WASHINGTON STATE DEPARTMENT OF
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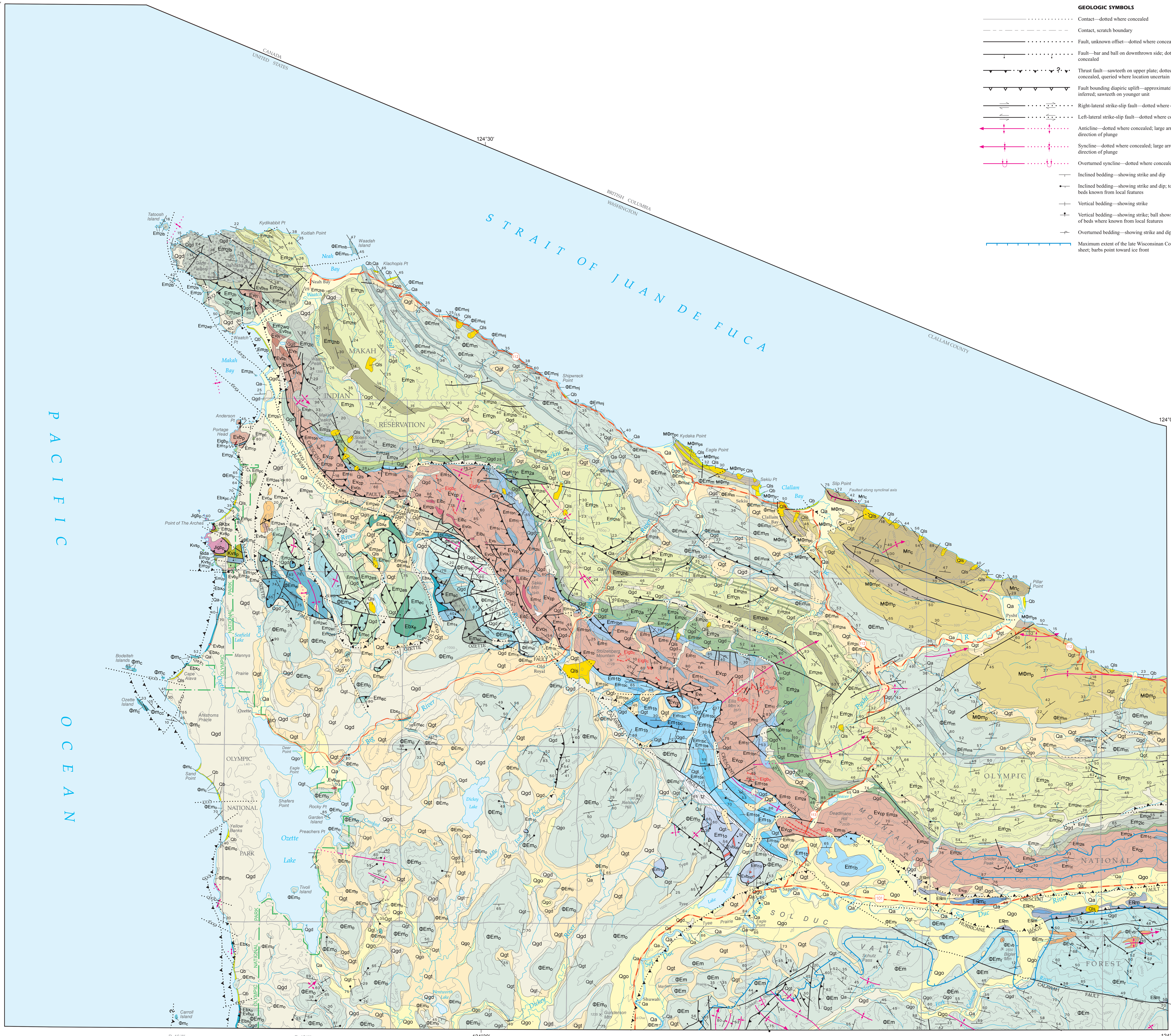


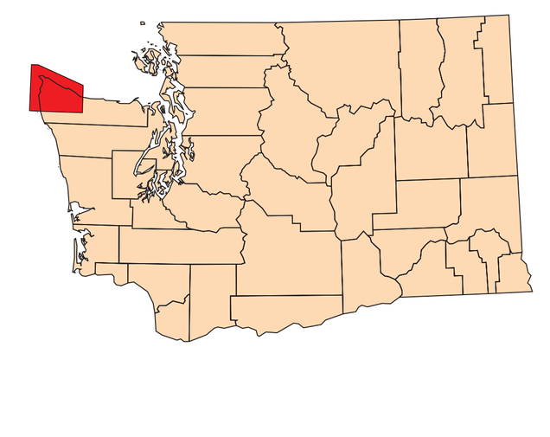
GEOLOGIC SYMBOLS

Contact—dotted where concealed
Contact, scratch boundary
Fault, unknown offset—dotted where concealed
Fault—bar and ball on downthrown side; dotted where concealed
Thrust fault—sawteeth on upper plate; dotted where concealed, queried where location uncertain
Fault bounding diapiric uplift—approximately located or inferred; sawteeth on younger unit
Right-lateral strike-slip fault—dotted where concealed
Left-lateral strike-slip fault—dotted where concealed
Anticline—dotted where concealed; large arrowheads show direction of plunge
Syncline—dotted where concealed; large arrowheads show direction of plunge
Overturned syncline—dotted where concealed
Inclined bedding—showing strike and dip
Inclined bedding—showing strike and dip; top direction of beds known from local features
Vertical bedding—showing strike
Vertical bedding—showing strike; ball shows top direction of beds where known from local features
Overturned bedding—showing strike and dip
Maximum extent of the late Wisconsinan Cordilleran ice sheet; barbs point toward ice front

Lambert Conformal Conic Projection
1927 North American Datum
Washington Coordinate System, South Zone
Base map information from the Washington Department of Natural Resources, Geographic Information System, 1997
Washington Division of Geology and Earth Resources
Digital cartography by Anne C. Heinitz and Chuck Caruthers

SCALE 1:100,000

contour interval 500 feet; supplementary contours at 140 feet and 320 feet



Geologic Map of the Washington Portion of the Cape Flattery 1:100,000 Quadrangle

by Henry W. Schasse

2003

INTRODUCTION

This map of the Cape Flattery 1:100,000-scale quadrangle was compiled to support construction of the northwest quadrant of the 1:250,000-scale geologic map of Washington (Dragovich and others, 2002). The quadrangle is situated in the extreme northwest part of the Olympic Peninsula. This map is also available electronically as a series of digital geographic information system (GIS) coverages, which can be obtained by contacting the Washington Division of Geology and Earth Resources, PO Box 47007, Olympia, WA 98504-7007; phone (360) 902-1450; fax (360) 902-1785; e-mail geology@wadnr.gov.

