Snoqualmie Pass

DESCRIPTION OF MAP UNITS

[Number in brackets refers to obscure place name on fig. 4]

MASS WASTAGE AND ALLUVIAL DEPOSITS

m **Man-Modified land (Holocene)—**Gravel or diamicton as fill, or extensively graded natural deposits, that obscure underlying units

Qa **Alluvium (Holocene and Pleistocene)—**Moderately sorted cobble gravel along rivers to poorly sorted gravelly sand on small-tributary fans; some fan material is lithologically similar to that included in talus (unit **Qt)**. Includes postglacial terrace gravels that are perched above present-day flood-plain surfaces

Qb **Bog deposits (Holocene and Pleistocene)—**Peat and alluvium. Poorly drained and at least intermittently wet. Grades into alluvium and lahar deposits (units **Qa** and **Qlh)**

Ql **Landslide deposits (Holocene and Pleistocene)—**Diamicton of angular clasts of bedrock and surficial deposits derived from upslope. Mostly shown with arrow(s) depicting downslope movement direction

Qmw **Mass-wastage deposits (Holocene and Pleistocene)—**Colluvium, soil, or landslide debris with indistinct morphology, mapped where sufficiently continuous and thick to obscure underlying material. Unit is gradational with landslide deposits (**Ql**) and alluvium (**Qa**)

Qt **Talus deposits (Holocene and Pleistocene)—**Nonsorted angular boulder gravel to boulder diamicton. Found low on hillslopes, gradational with alluvium (**Qa**). At higher altitudes, includes small rock-avalanche deposits as well as some Holocene moraine, rock glacier, and protalus rampart deposits that lack characteristic morphology. Generally unvegetated

Qlh **Lahar deposits (Holocene and Pleistocene)—**Nonsorted muddy boulder diamicton to moderately sorted sand in the White River valley and adjacent lowlands. Includes deposits of numerous Holocene catastrophic mudflows from Mt. Rainier volcano south of the Snoquallmie Pass quadrangle. Most extensively exposed is the Holocene Osceola Mudflow (Crandell and Waldron, 1956). Also includes hyperconcentrated streamflow deposits (Smith, 1986) originating from volcanic source terrane and inferred to result from volcanic activity

GLACIAL DRIFT AND RELATED DEPOSITS

Qu **Surficial deposits, undivided (Holocene and Pleistocene)**

Qag **Alpine glacial deposits (Pleistocene)—**Glacial deposits ranging from boulder till in uplands and up valley to gravel or sand outwash on broad valley floors. On valley sides and uplands includes areas veneered with drift but also includes bedrock, alluvial fans, colluvium, or talus deposits. On valley floors also includes small fans, bogs, and modern stream alluvium. Areas of thin, sparse drift not

distinguished from bedrock. In headward reaches of high alpine streams, grades into unit **Qgt**

Deposits of Vashon stade of Fraser glaciation of Armstrong and others (1965) of Cordilleran ice sheet (Pleistocene)—Divided into:

Qvr **Recessional outwash deposits**--Stratified sand and gravel, moderately to well sorted, and well-bedded silty sand to silty clay deposited in proglacial and ice-marginal environments. Subscripts (1-7) indicate chronologic sequence of major fluvial deposits, with 1 being the oldest

Qvi **Ice-contact deposits**--Stratified water-laid sand and gravel, silt, clay, and minor till with abrupt grain-size changes and collapse features indicating deposition adjacent to active or stagnant ice. Subscripts (1-5) follow the same chronology as for unit **Qvr** and indicate probable ice-marginal zones during deposition of corresponding recessional outwash deposit

Qvt **Till**--Mainly compact diamicton with subangular to rounded clasts, glacially transported and deposited. Includes minor stratified fluvial deposits. In ice-marginal areas and where covered by thin layer of recessional outwash, contact with recessional-outwash or ice-contact deposits (**Qvr** or **Qvi)** is gradational

Qva **Advance outwash deposits**--Well-bedded gravelly sand to fine-grained sand, generally unoxidized, deposited in proglacial streams. Includes minor stratified sediments that predate the Fraser glaciation

Qvu **Vashon Drift, undivided**

Qpf **Glacial and nonglacial deposits of pre-Fraser glaciation age (Pleistocene)—**Firm gray clay and deeply weathered stratified sand and gravel. Evidence of strong in-place weathering throughout exposures, includes oxidation, weathering rinds, and clay-mineral replacement

