GEOLOGIC STRIP MAP OF THE NINEMILE CREEK–WILMONT CREEK–HUNTERS CREEK AREA, FERRY AND STEVENS COUNTIES, WASHINGTON

By

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INTRODUCTION

The accompanying map surveys the structure and stratigraphy of the Lower Paleozoic Covada Group across strike at its widest extent. The Covada Group is a diverse assemblage of quartzo-feldspathic wacke and arenite, pillow basalt, volcaniclastic rock, limestone, phyllite, slate, chert, and argillite. It underlies a large area of northeastern Washington, and correlative strata extend several hundred kilometers northward into British Columbia (Smith and Gehrels, 1988). The Covada Group is complexly deformed, metamorphosed to greenschist to amphibolite facies, and bears thermal effects related to intrusion of Eocene, Cretaceous, and perhaps older rocks. Miogeoclinal strata (in part coeval) are in fault contact with the Covada Group to the east (Snook and others, 1981). The tectonic significance of this boundary, which separates rocks of similar age but dissimilar facies, is still controversial.

The Covada Group was originally defined to include exposures of greywacke and greenstone west of Franklin D. Roosevelt Lake and was assigned a Carboniferous age on the basis of a flora collected from a location north of the present map area (Pardee, 1918). Rocks east of Franklin D. Roosevelt Lake were later included in the Covada Group by Campbell and Raup (1964) and Snook and others (1981, 1990). The definition of the Covada Group was expanded to include a belt of fine-grained strata, chert, argillite, conglomerate, and volcanic rocks present to the east of the greywacke and basalt sequence and west of exposures of Lower Paleozoic miogeoclinal strata (Snook and others, 1981, 1990). The Carboniferous age now appears questionable, as neither the fossil nor the fossil locality can presently be located (N. L. Joseph, WA Div. of Geology & Earth Resources, oral commun., 1988). At least part of the sequence is Early Ordovician in age, based on analysis of megafossils and conodonts collected from tuff and limestone approximately 20 mi north of Hunters (Snook and others, 1981). The age of the Covada Group as a whole is thus inferred to be early Paleozoic, in part Early Ordovician.

The map area is approximately 3 mi wide and 30 mi long and extends from the Hunters area on the east side of Franklin D. Roosevelt Lake (Columbia River) to the Keller graben on the west side. The Hunters area was mapped previously by Campbell and Raup (1964); the Wilmont Creek area was mapped by Becraft (1966). The map area is also included on a compilation map by Atwater and others (1984). The stratigraphy of the Covada Group as defined by these and other studies (e.g., Snook and others, 1990) was thought to consist of a lower unit of chert, argillite, and other fine-grained strata, a middle unit of greenstone and limestone, and an upper unit of sedimentary rock with some interbedded volcanic rock.

Recent detailed mapping in an area approximately 19 mi north of Hunters (Smith, 1990, in press) suggests division of the Covada Group into two informal units, the sedimentary Daisy sequence and the volcanic Butcher Mountain sequence, and the exclusion of much of the fine-grained strata, which are given the informal name Bradeen Hill assemblage. On the basis of examination of facing indicators, contacts, and provenance links, the Daisy sequence is interpreted as the older unit and the Bradeen Hill assemblage as the younger. This interpretation and terminology are adopted for this report.

MAP UNIT DESCRIPTIONS

Qsd **Quaternary surficial deposits, undifferentiated**

This unit includes mappable accumulations of glacial terrace deposits, till, reworked glacial deposits, fluvial deposits, and alluvium.

Td **Tertiary dikes and sills, undifferentiated**

This unit includes at least three intrusive suites, which are broadly described as follows:

(1) *Leucocratic granite, aplite, and pegmatite dikes and sills.* The granite is in general heavily weathered and cut by more resistant aplite and pegmatite layers.

(2) *Porphyry dikes and sills.* These encompass a wide compositional range from light-grey quartz-plagioclase porphyry to dark-grey hornblende-plagioclase porphyry. In the map area, these dikes are correlated with the hypabyssal intrusive suite of Cody Lake of Atwater and others (1984); the latter has yielded K-Ar ages from 47 to 50 Ma. The map symbol is **Th.**

(3) *Greenstone dikes.* Rocks of this type are sparsely distributed and designated **gs** where differentiated.