The Olympic Peninsula is underlain by sequences of Tertiary marine and nearshore sediments, volcanogenic rocks, and sediments deposited in deep-water environments from sandy debris flows. At least four major lithotectonic units or 'terranes' make up the geology of the Cape Flattery 1:100,000-scale quadrangle. Three of these are highly disrupted, subduction-related mélange and turbidite units (Snavely and others, 1993; Snavely, 1987): (1) the lower Oligocene to lower Eocene Ozette terrane; (2) the lower Oligocene to Jurassic Sooes terrane; (3) and the Oligocene to lower Eocene unnamed terrane situated between the Crescent and Calawah faults. Collectively, these terranes are called the 'core rocks' by Tabor and Cady (1978) and the 'Olympic subduction complex' by Brandon and Calderwood (1990). Snavely and others (1993) subdivided the aforementioned terranes into discrete tectonically bounded sequences, which they refer to as 'blocks' (Fig. 1).

A fourth terrane, called the Crescent terrane by Babcock and others (1994), is composed of the Eocene Crescent Formation and associated Miocene to Paleocene(?) sedimentary rocks. The rocks included in the Crescent terrane correspond to the 'peripheral rocks' of Tabor and Cady (1978) and were referred to as rocks of "the marginal basin northeast of the Crescent fault" by Snavely and others (1993). These rocks form a horseshoe-shaped outcrop belt surrounding the inboard or east side of the Olympic subduction complex (see Dragovich and others, 2002, sheet 3, fig. 4).

The three major source maps used to compile the Cape Flattery 1:100,000-scale map are Snavely and others (1993), Tabor and Cady (1978), and Gower (1960). The bedrock geology shown on this map is that of Snavely and others (1993), who described the geology of their map area within the framework of the terranes described above. I have relied heavily upon their unit descriptions (with selected modifications and deletions of some details) in preparing this compilation. The coastal geology shown in the Coastal Zone Atlas of Washington (Wash. Dept. of Ecology, 1978) was used locally. Unit symbols follow the time-lithology symbology applied by the Washington Division of Geology and Earth Resources (DGER) in Dragovich and others (2002). The geologic time scale of Palmer and Geissman (1999) was used for the ages of the bedrock units. Provincial biostratigraphic stage correlations are from the Correlation of Stratigraphic Units of North America project of the American Association of Petroleum Geologists (Salvador, 1985) and were slightly modified to match parts of the time scale of Palmer and Geissman.

I have subdivided the Quaternary surficial (glacial) geology of the Cape Flattery 1:100,000-scale quadrangle, which was not subdivided in the maps of Snavely and others (1993), Tabor and Cady (1978), and Gower (1960). This was achieved by deriving a map of the soil parent materials from a soil survey of the Clallam County area (Halloin, 1987) and augmenting those data with spot checks in the field and reconnaissance mapping. Long (1975) produced unpublished manuscripts of his field observations of Quaternary deposits for the Olympic Peninsula during his many years of work with the U.S. Forest Service. Long's interpretation of the maximum extent of the late Wisconsinan Cordilleran ice sheet was used in this compilation.

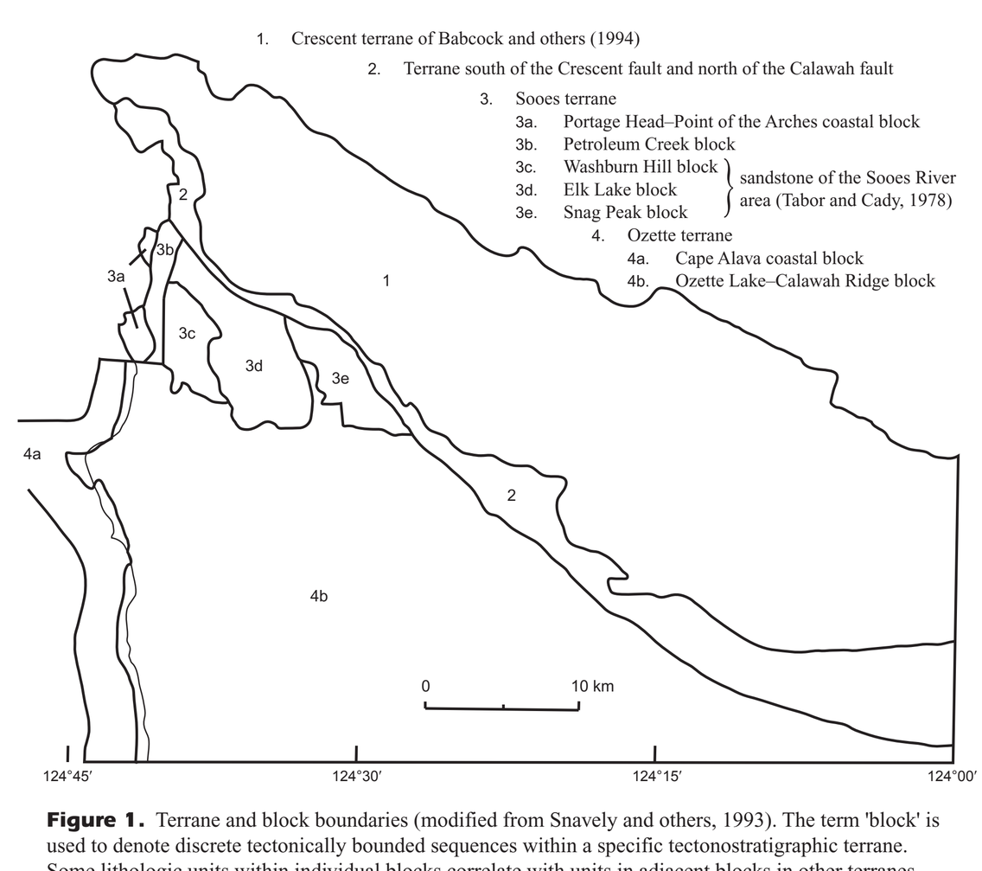


Figure 1. Terrane and block boundaries (modified from Snavely and others, 1993). The term 'block' is used to denote discrete tectonically bounded sequences within a specific tectonostratigraphic terrane. Some lithologic units within individual blocks correlate with units in adjacent blocks in other terranes.

