01–0.09 m thick, are massive (unstratified), ripple cross-laminated, and contain load structures (convolute bedding, flame, ball-and-pillow-structures). These strata are interstratified locally with <0.05-m-thick beds of normally graded pebble conglomerate and sandstone. Facies Se, consisting of 0.05–2.3-m-thick beds of massive and horizontal-laminated sandstone, is subordinate to the siltstone strata within which they are encased. The channel-confined sandstone beds fine upward, contain rip-up clasts, and locally are capped by horizontally laminated to climbing ripple cross-laminated, fine-grained sandstone. Intercalated < 0.02-m-thick horizons of macerated, coalified plant debris often separate individual siltstone strata, but identifiable plant macrofossils, root traces, or evidence of pedogenesis are rare.

Interpretation

The laterally persistent siltstone strata and normally graded beds of pebble conglomerate and sandstone that dominate WL-FA4 largely accumulated during episodic sheetfloods on the distal portions of alluvial fans. Limited channel incision, the absence of lateral textural changes, and the prevalence of plane stratification are evidence for broadly unconfined flows (Blair and McPherson 1994; Blair 2000). The fining-upward, sand-filled channel beds (Se) encased within thicker siltstone beds are interpreted as incised channel fills that accumulated during the waning stages of flow. The thin layers and lenses

Fig. 7. Distinctly bedded sheetflood deposits in WL-FA4 exposed in the western White Lake Basin.



of coal interstratified between individual siltstone beds signal episodes marked by reduced flow strength and (or) ponding. Similar accumulations of organic matter within fluvial and sheetflood deposits elsewhere have been characterized by "pause planes" (Dreyer 1993, p. 347). The paucity of macrofossils, root-traces, or pedogenic features in this association suggests frequent floods may have prevented the development of soil profiles or long-term colonization by plants.

Skaha Formation

The 0.3-km-thick Skaha Formation unconformably overlies the eroded upper surface of the gently tilted White Lake Formation and consists of pervasively shattered, coarse-grained breccia and conglomerate that indicate a time of increased tectonism and mass wasting. Skaha strata were initially examined by Bostock (1941) and formally named and divided into two members by Church (1973). The Lower Member consists of crudely stratified to dominantly unstratified, monolithic breccia. Rocks of the Upper Member consist of massive (unstratified) and stratified, coarse-grained, heterolithic conglomerate (Church 1973). Two facies associations are recognized within the Skaha Formation: (1) rock avalanche and rock slide deposits (SK-FA1), and (2) sheetflood deposits (SK-FA2) (Fig. 2). Volcanic flow rocks are notably rare and limited to a columnar-jointed potassic trachyte lava bed exposed near the base of the Formation.

The bulk of the gravel-sized clasts in the Skaha Formation were derived from Paleozoic – Upper Triassic metamorphic basement (Shoemaker and Old Tom formations) and Mesozoic–Cenozoic granitic sources. A subordinate number of clasts originated from Eocene volcanic sources (Marron and Marama formations), indicating that most of the volcanic cover exposed in the hanging wall of the OVF had been removed by the end of White Lake Formation deposition. SK-FA1 displays a trend in clast composition from (1) basal breccia beds dominated by Paleozoic – Upper Triassic metachert, quartzite, and limestone to (2) middle and upper breccia beds that consist of Mesozoic–Cenozoic biotite-granite and Eocene volcanic clasts. SK-FA2 deposits are strongly heterolithic and consist of a mixture of metamorphic, volcanic, and plutonic igneous clasts. Clasts of deformed quartz–chlorite–mica schist, quartzo-feldspathic gneiss, and mylonitic ± garnet–chlorite–mica schist, apparently derived from shear zone and lower plate rocks of the Shuswap complex, are important constituents near the top of SK-FA2 (Fig. 8). This metamorphic clast assemblage records the breaching and erosion of the OVF shear zone and Shuswap complex carapace.

