

INDUSTRIAL MINERAL POTENTIAL OF THE TERTIARY ROCKS, VERNON (82L) AND ADJACENT MAP AREAS

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KEYWORDS: Industrial minerals, Kamloops Group, Penticton Group, diatomite, precious opal, kadinite.

INTRODUCTION

This report summarizes the results of 40 days of fieldwork investigating the occurrences of industrial minerals, and some of those aspects of the Tertiary stratigraphy which control their development, in a southeasterly trending area extending 150 kilometres from east of Kamloops (92I) through the Vernon map area (82L) to north of Beavertown (82E). In this area, the industrial minerals of major interest are kaolinite, diatomaceous earth, swelling clay, zeolites, perlite, precious opal, gypsum and dimension stone, of which the first five are found in Tertiary strata elsewhere in the province. The regional geology of Cockfield (1948) and Monger and McMillan (1989) for the Ashcroft area (92I), Jones (1959) for the Vernon area (82L), Tempelman-Kluit (1989) for the Penticton area (82E), and Okulitch (1979) for the entire region give the geological framework. Mapping by Church (1980) and Christopher (1978), and D. Duba's (1988) unpublished mapping around Whiteman and Bouleau creeks, provided by K. Daughtry, Discovery Consultants Ltd., augment the detailed geological information in some areas of Tertiary rocks. Four major highways and railways effectively link this area to nearby major population centres.

At present, the gypsum quarry at Falkland and a flagstone quarry south of Revelstoke are the main industrial mineral producers in the Vernon map area. The potential for diatomaceous earth, swelling clays, precious opal, kaolinite, zeolites and perlite in the Tertiary strata of the area provide industrial mineral opportunities for the future.

TERTIARY STRATIGRAPHY

KAMLOOPS AND PENTICTON GROUPS

The volcanic-dominated rocks of the Kamloops and Penticton groups form a continuous sheet stretching 150 kilometres north-northwest from Trepanier on the west side of Okanagan Lake (82E) (Figure 1) to north of the South Thompson River east of Kamloops (92I) (Figure 2). The 25 to 30 kilometre wide belt is broken only where the deeply incised, east or west-flowing drainages of Whiteman Creek, and Salmon and the South Thompson rivers cross it. West of Falkland, Estekwalan and Tuktakamin mountains expose a minimum thickness of 600 metres of mainly volcanic

rocks deposited on a paleotopography with a relief of hundreds of metres.

KAMLOOPS GROUP

North of Kamloops, basal sediments along the northeastern edge of the Eocene belt belong to the Chu Chua Formation (Uglow, 1922). In the Kamloops area, the Kamloops Group consists of a lower succession of sediment-tuff±flows of the Tranquille Formation which underlies several members of the 1000 metre thick basalt/andesite Dewdrop Flats Formation. Ewing (1981, p. 74) noted that the basal sediments and intercalated volcanics comprising the Tranquille Formation are laterally restricted because they accumulated in a fault-bounded, northwest-trending basin. Because the typical andesite/basalt rocks of the Dewdrop Flats Formation are extensive east of Kamloops, the formation name has been retained to the east and south.

Ewing's detailed investigation of the Kamloops Group around Kamloops and Church's (1980) mapping of the Eocene rocks west of Vernon resulted in Ewing (1981) proposing a stratigraphy for the Eocene rocks in the area between Vernon and Kamloops where he did no detailed mapping. The informal stratigraphy adopted in this report partly draws on Church's suggestions (1979; 1982) and modifies those suggested by Ewing by replacing the name Tuktakamin breccia with the better exposed Estekwalan tephra on Estekwalan Mountain, and replaces Ewing's suggested Morte Lake basalt with the Dewdrop Flats Formation.

CHU CHUA FORMATION (units Esx, Escg, and Essr)

Along the northeastern side of the Eocene belt, the Chu Chua Formation occurs as a few basal lenses of Eocene sediments in Shorts and Bolean creeks, and at the east end of Pinaus Lake, but does not form the numerous lenses shown by Okulitch (1979). In Shorts Creek, tuffaceous shale to grit and rare carbonaceous shale form an unfaulted lens 15 metres thick at the base of the Eocene. Near the valley floor on the north side, the lens thickens to 50 metres of sedimentary breccia comprising angular siltstone and rare granitic clasts up to 40 centimetres on edge. On the southwest side of Bolean Creek, south of Pillar Lake, a few roadcuts expose a lens of sedimentary breccia (Esx) 3 kilometres long that reaches a thickness of 125 metres. Angular clasts of grey phyllite, greenstone and granitic rocks up to 1 metre long lie in a crudely bedded matrix of lithic grit. On the north side of Pinaus Lake, within a kilometre of the east end, a few lakeshore outcrops expose a succession of subangular peb-

