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Geology of the Oyama map sheet, Vernon map area, British Columbia[1]

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Abstract: The Oyama (82 L/3) map area straddles the boundary between Paleozoic to Late Proterozoic high-grade rocks of the Shuswap metamorphic complex and medium- to low-grade Permian to Triassic rocks presently assigned to the allochthonous Quesnellia terrane. The high-grade rocks are composed of a paragneiss succession intruded by foliated and massive plutons of various ages, and reached peak metamorphic conditions above the second sillimanite isograd. A north-striking, west-dipping zone of ductile shear is exposed in the high-grade rocks along the east side of Kalamalka Lake. The low-grade rocks are less penetratively deformed, have locally been metamorphosed to garnet grade, and are intruded by Jurassic and Eocene plutons. Eocene sedimentary and volcanic rocks occur as erosional outliers resting conformably on basement rocks, and within small fault-bounded basins preserved within present-day valleys. Steep, brittle normal faults have juxtaposed high- and low-grade rocks and are overlapped by Eocene volcanic breccia.

Résumé : La région cartographique d'Oyama (SNRC 82 L/3) chevauche la limite séparant les roches de degré élevé de métamorphisme du complexe métamorphique de Shuswap (Protérozoïque tardif à Paléozoïque) de roches du Permien-Trias de degré de métamorphisme intermédiaire à faible qui sont pour l'instant attribuées au terrane allochtone de Quesnel (Quesnellie). Les roches de degré élevé de métamorphisme se composent d'une succession de paragneiss traversés par des plutons à texture foliée ou massive d'âges variés. Les conditions maximales du métamorphisme responsable de la formation des paragneiss ont dépassé celles associées au deuxième isograde de la sillimanite. Une zone de cisaillement ductile de direction nord et de pendage ouest peut être observée dans les roches de degré élevé de métamorphisme le long de la rive sud du lac Kalamalka. Les roches de plus faible degré de métamorphisme ne présentent pas une déformation pénétrative aussi développée, témoignent de conditions de métamorphisme qui ont pu atteindre celles de la zone à grenat et sont recoupées par des plutons du Jurassique et de l'Éocène. Des roches sédimentaires et des roches volcaniques de l'Éocène forment des lambeaux d'érosion qui reposent en concordance sur les roches du socle; on en observe également dans de petits bassins limités par des failles qui ont été conservés dans les vallées actuelles . Des failles normales à fort pendage témoignant d'une déformation fragile ont mis en contact les roches de degré élevé de métamorphisme avec celles de degré plus faible et sont recouvertes de brèches volcaniques de l'Éocène.

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[1] Contribution to the Ancient Pacific Margin NATMAP Project

INTRODUCTION

As one of the three map areas in the southern component of the NATMAP Ancient Pacific Margin Project, the Vernon map area (Fig. 1) is currently the locus of detailed geological mapping at 1:20 000 scale. The Vernon area straddles the boundary between the pericratonic Kootenay terrane and the presumed allochthonous Quesnellia terrane. The nature of this boundary has been the subject of recent debate (Thompson and Daughtry, 1997; Erdmer et al., 1999; Thompson et al., 1999).

South of Vernon, the Okanagan Valley coincides with the boundary between high-grade metamorphic and plutonic rocks of uncertain affinity (Wheeler et al., 1991) and low-grade Paleozoic to Triassic metasedimentary and metavolcanic rocks intruded by mid-Jurassic plutons. The Okanagan Valley has been interpreted as the locus of a major, crustal-scale, shallowly west-dipping detachment with estimates of dip-slip ranging from 80 km to 90 km near Kelowna (Tempelman-Kluit and Parkinson, 1986; Bardoux, 1993), to 30 km near Sicamous (Johnson, 1994). Preliminary mapping for the Vernon map project led to observations inconsistent with currently proposed detachment models (Thompson and Daughtry, 1996). These observations have spurred a renewed interest in shear-zone fabrics within the Vernon area (Erdmer et al., 1998; Glombick et al., 1999), in an effort to determine their role and reconcile current models with geological evidence.

