GEOLOGIC MAP OF THE OLD COPPER HILL–BUTCHER MOUNTAIN AREA, STEVENS COUNTY, WASHINGTON

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Plate 1. Geologic map of the Old Copper Hill–Butcher Mountain area, Stevens County, Washington [accompanies text]

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INTRODUCTION

The Covada Group is a diverse assemblage of quartzo-feldspathic wacke and arenite, mafic volcanic and volcaniclastic rock, limestone, and fine-grained sedimentary rock that underlies a large area around Franklin D. Roosevelt Lake in northeastern Washington. The Covada Group was named by Pardee (1918) for basalt and graywacke exposures on the Colville Indian Reservation west of Franklin D. Roosevelt Lake. It was broadly assigned a Carboniferous age based on a report of a leaf fossil recovered from near the Silverleaf mine, south of Inchelium. Recent efforts to substantiate this report have met with no success (N. L. Joseph, Wash. Div. Geol. and Earth Res., oral commun., 1988). More recently, the name Covada Group was applied to rocks east of Franklin D. Roosevelt Lake by Campbell and Raup (1964) in the Hunters quadrangle and by Snook and others (1981, 1990) in the Inchelium quadrangle. The latter authors expanded the usage of Covada Group to include a south-trending belt of fine-grained clastic rocks, chert, conglomerate, and volcanic rocks present east of the wacke/basalt sequence and west of exposures of Cambrian to Ordovician miogeoclinal strata. Snook and others (1981) also reported the first reliable fossil age from the Covada Group on the basis of identification of conodonts and megafauna of middle to late Early Ordovician age.

In an effort to more accurately describe and define the stratigraphic sequence in the Covada Group, approximately 10 mi^2 were mapped at a scale of 1:12,000 in parts of the Rice, Kentry Ridge, and Inchelium 7.5-minute quadrangles. The map area is dominantly underlain by units of the Covada Group, consisting of (1) quartzo-feldspathic wacke and arenite and (2) volcanic rock and limestone. Both assemblages are distinctive, mutually exclusive, and underlie large areas at predictable stratigraphic horizons. These assemblages are informally designated the Butcher Mountain sequence (volcanic rocks) and the Daisy sequence (sedimentary rocks) (Smith, 1990). The eastern chert-argillite-conglomerate-basalt assemblage is petrographically distinct from and probably younger than the Covada Group. It is designated the Bradeen Hill assemblage. This assemblage exhibits rapid facies changes along strike but is nonetheless continuous from the Hunters area to several miles north of the map area.

Reference to the accompanying geologic map is implied rather than stated explicitly for most of the following discussion.

MAP UNIT DESCRIPTIONS

As previously indicated, the Covada Group was divided into three units in the map area: the Daisy and Butcher Mountain sequences and a third unit informally designated the Bradeen Hill assemblage. These units and their relationships to each other are described in more detail below.

The Bradeen Hill assemblage lies between the Covada Group and exposures of Cambrian miogeoclinal strata. It consists of fine-grained shale, chert, chert-quartz sandstone, chert-pebble conglomerate, quartz arenite, and minor volcanic rocks. The Bradeen Hill assemblage differs from the Covada group because the Bradeen Hill contains quartz-rich and feldspar-poor sandstone and abundant fine-grained strata. However, it is linked to the

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Covada Group by provenance and other characteristics, which also help to define its age (Smith, 1990). The chert-pebble conglomerate unit contains gritty, quartzo-feldspathic clasts that (1) suggest derivation from the Covada Group and (2) establish the unit as younger than the Covada Group. Another link is the presence of pillow basalt mineralogically and otherwise similar to that in the Butcher Mountain sequence. The contact with the Butcher Mountain sequence is not exposed in the map area, but it is reported as conformable 5 mi to the south (Smith, 1982), thus suggesting that the assemblage is in part Ordovician in age. The assemblage resembles sequences of unnamed rocks in the Echo Valley and Flagstaff Mountain areas to the north, both of which contain strata of Devonian age (Adekoya, 1983; Yates, 1976; Webster and Beka, 1980; Mills, 1985; Mills and others, 1985). Devonian rocks have also been found in the fault zone separating the Bradeen Hill assemblage from miogeoclinal strata east of Hunters (Joseph, 1990). Lastly, some units resemble Silurian to Devonian strata in the Metaline area to the northeast (Greenman and others, 1977). Thus, the Bradeen Hill assemblage is interpreted as Ordovician(?) to Devonian in age.