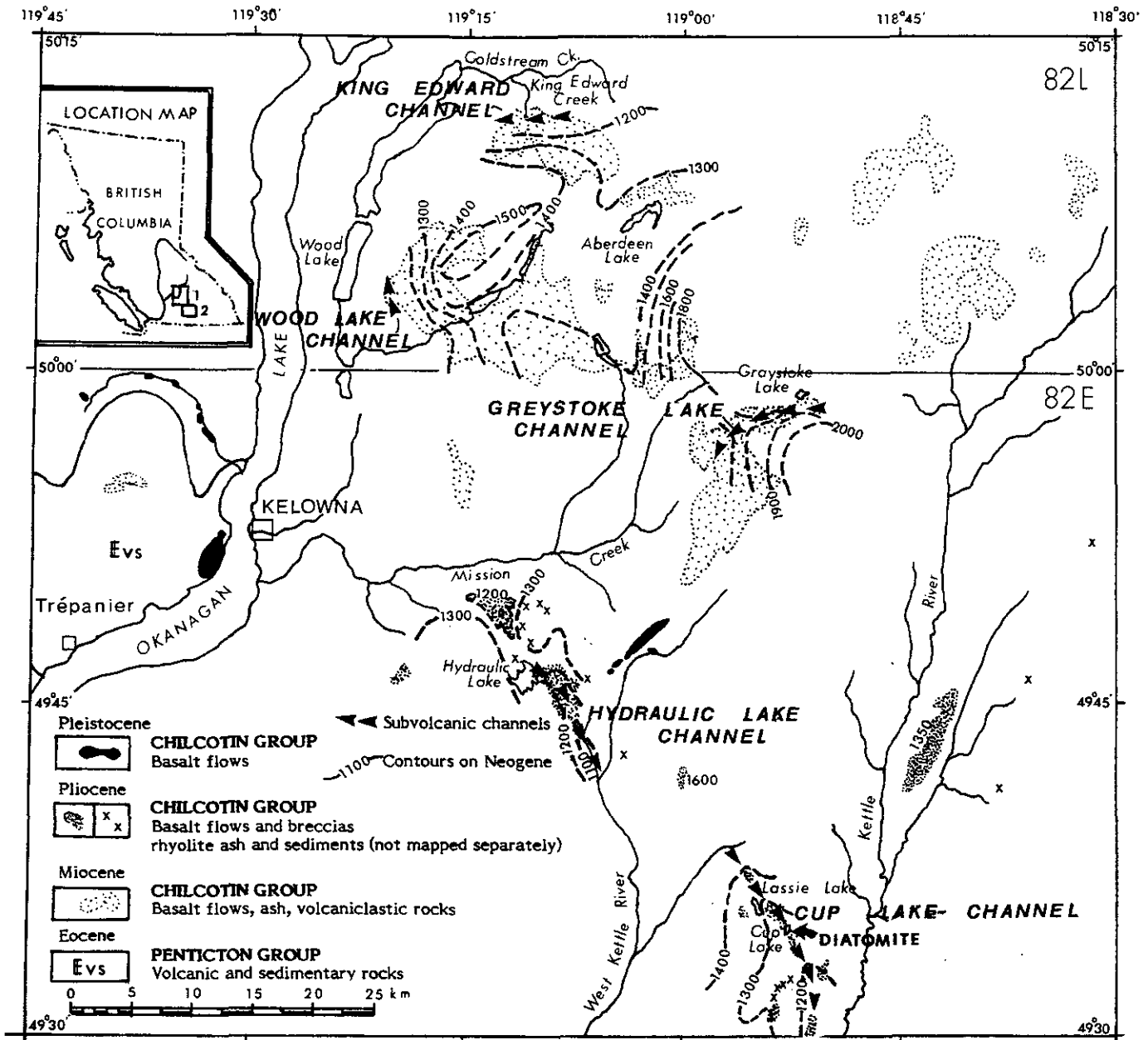


Figure 1. Regional geological map showing the distribution of the sedimentary and volcanic rocks of the Chilcotin Group and subvolcanic drainage channels near Okanagan Lake (82E). Adapted from Mathews (1988).

ble to cobble conglomerate, sandstone and rare carbonaceous shale of unit *Escg*. Outcrops of waterlain rhyolite ash-tuff (*Essr*) form small basal lenses on the south ridge of Siwash Rock Mountain and immediately south of Highway 97 and east of Ingram Creek.

In the basal sedimentary lenses correlated with the Chu Chua Formation, sedimentary breccia and subangular pebble to cobble conglomerate develop almost to the exclusion

of fine clastic sediments. Their dominance indicates that the sub-Eocene unconformity either initially had a high paleorelief, or, as favoured by Mathews (1981, p. 1313) for the Enderby area northeast of Vernon, the Eocene basement had a large paleorelief maintained by high-angle growth faulting during deposition. The large size and extreme angularity of the clasts, monomict composition of the breccias and their obvious local derivation support Mathews' interpretation,