Thicker dikes (and those encountered on foot traverse) are designated on the map. The general area affected by dike swarms of the first two types is designated by a light stippled pattern.

Ts **Sanpoil Volcanics**

The pink-brown, plagioclase-hornblende dacite flows and flow breccia of this unit are present on the east side of Franklin D. Roosevelt Lake and along the extreme western border of the map area. The age of these rocks is approximately 48-50 Ma (Atwater and others, 1984), based on K-Ar dating of correlative rocks.

To **O'Brien Creek Formation**

This unit consists of light-colored, plagioclase-, quartz-, and biotite-bearing rhyodacite tuff. Atwater and others (1984) report a K-Ar age of 54 Ma.

pgm **Porphyritic granodiorite of Manila Creek**

In the map area, this unit is primarily a garnet-bearing, muscovite-biotite granite. Coarse, felsic pegmatite is abundant along margins with the Covada Group and cross-cuts the main granitic phase. Medium-grained granite has a moderately well developed lineation and foliation that roughly parallel the foliation in the Covada Group. The contact with the Covada Group is extremely irregular, and numerous screens of Covada Group schist are present in the main body of granite. The unit is undated, although regional relations suggest it is probably older than 60 Ma (Atwater and others, 1984); it is here inferred to be of Jurassic or Early Cretaceous age.

hg **Hornblende gabbro**

Sill-like lenses of coarse, sheared, and weakly foliated green hornblende gabbro intrude the Covada Group east of Franklin D. Roosevelt Lake. The sills may be feeder intrusive equivalents of volcanic rocks in the Covada Group, or they may be younger and unrelated. The sills pre-date the main phase of deformation and metamorphism. The Paleozoic age is questioned.

Dl **Devonian limestone**

Medium-grey, fossiliferous, impure limestone is present in a single roadcut adjacent to the Greenwood Cemetery in the eastern portion of the map area. Fossils of late Devonian age were identified by Dutro and Gilmour (1989) and A. G. Harris (*in* Joseph, 1990). This unit is fault-bounded, and the stratigraphic relationship to other units in the immediate area is not known. Carbonate of Devonian age is also known from the Flagstaff Mountain sequence in the Northport area, 60 mi to the north (Yates, 1976; Webster and Beka, 1980), and from the Echo Valley area to the northeast (Mills, 1985). The Flagstaff Mountain and Echo Valley strata are correlated with the Bradeen Hill assemblage by Smith (1990), and thus the Dl unit may also be part of the Bradeen Hill assemblage.

Bradeen Hill Assemblage

The Bradeen Hill assemblage as defined in the Old Copper Hill area approximately 20 mi to the north (Smith, 1990, in press) includes slate, chert, argillite, chert-quartz arenite, chert-pebble conglomerate, and minor quartz arenite and volcanic rocks. Units in the Hunters area are primarily restricted (by faulting and/or facies changes) to fine-grained strata and chert. Except where noted, units are fault bounded and are described below with no implied stratigraphic order.

lPp **Phyllite**

Dark-grey to black phyllite, slate, and minor black quartzite are present in the northeastern part of the map area and along the west bank of Franklin D. Roosevelt Lake.

lPc **Carbonate**

This unit consists of thin lenses of grey, recrystallized limestone scattered throughout the lPp unit.

lPs **Siltite/chert**

This unit consists of:

(1) Distinctive grey-blue slate and siltstone with pronounced flaggy cleavage.
(2) Thin to medium beds of black to grey, recrystallized chert (designated **ch** where divided).
(3) Rare limestone (**ls** where divided). It is hornfelsed to black, massive rock with light-grey chert layers in the southeast corner of the map area. A 0.5-meter-thick layer of chert-pebble conglomerate crops out in the southwest corner of sec. 35, T. 31 N, R. 37 E.

lPch **Chert**

Dark-grey to black, recrystallized, bedded chert with phyllitic partings forms thin layers and lenses interbedded with phyllite (lPp) and tuff (lPv).

lPv **Volcanic rock**

Layers and lenses of sheared mafic tuff and pillow basalt are interbedded with the lPp and lPc units. This unit is essentially indistinguishable from the Butcher Mountain sequence except by its association with other Bradeen Hill units.