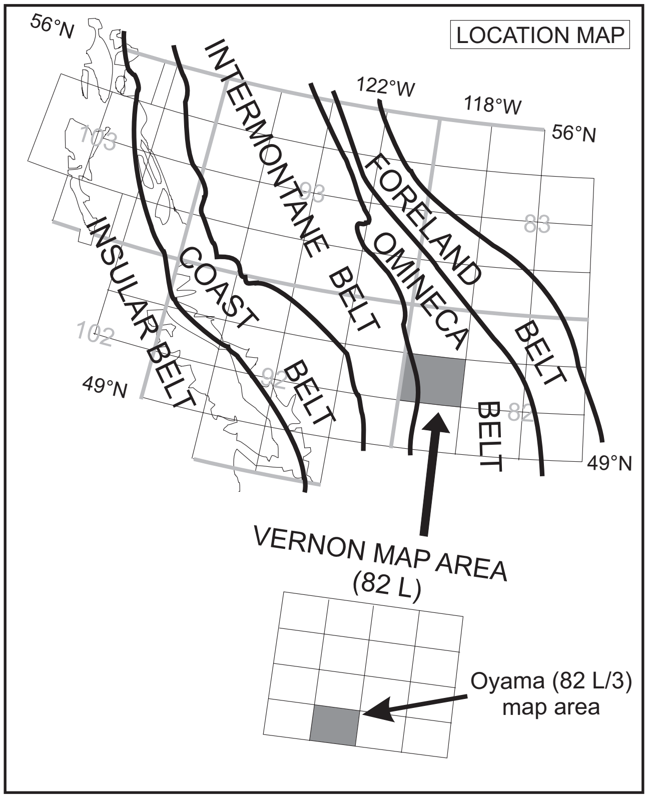


Figure 1. *Location of the Vernon map area within the NTS grid, and outline of geological-morphological belts of the Canadian Cordillera.*

Fieldwork in 1999 focused on the continuation of earlier work and was concentrated in the Oyama (NTS 82 L/3) 1:50 000 scale map area (Fig. 2, 3). Reconnaissance study of shear-zone fabrics was also conducted in the vicinity of Kelowna, Silver Star Mountain, and the Trinity Hills.

DESCRIPTION OF MAP UNITS IN THE OYAMA AREA

High-grade metamorphic rocks

High-grade metamorphic rocks underlie most of the map area and dominate the western half. They include paragneiss intruded by foliated and massive plutons of uncertain age. Metamorphic grade is consistently above the second sillimanite isograd. Jones (1959) included the rocks in the Neoproterozoic Monashee Group, and inferred a Precambrian age of metamorphism. Okulitch (1984) included the rocks southeast of Vernon in a subunit of the Shuswap metamorphic complex, named the Okanagan plutonic and metamorphic complex, inferred to be the remnant of a Mesozoic arc built on North American continental crust. The paragneiss succession exposed east of Kalamalka Lake has been correlated with the Late Proterozoic to early Paleozoic Silver Creek Formation by Thompson and Daughtry (1996), who suggested that there is no major structural break across the Coldstream Valley.

Biotite-sillimanite schist, hornblende schist, garnet schist (unit Ps)

The principal rock type in the paragneiss succession is medium- to coarse-grained quartz-potassium feldspar-biotite-sillimanite-garnet schist. Sillimanite is dominantly fibrous and fine grained, but is locally up to 1 cm long. Dark red almandine garnet, several millimetres across, is common within pelitic layers. Muscovite is rare. Less pelitic horizons commonly contain hornblende, locally more abundant than biotite. Contacts between pelitic and mafic layers are gradational and parallel to foliation. Biotite-sillimanite-garnet schist is locally migmatitic, with thin and discontinuous bands of leucocratic quartzofeldspathic material and a dark garnet-rich melanosome. Near Kalamalka Lake, leucocratic bands have been disaggregated by shearing, forming broken and milled feldspar porphyroclasts visible on mica-rich foliation surfaces. Quartz-feldspar pegmatite layers, centimetres to metres thick, are common and parallel to the foliation.

Calc-silicate, quartzite, marble (unit Pc)

Within the paragneiss succession occur layers of calc-silicate, quartzite, marble, calcareous quartzite, and siliceous marble. Calc-silicate rock includes quartz, feldspar, calcite, diopside, grossular garnet, hornblende, and biotite. The different rock types may be finely interlayered or gradational. Contacts with biotite-sillimanite schist are sharp and are parallel to foliation. The rocks form resistant layers several hundreds of metres in thickness within the paragneiss succession that constitute marker horizons. Turtle Point, a resistant ridge which