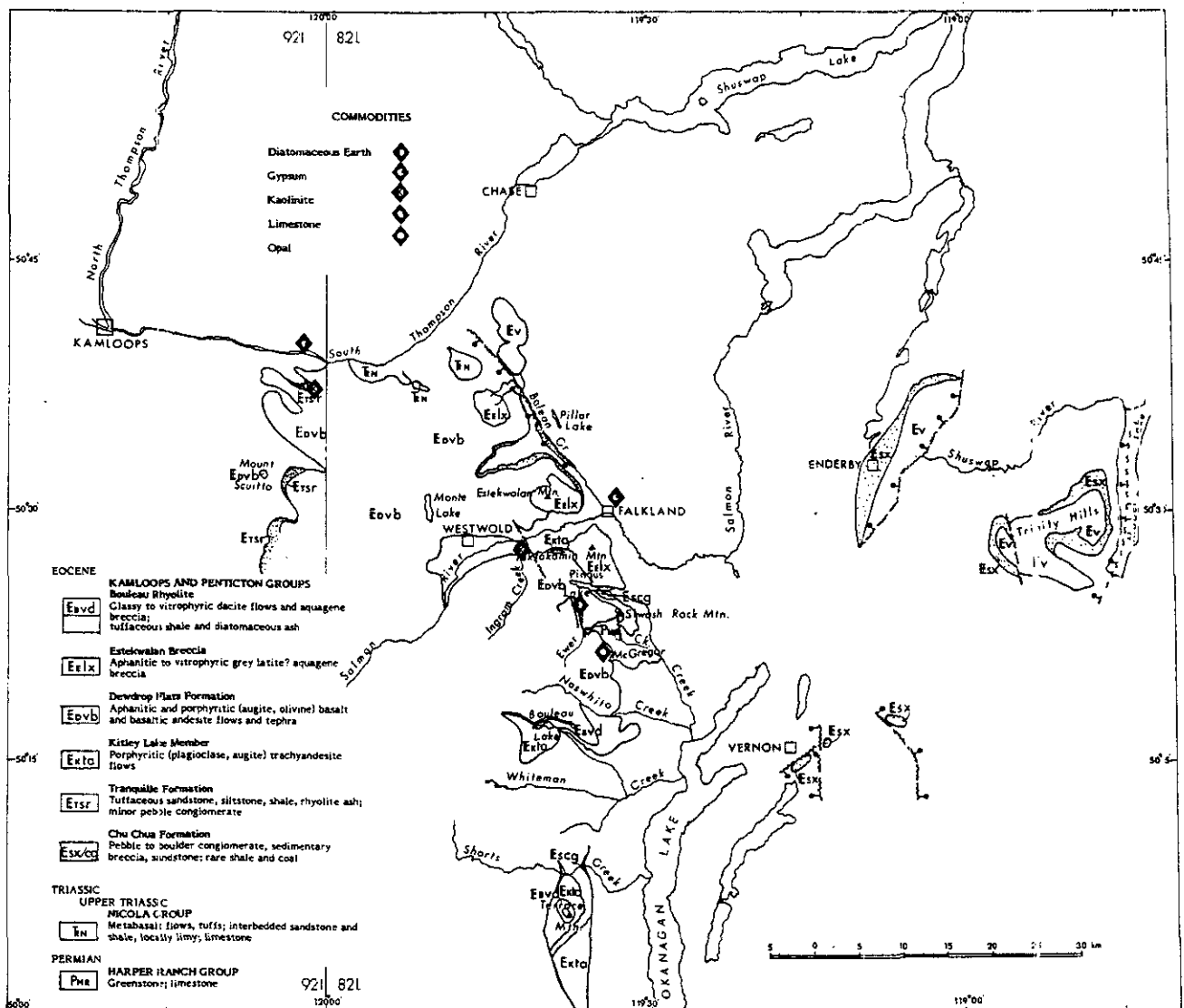


Figure 2. Regional geological map showing the distribution of the sedimentary and volcanic rocks of the Kamloops and Pentiction groups of Eocene age.

which may be extended to include the Eocene sediments in the Trinity Hills associated with a north-northeast striking growth fault along Mabel Lake, and, with less certainty, the Eocene sediments in Bolean Creek with a subjacent north-northwest striking growth fault along the creek. By contrast, in the Kamloops Group at Buse Lake and Scuitto Creek, coarse clastic rocks are absent from the basal sedimentary lenses of the Tranquille Formation, which in these two areas probably formed under lacustrine or paludal conditions.

TRANQUILLE FORMATION (unit Etsr)

Typically tuffaceous sediments locally fill the paleotopographic lows at or near the base of the Eocene succession and form lenses up to 125 metres thick and a few

kilometres long. At Buse Lake, on the southwest side of the Eocene belt, a white-weathering airfall and waterlain crystal-vitric rhyolite ash up to 60 metres thick dominates a succession which includes plant-bearing shale and tuffaceous sandstone correlated with the Tranquille Formation (Photo 1). These lenticular sediments and ashes of unit Etsr outcrop at Buse Lake and on the divide between Scuitto and Woodland creeks, but not on the east ridge of Mount Scuitto as indicated by Cockfield (1948).

DEWDROP FLATS FORMATION (units Edvb and Epbs)

The Dewdrop Flats Formation contains the volcanic-dominated part of the Kamloops Group. Augite-olivine ba-

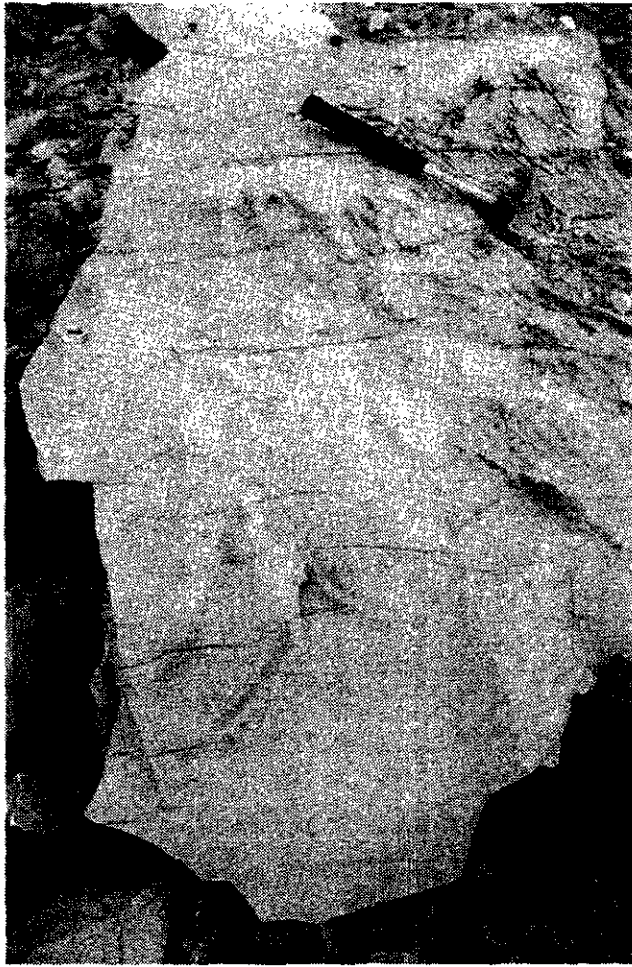


Photo 1. Waterlain rhyolite vitric-crystal tuff of the Tranquille Formation exposed in Buse Lake quarry where it is worked for its kaolinite content.

salt and basaltic andesite flows, interflow breccia and minor basaltic tuff extend from southeast of Kamloops to west of Vernon. Because the rocks in this area cannot be distinguished from those of the Dewdrop Flats Formation, Ewing's suggested name of 'Monte Lake basalt' for these rocks has been discarded. Medium to dark grey, aphanitic to porphyritic (5-15% olivine) basalt flows and interflow breccia of unit *Epvb* extend over 50 kilometres southeasterly from southeast of Kamloops to west of Vernon. Southeast of Kamloops, the mapped area east of Mount Scuitto includes the basal 100 metres of an unknown thickness of basalt flows. Farther to the southeast around Monte Lake, the unit exceeds 300 metres with the top outside the map area, and south of Pinaus Lake it is about 300 metres thick beneath the overlying Bouleau Member. To the southeast on the Klinker property north of McGregor Creek, the member is about 200 metres thick and consists of mostly breccia and lahar with only a few flows. Between McGregor and Naswhite creeks, the formation may end because Church (1979; 1980) mapped a sequence of thin-bedded, fine-grained andesite and dacite lavas immediately under the Bouleau Member.

Well bedded, grey lithic tuff lenses of unit *Epbs* lie within the basalt flows of the Dewdrop Flats Formation. Each tuff lens is less than 2 kilometres long and 100 metres thick, of basalt/andesite composition, and probably of airfall origin. A lens cut by an old logging road at 1450 metres (4750 feet) elevation, on the south side of Siwash Rock Mountain, and another exposed at 1370 metres (4500 feet), on the powerline access road south of the east end of Pinaus Lake, are about 250 metres above the base of the Eocene. Straddling Salmon River valley, another lens outcrops low on the valley sides about half way between Falkland and Westwold. It is less than 100 metres above the base of the Eocene. None of these lenses is locally opalized.