Skaha facies association 1 (SK-FA1) — rock avalanche and slide deposits

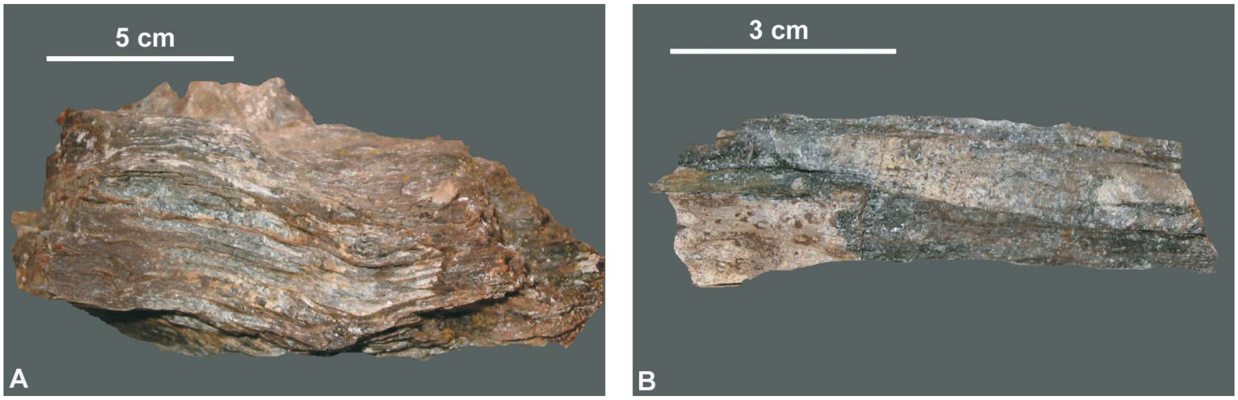
Description

SK-FA1 is characterized by stacked and interfingered beds of clast-supported boulder- and megaclast-rich breccia (Gba) facies, and brecciated megablocks (Gbb) (Fig. 9E). Megabreccia deposits of SK-FA1 are exposed in central to eastern portions of the White Lake Basin in cliff-forming outcrops at Indian Head, Mahoney Lake, and surrounding "The Hole" (Church 1973, fig. 1.2) (Fig. 2). Clast-supported gravel facies consist of a series of amalgamated 1–16.5-m-thick, massive (unstratified), poorly sorted breccia beds (Fig. 10A). Gravel clasts (maximum diameter = 6.5 m) are pervasively shattered, display well-developed crackle and jigsaw breccia, and are surrounded by a poorly sorted, coarse-grained sandstone matrix; the sandstone is the crushed equivalent of the larger, gravel-sized clasts. Brecciated metamorphic, volcanic, and plutonic igneous megablocks (minimum diameter = 10 m) are interstratified with or rest upon clast-supported breccia (Fig. 10B). Megablocks derived from volcanic and plutonic sources are up to 70 m across, whereas those derived from pre-Tertiary metamorphic sources may exceed 500–600 m across. These giant blocks lack discernible matrix and have limited internal brecciation, except for comminuted slip surfaces; relatively undisturbed igneous dikes, joints, and veins can be traced over tens of metres. Shattering and crackle and jigsaw fabrics, most common near the base and periphery of blocks, generally decrease upwards.

Interpretation

The textural and compositional characteristics of SK-FA1 suggest that these deposits accumulated on the steeply sloping surfaces of alluvial fans. Pervasive crackle and jigsaw textures, highly angular clasts, and compositional uniformity between clasts and matrix in clast-supported breccia (Gba) are typical features generated by rock avalanches, rapidly moving, inertial granular flows. These textural and compositional characteristics correspond well to the disrupted zones of large rock avalanches described from the highly ex-

Fig. 8. Representative metamorphic clasts found in the upper Skaha Formation (SK-FA2). (A) Deformed quartz–chlorite–mica schist. (B) Mylonitic chlorite–mica schist with deformed quartz ribbons.



tended metamorphic core complex terranes of the USA. southern Cordillera (Yarnold and Lombard 1989; Yarnold 1993; Beratan 1998). Megablocks (Gbb) resting on top of and intertonguing with megabreccia facies closely resemble matrix-poor zones of large rock avalanches described by Yarnold and Lombard (1989). The enormous sizes of coherent blocks and their juxtaposition with avalanche deposits suggests that these blocks were deposited by rock slides that broke away from oversteepened bedrock cliffs along faults or fractures. Rock slides typically originate on slopes with gradients >35°–40° and move tens to hundreds of metres away from their sources (Keefer 1999). Rotation of some megablocks suggests they were tilted along listric normal faults. Failure of bedrock edifices may have been triggered by seismic activity or climatic fluctuations.