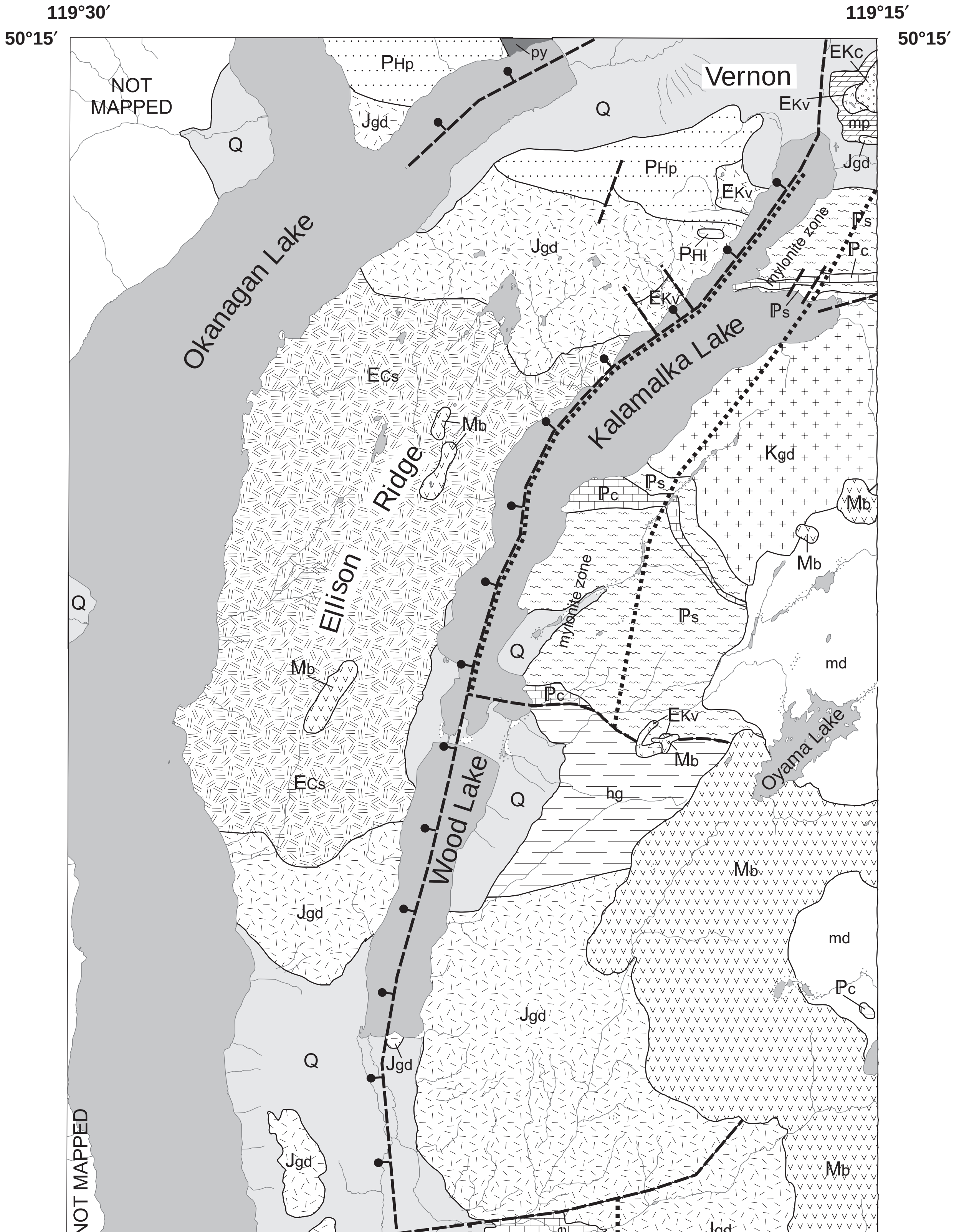


Figure 2. Geological map of Oyama NTS 82 L/3 (west half) map area. Distribution of Quaternary deposits modified from Fulton (1969).