Covada Group

The Covada Group as strictly defined by Smith (1990) consists of the Butcher Mountain sequence (volcanic rocks) and Daisy sequence (quartzo-feldspathic sandstone). These are further subdivided into the map units defined below. Carbonate bodies are present in both sequences. On the map, all carbonate bodies are given the designation lPcc (see below) and are not differentiated by their presence in either sequence.

Butcher Mountain sequence

lPcg1 Primarily pillow basalt with ubiquitous calcite- and/or chlorite-filled amygdules; rocks are commonly pyroxene-porphyritic and highly sheared. Massive greenstone is also included in this unit. Although some protolith features (pillows, etc.) are present, few original mineral phases are preserved. The groundmass is dominantly composed of chlorite, albite, actinolite, titanite, epidote, and opaque minerals. Relict augite phenocrysts are largely to entirely replaced by actinolite. Phenocrysts completely replaced by serpentine were likely olivine. The presence of skeletal ilmenite and a pink-brown pleochroism in some augite grains are indicative of high Ti content of the basalt.

lPcg2 Tuff that ranges from finely laminated ash-tuff to coarse lapilli tuff. It is interbedded with unit lPcg1. Thin tuff layers are also sparsely distributed throughout the Daisy sequence.

lPcg3 Calcareous greenstone, which is well foliated and has a striking, irregular weathering pattern.

Daisy sequence

The Daisy sequence consists of thin to massively bedded quartzo-feldspathic sandstone with slaty interbeds. The sandstone is characterized by moderate to poor sorting and angular to subrounded grains, and it spans a compositional and textural range from feldspathic wacke to rare quartz arenite. Coarser rocks typically have a "gritty" appearance; large bluish quartz and feldspar grains are dispersed in a medium-grained sandstone matrix. Wackes predominate to the west (notably west of Wilmont Creek), and relatively well-sorted, quartz-rich rocks and grit are more common to the east. Primary sedimentary structures (other than bedding) are rare, but include grading and small-scale cross beds. Bouma AE divisions, typical of proximal turbidites, predominate throughout much of the section. True bedding attitudes are extremely difficult to decipher across much of the central portion of the map area; sandstone is massively bedded and poorly exposed and possesses a potentially misleading flattening fabric. Detrital grains include (in decreasing order of abundance) monocrystalline quartz, potassium feldspar (commonly microcline), plagioclase, polycrystalline quartz, muscovite, tourmaline, zircon, and other accessories. Biotite and sedimentary lithic grains are locally common, but generally lacking. Three map units are distinguished:

lPcs1 Green sandstone with black, grey, or green slaty interbeds.

lPcs2 Grey-buff sandstone with grey or black slaty interbeds.

lPcs3 Stratigraphic intervals that are predominantly (>50%) dark-gray slate and siltite.

Undifferentiated rock units

lPcc Carbonate

This unit encompasses carbonate rocks of differing ages and affinities, including the following types:

(1) Limestone lenses, generally from 1 to 10 m thick, are present in the eastern part of the map area. The limestone is medium grey and recrystallized, in places sandy, with phyllitic partings. This unit is most commonly present along margins between the Daisy and Butcher Mountain sequences.

(2) White to grey marble and grey to greenish calc-silicate rock are present in a horizon adjacent to the Manila Creek intrusive body (unit pgm) in the southwestern part of the map area.

(3) A regionally extensive unit mapped in the northwestern part of the map area ranges from pure, medium-grey limestone and dolostone (western exposures) to calcareous phyllite (eastern exposures). Small unidentified gastropod fossils were recovered from one locality, which may provide clues to its age and identity. The contacts with adjacent Covada Group exposures are not yet well constrained; it is probably in fault contact with the Covada Group to the south, but may lie depositionally over the Covada Group unit lPcs3 and/or interfinger with it. Additional work will be necessary to resolve this question.

lPcch Chert breccia

This reddish-weathering unit may be a sedimentary horizon within the regionally extensive carbonate unit (lPcc).

Miogeoclinal Strata

Ols Ledbetter Slate

The Ledbetter Slate consists of medium- to dark-grey, finely laminated to thin-bedded slate and siltite, as well as minor silty limestone. It is present in the easternmost part of the map area and is poorly exposed and unfossiliferous in the map area. Nearby outcrops have yielded Middle Ordovician graptolites (Campbell and Raup, 1964).