TABLE I
LOCATION, OPTICS AND X-RAY CHARACTERISTICS OF COMMON AND PRECIOUS OPALS, VERNON MAP AREA

Unit Sample	Location		Refractive Indices	X-Ray Diffraction Classification*
	mE	mN		
Bouleau Member V5M	314650	5583760	1.448 ± 0.005	opal-CT
Estekwalan tephra V33Q	314520	5598530	1.545+<D>0.005	quartz
V33AA	314300	5597160	1.46-1.47	opal-CT ± quartz
V34E1	312730	5598050	1.430 ± 0.005	opal-CT ± quartz
V35E	314430	5596950	1.445 ± 0.005	opal-CT ± quartz

Klinker property (data from D. Awram)
317680 5581500

*X-ray diffraction classification of Jones and Segnit (1971)

Ewing's (1981) single whole-rock analysis (Table 1, 27-5) indicates that these rocks lie close to the boundary between basaltic andesite and basalt. The scattered appearance of biotite and hornblende, and sanidine rims on plagioclase suggest that the rocks of this unit may include basaltic trachyandesite and trachybasalt. In thin section, augite phenocrysts are common and olivine is largely pseudomorphed by "iddingsite" ± carbonate. A few rocks contain red-brown pleochroic biotite flakes which are resorbed with opaque-rich margins, and partly resorbed basaltic hornblende is rare. Rounded plagioclase phenocrysts (An₅₅₋₆₂) are sparse and some have sanidine rims. The typical matrix is granular augite and fine plagioclase microlaths with some rocks having fine, pleochroic brown biotite flakes.

PENTICTON GROUP

When Church (1982) proposed the name Pentiction Group for the Eocene volcanic and sedimentary rocks of the Okanagan-Boundary region, he did not indicate how to distinguish them from the physically continuous rocks of the long-recognized Kamloops Group (Drysdale, 1914; Rose, 1914) to the northwest. The present map area partly covers the gap between Church's Pentiction Group west of Vernon and the type locality of the Kamloops Group. The distinction

between the two groups is presently unclear, and upon further study, may disappear because of the priority of the term "Kamloops Group". In the present area, those units which tentatively correlate with members of Church's Pentiction Group near Terrace Mountain are assigned to that group. The other units which extend to Kamloops have been placed in the Kamloops Group. In view of the high alkali content of Estekwalian tephra and its restriction to the southeast edge of the Eocene volcanic belt, it is assigned to the Pentiction Group.

ESTEKWALAN TEPHRA (units Eglx and Egvd)

West and south of Falkland, a section of aphanitic to vitrophyric latite (potassic trachyandesite) and trachyclacite aquagene breccia at least a 800 metres thick, forms north-westerly trending belt. It underlies the northeastern edge of the Eocene belt and forms the upper parts of Siwash Rock, Tuktakamin and Estekwalian mountains. The east end of the south face of Estekwalian Mountain exposes white-weathering, grey vitric and vitrophyric tephra of unit Egvd, containing angular clasts averaging 6 centimetres on edge, and scattered lenses of light grey to white rhyolite ash (Photo 2). Locally the ash is waterlain, zeolitized (heulandite-clinoptilolite), and here and there opalized with opal-CT ± quartz