The Covada Group is divided into the Daisy sequence*, dominantly composed of quartzo-feldspathic wacke and arenite, and the Butcher Mountain sequence, which is mostly mafic volcanic rocks and limestone. Appropriate type localities for the Butcher Mountain and Daisy sequences are in the map area. (See Smith (1990) for locations.) In contrast to previous interpretations, mapping and facing indicators suggest that the volcanic unit is the younger of the two sequences and that the succession is progressively younger eastward. Covada Group rocks are everywhere metamorphosed to low greenschist facies; hence, the modifier "meta" should be inserted before all lithologic types.

The Butcher Mountain sequence is a diverse assemblage of pillow basalt, tuff, massive basalt, and limestone. It is in part of middle Early Ordovician age, based on identification of conodonts from a limestone lens and megafauna recovered from an ash tuff layer (Snook and others, 1981). An additional fossil locality was found to the south of the original locality in the SW¼ sec. 2, T. 33 N., R. 37 E. by members of a Washington Division of Geology and Earth Resources field trip in August 1988. The new collection, primarily consisting of molds of trilobites and brachiopods, was examined by R. Ross and tentatively assigned an Early Ordovician (Arenigian) age (Linda McCollum, Eastern Wash. Univ., oral commun., 1988; Joseph, 1990). No additional fossil localities were found during a careful search in 1989. The bottom of the sequence is defined as the base of the stratigraphically lowest occurrence of volcanic rocks. The top of the Butcher Mountain sequence is defined as the contact between the volcanic rocks and overlying chert and siliceous argillite of the Bradeen Hill assemblage. The upper contact is not exposed in the map area, but it is described as conformable 5 mi to the south (Smith, 1982). Lenses of the Butcher Mountain sequence volcanic rocks are also found in the Daisy sequence. These occurrences typically have covered contacts and are either fault slivers, other stratigraphic horizons, or both.

The Daisy sequence consists dominantly of thick-bedded, medium- to coarse-grained, poorly sorted subarkosic wacke and arenite with finer grained interbeds. Thick beds of coarse sandstone typically display normal grading, but have reverse grading in the upper few centimeters. Coarser sediments are channelized in outcrop; coarse beds greater than 2 m thick are generally well exposed and may represent channels, whereas areas of poor exposure may be underlain by finer grained rocks representing overbank deposits. Walker and Mutti's (1973) submarine fan facies A, B, and C (mostly mid-fan channel and classic proximal turbidites) dominate the section exposed in the map area. In thin section, the sandstone is poorly sorted and grains are subangular to subrounded, although a few well-rounded grains are also present. Monocrystalline quartz, plagioclase, microcline, muscovite, sedimentary lithic grains, biotite, tourmaline, and zircon are the dominant grain types, in decreasing order of abundance. The base of the Daisy sequence is not exposed.

* In Smith and Gehrels (1991), the Daisy and Butcher Mountain sequences are referred to as formations. To date, however, no formal description of the units has been published. These names do not, therefore, meet the requirements of the North American Strtatigraphic Code, and they are termed sequences herein to make clear their informal status.

Post-Paleozoic Units

Qs **Quaternary surficial deposits, undifferentiated**
This unit includes all appreciable (greater than a few meters thick) deposits of unconsolidated sediments, including till, outwash, fluvial and lacustrine deposits, and alluvium.

Kq **Cretaceous quartz monzonite**
This undeformed, coarse-grained biotite quartz monzonite intrudes the southeast part of the map area. The contact with host rocks is extremely irregular; sills of granitic material extend more than 100 m into adjacent rocks. Intrusion has resulted in contact metamorphism of the surrounding country rock.

Paleozoic Units

ds **Dioritic and gabbroic sills**
This unit consists of dark-green, foliated sills ranging from 0.5 to 15 m in thickness and as much as several hundred meters in length. They are commonly spatially associated with the limestone/slate unit in the upper (eastern) sedimentary sequence of the Covada Group. The sills range from altered plagioclase hornblende diorite to coarse hornblende pyroxene gabbro or ultramafic rock to fine-grained mafic rocks resembling flows or very shallow intrusive rocks. The rocks are sheared and contain the same metamorphic mineral assemblage as the Covada Group. Therefore, they are interpreted to be older than the regional metamorphic event. As mapped, the unit may include some younger (post-metamorphic) rocks.

Bradeen Hill assemblage

The Paleozoic map units (post-Early Ordovician, but signified by **P** in the unit symbols below))comprising the Bradeen Hill assemblage are described below in possible stratigraphic order from youngest to oldest.

Pcg **Conglomerate**
This unit consists chiefly of thick, massively bedded, matrix-supported pebble conglomerate, but ranges from a pebbly sandstone to clast-supported conglomerate. Pebbles are dominantly well-rounded to subangular, gray to black and rarely white or greenish chert and siliceous argillite, with lesser amounts of sandstone (in part derived from the Covada Group wacke sequence), shale, and vein quartz clasts. Matrix sandstone is chert-quartz arenite, with quartz, chert, argillite, siltstone, sandstone, plagioclase, and microcline clasts in descending order of abundance. Strata along the eastern contact are thin to medium bedded and gradational down-section into the Ps unit.