OCl Limestone of Late Cambrian or Early Ordovician age

This unit consists of medium-grey, fine- to medium-grained platy limestone with slate partings. The most southerly outcrop, a roadcut on the Hunters-Springdale Road, has yielded conodonts of Late Cambrian or perhaps Early Ordovician age (Joseph, 1990). Other outcrops are assigned to the unit on the basis of their structural position in the overall sequence, being present everywhere at the western margin of the Ledbetter Slate.

DEFORMATION

The Covada Group and related strata are complexly deformed, having undergone at least two phases of deformation: (1) a contractional event of probable Jurassic to Cretaceous age; and (2) an extensional event of Eocene age.

Penetrative Fabric Elements

All lithologic types, with the exception of some massive volcanic rocks and coarse sedimentary layers, possess a cleavage or foliation, the latter defined by parallel orientation of metamorphic phyllosilicate minerals and less commonly by flattened volcanic or lithic clasts or amygdules. Foliation is also defined to include a weak flattening fabric present in most sandstone. It is typically subparallel to bedding or axial planar to large folds. Foliation gradually becomes very pronounced (schistose) in the southwestern part of the map area, adjacent to the Manila Creek intrusion. Cleavage and foliation refraction are commonly present in bedded sedimentary rocks. Foliation in most areas strikes approximately north-northeast; it has moderate to steep dips that alternate between west- and east-dipping domains. There is a fair amount of variation in foliation orientation in the southwestern part of the map area, where dips tend to be moderate to shallow. Rocks in this area conform in a general sense to the margins of the Manila Creek intrusion.

A weak (second phase?) axial planar cleavage is developed in association with small kink and crenulation folds in fine-grained rocks. Orientations are steep and of various strike directions.

Folds that have wavelengths of tens to hundreds of meters are common, but their precise geometry is difficult to elucidate due to poor outcrop and lack of top indicators. Fold axial areas are rarely exposed and generally must be inferred from changes in foliation orientation. Folds are best exposed along the ridges north and south of Hunters Creek and northwest of Coyote Creek. In the former locality, folds are open to tight with angular fold closures. Fold axes range from nearly horizontal to gently north-plunging and trend north to north-northeast. Axial planes are vertical to steeply inclined. Folds in the Coyote Creek area have similar geometries, and first-phase cleavage is developed in an axial planar manner. Overturned bedding attitudes in a few locations indicate that some folds are tight to isoclinal in nature and overturned. North- to north-northeast-trending folds are interpreted to have formed during the main (first phase) deformation.

Folds on a hand sample to microscopic scale are primarily of the kink and crenulation type and developed only in fine-grained rocks. They have a range of orientations but predominantly trend east, nearly orthogonal to the axes of larger folds. They are sporadically developed throughout the map area. They are interpreted to have formed under slightly more brittle conditions, perhaps during pre-Eocene unroofing of the Covada Group.

The Covada Group is divided into a series of panels or domains in which foliation attitudes alternately dip west or east. For example, most foliation attitudes east of approximately the R. 34 E./R. 35 E. line west to the Columbia River dip west, whereas rocks are predominantly east-dipping west of this line. Poor exposure precludes identification of the structures which produce this configuration.

Stretching and mineral lineations are well developed in rocks with schistose foliation in the southwestern part of the map area but are generally lacking in others. Large quartz and feldspar clasts in coarse, gritty rocks assume elongate habits, and metamorphic biotite, muscovite, chlorite, and tourmaline commonly form mineral lineations. This lineation consistently trends east to northeast.

Faults

Faults are difficult to recognize in the field due to poor exposure; many are parallel to bedding or foliation. Their presence must generally be inferred from unlikely juxtapositions of different rock types, age discrepancies, and unusual geomorphologic features (for example, unusually linear, steep-walled valleys).