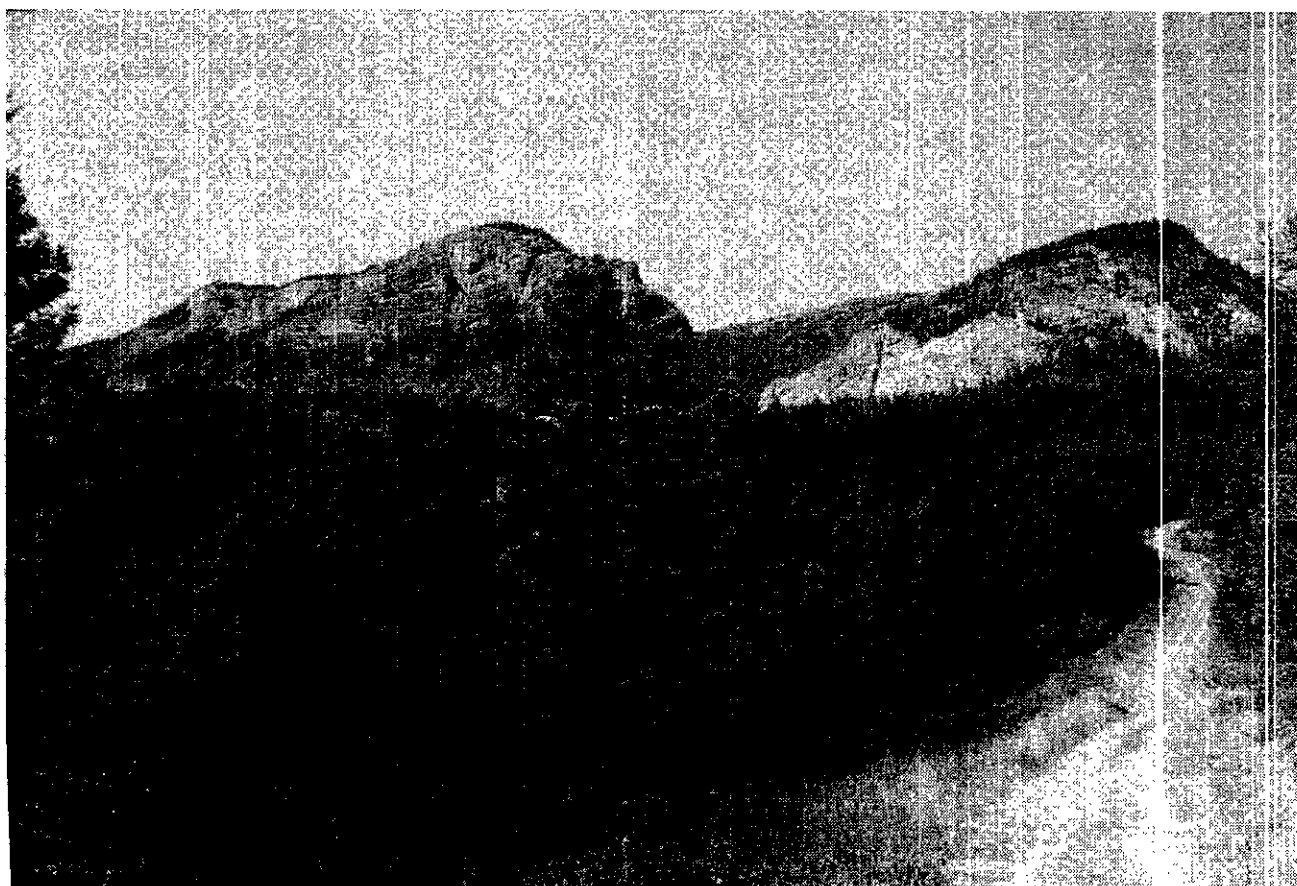


Photo 2. The south face of Mount Estekwalian showing coarsely bedded west-dipping aquagene latite? breccia of Estekwalian tephra (Eglx).

(see Precious Opal Potential). Present mapping indicates that the dacite tephra of Estekwalan and Tuktakamin mountains lie on a westward-dipping unconformity. The white-weathering dacite tephra pass upward into buff-brown latite tephra. Because the Estekwalan tephra is particularly prone to rock slides, its basal contact is covered in all but a few localities. The resulting slide debris renders thickness estimates uncertain but they lie between 500 and 1000 metres. On Estekwalan Mountain, the bedding, probably foreset, dips gently westward and indicates, as Ewing noted (1981, p. 70-71), that the Estekwalan tephra forms the western flank of an eruptive centre.

Ochre-brown weathering glassy to vitrophyric (augite, pseudomorphed olivine, rare resorbed plagioclase plated by sanidine, and biotite) latite breccia of unit **EFlx** underlies a belt 20 kilometres long extending northwesterly from the east side of Siwash Rock Mountain through the top 300 metres of Tuktakamin Mountain to the north side of Estekwalan Mountain. It may extend a further 15 kilometres northward through Mount Martin. The breccia has 2 to 10-centimetre, angular clasts in a soft, ochre-brown weathering palagonite matrix (Photo 3) which is unbedded in outcrop but on some hillsides shows crude bedding with a gentle westward dip (Photo 2). Thin sections show euhedral augite phenocrysts and glomerocrysts with associated coarse apatite prisms, resorbed and euhedral plagioclase laths (An40-45) plated by thin sanidine rims, olivine partly replaced to totally pseudomorphed by "iddingsite" ± carbonate, and rare

resorbed biotite with opaque-rich rims. The matrix consists of feldspar microlaths, granular augite and glass. The unit is at least 300 metres thick, rests on a gently dipping basement and, west of mounts Estekwalan and Tuktakamin, overlies flows of the Dewdrop Flats Formation.

KITLEY LAKE MEMBER (unit **EKLta)**

On the south wall of Salmon River valley west of Falkland, a tongue of grey porphyritic trachyandesite flows of unit **EKLta**, 3 kilometres long, contains sanidine-rimmed plagioclase, augite and rare biotite phenocrysts. It lies between the basement and the overlying Dewdrop Flats basalt flows and basalt lithic tuff. The unit is tentatively correlated with the Kitley Lake Member of the Marron Formation. Around 1310 metres (4300 feet) elevation, immediately south of the road to the summit of Tuktakamin Mountain, the outcrop pattern of **EKLta** implies a truncation of the unit and its overlap by Dewdrop Flats basalt flows.

BOULEAU MEMBER (units **EBSr and **EBvd**)**

Within and north of the headwaters of Ewer Creek, a gently west dipping sequence of glassy dacite flows and lapilli tuff of unit **EBvd** overlies a thin tuffaceous (vitric rhyolite) shale and siltstone unit **EBSr** which together exceed 100 metres in thickness. The units are tentatively correlated with Church's (1979) Bouleau rhyolite which extends some 30 kilometres southward to Terrace Mountain where radiometric dating gave a biotite K-Ar age of 52.3 ± 1.8 Ma. The unit rests on the top of the Dewdrop Flats Formation.



Photo 3. Exposures of palagonitic latite? tuff-breccia at the microwave tower on the summit of Mount Tuktakamin.

Cream-weathering, tuffaceous shale and siltstone, containing diatoms, palynomorphs, plant and fish fossils, form a poorly exposed lens of unit **E_{BSr}** which is at least 4 kilometres long and no more than a few tens of metres thick. The presence of diatoms, siliceous sponge spicules and fossil fish indicate the lacustrine setting of this locally opalized unit (*see* Precious Opal Potential) at the base of the Bouleau Member.

Most of the Bouleau Member is a light to dark grey, vitrophyric dacite lapilli tuff of unit **E_{Bvd}** with sparse phenocrysts of augite, hypersthene, partly resorbed plagioclase, and rare hornblende and opaque-dusted biotite. Coarse apatite prisms lie in or on the pyroxene phenocrysts which here and there show augite plating rounded hypersthene cores. The plagioclase phenocrysts range from An₃₇₋₄₅, and in distinction to those of the Estekwalan latite, they lack sanidine rims. The angular clasts range from 2 to 10 centimetres on edge and lie in a white ash matrix. The remainder of the unit is glassy dacite flows. The member is less than 100 metres thick and is capped by a plagiophyric andesite west of the mapped area.

CHILCOTIN GROUP

On the east side of Okanagan Lake, basalts and minor sediments of the Chilcotin Group form residua ranging in area from 0.2 to 140 square kilometres. They lie in a belt up to 50 kilometres wide which extends 90 kilometres from the south side of Coldstream Valley (82L) to the west side of the West Kettle River valley (82E) (Figure 1). Olivine basalt flows, tephra and underlying sediments form the Middle Miocene King Edward Creek Formation and the Late Miocene to Early Pliocene Kallis Formation that compose the Chilcotin Group in the Okanagan Highlands (Mathews, 1988). The Middle Miocene basalt, up to 200 metres in thickness, and Mio-Pliocene basalts, to as much as 100 metres thick, protect underlying and locally intercalated sediments which aggregate to as much as 74 metres in thickness (Christopher, 1983). The sediments comprise fluvial conglomerate and sandstone, and here and there, overbank swamp deposits of carbonaceous shale, waterlain rhyolite ash and diatomaceous earth. Both the basalts and sediments form scattered remnants of paleo-valley fillings of a formerly extensive drainage system in the Middle and Late Miocene. If one assumes only minor regional tilting since their formation, the systems drained southerly.