Ps **Sandstone and siltstone**
This unit consists of thin- to medium-bedded, fine- to medium-grained sandstone, siltstone, and shale. Sandstone is largely chert-quartz arenite similar in composition and texture to the matrix of the conglomerate. The unit also contains small amounts of quartz arenite. In a few places, coarse sand and rare chert-pebble conglomerates form beds as much as 1 m thick. Clast composition in the lithic arenite is approximately 45–80 percent quartz, 19–54 percent chert and siliceous argillite, and 2–5 percent other clasts, mostly lithic fragments. Sedimentary structures in addition to bedding are rare, although grading in thin sand-silt couplets was observed in the NE¼NE¼NW¼ sec. 35, T. 34 N., R. 37 E., immediately east of the Pcg contact. This unit is gradational westward into the Pcg unit.

Pqa **Quartz arenite**
Although quartz arenite is a constituent of the Ps unit, a 3- to 5-m-thick laterally continuous bed within the Ps unit is mapped as a separate unit in sec. 35, T. 34 N., R. 37 E. The quartz arenite is medium to dark gray, massively bedded, and featureless and contains abundant white quartz veins. In thin section, the unit is thoroughly recrystallized, but under plane-polarized light, grain outlines are defined by opaque minerals. Grains are well rounded and show a bimodal size distribution.

Psl **Slate and phyllite**
This unit is dominantly composed of sheared, dark-gray to black slate and phyllite. As mapped, it probably represents a number of different horizons throughout the Bradeen assemblage rather than a single stratigraphically unique horizon. It is gradational into both the Ps and Pch units.

Pv Volcanic rocks
A thin, north-trending lens of pillow basalt is present in sec. 26, T. 34 N., R. 37 E. The basalt is sparsely amygdaloidal and porphyritic; sparry calcite fills the areas between pillows. Additional thin lenses are present to the southeast of this lens and along the northwest flank of Old Copper Hill. A lens of hornfelsed calcareous material of presumed volcanic affinity is located on the extreme east end of Old Copper Hill.

Plc Limestone-clast breccia
This distinctive unit consists mostly of elongate, cigar- or pancake-shaped limestone blebs typically 1–2 cm thick and several centimeters long floating in a matrix of black to gray, fine-grained phyllitic or argillitic material. At one locality near the summit of Butcher Mountain, thin-bedded limestone is interbedded with argillite on a centimeter scale; thus, the limestone clasts are probably intraformationally derived.

Pch Chert and siliceous argillite
This unit is composed of thin- to medium-bedded, black to gray siliceous argillite and chert. Beds are typically separated by shale partings. As mapped, the unit contains black shale and phyllite intervals. The unit as mapped is not a single sedimentary unit. This is the lowest unit in the Bradeen Hill assemblage, and it is either interbedded or structurally interleaved with all units described above stratigraphically up to the Ps unit.

Covada Group

Butcher Mountain sequence

The Butcher Mountain sequence, of Early Ordovician age, is approximately 550 m thick across the top of Butcher Mountain and consists of the following map units:

Ocv Volcanic and volcaniclastic rocks
Basaltic rocks of this unit are medium to dark green, aphanitic, and abundantly vesicular and/or amygdaloidal with calcite- or chlorite-filled amygdules. Pillow rims are darker than the cores, and sparry calcite commonly fills spaces between pillows. Some flows have a ropy or brecciated appearance, and others are pyroxene-porphyritic. Massive volcanic flows range from medium to dark green to gray-blue, typically lack vesicles or amygdules, and range from aphanitic to pyroxene-porphyritic. The southeastern exposures of this unit are foliated greenschist for which the protolith is uncertain.

Volcaniclastic rocks range from ash tuff (less common) through lapilli and lapilli-block tuff (more common). The most common lithology is massively bedded lapilli tuff composed of angular clasts in a sparry calcite matrix. Coarser layers appear channelized, and fine-grained rocks display weakly developed, thin to medium bedding. Bedding elsewhere is massive.

A typical basalt sample contains phenocrysts of pyroxene (titaniferous augite) and minor hornblende, both partially replaced by actinolite, and olivine(?) phenocrysts totally replaced by serpentine. Rare plagioclase phenocrysts are albitized. The matrix is very fine grained and recrystallized and consists dominantly of albite, actinolite, chlorite, calcite, epidote, and opaque minerals. Tuffaceous clasts typically contain abundant small albitized plagioclase laths and rare pyroxene phenocrysts. Ash tuff is very well preserved in some localities; clasts are composed of angular devitrified glass shards, plagioclase laths, and pumice fragments.