DESCRIPTION OF MAP UNITS

Quaternary Surficial Deposits

NONGLACIAL DEPOSITS

Qb **Beach deposits (Holocene)**—Sand and (or) gravel with minor shell fragments deposited along shorelines; locally includes back-beach dune fields and minor estuarine deposits; clasts are typically well rounded.

Qa **Alluvium (Holocene and Pleistocene?)**—Sorted combinations of silt, sand, and gravel deposited in stream and river beds; surface relatively undissected by streams; locally includes sand and gravel of low-lying river terraces, alpine drift, and lacustrine and landslide deposits. Most alluvium is Holocene age, but some, particularly along the Sol Duc River, may in part be Pleistocene.

Qls **Landslide debris (Holocene and Pleistocene)**—Poorly sorted and chaotically mixed clay, silt, sand, and gravel in debris flows, which locally include large coherent glide blocks along Strait of Juan de Fuca; mapped only where readily discernible.

CONTINENTAL GLACIAL DEPOSITS OF THE FRASER GLACIATION

Qgo **Undifferentiated outwash (Pleistocene)**—Unconsolidated, well-stratified cobbles in a loose, gravelly sand matrix; boulders are common in poorly sorted deposits; locally includes alpine outwash. Gerstel and Lingley (2000) report a radiocarbon age date of about 12,500 yr B.P. from outwash exposed in a bank of the Sol Duc River near its contact with underlying till in the adjoining Forks 1:100,000-scale quadrangle to the south, suggesting that ice had retreated from the Forks area by then.

Qgl **Glaciolacustrine deposits (Pleistocene)**—Laminated sand, silt, and clay with disseminated dropstones deposited in proglacial lake about 2 mi east of the south end of Ozette Lake.

Qgt **Glacial till (Pleistocene)**—Unsorted, unstratified, compact mixture of clay, silt, sand, gravel, and boulders deposited by the Juan de Fuca lobe of the Cordilleran ice sheet; may contain interbedded stratified sand, silt, and gravel. The Juan de Fuca lobe of the continental ice sheet occupied the Strait of Juan de Fuca and covered the northern edge of the Olympic Peninsula from about 15,000 yr B.P. (Heusser, 1973) to about 13,000 yr B.P. (Gerstel and Lingley, 2000). A radiocarbon date on wood collected from till in the Dickey River drainage during this study yielded an age of 13,200 ±170 yr B.P. In the same region, Heusser (1973) also reported ages from wood in till that range from about 13,010 to 13,380 yr B.P. Heusser (1973) interpreted the younger ages to suggest that the dated wood originated from trees growing on dead ice that subsequently collapsed, burying the trees on an ablation moraine, implying a gradual stagnation of the ice in the region over nearly two millennia.

Qgd **Glacial drift (Pleistocene)**—Till and outwash deposits from continental and alpine glaciers; locally includes lacustrine deposits and glacial deposits modified by stream terracing; in most places, contacts between glacial drift and bedrock are inferred.

Tertiary Sedimentary and Volcanic Rocks

CRESCENT TERRANE OF BABCOCK AND OTHERS (1994) (PERIPHERAL ROCKS OF TABOR AND CADY, 1978)

Mn$_{c}$ **Clallam Formation (lower Miocene)**—Sandstone and conglomerate with minor siltstone. Shallow marine sandstone is micaceous, feldspathic, quartzose, and typically thick bedded and locally pebbly, bioturbated, and cross-bedded; commonly mollusk bearing and carbonaceous; locally contemporaneously deformed. Conglomerate is composed of rounded pebbles and cobbles of white quartz, dark-gray chert, phyllite, and light-gray felsic tuff; foraminiferal assemblages are referred to the Saucesian Stage by Rau (1964, 1981); mollusks are assigned to the Pillarian Stage by Addicott (1976a,b, 1981).

MΦm$_{p}$ **Pysht Formation (lower Miocene and upper Oligocene)**—Massive and thin-bedded, poorly indurated, olive-gray sandy siltstone and mudstone; mollusk bearing and concretionary with beds of fine- to medium-grained, thin-bedded, subfeldspathic sandstone; highly susceptible to landsliding. Foraminiferal assemblages are assigned to lower part of the Saucesian and upper part of the Zemorrian Stages by Rau (1964, 1981; and in Snavely and others, 1980); mollusks are indicative of the Juanian Stage (Addicott, 1976b, 1981). Locally divided into:

MΦm$_{ps}$ **Sandstone**—Medium- and coarse-grained, micaceous, lithic and quartzofeldspathic sandstone.

MΦm$_{pc}$ **Conglomerate**—Channel deposits of thick- to medium-bedded, polymictic conglomerate.

ΦEm$_{m}$ **Makah Formation (Oligocene and upper Eocene**—Thin-bedded sandstone and siltstone; commonly contains calcareous concretions; contains four mappable members consisting of turbidite sandstone (units ΦEm$_{mt}$, ΦEm$_{mk}$, ΦEm$_{md}$, and ΦEm$_{mb}$) that range in thickness from 45 to 130 m and are interbedded with thin laminated to micro cross-laminated beds of very fine-grained sandstone and siltstone; also contains two other mapped sandstone units (units Φm$_{f}$ and ΦEm$_{ms}$), olistostromal blocks (unit ΦEm$_{mj}$), and thin, siliceous water-laid tuff beds (Carpenters Creek Tuff Member); contains Zemorrian, Refugian, and upper Narizian foraminifera (W. W. Rau in Snavely and others, 1980). Locally divided into:

Φm$_{mf}$ **Falls Creek unit (Oligocene)**—Thick-bedded, lithic, feldspathic sandstone.

ΦEm$_{mj}$ **Jansen Creek Member (Oligocene–Eocene)**—Contemporaneously deformed basaltic to feldspathic sandstone and siltstone; locally encloses tabular olistostromal blocks (1–200 m long) of shallow-marine fossiliferous basaltic pebble conglomerate and sandstone; represents an ancient submarine slump deposit derived from the Vancouver Island (B.C.) shelf.