In the eastern portion of the map area, a fairly consistent structural stratigraphy can be mapped, but units vary profoundly in thickness over short distances along strike and are absent in some areas. The Bradeen Hill assemblage varies from a cumulative thickness of several kilometers in some areas to less than 100 m of brecciated chert north of the Hunters-Springdale road. In this area, the Butcher Mountain sequence, of Early Ordovician age, is adjacent to Cambrian to Ordovician(?) limestone, which in turn is juxtaposed against Devonian limestone and Middle Ordovician rocks of the Ledbetter Slate, clearly indicating fault imbrication of units. The eastern margin of the Covada Group is thus inferred to be in fault contact with miogeoclinal strata along a high-angle, anastomosing shear zone of regional extent. Foliation is disrupted in some areas, indicating that latest movement on this zone is post-foliation and thus post-Jurassic. No evidence precludes the possibility of earlier (post-Devonian) movement. Reliable kinematic indicators are lacking from this fault zone.

High-angle, bedding-parallel shear zones are present throughout the Butcher Mountain sequence in the vicinity of Hunters, although the magnitude of offset along these shears is probably minimal.

There is limited evidence for a low-angle fault contact between the Butcher Mountain sequence and the Daisy sequence northeast of Hunters, where foliation and bedding attitudes in both units appear to trend into each other. Whereas the depositional contact between the Daisy and Butcher Mountain sequences typically grades through fine-grained strata and limestone over several tens of meters, only a few meters of covered area separate coarse wacke and basalt in this area. Thus the contact is interpreted to be a low-angle fault.

West of the Columbia River, the contact between the Bradeen Hill assemblage and Covada Group was previously interpreted as a high-angle fault by Becraft (1966). Mapping for this study indicates that the contact is moderate- to low-angle in nature, and strike directions wrap around from north-south to nearly east-west in the southern portion of its mapped extent. It is thus interpreted to be a sheared depositional contact, rather than a major high-angle fault.

High-angle faults were mapped by Becraft (1966) in the valley of Wilmont Creek, in Coyote Creek, and trending northeast across the top of Gold Mountain Ridge. The faults may exist in Wilmont and Coyote Creeks, in the former because of shear fabrics developed in rocks on the east side of Wilmont Creek in sec. 4 and on the southwestern side of Wilmont Creek in sec. 15, and in the latter primarily because of the odd configuration and drainage pattern in Coyote Creek. The faults are of a brittle nature and are likely Eocene or younger in age. No evidence for the faults previously mapped across Gold Mountain Ridge could be found.

In the western part of the map area, the carbonate unit is inferred to be in fault contact with the Covada Group to the south based on trends of bedding attitudes (the fault is nowhere exposed), but the continuation of the fault to the northeast cannot be mapped with certainty due to poor exposure. It is conceivably related to the Gibson Creek thrusts mapped by Atwater and others (1984) to the northeast.

A high-angle, post-Eocene, north-striking fault juxtaposes Eocene volcanic rocks of the Keller graben against Covada Group strata along the extreme western margin of the map area.

METAMORPHIC EFFECTS AND TIMING

The Covada Group is everywhere elevated to at least the greenschist facies and is locally of amphibolite grade. Regional metamorphic grade is difficult to evaluate in pelitic rocks, which contain fine-grained chlorite, albite, quartz, calcite, titanite, and sericite. Regional metamorphic grade is elevated around the Manila Creek intrusive (unit pgm). Here the Daisy sequence (units lPcs1 and lPcs2) is upgraded to coarse, kyanite-bearing quartz-mica schist, and rocks of unit lPcs3 are upgraded to silver-gray semischist, biotite schist, and black, tourmaline-bearing schist. This observation and the conformable nature of foliation around and within the Manila Creek intrusive suggest that its emplacement was synkinematic with respect to the regional Mesozoic deformational event.

Contact metamorphic effects are in evidence in the southeastern part of the map, where rocks are near plutons of Cretaceous age that crop out immediately to the south and east of the map area (Campbell and Raup, 1964). Rocks in this area are black, fine-grained, and very hard. Primary features, particularly in basalt, are difficult to resolve. Small carbonate bodies are marbleized, and chert is light grey. Large (5-10 cm) andalusite crystals are developed in some pelitic rocks. Effects of this contact-metamorphic event are not seen north of Hunters Creek and become progressively less well developed westward. The approximate limits of the area affected by contact metamorphism are outlined on the map.

Relations in the map area suggest that first-phase metamorphism and deformation are synkinematic with emplacement of the Manila Creek intrusive body and predate emplacement of Cretaceous plutonic rocks. Deformation and metamorphism also clearly predate intrusion of Eocene dikes, as evidence by their undeformed nature. An accurate radiometric date on the Manila Creek intrusion would help define the timing of deformation in the southern Kootenay Arc.