Ocvl Limestone
Limestone layers in the volcanic sequence are typically lensoidal and may exceed 50 m in thickness and several hundred meters in length. They are massively bedded to weakly foliated, medium to coarse grained and recrystallized, medium gray on weathered surfaces and medium gray to white or tan on fresh surfaces. No megafossils have been recovered from these limestones, although a single conodont locality constrains one lens to Lower Ordovician in age (Snook and others, 1981).

Daisy sequence

The Daisy sequence, which is Early Ordovician to Cambrian? in age, is in excess of 1,500 m thick in the map area and consists of the following three units:

Ocsl Limestone
Limestone, restricted to the eastern exposures of the Daisy sequence, is fine grained and dark gray on fresh surface. Limestone is thin to medium bedded, rarely thick bedded, and normally interlayered with gray and green slate. The total thickness of a typical limestone unit is approximately 20 m, and the units are laterally persistent along strike for distances of at least a few hundred meters.

Ocss Slate
Slate is common throughout the Daisy sequence as beds less than 2 m thick; however, map-scale exposures of medium- to dark-gray slate (unit Ocss) are associated with unit Ocsl near the top of the Daisy sequence. Persistent cleavage obscures original bedding in most places; however, thin beds and laminations were observed at a few locations.

Ocs Quartzo-feldspathic wacke and arenite
This unit includes medium- to thick-bedded, poorly sorted, quartzo-feldspathic sandstone and is the most voluminous unit in the map area. The unit west of Jennings Creek consists of an overall eastward-fining sequence of medium-grained, thick-bedded subarkosic arenite. Medium-grained subarkosic arenite is present east of Jennings Creek to the first prominent break in slope, where the sandstone becomes coarser, gritty, and less well sorted and feldspathic. This unit fines eastward (upsection) and is interbedded with limestone and slate (units Ocsl and Ocss) near the contact with the Butcher Mountain sequence.

Cambrian Miogeoclinal Strata

Outcrops of miogeoclinal strata are restricted to the extreme eastern margin of the map area and are in fault contact with rocks of the Covada Group. The top of the Metaline Limestone is of Middle Ordovician age (late Arenigian) in the Clugston Creek area, Stevens County (Schuster and others, 1989), but this unit is mapped as Cambrian in this report.

Ꞓm Metaline Limestone
The Middle Cambrian Metaline Limestone in the map area consists of medium- to dark-gray, fine- to medium-grained platy limestone, in places sooty.

Ꞓa Addy Quartzite?
Gray, calcite-cemented (rarely silica-cemented) quartz arenite in association with the Metaline Limestone in the extreme eastern portion of the map area may be Addy Quartzite. The quartz grains are well rounded and well sorted; rare argillite chips are present in some samples. The arenite is generally massive in outcrop.

FACIES ANALYSIS AND TECTONIC INTERPRETATION

Bradeen Hill Assemblage

The Bradeen Hill assemblage reflects deep-water, distal fan, and/or starved basin conditions of deposition and coeval volcanic activity. The quartz arenite is likely derived from recycled quartzite from the continental platform and shelf and resembles deposits of Middle and Late Ordovician age on the continental shelf and platform

Intermittent basaltic volcanism during this period may be indicative of a partly extensional tectonic regime, similar in nature to that reflected in the Butcher Mountain sequence. Uplift (block faulting?) and erosion of the chert unit (Pch) and minor Covada Group rocks provided detritus for the chert-pebble conglomerate unit (Pcg), which accumulated in a nearby restricted (channelized or fault bounded?) area.

Butcher Mountain sequence

Three volcanic rock samples from the map area were analyzed for major- and trace-element abundances to help further constrain tectonic environment of formation. These samples consist of (1) vesicular pillow basalt, (2) a basaltic andesite tuff clast, and (3) massive basalt. Trace-element data indicate that the samples are of within-plate and possibly alkalic affinity (Smith, 1990). Geochemical composition is consistent with extrusion in a passive margin or marginal basin setting.

Thick layers of nearly matrix-free, coarse lapilli tuff that dominate the western exposures of the volcanic sequence are proximal in nature and may represent primary aquagene tuff or perhaps talus deposits shed off submarine scarps. I favor the former interpretation due to differences in appearance in thin section and more intermediate composition of this tuff relative to overlying(?) flow rocks. Large vesicles in the overlying pillow flows suggest extrusion in relatively shallow water. Limestone layers interbedded with the volcanic rocks are thick and featureless, lack fossils, and are laterally persistent along strike, and thus may represent interbedded turbidites.