Skaha facies association 2 (SK-FA2) — sheetflood deposits

Description

SK-FA2 consists of clast-supported conglomerate (Gma), matrix-supported conglomerate (Gms), and scour-filling boulder-rich sandstone (Ss) facies that overlie SK-FA1 in cliff-forming outcrops east of "the Hole" (Figs. 2, 9F, 11A). These strata are the youngest Eocene deposits in the study area. Clast-supported gravel beds consist of unstratified to well-stratified, ungraded, 0.2–1-m-thick beds of locally boulder- and cobble-rich conglomerate. Boulder-rich beds have discontinuous sheet-like geometries, while cobble-rich beds are more continuous laterally. Clasts (maximum diameter = 3 m) are poorly sorted in a matrix of very fine- to coarse-grained sandstone. Clast-supported conglomerate beds also have gradational contacts with interstratified 1–2.5-m-thick, massive (unstratified), ungraded, poorly sorted, matrix-supported conglomerate beds. Channel-confined lenses of facies Ss that have been infilled by <0.5-m-thick and <2-m-wide beds of massive (unstratified) to horizontally stratified, ungraded to inversely graded sandstone are encased within stratified conglomerate beds (Fig. 11A). Clast clusters, pebble-rich lenses, and outsized boulders are common within sand-rich facies Ss. Normal faults cut SK-FA2 deposits near Green Lake; overlying conglomerate deposits of SK-FA2 thicken towards the downthrown sides of these faults (Fig. 11B).

Interpretation

The sheet-like character of the conglomerate, with channel-confined sandstone beds, and megaclasts in SK-FA2 are evidence that sediment was transported to steep alluvial fan surfaces via sheetfloods and debris flows, likely common processes in the moist, middle Eocene climate. The diffuse stratal contacts, clast-supported framework, and stratification in gravel-rich facies (Gma) are evidence that these beds were deposited by unconfined, sheet-like hyperconcentrated flood flows. Massive, matrix-supported, ungraded and disorganized conglomerate (Gms) are interpreted as debris flow deposits (Nemec and Steele 1984). Hyperconcentrated flood flows and debris flows are especially favored on alluvial fans where ephemeral (flashy) discharges are common (Flint and Turner 1988). The channelized sandstone beds (Ss) are consistent with deposition in gullies during waning flood stages (Blair 1987, 2000; Blair and McPherson 1994). The thickening of conglomerate within SK-FA2 towards the downthrown sides of normal faults is interpreted as evidence for syndepositional extensional faulting.

Discussion: regional stratigraphic and tectonic implications

Middle Eocene stratified deposits in the White Lake Basin are the apparent age equivalent of stratified volcanogenic rocks of the Klondike Mountain Formation in the Republic Graben and Torada Creek Half-graben in northernmost Washington (USA.) (Church 1973; Cheney 1994; Cheney and Rasmussen 1996). Both the White Lake and Klondike Mountain sedimentary successions have been described as the translocated remains of a single or composite regional-scale basin that later was dissected and preserved in a post-depositional structural low (Parrish et al. 1988; Cheney 1994; Cheney and Rasmussen 1996). The regional-scale basin proposed by Parrish et al. (1988) and Cheney (1994) may have existed, at least in part, during deposition of the Springbrook and Marron–Marama formations (O'Brien Creek Formation and Sanpoil Volcanics, northern Washington) (Matthews 1997) during the early to middle Eocene, but evidence does not support such an interpretation during accumulation of the White Lake and Skaha formations. The sedimentary–tectonic relations between White Lake and Skaha strata with the surrounding geology and facies trends strongly suggest that the White Lake Basin developed as an isolated, tectonically active basin (Table 2). This basin formed during the latest