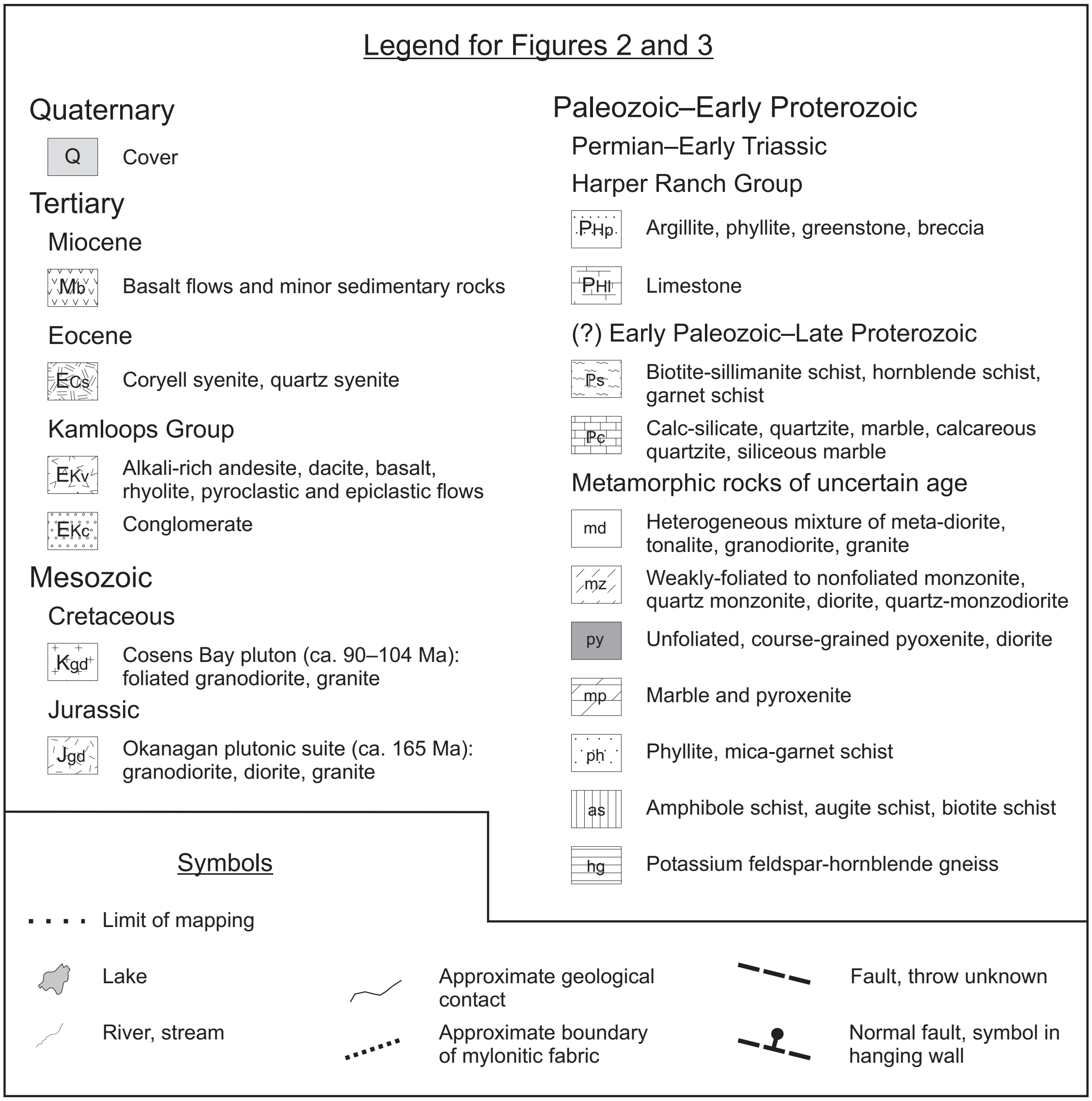
juts out into the north end of Kalamalka Lake (Fig. 4), is underlain by calcareous quartzite which dips gently north and can be traced several kilometres eastward to where it is masked by Miocene plateau basalt. Southeast of Bluenose Mountain, several calc-silicate marker horizons dip gently to the north-northeast and may be stratigraphic continuations of the Turtle Point unit.

Metadiorite, tonalite, granodiorite, granite (unit md)

The central part of the map area is underlain by a heterogeneous mixture of metaplutonic and plutonic rocks, locally containing rafts of the paragneiss succession it intrudes. From crosscutting relationships, the oldest phase is a foliated, medium- to coarse-grained hornblende amphibolite to diorite (Fig. 5). Foliation is commonly discordant with the fabric in surrounding phases. This phase is commonly contained as blocks with wispy and rounded edges within younger phases. The blocks are cut by coarse-grained feldspar veins, and appear to be boudins. The next youngest phase is medium- to coarse-grained hornblende tonalite to granodiorite. It is the most abundant and is weakly foliated to massive. The youngest phase is fine- to medium-grained, biotite- and/or hornblende-bearing granite to granodiorite, which cuts all earlier phases and postdates the main tectonic fabric, although it may be weakly foliated locally. The age of any phase is unknown.

Potassium feldspar hornblende gneiss (unit hg)

Between Oyama Lake and Wood Lake, a separate gneiss unit includes quartz, potassium feldspar, and hornblende. Biotite is rare and muscovite is absent. Chlorite and epidote are present as alteration minerals. Granitic veins several centimetres thick, both parallel to and cutting foliation, are common. Foliation is wavy on the outcrop scale. The unit has been silicified and chloritized locally, resulting in bleached appearance and pale green hue. Rare layers of amphibolite several metres thick and a unit of similar thickness with a marble matrix containing blocks of amphibolite, tens of centimetres to metres