Daisy sequence

Daisy sequence subfeldspathic wacke and arenite are generally thick bedded; beds are massive to normally graded. Most of the section contains very little siltstone or shale (sand:shale ratios in excess of 10:1), except for exposures within several hundred meters of the contact with the Butcher Mountain sequence, which consist of alternating shale/limestone and very coarse, channelized, granule conglomerate to coarse sand units. The more westerly exposures in the map area are finer grained, less channelized, and more shale-rich (sand:shale ratios of as much as 5:1) than those higher in the section. Overall, the Daisy sequence exposed in the map area may consist of a prograding submarine fan system, from supra-fan lobe through mid-fan channel to perhaps upper-fan channel environments.

The clast composition and textural immaturity of strata in the Daisy sequence indicate that the sediment is dominantly first cycle and was derived from a gneissic or plutonic source terrane of quartzo-feldspathic composition. Some sediment may also have been recycled from the Windermere Supergroup, which contains strata of very similar texture and modal composition. Derivation may have been from both because detrital grains (particularly quartz and zircon) exhibit varied degrees of rounding, reflecting a range of transport histories.

U-Pb analyses of ten small fractions and five single grains of detrital zircon from the Daisy sequence (Smith and Gehrels, 1991) yield $^{207}Pb/^{206}Pb$ ages between 1.7 and 2.5 Ga. This range of ages is consistent with data obtained from basement cores from southern Alberta, from the Windermere Supergroup, and from orthogneiss in the Monashee Complex (Parrish and others, 1989). However, the Windermere Supergroup in many localities contains an older component (>2.5 Ga) not yet detected in the Covada samples. Thus the Covada Group was likely derived wholly or in part from sources other than the Windermere Supergroup.

STRUCTURE AND METAMORPHISM

Most strata in the map area have a uniform moderate to steep east dip and strike north-northeast. Late kinematic(?) foliation-(sub)parallel faults are common in the map area. The rocks underwent synkinematic low-greenschist-facies metamorphism and postkinematic contact metamorphism.

The structural and metamorphic history of the map area is similar to that of the Hunters area (Smith, 1991) and is thus likely to be recognized in areas in between.

Planar features

Primary bedding in the area is easily recognized in all but the coarsest clastic rocks. Indications of facing direction are not abundant except in the southwest corner of the map area (W½ sec. 10, T. 33 N., R. 37 E.) where grading in coarse beds, rare load structures, and crossbeds consistently yield top to-the-east (upright) orientations. No reliable "up" indicators were observed in the Daisy sequence nearer to the Butcher Mountain

sequence contact. A single observation of a channelized coarse, blocky tuff unit in the Butcher Mountain sequence is also consistent with an upright orientation. Two observations of centimeter-thick graded beds in the unit Ps indicate the unit may be overturned.

A cleavage is developed in fine-grained rocks, a weak foliation in volcanic rocks and limestones, and a platy spaced cleavage and minor flattening fabric in coarse clastic rocks. Cleavage and foliation are generally parallel or subparallel to bedding and axial planar to fold hinges.

Folds

Folds are difficult to identify in the map area due to poor exposure. They have wavelengths of tens to hundreds of meters and trend approximately north-northeast; they have horizontal or gently plunging axes. They are open to tight and verge westward, generally with short, vertical to steeply west-dipping limbs, longer, gently-dipping east limbs, and chevron-type geometry.

Faults

At least three faults with significant offset are present in the map area. The westernmost is a north-northeast-striking fault that juxtaposes the Daisy sequence against the Butcher Mountain sequence. At least some of the offset is right-lateral, as reflected in offsets of lithologies, contacts, and two large folds.

A moderately east-dipping fault places the chert-pebble conglomerate (unit Pcg) over other units of the Bradeen Hill assemblage and the Covada Group. The younger-over-older relation of units along this fault suggests that it may be a normal fault, but no kinematic indicators were observed. The structure is probably older than (cut by) the north-northeast-striking fault mentioned above.

The third large fault juxtaposes the Covada Group and Bradeen Hill assemblage against Precambrian to Ordovician miogeoclinal strata. The fault may be vertical or perhaps west dipping. Orientation, timing, and nature of this faulting cannot be tightly constrained because much of it is covered. However, the fault must be of a magnitude sufficient to bring coeval strata from different tectonic environments in contact with each other (Snook and others, 1981).

Foliation-parallel shears are common throughout the map area. The magnitude of displacement on and kinematic significance of these shears is not known.

The major structures described above are shown on the cross section (on the plate), which has been drawn perpendicular to most structural trends.

Metamorphism

Rocks in the map area have undergone early low-grade regional metamorphism and later contact metamorphism. The regional event is barely discernible in the sedimentary part of the section, but it has imparted a green color to the volcanic rocks, which contain a low-greenschist-facies assemblage of albite + chlorite + quartz + epidote + calcite + titanite +/- actinolite. These minerals are present as a fine-grained groundmass and as chlorite and actinolite replacing pyroxene phenocrysts. Matrix material in the sandstone consists primarily of fine-grained albite, chlorite, quartz, and white mica.