ΦEm$_{mt}$ **Third Beach Member (Oligocene–Eocene)**—Thick-bedded to very thick-bedded, concretionary, biotite-rich, feldspathic sandstone.

ΦEm$_{mk}$ **Klachopis Point Member (Oligocene–Eocene)**—Thick-bedded to very thick-bedded, micaceous feldspathic sandstone.

ΦEm$_{md}$ **Dtokoah Point Member (Oligocene–Eocene)**—Thin- to medium-bedded, lithofeldspathic, quartzose sandstone.

ΦEm$_{mb}$ **Baada Point Member (Oligocene–Eocene)**—Thin- to thick-bedded, fine- to medium-grained, concretionary, lithofeldspathic sandstone.

ΦEm$_{ms}$ **Unnamed sandstone (Oligocene–Eocene)**—Very thin- to thick-bedded, light-gray sandstone; generally occurs as lenses that locally grade down into interbedded sandstone and siltstone; lenses locally consist of sandstone and siltstone in nearly equal proportions (Gower, 1960).

Em$_{2h}$ **Hoko River Formation (upper Eocene)**—Siltstone and sandy siltstone with lenses of pebble–cobble conglomerate; also contains iron-stained concretionary siltstone and sandy siltstone with minor thin-bedded, quartzofeldspathic, very fine-grained to medium-grained sandstone beds; pebbly mudstone, mudflow breccia, sandstone dikes, and thin tuff beds occur locally. Contains upper Narizian foraminifera (W. W. Rau in Snavely and others, 1980). Locally divided into:

Em$_{2hs}$ **Turbidite sandstone**—Thick- to thin-bedded, lithofeldspathic sandstone.

Em$_{2hb}$ **Phyllitic and basaltic sandstone**—Thick- to thin-bedded, carbonaceous, calcite-cemented phyllitic and basaltic sandstone.

Em$_{2hc}$ **Conglomerate**—Channel deposits with clasts consisting of cobbles and boulders of basalt, phyllite, meta-igneous rocks, and pebble conglomerate; clasts are angular to rounded and are as much as 4.5 m in diameter.

Em$_{2lc}$ **Em$_{2ls}$** **Lyre Formation (middle Eocene)**—Conglomerate and sandstone; subdivided into lenticular or channel deposits of thin to very thick-bedded, well-rounded pebble to boulder conglomerate and pebbly sandstone (unit Em$_{2lc}$) composed of clasts of dark-gray to black argillite, quartzite, chert, metavolcanic rocks, gneiss, quartz, and minor basalt. Conglomerate unit overlies and is interbedded with thick-bedded, well-indurated, lithic, phyllitic, quartzose sandstone and minor thin-bedded sandstone and siltstone (unit Em$_{2ls}$); large siltstone rip-ups and pebbly mudstone are common near lower contact. Foraminifera are assigned to the upper Narizian Stage by W. W. Rau (in Snavely, 1983). Locally divided into:

Em$_{2lb}$ **Breccia and conglomerate of Cape Flattery**—Nonbedded to poorly bedded sedimentary breccia; includes graded thick-bedded, lithic, quartzose sandstone, which is commonly cross-bedded and channeled, and minor siltstone interbeds; provenance of clasts is from near Leech River and San Juan fault zones on Vancouver Island, B.C. (MacLeod and others, 1977; Ansfield, 1972).

Em$_{2a}$ **Aldwell Formation (middle Eocene)**—Thin, well-bedded, phyllitic, lithic quartzose and basaltic sandstone and siltstone; upper part of sequence consists of nonbedded to poorly bedded siltstone with 1 to 1.5 m thick sandstone channels; a 4 m thick, medium-grained, lithic quartzose sandstone bed occurs locally near base of unit. Foraminifera are assigned to the upper and lower Narizian Stage by Rau (1964, 1981; and in Snavely, 1983). Locally divided into:

Em$_{2as}$ **Siltstone**—Massive to poorly bedded siltstone with 1 to 1.5 m thick sandstone channels.

Em$_{1bn}$ **Siltstone of Brownes Creek (middle Eocene)**—Massive to poorly bedded concretionary siltstone and mudstone with a few thin sandstone beds; commonly sheared; contains lower Narizian and upper Ulatisian foraminifera (W. W. Rau in Snavely, 1983).

Em$_{1l}$ **Basaltic sandstone and conglomerate of Lizard Lake (middle to lower? Eocene)**—Basaltic sandstone and siltstone overlying basaltic conglomerate and mudflows; sandstone and siltstone are thick- to medium-bedded and locally contain coral, mollusk fragments, and carbonized wood; conglomerate is massive to thick-bedded; composed almost entirely of detritus eroded from the underlying Crescent Formation. Foraminiferal fauna assigned to the upper Ulatisian Stage by W. W. Rau (in Snavely and others, 1993).

Ev$_{cp}$ **Crescent Formation (middle and lower Eocene)**—Basalt pillow lava and breccia; dense to very amygdaloidal; lower part of sequence contains 1 to 5 m thick beds of foraminifera-bearing pelagic red and white limestone and calcareous red and brown siltstone; upper part of sequence contains several thick interbeds of foraminifera-rich siltstone, basaltic sandstone, basalt breccia or conglomerate, and a few 1 to 2 m thick interbeds of lithofeldspathic sandstone and 0.25 to 2 m thick siliceous tuff beds. Foraminiferal assemblages are referred to the Ulatisian and Penutian Stages by Rau (1981) and Snavely and others (1986); in the adjacent Port Angeles 1:100,000-scale quadrangle, Babcock and others (1994) report $^{40}Ar/^{39}Ar$ plateau ages ranging from 45.4 to 52.9 Ma. Locally divided into:

Em$_{1c}$ **Siltstone and sandstone**—Interbedded basaltic siltstone and fine-grained sandstone; siltstone is locally concretionary and 10 to 100 m thick; minor interbeds of red and green limy argillite.

Eib$_{c}$ **Silicified intrusive volcanic rocks**—Pipe-like bodies of hypersthene basalt breccia set in an opaline matrix; opaline veins are pervasive within and adjacent to areas of silicification.

Eigb$_{c}$ **Diabase and gabbro**—Dikes and sills of diabase and gabbro; occurs in lower part of formation; sills and dikes less than 2 m thick not differentiated on map.