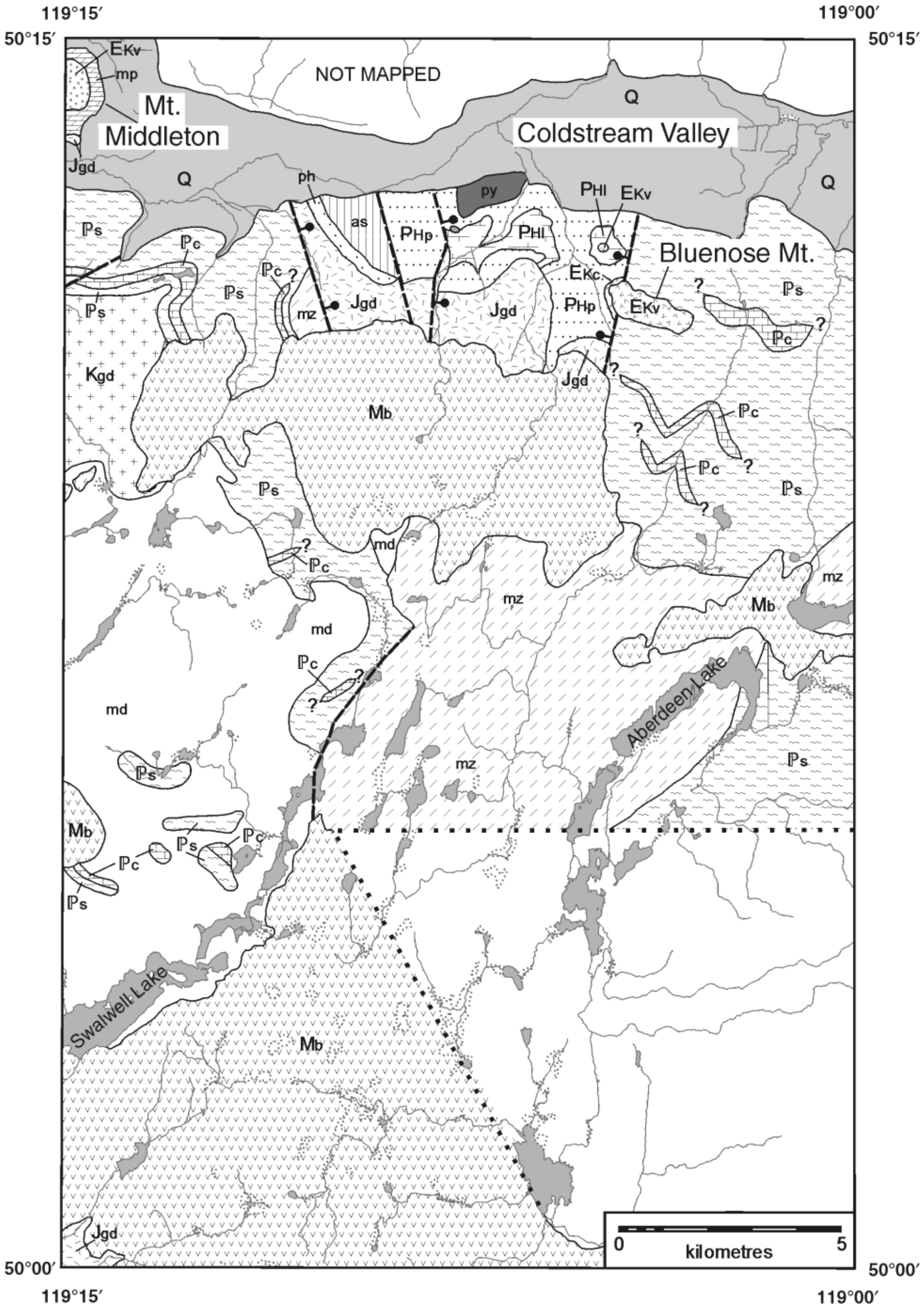


Figure 3. Geological map of Oyama NTS 82 L/3 (east half) map area.

Figure 4. *View of Kalamalka Lake looking northwest. Calc-silicate marker unit forms the resistant ridge (Turtle Point) which extends into the lake. Low-grade Permian rocks, Jurassic intrusive rocks, and Eocene volcanic rocks in*

Figure 5. *Foliated hornblende diorite gneiss of the high-grade metamorphic suite. Earlier foliation-parallel and later discordant tonalitic veins are visible.*

Figure 6. *Fractured and altered quartzofeldspathic gneiss in the hanging wall of the proposed Okanagan Valley fault, north of Kekuli Bay Provincial Park.*

across, occur. The blocks of amphibolite within the marble are medium grained and angular. Contacts between rock types are parallel to foliation. To the south, the contact with a Jurassic pluton is a complex zone of mixing, where marginal phases of the pluton intrude the gneiss in the form of irregularly shaped dykes and sills. Alteration within the contact zone is intense, and brittle faults of uncertain extent occur in several localities.

Similar gneiss is found in rafts tens of metres across within the Jurassic pluton to the south and may be part of the same unit. Rafts occur within the plutonic rocks exposed in a railcut along the east shore of Wood Lake (Fig. 6) and along Highway 97 on the west side of Wood Lake. On the west shore of Kalamalka Lake, gneissic rocks are exposed in a railway cut near the lake. They appear to be in steep, brittle fault contact with the Eocene Coryell syenite to the west.