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MAP UNITS

Quaternary	Qsd	SURFICIAL DEPOSITS, UNDIFFERENTIATED
Eocene?	Td	TERTIARY DIKES AND SILLS, UNDIFFERENTIATED
Eocene	Ts	SANPOIL VOLCANICS
	Th	HYPABYSSAL INTRUSIVE SUITE OF CODY LAKE
	To	O'BRIEN CREEK FORMATION
Mesozoic?	pgm	PORPHYRITIC GRANODIORITE OF MANILA CREEK
Paleozoic?	hg	HORNBLENDE GABBRO
Lower Paleozoic	Dl	DEVONIAN LIMESTONE
		Bradeen Hill Assemblage
	lPp	PHYLLITE
	lPc	CARBONATE
	lPs	SILTITE AND CHERT
	lPch	CHERT
	lPv	VOLCANIC ROCK

Lower Paleozoic		**Covada Group**
		Butcher Mountain sequence
	lPcg1	PILLOW BASALT/MASSIVE GREENSTONE
	lPcg2	VOLCANICLASTIC ROCK
	lPcg3	CALCAREOUS GREENSTONE
		Daisy sequence
	lPcs1	GREEN SANDSTONE
	lPcs2	GREY-BUFF SANDSTONE
	lPcs3	SLATE/SILTSTONE
		Undifferentiated Units
	lPcc	CARBONATE
	lPcch	CHERT BRECCIA
		Miogeoclinal Strata
	Ols	LEDBETTER SLATE
	OCl	CAMBRIAN OR ORDOVICIAN LIMESTONE

MAP SYMBOLS

CONTACT — DASHED WHERE APPROXIMATE, DOTTED WHERE INFERRED, QUERIED WHERE INTERPRETATION IN DOUBT

FAULT — DASHED WHERE APPROXIMATE, DOTTED WHERE INFERRED, QUERIED WHERE LOCATION OR EXISTENCE IN DOUBT

AXIS OF LARGE FOLD
- ANTICLINE
- SYNCLINE
- DASHED WHERE APPROXIMATE

STRIKE AND DIP OF BEDDING
- TOP KNOWN
- TOP NOT KNOWN
- OVERTURNED
- VERTICAL
- HORIZONTAL

STRIKE AND DIP OF FOLIATION
- INCLINED
- VERTICAL
- SHEARED

STRIKE AND DIP OF CLEAVAGE

CLEAVAGE AND BEDDING PARALLEL

FOLIATION AND BEDDING PARALLEL

STRIKE AND DIP OF JOINT

TREND AND PLUNGE OF STRETCHING/MINERAL LINEATION

TREND AND PLUNGE OF AXES OF SMALL KINK AND CRENULATION FOLDS

HORIZONTAL TREND OF LINEATION

STRIKE AND DIP OF KINK PLANE

DIKE SWARM AREA

OUTCROP SYMBOLS

(PRESENCE ON MAP DENOTES LOCATION OF OUTCROP)

- SLATE/PHYLLITE/ARGILLITE
- SILTSTONE/FINE SANDSTONE
- PREDOMINANTLY SANDSTONE
- GRANULE CONGLOMERATE
- PILLOW BASALT OR MASSIVE VOLCANICS
- VOLCANICLASTIC ROCK
- CALCAREOUS GREENSTONE
- INTERMEDIATE VOLCANIC ROCK
- INTRUSIVE
- LIMESTONE
- CHERT
- BRECCIA

METAMORPHISM

APPROXIMATE LIMITS OF SCHISTOSE FOLIATION

APPROXIMATE LIMIT OF CONTACT METAMORPHIC EFFECTS

N

Scale 1:24,000

0 .5 1 MILE

1000 0 1000 2000 7000 FEET

1 .5 0 1 KILOMETER

* QUATERNARY/ BEDROCK CONTACT IS EVERYWHERE DASHED; ACTUAL PRECISION OF LOCATION VARIES

EXTENT OF QUATERNARY COVER BETWEEN WILMONT CREEK AND THE COLUMBIA RIVER LARGELY AFTER BECRAFT (1966)

OFR
91-4