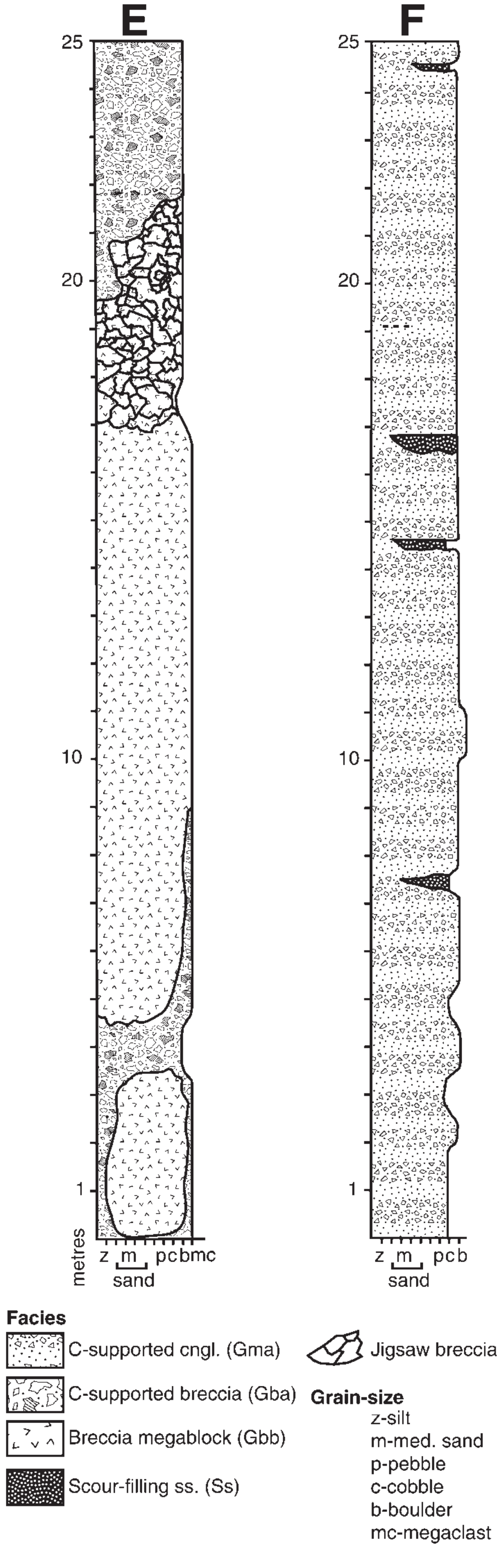


Fig. 9. Representative, partial 25-m-thick columnar stratigraphic sections of the Skaha Formation. (E) Rock avalanche and slide deposits (SK-FA1) (Total section thickness = 45 m), (F) Sheetflood deposits (SK-FA2) (Total section thickness = 40 m). Locations of stratigraphic sections are shown in Fig. 2. Abbreviations as in Fig. 3.

stages of Eocene metamorphic core complex exhumation and normal faulting that segmented early Eocene stratified rocks. The more complexly interstratified and post-depositionally disrupted nature of White Lake Basin strata, differences in clast composition and texture, and a more complete record of core complex unroofing distinguishes the White Lake and Skaha strata from the Klondike Mountain Formation, with which they otherwise share a similar tectono-sedimentary genesis (Suydam and Gaylord 1997; Gaylord et al. 2001).

Basin evolution

The following discussion and illustration displayed in Fig. 12 presents the polyphase succession of major sedimentologic and tectonic events posited for the paleogeographic evolution of the White Lake Basin during the middle Eocene. Figure 12 sections are oriented west–east, an alignment that roughly parallels tectonic transport of the upper plate (Parrish et al. 1988; Carr 1992; Bardoux and Mareschal 1994). Six major stages are depicted, deduced from a combination of field data and earlier published work (Church 1973; Templeman-Kluit and Parkinson 1986; Parrish et al. 1988; Templeman-Kluit 1989; Bardoux and Mareschal 1994). The schematic diagram presented in Fig. 12 is simplified, not to scale, and limited to upper plate development.

Onset of extension and basin opening (A)

Phase A displays the onset of extension and opening of a broad regional-scale depositional trough during the late Paleocene to early Eocene. Extension of the southern Canadian Cordillera immediately followed (within 3 million years) early Jurassic to late Paleocene compressional events and intrusion of Mesozoic batholiths (Parrish et al. 1988).