Medium- to low-grade rocks

Medium- to low-grade metamorphic rocks form a discontinuous east-west belt across the northern half of the map area. Jones (1959) included these rocks in the Carboniferous and Permian Cache Creek Group and described them as limestone, andesite lava and tuff, and argillite. As the volcanic rocks and argillite are interlayered in the Oyama area, we have grouped them together in one unit.

Permian to Early Triassic

Argillite, phyllite, greenstone, breccia (unit Php*)*

This unit includes Jones' (1959) argillite and andesite unit. It is mainly dark grey to dark grey-green massive siliceous argillite. Primary sedimentary structures are rare. The argillite has platy cleavage, but near intrusions, where silicification is common, phyllitic cleavage is locally developed. Fine-grained biotite, muscovite, and chlorite are characteristic. Andesitic flows and breccia are interbedded with the argillite. The flows are fine grained, dark green to grey-green, and massive. Flow breccia is common. The clasts are subangular to angular and appear to be autolithic. Clasts range from several millimetres to several centimetres across. Breccia is typically altered to rusty brown and contains secondary calcite, epidote, and chlorite.

Limestone (unit Phl*)*

Horizons of microcrystalline, beige to dark grey limestone occur within the argillite and andesite. Contacts are sharp and lack evidence of strain. Discontinuous and wispy colour banding occurs in several outcrops, but its relationship to original bedding is uncertain. Limestone on the south flank of the Coldstream Valley is tens of metres thick and flat lying, or dips gently south. Southwest of Vernon, on the northwest shore of Kalamalka Lake, limestone forms a southeast-plunging syncline. Several fossiliferous pinnacles of limestone outcrop immediately west of Vernon. Jones (1959) reported fossils of probable Permian age in limestone near Bluenose Mountain (Fig. 3).

Medium-grade metamorphic rocks of uncertain age

Medium-grade marble, phyllite, and schist of uncertain affinity occur on the south side of the Coldstream Valley and at the base of Mount Middleton. They are generally more metamorphosed than the Permian rocks described above, and less metamorphosed than the adjacent biotite-sillimanite schist.

Marble (unit mp*)*

White, coarse-grained marble is cut by coarse-grained and altered pyroxenite and diorite at the base of Mount Middleton. The marble may be Permian, and recrystallized due to its proximity to pyroxenite. Pyroxenite appears to be exclusively associated with Permian rocks in other places within the Vernon map area.

Phyllite, mica-garnet schist, amphibole schist, augite schist, biotite schist (units ph *and* as*)*

The south side of the Coldstream Valley, 5 km east of Mount Middleton, exposes rocks more metamorphosed than Permian rocks immediately to the east. Rock types include phyllite, mica-garnet schist, amphibole schist, augite schist, and biotite schist. Phyllite and garnet-mica schist include quartz, feldspar, biotite, muscovite, hornblende, chlorite, and garnet. Compositional layering is parallel to a strong cleavage. There is a second, weaker crenulation cleavage developed at high angle to the strong cleavage. Garnets up to 1 cm in diameter grew statically across the mica-defined foliation. Hornblende blades are randomly oriented on the main foliation surface. The fabric in the amphibole schist, augite schist, and biotite schist units is parallel to that in the metasedimentary rocks. The succession is cut by medium-grained hornblende diorite to the west and is inferred to be Permian.

Plutonic rocks

Cretaceous

Cosens Bay pluton (unit Kgd*)*

Within the map area, the only igneous body of known Cretaceous age is the Cosens Bay pluton, a large, foliated intrusive body exposed on the east shore of Kalamalka Lake, immediately south of Kalamalka Lake Provincial Park. The pluton is largely homogeneous, ranging from medium- to coarse-grained biotite- and/or hornblende-bearing granodiorite to granite. It contains rafts of biotite-sillimanite schist near its margins, where foliation is better developed. Quartzofeldspathic veins, centimetres to millimetres thick, parallel to the foliation are present in most outcrops.

The age of emplacement of this unit is between 104 Ma and 90 Ma from U-Pb zircon data (Heaman et al., 1999).

Jurassic

Okanagan plutonic suite (unit Jgd*)*

Jurassic plutonic rocks are common in the western half of the map area and are associated with low- to medium-grade metamorphic rocks. Compositions include granite, granodiorite, and quartz diorite. The plutons are generally massive. Older foliated phases appear to be partly assimilated by younger massive phases of similar composition. Hornblende is widespread, and biotite is less common.