Timing of the metamorphism is not tightly constrained by geologic relations in the map area, but it is likely to have been Jurassic or Early to middle Cretaceous on the basis of regional considerations.

Contact metamorphic effects are restricted to the areas adjacent to the quartz monzonite intrusion and are seen mainly in the Bradeen Hill assemblage on the southeast end of Old Copper Hill. Rocks in this area are statically recrystallized, with dark chert upgraded to white or light-gray hornfels and the limestone-clast conglomerate transformed into calc-silicate hornfels.

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REFERENCES CITED

Adekoya, A. A., 1983, Conodont analysis of a limestone lense in the black shale belt of northeast Washington: Washington State University Master of Science thesis, 65 p.

Campbell, A. B.; Raup, C. B., 1964, Preliminary geologic map of the Hunters quadrangle, Stevens and Ferry Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-276, 1 sheet, scale 1:48,000.

Greenman, C.; Chatterton, B. D. E.; Boucot, A. J.; Berry, W. B. N., 1977, Coarse Silurian(?) and Devonian detrital rocks in northeastern Washington—Evidence of Silurian and Devonian tectonic activity. *In* Stewart, J. H.; and others, editors, Paleozoic paleogeography of the Western United States; Pacific Coast Paleogeography Symposium 1: Society of Economic Paleontologists and Mineralogists Pacific Section, p. 467-479.

Joseph, N. L., compiler, 1990, Geologic map of the Nespelem 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-16, 47 p., 1 pl.

Mills, J. W., 1985, Geology of the Kettle Falls, Marcus, Colville, and Echo Valley quadrangles, northeast Washington: Washington Division of Geology and Earth Resources Open File Report 85-4, 6 p.

Mills, J. W.; Duncan, G. W.; Brainard, R. C.; Hogge, C. E.; Laskowski, E. R., 1985, Geologic maps of the Echo Valley and north part of the Colville 7½-minute quadrangles, Washington: Washington Division of Geology and Earth Resources Open File Report 85-7, 2 sheets, scale 1:24,000.

Pardee, J. T., 1918, Geology and mineral deposits of the Colville Indian Reservation, Washington: U.S. Geological Survey Bulletin 677, 186 p., 1 pl.

Parrish, R. R.; Ross, G.; Carr, S. D.; Coleman, V.; Journeay, J. M., 1989, Single grain U-Pb provenance ages of detrital zircons from metaquartzites of the southern Omineca Belt, British Columbia [abstract]: Geological Society of America Abstracts with Programs, v. 21, no. 5, p. 127.

Schuster, J. E.; Repetski, J. E.; Carter, Claire; Dutro, J. T., Jr., 1989, Nature of the Metaline Formation–Ledbetter Formation contact and age of the Metaline Formation in the Clugston Creek area, Stevens County, Washington—A reinterpretation: Washington Geologic Newsletter, v. 17, no. 4, p. 13-20

Smith, B. L., 1982, Geology of the southeastern portion of the Inchelium quadrangle, Stevens County, Washington: Eastern Washington University Master of Science thesis, 60 p., 2 pl.

Smith, M. T., 1990, Stratigraphic, structural and U-Pb geochronologic investigation of lower Paleozoic eugeoclinal strata in the Kootenay Arc, NE Washington and SE British Columbia: University of Arizona Doctor of Philosophy thesis, 262 p., 2 pl.

Smith, M. T. ,1991, Geologic map of the Ninemile Creek–Wilmont Creek–Hunters Creek area, Ferry and Stevens Counties, Washington: Washington Division of Geology and Earth Resources Open File Report 91-4, 9 p., 1 pl. , scale 1:24,000.

Smith, M. T.; Gehrels, G. E., 1991, Detrital zircon geochronology of Upper Proterozoic to Lower Paleozoic continental margin strata of the Kootenay Arc—Implications for the Early Paleozoic tectonic development of the eastern Canadian Cordillera: Canadian Journal of Earth Sciences, v. 28. no. 8, p. 1271-1284.

Snook, J. R.; Campbell, A. B.; Lucas, H. E.; Abrams, M. J.; Janzen, J. H.; Smith, B. L., 1990, Geologic map of the Inchelium quadrangle, Stevens and Ferry Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1752, 1 sheet, scale 1:48,000.

Snook, J. R.; Lucas, H. E.; Abrams, M. J., 1981, A cross section of a Nevada-style thrust in northeast Washington: Washington Division of Geology and Earth Resources Report of Investigations 25, 9 p.