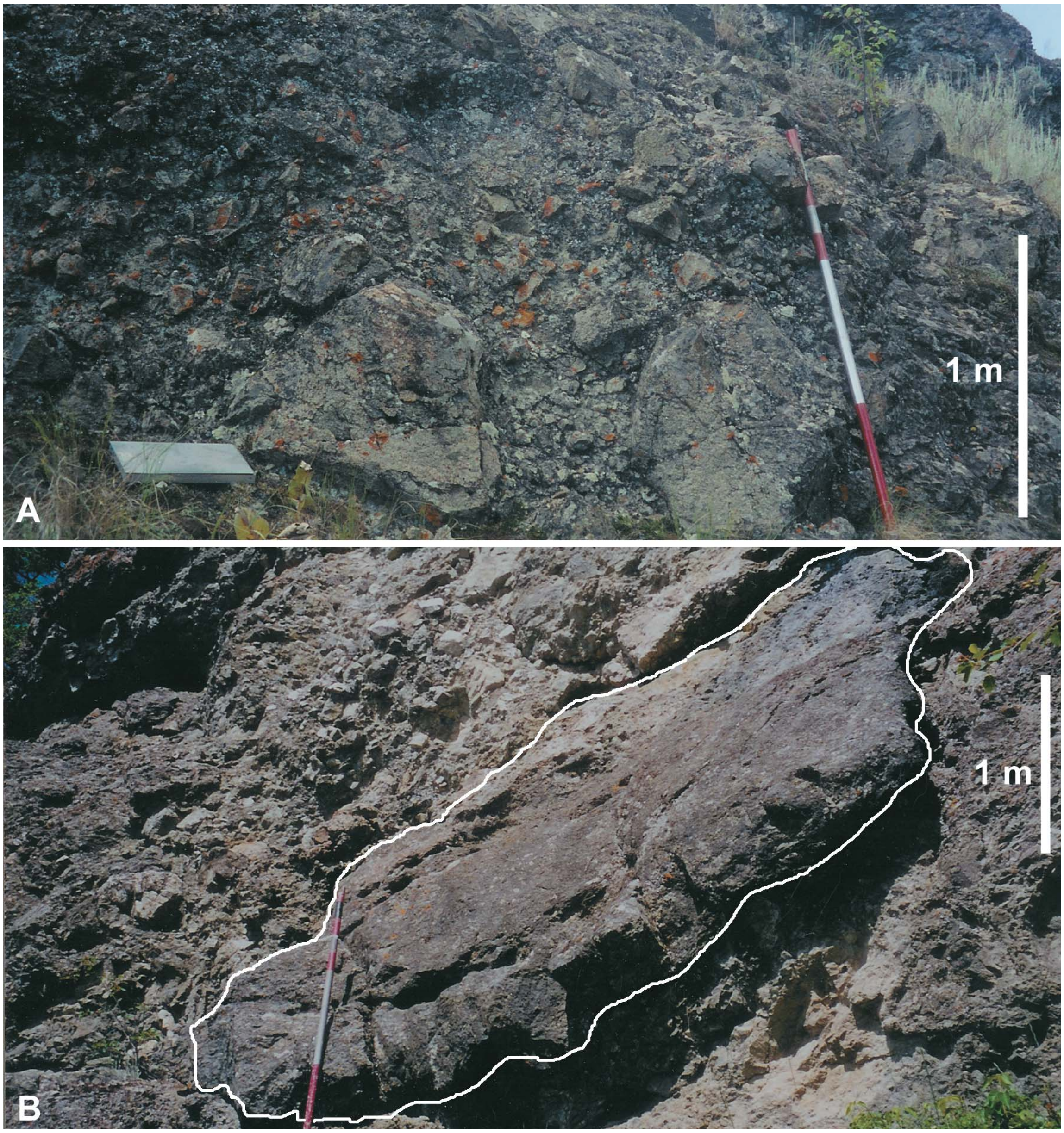
Deposition of the Springbrook Formation (B)

The regional distribution of the late Paleocene to early Eocene Springbrook Formation across the Okanagan Highlands indicates that these deposits accumulated within a broad trough created during early stage extension in southern British Columbia. Post-depositional dissection and block rotation of the Springbrook Formation is indicated by angular unconformities between these strata and the overlying Marron Formation volcanics. Dissection of this basin either occurred along the OVF (Templeman-Kluit and Parkinson 1986) or along multiple extensional faults (Parrish et al. 1988).

Deposition of the Marron and Marama formations (C)

Marron and Marama volcanic rocks were deposited as part of a relatively continuous volcanic belt that extended across British Columbia and northern Washington during the early to middle Eocene. These rocks were deposited and subsequently tilted in incipient half-grabens that developed concurrently with extensional faulting (including OVF motion) (Thorkelson 1989; Dostal et al. 2001). Geochronological data confine Marron Formation deposition to one normal polarity

Fig. 10. Rock avalanche breccia in SK-FA1 exposed in the eastern White Lake Basin. (A) Boulder-rich, clast-supported breccia. (B) Metachert megaclast (outlined) floating in clast-supported breccia.



chron (Bardoux and Irving 1989). Chrons in the early–middle Eocene do not exceed 1 million years (Hartland et al. 1982), thus indicating that these strata probably accumulated in < 1 million years (Bardoux and Irving 1989). The relatively limited time span indicates that tilting of Marron volcanic rocks along the OVF must have closely followed deposition (Bardoux and Irving 1989).

Deposition of the White Lake Formation (D)

The composition, textures, and spatial relations between facies associations of the White Lake Formation are consistent with fault-controlled subsidence and deposition within a tectonically active, asymmetric half-graben basin (Table 2). The geometries and distribution of facies associations in the White Lake Formation indicate that much of the original basin is intact and that internal rather than through-flowing axial drainages developed within the basin. Sedimentary and volcanic strata accumulated on west-sloping, alluvial fans fed by ephemeral streams that drained volcanically active hanging-wall source areas in the Okanagan Highlands to the east. Volcanism, local basin geometry, the humid-temperate Eocene climate, and fault-controlled subsidence along the OVF influenced sedimentary and stratigraphic characteristics. Synsedimentary subsidence and footwall uplift along the OVF is implied from rapid lateral facies changes from coarse, basin-margin debris flows along the OVF to finer grained fluvial and sheetflood facies at distal basin margins (Fig. 2). The tilting of White Lake strata and angular unconformity with the overlying Skaha Formation also indicates active basin-margin faulting during deposition of the White Lake Formation. Similar distribution patterns of volcanogenic sedimentary rocks within an asymmetric half-graben are re-