ERm **Blue Mountain unit of Tabor and Cady (1978) (Eocene to Paleocene?)**—Gray to black lithic sandstone, semischist, siltstone, slate, granule or pebble conglomerate, and siltstone- or slate-clast breccia; very dark gray to purple-gray; commonly laminated and rhythmically bedded; local very thick sandstone beds; abundant muscovite and basalt detritus. Foraminiferal assemblages referable to the Ulatisian or older stages (Rau, 2000); Babcock and others (1994) report $^{40}Ar/^{39}Ar$ ages from overlying beds of Crescent Formation volcanic rocks of 56.0 to 45.4 Ma. Locally divided into:

ERm$_{c}$ **Conglomerate and pebbly sandstone**—Thick-bedded to massive conglomerate and pebbly sandstone or semischist with minor interbedded slate or argillite; subrounded pebbles and minor cobbles of dark-gray chert and volcanic rocks with less-abundant light-gray sandstone; very dark gray to grayish-black angular siltstone rip-up clasts common and locally form slate-chip breccia; interbedded with rocks of Eocene to Paleocene age (see unit ERm).

OLYMPIC SUBDUCTION COMPLEX OF BRANDON AND CALDERWOOD (1990) (CORE ROCKS OF TABOR AND CADY, 1978)

Terrane South of the Crescent Fault and North of the Calawah Fault

ΦEm$_{r}$ **Marine rhythmites and other thin-bedded sedimentary rocks (Oligocene–Eocene)**—Undifferentiated slate and siltstone (90%) and micaceous sandstone (10%); includes minor conglomerate and interbedded basalt flows, breccia, and diabase and (or) gabbro (unit ΦEvb); includes part of the Needles–Gray Wolf lithic assemblage of Tabor and Cady (1978). Detrital zircon fission-track minimum ages range from about 27 to 39 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999).

ΦEvb **Basaltic rocks (Oligocene–Eocene)**—Pillow basalt and basalt flow breccia and less-abundant massive lava flows; mostly fine grained; amygdaloidal with vesicles filled with calcite, zeolites, pumpellyite, and quartz; minor diabase and (or) gabbroic sills or dikes; interbedded tuffs and volcanic-rich sediments include rare gray, red, and green chert and tuffaceous green or maroon slate; includes part of the Needles–Gray Wolf lithic assemblage of Tabor and Cady (1978).

Em$_{2b}$ **Sandstone of Bahobohosh (middle Eocene)**—Thin- to thick-bedded, graded, lithic, feldspathic sandstone and lithic quartzose sandstone with lenses of pebble and cobble conglomerate and mudflow breccia; sandstone is laminated to cross-stratified; conglomerate clasts commonly are volcanic-lithic sandstone but also include reworked calcareous concretions, diabase, basalt, felsic volcanic rocks, micaceous feldspathic sandstone, chert, phyllite, and fragments of wood and mollusks. Sparse foraminifera are assigned to the Narizian Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{2wp}$ **Siltstone of Waatch Point (middle Eocene)**—Laminated and micro cross-stratified, very thin-bedded to thin-bedded siltstone and sandstone with small-scale slump folds and flame and load casts. Siltstone is locally bioturbated; includes mudflow lens up to 3 m thick of altered blocks of pillow lava and basalt-breccia and argillite; common calcareous nodules and concretionary lenses. Contains sparse Narizian foraminifera identified by W. W. Rau (in Snavely and others, 1993).

Em$_{2wq}$ **Siltstone and sandstone of Waatch Quarry (middle Eocene)**—Thin-bedded siltstone with irregular interbeds of fine-grained gritty sandstone; mudflow conglomerate and breccia and pebbly mudstone occur near the base of the unit; conglomerate contains clasts derived from underlying Hobuck Lake unit (unit Evs$_{h}$); channel deposits of coarse- to medium-grained lithic and quartzofeldspathic sandstone up to 7 m thick and lenses of well-sorted, fine-grained basaltic sandstone up to 3 m thick occur near base of the sequence. Foraminifera are assigned to the lower part of the Narizian Stage by W. W. Rau (in Snavely and others, 1993). Unit probably represents a facies of the Aldwell Formation (unit Em$_{2a}$).

Em$_{1b}$ **Siltstone and sandstone of Bear Creek (middle to lower? Eocene)**—Medium- to thin-bedded concretionary siltstone and fine-grained sandstone; well indurated near the Crescent fault. Siltstone beds are intensely sheared and folded and contain olistostromal blocks of Crescent Formation basalt below the Crescent fault. Sparse foraminifera from siltstone beds are assigned to the lower Narizian or upper Ulatisian Stages by W. W. Rau (in Snavely and others, 1993). Locally divided into:

Em$_{1bc}$ **Conglomerate and mudflow deposits**—Blocks of mollusk-bearing sandstone, red argillite, siltstone, and green and red chert pebbles; mollusks are assigned an early-late to late-middle Eocene age by W. O. Addicott (in Snavely and others, 1993). Foraminifera in mudflow deposits, considered to be reworked from the Crescent Formation, are assigned to the lower Eocene Penutian Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{1bs}$ **Sandstone**—Thick- to medium-bedded, carbonaceous, lithofeldspathic, concretionary sandstone.

Evs$_{h}$ **Sedimentary and basaltic rocks of Hobuck Lake (middle to lower Eocene)**— Thin-bedded siltstone with interbedded basaltic tuff-breccia and quartzose sandstone; overlain by mudflow deposits, pillow lava, and breccia. Locally divided into:

Evb$_{hs}$ **Pillow basalt and breccia**—Pillow basalt and breccia, commonly altered, with minor interbeds of basaltic siltstone, basaltic sandstone, and red argillite; includes a sill of gabbro.

Ev$_{h}$ **Evb$_{h}$** **Volcanic rocks**—Iron-oxide-stained tuff-breccia with minor interbedded basaltic sandstone and siltstone; isolated blocks and flows of hematite-stained pillow basalt and breccia and minor diabase sills; includes very thin to 150 m thick pillow basalt flow (mapped separately as unit Evb$_{h}$) and mudflows that contain clasts of hornblende-phyric basalt, siltstone, and red limey argillite together with blocks of feldspathic sandstone; includes a massive basaltic breccia sequence more than 100 m thick; foraminifera from siltstone interbed in breccia are assigned to the upper part of the Ulatisian Stage by W. W. Rau (in Snavely and others, 1993).

Evc$_{h}$ **Siltstone**—Thin- and wispy-bedded tuffaceous siltstone with interbedded basaltic fine tuff to tuff-breccia and thin-bedded to massive siltstone with thin quartzose sandstone interbeds; includes several massive to thick-bedded, quartzose, lithofeldspathic sandstone beds (1 to 5 m thick) along the outcrop area.