Walker, R. G.; Mutti, Emiliaus, 1973, Turbidite facies and facies associations. *In* Middleton, G. V.; Bouma, A. H., chairmen, Turbidites and deep water sedimentation—Lecture notes for a short course: Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 119-157.

Webster, G. D.; Beka, F. T., 1980, A Devonian age for parts of the black shale belt northwest of Northport, Washington [abstract]: Geological Society of America Abstracts with Programs, v. 12, no. 3, p. 159.

Yates, R. G., 1976, Geology of the Deep Creek area, Washington, and its regional significance: U.S. Geological Survey Open-File Report 76-537, 435 p.

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Raymond Lasmanis, State Geologist

Plate 1
OPEN FILE REPORT 91-6

GEOLOGIC MAP OF THE OLD COPPER HILL - BUTCHER MOUNTAIN AREA, STEVENS COUNTY, WASHINGTON

Geology by MOIRA SMITH, 1991

MAP UNITS

Quaternary	Qs SURFICIAL DEPOSITS, UNDIFFERENTIATED	Early Ordovician	**Covada Group** (Butcher Mountain sequence)
Cretaceous	Kq QUARTZ MONZONITE		Ocv VOLCANIC AND VOLCANICLASTIC ROCKS
Paleozoic (post Early Ordovician)	ds DIORITIC AND GABBROIC SILLS		Ocvl LIMESTONE
	Bradeen Hill assemblage	Early Ordovician-?Cambrian	(Daisy sequence)
	Pcg CONGLOMERATE		Ocsl LIMESTONE
	Ps SANDSTONE AND SILTSTONE		Ocss SLATE
	Pqa QUARTZ ARENITE		Ocs QUARTZO-FELDSPATHIC WACKE AND ARENITE
	Psl SLATE AND PHYLLITE		
	Pv VOLCANIC ROCKS	Cambrian	Ꞓm METALINE LIMESTONE
	Plc LIMESTONE-CLAST BRECCIA		Ꞓa ADDY QUARTZITE?
	Pch CHERT AND SILICEOUS ARGILLITE		