Of the diamond-drill core samples collected by Z.D. Hora from several properties in the Cup Lake and Hydraulic Lake paleochannels, core from twelve out of the fourteen holes sampled from Cup Lake contains diatomaceous siltstone and shale sections up to 8 metres thick. An age determination by J.M. White, based on palynomorphs from one of the four most carbonaceous of the diatomaceous samples, yielded a possible Late Miocene to Early Pliocene date which is consistent with the age restriction imposed by the oldest K-Ar age of the overlying basalt flows at 5.9 ± 0.3 Ma (latest Miocene).

STRUCTURE

Because this study concentrated on the Eocene and younger rocks of the region, only structures in this age range are considered. Although the sub-Eocene unconformity records the type and amount of Eocene and younger deformation, uncertainty concerning the amount of relief of the Eocene paleotopography, and the poor exposure near the base of the Eocene, complicate the reading of this record.

On either side of the Eocene belt stretching from Okanagan Lake to east of Kamloops, inward-dipping bedding attitudes outline a large, upright syncline which extends for more than 150 kilometres to the north-northwest. From south to north, the crossing valleys of Lambly, Shorts, Whiteman, Ewer and Equisis creeks and Salmon River provide glimpses of the inward-dipping limbs of the syncline. High-angle normal faults, with hundreds of metres or less of throw, locally modify the syncline. Near the north end of Okanagan Lake, Thompson and Daughtry (1994) mapped a number of north to northeast-striking high-angle normal faults which are usually west-side down and are consistent in attitude and movement with an Eocene growth fault mapped by Mathews (1981) near Enderby. Midway between Falkland and Westwood a high-angle, west-side-down normal fault traverses the Eocene and offsets an airfall tuff lens to yield a throw of 100 metres. On Bolean Creek, restriction of the Eocene sedimentary breccia to the southwest bank requires either a fault immediately northeast of the breccia outcrops or a steep paleovalley wall. Because minor faults cut the breccia, I prefer a fault. Elsewhere, incomplete mapping of the unconformity shows that elevation differences of up to 600 metres along it probably resulted from Eocene paleotopography rather than faulting.

INDUSTRIAL MINERAL POTENTIAL

DIATOMITE POTENTIAL

In British Columbia, the fluvial and lacustrine sediments of the lower part of the Chilcotin Group, that is the Fraser Bend and Deadman River formations, have the greatest diatomite potential. These formations encompass the sediments developed in drainage systems with paludal (swamp) and lacustrine settings that involved silica-charged waters derived from the weathering of a slightly older rhyolite crystal-vitric ash-tuff. Diatoms flourished. Because the deposits are only 5 to 15 Ma old, the diatoms have not recrystallized, lost their porosity and industrial usefulness, as commonly has happened with diatoms found in Eocene rocks in British Columbia (but *see* below). Prior to this investigation, recorded diatomite occurrences clustered along the Fraser River for 175 kilometres from north of Quesnel (93G; Hora and Hancock, 1995) to Gang Ranch (92O) in the south (Read, in press), and from there 125 kilometres southeast to Red Lake east of Deadman River (92I and 92P; Hora, 1986) and Mount Guichon (McMillan, 1978).

The discovery of diatomaceous earth at Cup Lake extends diatomite occurrences a further 220 kilometres to the southeast (Figure 1). Although cursory sampling of the drill core from properties surrounding Cup Lake did not encounter diatoms, it is likely that 15 to 20 years ago the carbonaceous shale which hosts the diatoms was selectively removed for chemical analysis. Present sampling shows that only the sediments of the southerly flowing Cup Lake channel are diatomaceous, but the core from the sediments of a contemporaneous channel through Hydraulic Lake needs close examination as does that from older channels near Graystoke Lake, Wood Lake and King Edward Creek.

In the Vernon map area, several occurrences of Eocene sediments with unrecrystallized diatoms suggest that, locally, Eocene rocks have diatomaceous earth potential. Although diatoms were discovered many years ago in the Eocene rocks of Vermilion Bluffs in the Princeton Basin (Hills 1962, p. 49), widespread zeolite facies regional metamorphism of these diatomaceous rocks has resulted in the recrystallization of the diatoms and a loss in porosity which has rendered them useless as an industrial mineral. Eocene diatomites will survive only in areas with an absence of later recrystallization. A clue that the subsequent recrystallization of the rocks is only slight is the presence of ubiquitous vesicles or fractures, and amygdules filled with agate, opal, chalcedony and strongly hydrated zeolites, such as ferrierite, erionite, mesolite, thomsonite, chabazite and stilbite. These textures or mineral assemblages imply that the rocks have undergone a subsequent alteration involving little silica recrystallization. However, the presence of quartz, prehnite, chlorite, epidote, albite and the common less-hydrated zeolites such as heulandite-clinoptilolite, laumontite and wairakite indicate that the rocks have suffered alteration sufficient to recrystallize the diatoms.

DESCRIPTIONS OF OCCURRENCES

Diatomaceous tuffs lie at the base of the 100 metre thick Bouleau Member which grades up through tuff and breccia to dacite flows. Although oil-immersion grain mounts show that clay minerals, quartz and feldspar dominate over diatoms, they indicate, more significantly, the occurrence of unrecrystallized diatoms and siliceous sponge spicules in the Eocene of British Columbia.

D1 Pinaus MINFILE: 082LSW159
 STATUS: Showing NTS: S082L/05E
 TYPE: Sedimentary LAT/LONG.: 50°23'41";
 119°36'41"
 ELEVATION: 1335 m (4375 feet)
 UTM: LF0313950mE; LF5585550mN

The Pinaus showing is located in a roadcut of cream-weathering, diatomaceous and tuffaceous shale and siltstone with plant fossils and, reportedly, fish fossils. Oil-immersion grain mounts show about 25% unrecrystallized diatoms in a matrix of montmorillonite-altered glass (determined by x-ray diffraction), and minor amounts of quartz and feldspar. The roadcut crosses a few metres of thickness with neither the top or base exposed. Similar appearing, but

sparsely diatomaceous sediments with 10% or less unrecrystallized diatoms, form roadcuts and angular blocks of float at LF0313950mE and LF5586600mN at 1335 metres (4375 feet) elevation and under the powerline at LF0313920mE and LF5587120mN at 1365 metres (4475 feet) elevation. In total, the scattered outcrops of diatomaceous earth indicate a strike length of 1.9 kilometres, with both ends open, and a minimum thickness of a few metres.