Sooes Terrane

PORTAGE HEAD—POINT OF THE ARCHES COASTAL BLOCK

ΦEm$_{p}$ **Sandstone and siltstone (Oligocene–Eocene)**—Thick- to thin-bedded, light-gray, lithic quartzose turbidite sandstone with minor siltstone interbeds; basal part is thin-bedded sandstone and siltstone; sandstone is fine to medium grained, commonly laminated and locally bioturbated, and cemented with calcite; siltstone interbeds contain foraminifera assigned to the Refugian and upper Narizian Stages by W. W. Rau (in Snavely and others, 1993).

Em$_{2p}$ **Conglomerate and sandstone (upper to middle Eocene)**—Poorly sorted and bedded, subangular to rounded pebble to boulder conglomerate interbedded with gritty, coarse-grained, lithic pebbly sandstone; south of Portage Head, conglomerate consists of angular to rounded clasts of limestone (up to 2 m long), phyllite, diorite, and metavolcanic rocks and grades upward into thin-bedded sandstone and siltstone; correlates with unit Em$_{2lb}$ northeast of the Crescent thrust fault; on the north and south sides of Point of the Arches, conglomerate consists chiefly of clasts derived from and deposited marginally to pre-Tertiary rocks of the olistostromal block that makes up the point; south of Portage Head, contains 20 m thick interbed of foraminifer-bearing concretionary siltstone assigned to the upper Narizian Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{1p}$ **Sandstone and siltstone (middle to lower Eocene)**—Thick- to medium-bedded, medium-grained, quartzose, concretionary, carbonaceous lithic sandstone with thin siltstone interbeds; on north side of Portage Head, contains a few interbeds of basaltic lapilli-tuff and chert-bearing volcanic pebble conglomerate; probably correlates with thick-bedded quartzose lithic sandstone of unit Evc$_{h}$; siltstone interbeds contain foraminifera assigned to the Ulatisian Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{1pc}$ **Conglomerate and breccia (lower? Eocene)**—Pebble and cobble conglomerate and mudflow breccia composed chiefly of angular to subangular clasts of silicified, fine-grained, slightly micaceous, feldspathic, quartzose sandstone and siltstone and minor metabasalt and diorite; conglomerate commonly brecciated and recemented by calcite and silica.

Evb$_{p}$ **Pillow basalt (lower Eocene)**—Pillow basalt, isolated pillow breccia, and mudflow breccia with minor interbeds of basaltic sandstone and siltstone and red calcareous argillite; pillows are commonly amygdaloidal and are porphyritic with phenocrysts of augite and plagioclase set in a fine-grained groundmass; pervasively sheared and laced with veins of laumontite, calcite, epidote, quartz, and prehnite; basalt correlates with the Crescent Formation (unit Ev$_{c}$) north of the Crescent fault; coccoliths from calcareous argillite beds in the pillow lavas are assigned an early Eocene age by David Bukry (in Snavely and others, 1993). Locally divided into:

Eigb$_{p}$ **Intrusive rocks (Eocene)**—Gabbro or diabase sills as thick as 30 m cutting unit Evb$_{p}$.

Rida **Intrusive dacite (Paleocene)**—Light-gray, fine-grained, hornblende-bearing dacite sill; intrudes sedimentary rocks (unit Kvs$_{p}$) along base of sea cliff in central part of Point of the Arches; hornblende K/Ar age of 59 ±3 Ma by R. W. Tabor (in Snavely and others, 1993).

RKbx **Mélange (Paleocene and (or) Cretaceous)**—Intensely sheared mélange containing phacoidal or angular polished blocks of pre-Tertiary rocks that include silicified feldspathic quartzose sandstone, metadacite, metatuff, basalt, and phyllite.

Kvs$_{p}$ **Sedimentary rocks and pillow basalt (Cretaceous)**—Feldspatholithic sandstone and lithofeldspathic quartzose sandstone interbedded with pillowed, brecciated metabasalt, mudflow breccia, and conglomerate; feldspatholithic sandstone is medium-gray, thick-bedded, fine- to medium-grained, micaceous; lithofeldspathic quartzose sandstone is light-gray and silicified, with interbeds of chert and dark-gray, thin-bedded argillite; sedimentary rocks are intruded by Paleocene dacite sill (unit Rida); interbed of chert contains radiolarians indicative of an Early Cretaceous age (Snavely and others, 1993).

Jigb$_{p}$ **Gabbro and diorite (Jurassic or older)**—Gabbro and nonfoliated to gneissic pyroxene- hornblende-bearing quartz diorite; diorite contains irregularly shaped masses of hornblende-rich pegmatite and alaskite(?) and is cut by quartz veins; partially altered to uralite, sphene, calcite, chlorite, hydrogarnet, and prehnite; diorite is Jurassic or older based on K/Ar hornblende age of 144 ±2.4 Ma (Snavely and others, 1971); the nonfoliated phase, now recognized to be an oceanic crust cumulate, has produced a U/Pb age of 160 Ma (R. J. Stewart, Univ. of Wash., oral commun., 2003).

PETROLEUM CREEK BLOCK

Em$_{pc}$ **Siltstone and sandstone (middle? Eocene)**—Thin-bedded to laminated siltstone and very fine-grained sandstone with carbonate stringers 1 to 10 cm thick; commonly sheared and drag-folded.

Ebx$_{pc}$ **Mélange (middle to lower Eocene)**—Siltstone mélange with phacoidal blocks of basalt, conglomerate, and calcite-cemented sandstone; inferred to occur in the lower plate of a folded thrust below the Portage Head–Point of the Arches and Washburn Hill blocks; contains sparse lower Narizian and Ulatisian foraminifera identified by W. W. Rau (in Snavely and others, 1993).

WASHBURN HILL BLOCK

ΦEm$_{w}$ **Turbidite sandstone (Oligocene–Eocene)**—Light-gray, thick- to medium-bedded, quartzose sandstone and thin-bedded, fine-grained sandstone and siltstone interbeds; sedimentary features include casts of borings, parallel laminations, and micro cross-laminations; contains a single 1 m thick bed of phyllite-rich sandstone; correlates with unit ΦEm$_{p}$.