A sample taken from the east side of Wood Lake, where the intrusive rocks are informally known as the Wood Lake pluton, yielded a U-Pb date of 164.4 ± 2.0 Ma from two multigrain fractions of concordant titanite.

Plutonic rocks of uncertain age

Pyroxenite, diorite (unit py*)*

Small, coarse-grained, massive bodies of pyroxenite and diorite occur on Okanagan Lake, at the base of Mount Middleton, and in the Coldstream Valley. The intrusions appear to be associated with the Permian Harper Ranch Group, although metamorphic grade is unusually high for Permian rocks near pyroxenite on Mount Middleton. Along Okanagan Lake, pyroxenite grades into fine-grained diorite towards its margin.

Monzonite (unit qm*)*

A large intrusion of quartz-poor plutonic rock occurs within the high-grade rocks in the eastern half of the map area. Phases include monzonite, quartz monzonite, quartz monzodiorite, and diorite. Grain size varies from fine to coarse and potassium feldspar megacrysts several centimetres in length are common in the most potassic phases. As for the Jurassic intrusive rocks, a complex relationship between foliated and massive phases exists, and the transition commonly is gradational. However, most of the pluton has weak foliation. Hornblende and biotite are common, and biotite is abundant in the potassium feldspar megacryst-bearing phase.

The composition and structure of the pluton is similar to the mid-Jurassic intrusions, suggesting that it may be part of the same suite. However, the Cretaceous Cosens Bay pluton is strongly foliated and no major structure appears to separate the two bodies.

Granite

Numerous small stocks and sills of medium- to fine-grained granite of uncertain age are present within the high-grade rocks. Sills are commonly parallel to the foliation and may, in places, be more voluminous than the host rock.

Tertiary plutonic, volcanic, and sedimentary rocks

Eocene

Eocene rocks include sedimentary rocks (predominantly conglomerate), high-level alkaline intrusive rocks, and associated volcanic rocks. They are preserved in small fault-bounded basins in the valleys and as erosional outliers on basement rocks. Jones (1959) included these rocks in the Eocene Kamloops Group.

Coryell syenite (unit Ecs*)*

Quartz-poor rocks of syenitic to alkali-feldspar–quartz syenitic composition underlie most of the area between Okanagan and Kalamalka lakes. Grain size is medium to coarse, although the pluton is fine grained near its margins. Weathered surfaces are pink to greenish pink, and the fresh surface is predominantly pink to beige.

Conglomerate (unit Ekc*)*

Eocene conglomerate occurs at the base of Mount Middleton and of Bluenose Mountain. At Mount Middleton, the conglomerate is poorly sorted, with equant clasts ranging from millimetres to tens of centimetres across. Clasts are rounded to subangular. Clasts include dacite (both massive and vesicular), rhyodacite, chert, medium-grained biotite-monzonite, pyroxenite, and coal fragments. The conglomerate is clast supported with a fine-grained grey to grey-green matrix. Fine-grained epiclastic rhyolite deposits are interbedded with conglomerate at the base of Mount Middleton. Graded bedding is present in several locations and coal fragments are common. At Bluenose Mountain, the conglomerate has the same characteristics, but lacks interbedded epiclastic layers.

Volcanic rocks (unit Ekv*)*

Eocene volcanic rocks occur as erosional outliers on basement rocks and in small fault-bounded basins in present-day valleys. They range from rhyolite to basalt, with dacite being the dominant composition. Flows are typically massive and fresh except near faults, where they have been altered by fluids. Vesicles are common, and are filled with calcite, chalcedony, or zeolites. Where the underlying rocks are exposed, the volcanic rocks rest stratigraphically on a basal conglomerate, such as at Bluenose Mountain, or are unconformable on older gneiss (Fig. 7). An erosional outlier exposed on the Oyama Lake road, 3 km east of the north end of Wood Lake, overlies a regolith developed in biotite-sillimanite schist. The regolith is rusty red to brown except near the top, where it is dark brown. The regolith is friable and contains clasts of schist in a weathered matrix that has foliation concordant with in situ schist a few metres lower.

Miocene

Basalt (unit Mb*)*

Erosional outliers of Miocene basalt overlie the basement rocks. The basalt is black and aphanitic, and plagioclase and olivine phenocrysts are visible with a hand lens. Vesicles are common. Spectacular cliffs displaying well developed columnar jointing are common at the edge of flows. In some areas, flows are underlain by fluvial, poorly sorted, sandy conglomerate with well rounded quartzite cobbles.

Figure 7. *Angular clast of foliated hornblende-quartz-feldspar gneiss in a basal Eocene dacite flow, Oyama Lake road. Lens cap for scale.*

Dykes of uncertain age

Scattered throughout the map area are fine-grained massive dykes of various compositions. They are black, chocolate-brown, reddish brown, or pink, and typically a few metres wide. On the basis of dominantly alkaline composition and lack of metamorphism they are inferred to be feeders of the Eocene and Miocene volcanic rocks.