PRECIOUS OPAL POTENTIAL

Agate¹ is widespread in the Eocene to Pliocene lavas of British Columbia, common opal² is sparsely scattered, and precious opal² occurs in very few localities. Only one or two chips of precious opal have been found in each of the three British Columbia localities reported by Leaming (1973). With staking of the Klinker claim in 1991 and the Ewer claim in 1992, R.W. Yorke-Hardy recorded the first significant discovery of precious opal in both British Columbia and Canada. The staking of other claims soon followed and covered an area of scattered opal showings which extends past a powerline 6.5 kilometres northwest of the original discovery. Within the staked area, agate is widespread, and a nearby sequence of tuffaceous shale and waterlain rhyolite ash at the base of the Bouleau Member (EBSR) is locally altered to a grey vitreous "chert" composed of common opal (Table 1, Sample V5M). Based on an x-ray diffraction identification, the common opal is opal-CT. Similar widespread agate and waterlain rhyolite ash, with locally developed common opal "chert" lenses form in the basal rhyolite ash of the Estekwalan tephra (EEvd) between 800 and 1100 metres (2600 and 3600 feet) elevation on the south flank of Estekwalan Mountain (Table 1, Samples V33Q to V35E). These similarities in silica minerals may indicate another area prospective for precious opal.

DESCRIPTIONS OF OCCURRENCES

O1 Klinker Property MINFILE: 082LSW125
 STATUS: Producer NTS: 082L/05E
 TYPE: Volcanic LAT/LONG.: 50°21'49";
 119°33'48"
 ELEVATION: 1490 m (4875 feet)
 UTM: LF0317680mE; LF5581500mN

The Klinker property, consisting of 24 mineral claims, covers several concentrations of precious opal developed in the basal 100 metres of the Dewdrop Flats Formation (EDvb) of the Kamloops Group. The hostrock is a volcanic breccia-lahar mixture composed of angular to rounded

¹ **agate** is microcrystalline quartz with a large number of micropores (Deer *et al.*, 1963). It displays a colour variation arranged in planar or concentric zones. Refractive indices fall in the range 1.534 to 1.539. ² **common opal** is a hydrous cryptocrystalline or colloidal form of silica with a composition of SiO₂.nH₂O with a water content around 6 to 10%. Refractive indices fall in the range 1.44 to 1.47. In **precious opal** a play of delicate colours is observed (Deer *et al.*, 1963).

clasts of basalt, ranging from 0.2 to 0.6 metre in diameter, in a lapilli tuff matrix. In the lahar, the tuff has bedding which swirls around the clasts. Lapilli tuff lenses up to 5 metres thick develop locally and indicate that the volcanic succession dips 20 to 30° to the west. Thin basalt flows and intrusions up to 4 metres thick are scattered throughout. On McGregor Creek Forestry Access Road, about 500 metres east of the Discovery pit (Figure 3), outcrops of grey-green meta-andesite flows and lapilli tuffs of the Harper Ranch Group of probable late Paleozoic age form the basement which dips gently westward and underlies the valley bottom of Ewer Creek north of the property.

On the property, precious opal, agate and common opal fill fractures in the Eocene rocks and permeate podiform rock masses which are up to 0.5 metre in diameter in the lahars. The podiform rock masses are smaller in the lapilli tuffs and absent in the flows or intrusions. Precious opal filled fractures preferentially develop in sets with three preferred strikes: $025 \pm 10^\circ$, $070 \pm 10^\circ$ and $330 \pm 15^\circ$; all sets have steep dips. The podiform masses commonly form beside or across opal-filled fractures. Precious opal fills voids developed during the formation of the host rock, and later open-

ings apparently formed by local dissolution of the host. Here and there the precious opal, agate and common opal have layering which is subhorizontal even in subvertically oriented fracture fillings. The presence of this subhorizontal layering in these materials, which is not subparallel to the orientation of the gently west dipping lapilli tuff, either implies that the precious opal, agate and common opal precipitated after the beds were tilted, or that the beds had a primary dip equal to the difference between the layering in the lahar and in the silica.

Of the six shallow pits exposing the precious opal on the Klinker property, the Discovery pit is the largest at 2100 square metres, and together with the smaller Bluebird pit, probably the richest because of subequally developed podiform masses and fracture fillings (Figure 3). A right-lateral strike-slip fault dips 80° northwest (slickensides trend/plunge $195/25S$), passes along the eastern side of the pit, and offsets the lahars an indeterminate amount. In the other shallow pits, the Tripod, Red Rock and the Caramel and its extension, podiform masses in the lahars developed at the expense of fracture fillings. A lapilli tuff underlies the eastern side of the Caramel pit. Outside the pit areas, the primary openings in the rock are either mostly empty or less commonly filled with agate, common opal, chabazite - a strongly hydrated zeolite ($CaAl_2Si_4O_{12} \cdot 6H_2O$), and other unidentified zeolites.