Em$_{2wc}$ **Sandstone and conglomerate (upper to middle Eocene)**—Thick- to medium-bedded, gritty, medium-grained, carbonaceous, phyllite-rich sandstone, cobble and pebble conglomerate, and pebbly mudstone; conglomerate is composed of clasts of metamorphosed felsic volcanic rocks, diorite, and siltstone; sandstone is flaggy locally and contains trace fossils along bedding planes; probably equivalent to unit Em$_{2p}$.

Em$_{2ws}$ **Sandstone (middle Eocene)**—Massive to medium-bedded, gritty, medium-grained, lithic quartzose sandstone and thin- to wispy-bedded fine-grained sandstone and siltstone; siltstone beds are massive to laminated and locally concretionary and contemporaneously deformed; includes a few pebbly mudstone or conglomerate beds; basaltic lapilli tuff with quartzose sandstone interbeds occurs locally near outcrop of tuff breccia (unit Evc$_{w}$); sandstone–siltstone sequence is probably a lateral facies of unit Evc$_{w}$; contains sparse lower Narizian foraminifera identified by W. W. Rau (in Snavely and others, 1993).

Evc$_{w}$ **Tuff breccia (middle Eocene)**—Massive to poorly bedded, iron-oxide-stained tuff breccia with minor interbeds of pebbly concretionary siltstone and basaltic sandstone; derived from unit Evb$_{w}$ as debris flows; breccia grades laterally into sedimentary rocks of unit Em$_{2ws}$; contains lower Narizian foraminifera identified by W. W. Rau (in Snavely and others, 1993).

Em$_{w}$ **Sandstone and siltstone (middle to lower Eocene)**—Thick- to medium-bedded, lithic quartzose turbidite sandstone with minor thin-bedded siltstone that contains calcareous bands and a 2 m thick altered tuff bed; locally contains mudflow breccia, siltstone, and fine-grained sandstone, with less-abundant basalt, sparse chert and diabase pebbles and cobbles, and rare mollusk shells; sandstone is finely micro cross-laminated and contains calcareous concretions and locally has siltstone rip-up clasts; burrows occur along bases of turbidites; carbonaceous or coaly material 2 to 5 mm thick occurs along bedding planes; sparse foraminifera are assigned to the lower Narizian and upper Ulatisian Stages by W. W. Rau (in Snavely and others, 1993).

Evb$_{w}$ **Basalt (lower Eocene)**—Fine-grained to very fine-grained, amygdaloidal, porphyritic pillow basalt and breccia; basalt contains 3 to 5 m thick interbeds of highly sheared microfossil-bearing brownish gray and brick-red siltstone; abundant planktonic foraminiferal assemblages assigned to the Ulatisian and Penutian(?) Stages by W. W. Rau (in Snavely and others, 1993); probably equivalent to units Ev$_{cp}$ and Evb$_{p}$.

ELK LAKE BLOCK

ΦEm$_{e}$ **Siltstone (Oligocene–Eocene)**—Nonbedded to well-bedded, concretionary, medium-gray siltstone with minor thin, fine-grained, lithic quartzose sandstone interbeds; siltstone is locally laminated and contains bioturbated concretions; contains several clastic dikes; contains Refugian and upper Narizian foraminifera according to W. W. Rau (in Snavely and others, 1993).

Em$_{2ec}$ **Conglomerate and sandstone (upper to middle Eocene)**—Nonbedded to thick-bedded pebble–boulder conglomerate and phyllite-rich, gritty, medium-grained sandstone; conglomerate clasts are subangular to rounded felsic metavolcanic rocks, diorite, phyllite, quartzite, green and black chert, and concretionary siltstone; probably correlates with unit Em$_{2p}$.

Em$_{2es}$ **Siltstone and sandstone (middle Eocene)**—Thin, graded beds of siltstone and fine-grained sandstone with thick- to medium-bedded, gritty, medium-grained, phyllitic sandstone in upper part of sequence; siltstone contains thin lenticular concretionary beds; sparse foraminifera are assigned to the Narizian Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{ec}$ **Sandstone and conglomerate (middle to lower Eocene)**—Thick- to thin-bedded, gritty, fine-grained, quartzose and phyllitic sandstone and minor thin-bedded siltstone; contains pebbly sandstone and 1 to 2 m thick conglomerate beds with clasts of chert, phyllite, schist, and vein quartz; chert pebbles contain radiolarians indicative of a Late Triassic (Carnian) age (David Jones, in Snavely and others, 1993); probably correlative with unit Em$_{sc}$; includes several isolated blocks or klippen south of the Elk Lake block in the Ozette terrane.

Ebx$_{e}$ **Mélange (middle? Eocene)**—Intensely sheared siltstone with broken or polished blocks 0.5 to 2.5 m in diameter of phyllitic sandstone (unit Em$_{ec}$) and micaceous feldspathic sandstone (unit ΦEm$_{o}$), and a few siltstone and red argillite clasts; may represent diapiric uplift of tectonic mélange along the Ozette thrust; correlative with unit Ebx$_{o}$.

SNAG PEAK BLOCK

ΦEm$_{st}$ **Siltstone (Oligocene and (or) upper Eocene)**—Thin-bedded siltstone with very fine-grained quartzofeldspathic sandstone interbeds; contains a few gritty phyllitic sandstone interbeds as much as 0.5 m thick.

ΦEm$_{sm}$ **Sandstone (Oligocene–Eocene?)**—Thick-bedded (2–30 m), gritty, medium-grained, lithic sandstone with 5 to 10 m thick interbeds of thin-bedded siltstone, fine-grained sandstone, and conglomerate channel (mudflow) deposits; pebble- to boulder-size clasts in conglomerate consist of argillite, amygdaloidal basalt, dacite, bioturbated calcareous concretionary conglomerate, red and black chert, quartz diorite, silicified sandstone, rare silicified tuff, and mollusks; may in part be correlative to thick-bedded sandstone sequence in upper part of unit ΦEm$_{sp}$.

ΦEm$_{sp}$ **Sandstone and siltstone (Oligocene–Eocene?)**—Very thick-bedded to medium-bedded, gritty, medium-grained, lithic sandstone with 50 to 100 m thick siltstone interbeds; sandstone is locally pebbly and contains siltstone rip-up clasts; contains several mudflow-breccia channel deposits; scattered large meta-tuff clasts occur in sandstone; siltstone in places is laminated and contains 10 to 30 mm thick sandstone interbeds; zones of laumontite as much as 6 m thick cross-cut sandstone beds.