STRUCTURE

Differences in the metamorphic grade and structural style indicate separate structural histories. The high-grade rocks have experienced temperatures high enough to produce partial melting and exhibit a multiphase deformational history. The medium- to low-grade rocks experienced much lower pressures and temperatures and displays poorly developed cleavage. The Eocene succession clearly postdates metamorphism, as does the steep, brittle normal fault network.

Fabrics

The high-grade metamorphic rocks exhibit well developed foliation defined by the alignment of micaceous minerals and compositional layering. Contacts between rock types are parallel to foliation. Leucocratic pods in migmatitic biotite-sillimanite-garnet schist are aligned parallel to the foliation, indicating that the fabric was formed under peak metamorphic conditions.

The medium- to low-grade rocks have poorly developed slaty cleavage. In several outcrops, particularly near intrusions, the primary cleavage is better developed, and a weak, second slaty cleavage is present.

Folding

Foliation within the high-grade succession has a range of orientations and evidence of least three deformation events is present. The oldest remnant event (D_1) was synchronous with the development of peak metamorphic conditions and formed the foliation and compositional layering (F_1). The second event (D_2) folded the F_1 foliation into upright, open, and roughly concentric folds with axes (L_2) plunging moderately southeast. Parasitic folds of centimetre amplitude are superimposed on metre-scale folds in outcrop (Fig. 8). A third deformation event resulted in the crenulation of D_2 folds. Although rarely visible in outcrop and poorly developed, the crenulations appear to have generally north-northeast-trending, gently to moderately plunging fold axes.

Cleavage in the medium- to low-grade rocks is best developed a few kilometres east of Vernon in the Coldstream Valley and is generally steeply dipping, northwest-striking, and parallel to compositional layering. However, farther east, Permian limestone appears to be nearly flat lying, or dips gently south.

Shear zones

A west-dipping zone of ductile shear over 1 km wide is exposed on the east shore of Kalamalka Lake and extends south to near the Kelowna airport. It is characterized by strong, gently west-plunging stretching lineation defined by aligned grains of sillimanite and quartz. Leucocratic bands of disaggregated quartzofeldspathic layers form stringers and porphyroclasts with asymmetric wings. Within calc-silicate horizons, intrafolial folds are common (Fig. 9). Shear-sense indicators such as delta and sigma porphyroclasts, C-S fabric, and back-rotated boudins consistently record top-to-the-west motion. Foliation has been transposed during shearing to a roughly horizontal orientation, although there are gentle, concentric folds with metre- to hundred-metre wavelengths, with axes parallel or subparallel to the stretching lineation. Most rocks within the zone are mylonite; cataclasite with a dark, massive, fine-grained matrix with rounded feldspar porphyroclasts is developed locally.

***Figure 8**. Parasitic D_2 folds within a larger outcrop-scale fold in migmatitic biotite-sillimanite-garnet schist.*

***Figure 9.** Intrafolial folds within calc-silicate from Turtle Point.*

Late, brittle faulting

Late, brittle, steep faults are common in and near the valleys where they have juxtaposed high- and low-grade rocks, such as across Kalamalka Lake and near Bluenose Mountain. The exposed faults are typically zones of a few metres of gouge and associated alteration. Faulting appears to have both pre- and postdated the Eocene sedimentary and volcanic rocks and may have accompanied deposition. Eocene sedimentary strata have moderately to steeply dipping bedding orientations, which are inferred to result from block tilting. At Bluenose Mountain and on the Oyama Lake road, Eocene volcanic rocks overlap normal faults without offset.

DISCUSSION

Near Kalamalka Lake, the interpretation of a gently west-dipping regional detachment appears to explain the juxtaposition of low-grade on high-grade metamorphic rocks. However, the presence of high-grade gneissic rocks in the hanging wall of the proposed detachment along the west shore of Kalamalka and Wood lakes is inconsistent with this interpretation. At Wood Lake, a Jurassic pluton appears to span the Okanagan Valley; steep normal faults are present which may have moved the pluton and adjacent high-grade metamorphic rocks from the hanging wall of a detachment into contact with the footwall rocks. At Bluenose Mountain, contacts between high- and low-grade rocks appear to be steep normal faults, and fabrics indicating noncoaxial shear are lacking in the adjacent high-grade rocks. If Permian and Triassic rocks rest unconformably on older basement, as suggested (Jones, 1959; Read and Okulitch, 1977), the peak metamorphic conditions in older rocks must have predated deposition of Permian strata. Uranium-lead geochronology of metamorphic minerals in hanging wall and footwall rocks is in progress to constrain the age of metamorphic events.

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