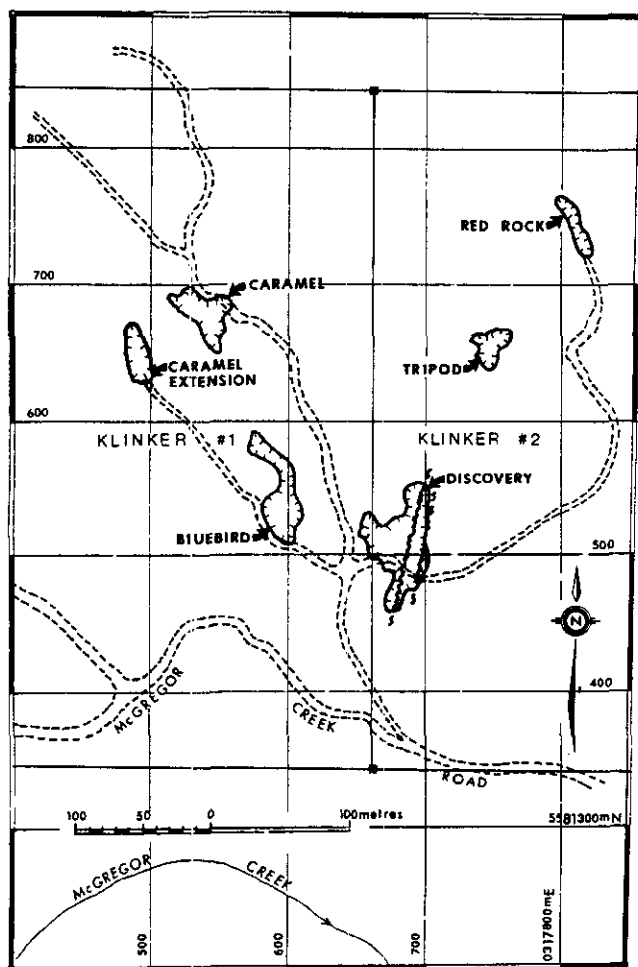


Figure 3. Open pits developed in the basal basalt lahars exposed on the Klinker property of Okanagan Opal Inc.

KAOLINITE POTENTIAL

In the interior of British Columbia, kaolinite has been reported from Tertiary rocks at Giscome Rapids north of Prince George (Cummings and McCammon, 1952), and at the Fairley prospect west of Princeton (Read, in press). Here and there, felsic volcanism heralded the widespread mid-Eocene volcanism of central British Columbia. Kaolinite deposits may develop where the airfall vitric ashes were deposited in palludal or lacustrine settings under the ambient warm temperate to subtropical climate. Such a combination of conditions probably generated the low-grade kaolinite occurrences at Buse Hill (K1) where kaolin has been quarried for more than 25 years, and east of the mouth of Will Creek (K2) immediately south of Highway 97, 7 kilometres east of Westwood. Although both of these occurrences are in mid-Eocene strata immediately above the unconformity, not all such ash-tuffs are altered to kaolinite-quartz. The mainly airfall, not waterlain, ash-tuff straddling Squitto Creek remains unaltered.

DESCRIPTIONS OF OCCURRENCES

K1	Buse Lake Quarry	MINFILE:	092INE123
	STATUS: Producer	NTS:	92I/09E
	TYPE: Sedimentary	LAT./LONG.:	$50^\circ 37' 57''$; $12^\circ 01' 32''$
	ELEVATION:		520 m (1700 feet)
	UTM:		GM0710400mE; GM5611790mN

The presently quarried rock was initially staked for its potential use as a building stone (Parks 1917, p. 179-181).



Photo 4. A view to the east in the upper quarry at Buse Lake where the white kaolinite-rich ash-tuff of the Tranquille Formation, exposed under the tree, overlies deeply weathered volcanics of the Nicola Group, exposed above the packsack.

Since 1968, Canada Cement Lafarge Company has operated a quarry at the base of a low hill near the southeast corner of Buse Lake. The company quarries a siliceous tuff of the Tranquille Formation for its high alumina (15.78%) and low alkali contents, and transports it 7.2 kilometres by road to its cement plant on the north side of the Thompson River near the village of Campbell Creek. Although production records are incomplete, the annual production from the quarry is in the range of 9400 (1970) to 26 200 tonnes (1973) with an average of about 20 000 tonnes/year. With an alternate and cheaper source of material, production from the quarry has declined recently to about 10 000 tonnes/year.

Scattered outcrops and two quarries within 300 metres of the southeast shore of Buse Lake expose the basal 100 metres of the Kamloops Group unconformably resting on a basement of metabasalt flows of the Upper Triassic Nicola Group and granitic intrusions. Near the lake, the lower quarry exposes the upper 20 metres of a 30-metre thickness of cream to pale buff rhyolite of unit *E_{trsr}*, and the upper quarry, 300 metres southeast of the lake, exposes the lower 20 metres of Eocene tuff and the underlying flows of the Nicola Group (Photo 4). The rhyolite forms a wispy layered to unbedded succession of mainly airfall vitric-crystal (quartz, biotite) ash with pieces of plant stems but no leaves. In the lower quarry, the upper 6 metres of rhyolite ash is well bedded, with prominent plant stems and tree trunks and intercalated carbonaceous shale layers which yield a palynological age of Eocene. The overlying 2.5 me-



Photo 5. The east wall of the lower quarry at Buse Lake exposes dark columnar basalt flows above white, altered flows, all of the Dewdrop Flats Formation. Lowest outcrops are gently dipping sandstone and carbonaceous shale of the Tranquille Formation.

tre thick andesite flow is amygdaloidal, altered and buff weathering. A thin (0.3 m) carbonaceous shale separates the underlying, altered flow from 16 metres of dark grey, fresh basalt flow with columnar jointing (E_{dvb}) capped by 20 metres of porphyritic (pyroxene) andesite flows and tephra (E_{dva}) (Photo 5). In agreement with Fulton's interpretation (1975), the rocks and above described section underlying the low hill southeast of Buse Lake are in place and not part of a landslide as suggested by Evans (1983, p. 73-75).

X-ray diffractograms of two samples from the lower quarry and one from the upper show that the Eocene rhyolite tuff is composed of kaolinite and quartz.

References: BCMEMPR (1972, 1986); Evans (1983); Foye (1987); Fulton (1975); Parks (1917); Meyers and Hubner (1991); Sandar (1971, 1974, 1975).

K2 Will Creek MINFILE: 082LSW158
 STATUS: Showing NTS: 082L/05E
 TYPE: Sedimentary LAT/LONG: 50°27'39";
 190°40'55"
 ELEVATION: 630 m (2075 feet)
 UTM: LF0309670mE; LF5593080mN

The showing is a light grey, unbedded crystal (quartz, biotite) rhyolite ash-tuff exposed in a road ditch immediately uphill from Paleozoic limestone float. Scattered exposures to the east limit any eastward extension of the kaolinite-bearing tuff, and to the west, overburden may limit its economic extension. A single x-ray diffractogram indicates that the material is essentially kaolinite and quartz.

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