Fig. 11. Sheetflood conglomerate in SK-FA2 exposed near Mahoney Lake. (A) Stratified gravel with encased channelized sandstone deposit (outlined). (B) Normal faults within SK-FA2 deposits near Green Lake; overlying gravel deposits of SK-FA2 thicken into the downthrown sides of these faults. Dashed lines indicate fault traces; solid, wavy lines indicate bedding surfaces.

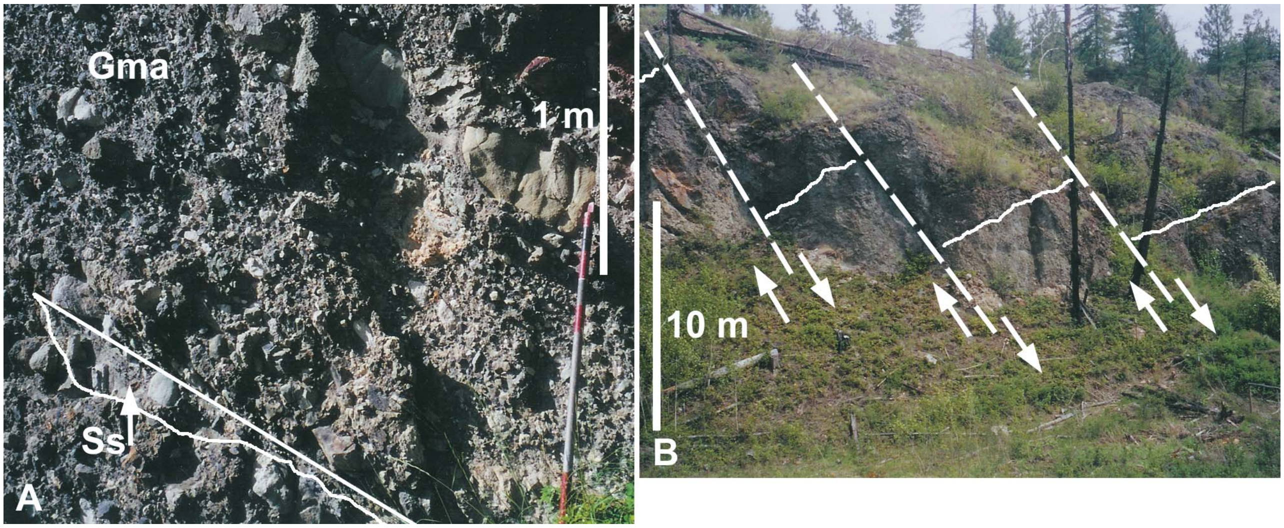


Table 2. Comparison of extensional basin models and the middle Eocene White Lake Basin.