ΦEm$_{ss}$ **Siltstone and sandstone (Oligocene–Eocene?)**—Thin- to medium-bedded siltstone and graded fine-grained sandstone; siltstone contains disc-shaped calcareous concretions 10 to 50 cm in diameter; contains minor thick interbeds (up to 3 m) of lithic, feldspathic, fine-grained sandstone. Siltstone is intensely sheared and drag-folded near major faults. Sparse foraminifera are assigned to the Refugian(?) Stage by W. W. Rau (in Snavely and others, 1993).

Em$_{sc}$ **Sandstone and conglomerate (middle to lower Eocene)**—Very thick- to medium-bedded, gritty, coarse-grained, locally graded sandstone and minor pebble conglomerate and mudflow channel deposits. Sandstone is quartzose with abundant lithic grains of phyllite, basalt, metabasalt, and distinctive mottled, polycrystalline, quartz-veined chert fragments; carbonaceous and coaly layers are present in some sandstone beds. Siltstone clasts in mudflows contain foraminifera assigned to the lower Narizian or Ulatisian Stages by W. W. Rau (in Snavely and others, 1993).

Em$_{1s}$ **Siltstone (middle to lower Eocene)**—Thin-bedded to nonbedded, concretionary, dark-gray siltstone and claystone; in places contains fine-grained, lithic turbidite sandstone beds as much as 1 m thick. Foraminiferal assemblage assigned to the Ulatisian(?) Stage by W. W. Rau (in Snavely and others, 1993).

Ozette Terrane

CAPE ALAVA COASTAL BLOCK

Φm$_{c}$ **Sandstone (Oligocene)**—Thick- to thin-bedded, coarse- to fine-grained, micaceous, lithofeldspathic sandstone with thin siltstone interbeds and minor conglomerate. Sandstone beds are locally pebbly and contain angular siltstone rip-up clasts. Thick cobble and pebble conglomerates, composed chiefly of clasts of sedimentary rock, and pebbly sandstone and pebbly conglomerate that contain boulder-size siltstone rip-up clasts and laminated concretions occur locally.

Φm$_{cc}$ **Conglomerate (Oligocene)**—Basaltic (mudflow) conglomerate and basaltic sandstone with interbedded, thin-bedded, indurated concretionary siltstone. Mudflow is composed of subangular to subrounded clasts of metabasalt and locally contains olistostromal blocks (as large as 10 m in diameter) of pillow basalt and breccia derived from the Crescent Formation. Sparse foraminifera are assigned to the Zemorrian(?) Stage by W. W. Rau (in Snavely and others, 1993).

OZETTE LAKE–CALAWAH RIDGE BLOCK

ΦEm$_{oc}$ **Conglomerate, sandstone, and siltstone (Oligocene–Eocene)**—Interbedded mudflow conglomerate, lithic sandstone, and siltstone; consists in part of channel-fill deposits. Conglomerate clasts (2–60 cm in diameter) consist of subangular to angular broken pillow lava, amygdaloidal basalt and basalt breccia, and concretionary siltstone and sandstone; contains pebbly, gritty sandstone interbeds with abundant siltstone rip-up clasts and carbonaceous debris. Contains a few beds of gray feldspathic sandstone with abundant reddish brown siltstone clasts and thin-bedded, reddish-brown, iron-rich siltstone. Foraminifera in siltstone are assigned to the Refugian or upper Narizian Stages by W. W. Rau (in Snavely and others, 1993); includes part of the Western Olympic lithic assemblage of Tabor and Cady (1978).

ΦEm$_{o}$ **ΦEm** **Sandstone and siltstone (Oligocene to Eocene)**—Medium- to very thick-bedded, light- to olive-gray, micaceous, quartzose, feldspathic and feldspatholithic sandstone; minor interbedded thin-bedded, fine-grained turbidite sandstone and siltstone; locally calcareous and carbonaceous with a few thin lenticular coal seams; contains thin laminae to thick interbeds of medium- to dark-gray siltstone; siltstone-chip sedimentary conglomerate, pebble conglomerate, and mudstone debris flows are present locally; interbeds of phyllitic or basaltic sandstone occur locally. Rocks exposed in the southeastern corner of the Cape Flattery 1:100,000-scale quadrangle, east of the fault that forms the Sol Duc River valley, are contiguous with rocks designated as unit ΦEm by Gerstel and Lingley (2000) in the adjacent Forks 1:100,000-scale quadrangle. I have continued their symbology for corresponding rocks in the Cape Flattery 1:100,000-scale quadrangle. The ages of units ΦEm$_{o}$ and ΦEm are moderately constrained by Narizian foraminifera (Tabor and Cady, 1978; Snavely and others, 1993) and early Eocene to late Oligocene detrital zircon fission-track minimum ages ranging from 24.3 to 54.6 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999). Includes part of the Western Olympic lithic assemblage of Tabor and Cady (1978).

Em$_{1o}$ **Evb$_{op}$** **Siltstone and basalt (middle and lower? Eocene)**—Thin-bedded, well-indurated siltstone, intensely sheared and drag folded, with interbeds of thin- to thick-bedded, fine-grained, lithic and quartzose sandstone and gritty basaltic sandstone. Less common are interbeds of volcanic breccia and nonlayered to pillowed basalt flows (unit Evb$_{op}$), which contain a few thin red argillite beds. Basalt ranges from aphyric to porphyritic and occurs as blocks or as interbeds as thick as 15 m. Calcite and lesser laumontite and quartz veinlets occur throughout the siltstone, breccia, and basalt.

Ebx$_{o}$ **Evb$_{ot}$** **Mélange (Eocene)**—Tectonically mixed blocks of sandstone and less-common basalt in a matrix of intensely sheared concretionary siltstone. Sandstone blocks consist of medium- to thick-bedded, micaceous, carbonaceous turbidites (unit ΦEm$_{o}$); basalt blocks are composed of pillow lava and breccia (unit Evb$_{ot}$). Blocks range from less than 1 m to more than 50 m, are fractured and veined by laumontite and calcite, and have slickensided and polished surfaces. Locally mélange is cut by vertical shear surfaces and is highly susceptible to landsliding. Sparse foraminifera are assigned to the Narizian Stage by W. W. Rau (in Snavely and others, 1993).

tz **tectonic zone**—Zone of penetrative shearing; large tectonic blocks mapped locally.

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