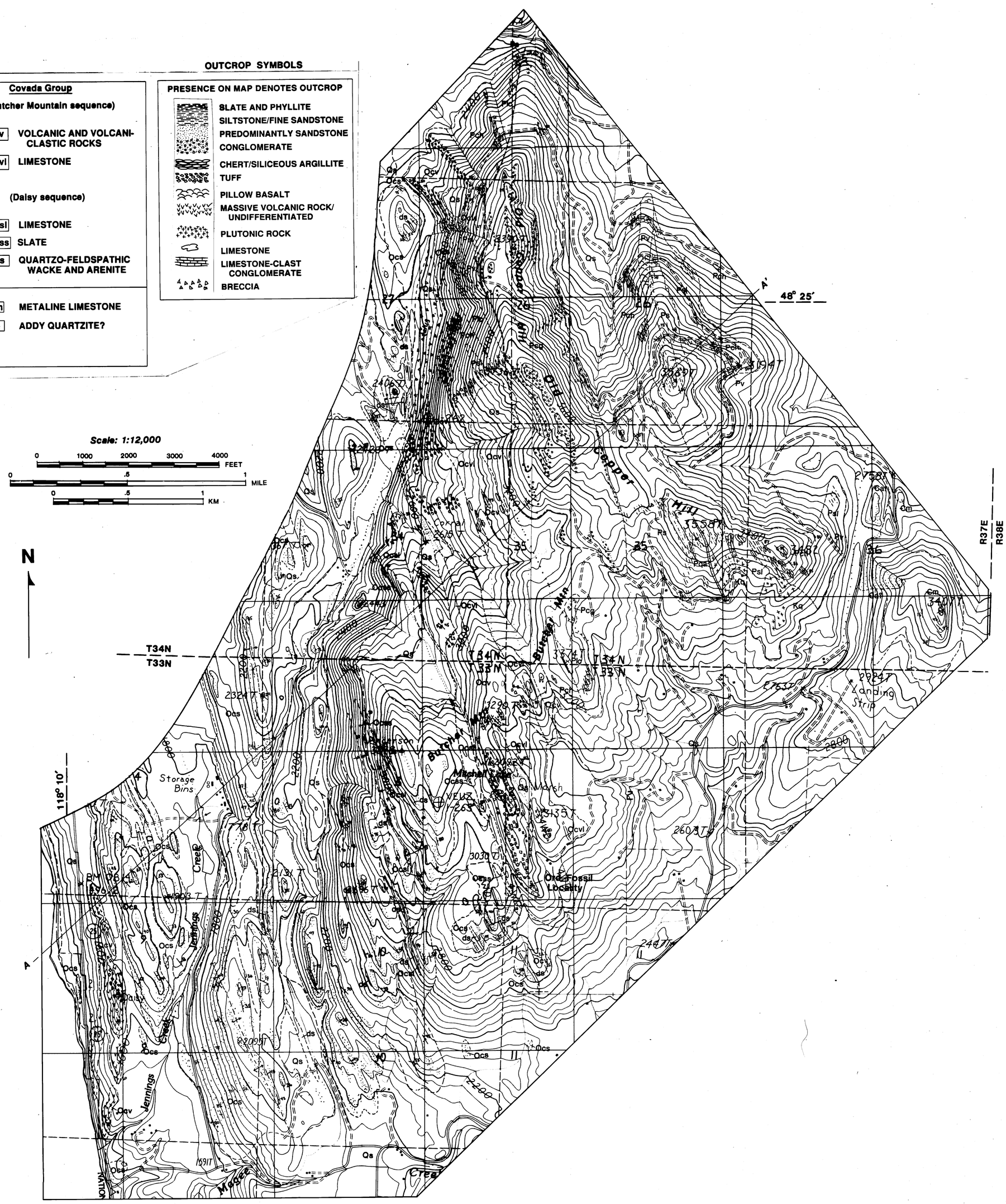
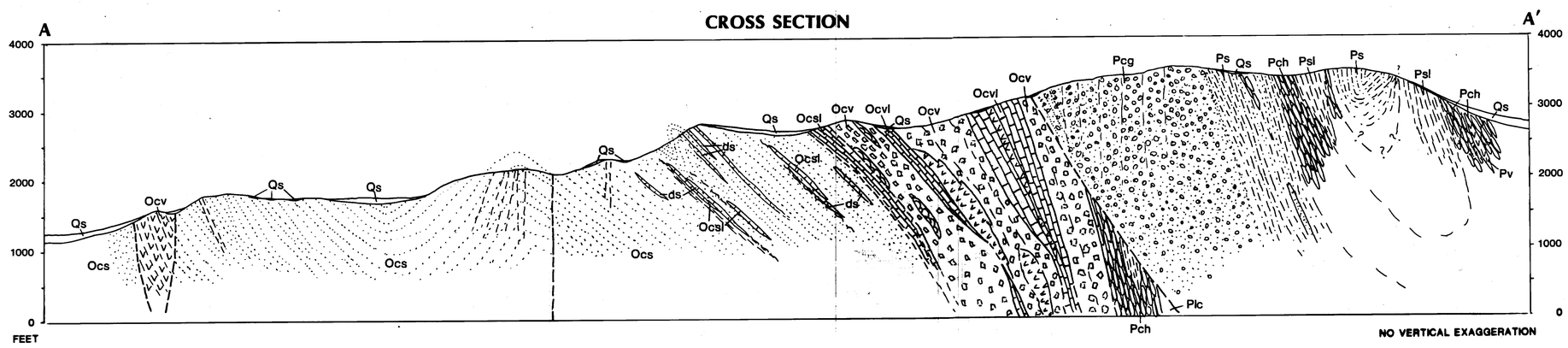
OUTCROP SYMBOLS

PRESENCE ON MAP DENOTES OUTCROP

- SLATE AND PHYLLITE
- SILTSTONE/FINE SANDSTONE
- PREDOMINANTLY SANDSTONE
- CONGLOMERATE
- CHERT/SILICEOUS ARGILLITE
- TUFF
- PILLOW BASALT
- MASSIVE VOLCANIC ROCK/ UNDIFFERENTIATED
- PLUTONIC ROCK
- LIMESTONE
- LIMESTONE-CLAST CONGLOMERATE
- BRECCIA

STRUCTURAL SYMBOLS

- CONTACT — DASHED WHERE APPROXIMATE, DOTTED WHERE CONCEALED, QUERIED WHERE EXISTENCE/ LOCATION QUESTIONABLE
- FAULT — DASHED WHERE APPROXIMATE, DOTTED WHERE CONCEALED, QUERIED WHERE EXISTENCE/ LOCATION QUESTIONABLE
- ANTICLINE
- SYNCLINE
- STRIKE AND DIP OF BEDDING
  - TOP KNOWN
  - TOP NOT KNOWN
  - OVERTURNED
  - VERTICAL
- STRIKE AND DIP OF FOLIATION
  - FOLIATION VERTICAL
- STRIKE AND DIP OF CLEAVAGE
- CLEAVAGE AND BEDDING PARALLEL
- FOLIATION AND BEDDING PARALLEL
- STRIKE AND DIP OF JOINT
- TREND AND PLUNGE OF LINEAR FEATURE (SMALL FOLD, STRETCHED CLASTS, ETC.)
  - HORIZONTAL LINEATION
- SMALL SHEAR



CROSS SECTION