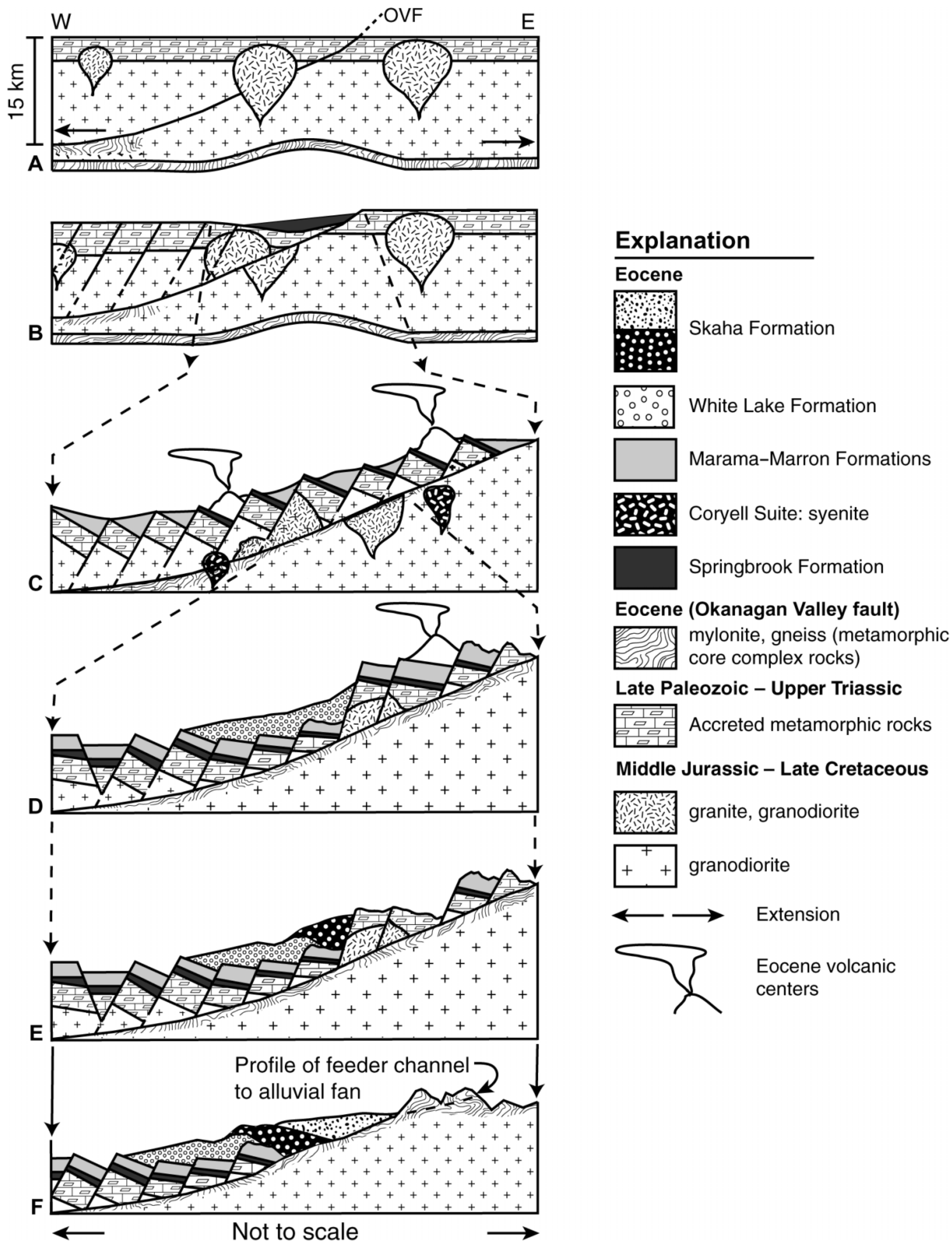
Rift basins (Leeder and Gawthorpe 1987)	Supradetachment basins (Friedman and Burbank 1995)	White Lake Basin (this study)
Drainage — axial or transverse from the hanging wall	Drainage — transverse, extension-parallel depositional systems	Drainage — transverse, extension-parallel depositional systems
Provenance — hanging wall	Provenance — footwall and limited hanging-wall sources	Provenance — WLF: hanging wall; SKF: hanging wall and footwall
Depocenters are near the basin-bounding fault	Depocenters 10–20 km from the basin-bounding normal fault	Depocenters 0–11+ km away from the basin-bounding fault
Basin fill can be >6–7 km	Basin-fill typically < 3 km thick	Sedimentary basin fill < 2 km thick
Deposition in fluvial and lacustrine environments	Deposition in alluvial fan-playa-lacustrine environments	Deposition in alluvial fan environments
Mass-wasting deposits are present, but not abundant	Mass-wasting deposits account for 30%–50% of the basin-fill	WLF: <20% mass-wasting deposits; SKF: >50% mass-wasting deposits
Angular unconformities are subtle	Pronounced angular unconformities	Unconformity between White Lake – Skaha formations.
Magmatism — thoeliitic-alkaline	Magmatism —calc-alkaline	Volcanic rocks — calc-alkaline.

ported from the Pickhandle Formation in the central Mojave Desert (Fillmore et al. 1994).

Deposition of the Skaha Formation (E–F)

Following the cessation of White Lake volcanism and sedimentation, progressive extension and tectonism modified the original half-graben basin geometry and contributed to the accumulation of the Skaha Formation within an evolving supradetachment basin (Table 2). Megaclast- and boulder-rich rock avalanche deposits, gravity-driven slide blocks, sheetflood facies, and debris flow deposits, as well as sedimentary provenance indicate that Skaha strata accumulated on steep-sloping alluvial fans originating from both hanging-wall and footwall sources exposed along the OVF. The presence of rock avalanche and slide deposits are evidence that Skaha facies were emplaced following catastrophic slope failures most likely triggered by earthquakes or slope-destabilizing high-rainfall events. Megabreccia deposits resulting from rock avalanches are recognized as important components of synextensional stratigraphy within supradetachment extensional basins of the USA. southern Cordillera; such deposits are typically associated with late-stage detachment faulting and uplift and exposure of the carapace of metamorphic core complexes (Beratan 1998). During such tectonically active times, supradetachment basins are small and closed, leading to spatially limited deposits (Beratan 1998). Similar relations are inferred for the geographically restricted Skaha Formation. Mylonite and schist clasts preserved within

Fig. 12. Interpretive sketches depicting the polyphase succession of major sedimentologic and tectonic events posited for White Lake Basin evolution. Note sedimentary sections and fault relations are not to scale. (A) Onset of extension and basin opening during the late Paleocene-early Eocene. (B) Generation of regional trough and accumulation of the Springbrook Formation. (C) Enlargement of central portion of B. Post-depositional dissection of trough and deposition of Marron-Marama formations. (D) Enlargement of central portion of C. Formation of an asymmetric half-graben basin and deposition of the White Lake Formation. Sediments derived from the hanging-wall blocks only. (E) Deposition of Skaha Formation facies association 1 (SK-FA1) in an evolving supradetachment basin. Sediments derived from hanging-wall blocks only. (F) Continued slip on the OVF and deposition of Skaha facies association 2 (SK-FA2). Sediments derived from hanging-wall and footwall sources.



sheetflood deposits of the upper Skaha Formation indicate progressive erosion of and movement along the OVF that exposed deformed footwall rocks of the Shuswap complex. The absence of interbedded volcanic strata within the Skaha Formation implies input of volcanic detritus into the basin was restricted, the locus of volcanic activity having shifted away from the basin, or deposition having occurred during a volcanically quiescent time. The relations between extension and volcanism are controversial (e.g., Gans et al. 1998; Axen et al. 1993), but as Gans and Bohrson (1998) have suggested, diminished volcanism corresponded with rapid rates of Oligocene–Miocene extension in the Basin and Range Province of the southwestern United States.

Post-depositional folding and faulting

Post-depositional compression resulted in deformation of upper plate strata into an east–west-trending syncline that is cut by pervasive normal and reverse faults. Continued motion along the OVF resulted in a cumulative tilting of White Lake and Skaha formation strata 25°–35° east (Fig. 2).

Summary and conclusions

The middle Eocene White Lake and Skaha formations in the White Lake Basin, British Columbia preserve a detailed record of synextensional sedimentation and volcanism that lends insight into the nature and timing of Shuswap metamorphic core complex exhumation and extensional tectonism in this region. Regional extension during the late Paleocene – Eocene facilitated the development of a broad regional basin that was a depocenter for the Springbrook Formation. This extension also led to the development of a complex array of low-angle detachment faults and high-angle normal faults that segmented this initial broad depocenter into numerous smaller grabens and half-grabens that served as depositional sites for middle Eocene volcanic and sedimentary strata. Continued extension ultimately contributed to the exposure of highly deformed mid-crustal rocks of the Shuswap complex.

The limited spatial extent and overall lithologic character of the White Lake and Skaha formations indicate that these deposits accumulated within a geographically restricted asymmetric half-graben and supradetachment basin that evolved adjacent to the Okanagan Valley fault system (OVF). Debris flow deposits, fluvial channel and overbank facies, fine-grained sheetflood deposits, and lava and tephra beds indicate that White Lake strata accumulated on sediment gravity flow- and fluvial-dominated alluvial fans that developed along the margins of volcanically active highland source areas. Facies trends indicate that primary sediment transport was from east to west. Volcanism, fault-controlled subsidence along the OVF, the humid-temperate Eocene climate, and the local basin geometry-controlled sedimentary distributions within the White Lake Formation.

Skaha Formation strata record the infilling of an evolving supradetachment basin during an active tectonic, but generally inactive volcanic, time. Rock avalanche, rock slide, debris flow, and sheetflood deposits accumulated in high-gradient alluvial fans shed from oversteepened and weakened upland source areas. Failure of source areas was likely triggered by active basin-margin faulting or climate fluctuations. Clasts of mylonite and deformed metamorphic carapace rocks in upper Skaha deposits imply rapid and significant footwall uplift along the OVF that exposed the Shuswap complex during deposition of the uppermost Skaha strata.

Variations in spatial distribution, complexity of interstratification, textural and compositional character, and a more complete record of core complex unroofing distinguish White Lake Basin strata from the Klondike Mountain Formation of northern Washington (USA.). Such differences between apparently age equivalent strata in the Pacific Northwest demonstrate the difficulties faced by those who wish to develop realistic sedimentary–tectonic–volcanic models for this region.

Acknowledgments

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