Qpfa **Alpine glacial drift of pre-Fraser glaciation age (Pleistocene)—**Deeply weathered till with oxidized matrix and weathering rinds on clasts

BEDROCK

Qra **Andesite of Mount Rainier (Pleistocene)—**Gray, porphyritic two-pyroxene andesite rich in phenocrysts of zoned plagioclase, augite, hypersthene, and opacitised hornblende. Pilotaxitic groundmass with plagioclase, pyroxene, and opaque minerals

Qcc **Basalt of Canyon Creek (Pleistocene)—**Light-gray olivine basalt. Olivine, partially altered to iddingsite rims, preseent as phenocrysts in intergranular groundmass of plagioclase microlites and clinopyroxene, opaque minerals, and olivine. In part vesicular. Described by Fischer (1970, p. 86-92). Locally, includes:

Qcct **Basaltic tuff and breccia**--Unconsolidated to partially consolidated and crudely bedded basaltic tuff and breccia

Tbd **Basalt of Dalles Ridge (Pliocene)—**Light gray, pilotaxitic basalt flows with phenocrysts of olivine, partially to completely altered to iddingsite, in groundmass composed of plagioclase, clinopyroxene, olivine, and opaque minerals. Described by Hartman (1973, p. 36-37)

Th **Howson Andesite (Miocene)—**Gray hornblende porphyry containing plagioclase and either oxyhornblende or common hornblende phenocrysts, in part with hypersthene microphenocrysts, in groundmass of plagioclase, potassium feldspar, quartz, and opaque minerals. Locally includes volcanic rock fragments

Tcp **Volcaniclastic rocks of Cooper Pass (Miocene)—**Tuffaceous sandstone and vocanic conglomerate. Light-green to dark-gray dacitic tuffaceous sandstone that grades into gray volcanic clast-rich conglomerate and breccia; hornblende-bearing dacite tuff with partially altered plagioclase and quartz. Well-bedded tuffaceous sandstone contains altered plagioclase, quartz (in part rounded and embayed), opaque mineral grains, and volcanic, sedimentary, metamorphic, and granitic lithic clasts in matrix altered to clay minerals. Sandy volcanic conglomerate and breccia contains volcanic, sandstone, siltstone, phyllite, schist, chert, and granitic clasts. Age is middle and late Miocene

Columbia River Basalt Group--In this area, consists of Yakima Basalt Subgroup**,** divided into**:**

Grande Ronde Basalt (Miocene)—Flows of fine-grained, aphyric to slightly plagioclase-phyric basalt (units Tgn_2 and Tgr_2 of Swanson and others,1979). Commonly columnar- or hackly jointed. Interbeds of tuffaceous fine-grained sandstone, siltstone, and mudstone abundant. Flows generally have dense interiors and vesicular upper zones. Invasive flows--lava flows that invade sedimentary deposits, generally as sill-like bodies--are common and have dense upper zones. Pillows present locally, such as 500 m southeast of Jungle Creek Campground [25] on the Little Naches River (D.A. Swanson, written commun., 1983). Divided into:

Tgn_2 **Flows of normal magnetic polarity**

Tgr_2 **Flows of reverse magnetic polarity**

Te **Ellensburg Formation (Miocene)—**Volcanic breccia, tuff, debris flows, and sandstone. Clasts mostly derived from Fifes Peak Formation, but hornblende dacite clasts and pumice are also present and locally dominate (G.A. Smith, written commun., 1986). Sandstone is parttially well cemented

Rocks of Snoqualmie batholith--Divided into:

Tsgs **Tonalite and granodiorite, southern phase (Miocene)—**Hornblende-biotite granodiorite and tonalite, medium grained, mostly equigranular with hypidiomorphic texture, locally with clinopyroxene. CI (Color Index) = 9-24. As indicated by normative minerals from chemical analyses (Erikson, 1969, appendix 2), southern phase of pluton is overall slightly more K-feldspar rich than northern phase (**Tstn**) described below. Southern phase is mostly light colored and coarsely jointed. Hammond (1963, p. 198-199) described a tonalite (his quartz diorite) border zone

Tsgf **Fine-grained monzonite (Miocene)—**Highly altered, light-colored, fine-grained monzonite containing cloudy plagioclase and chloritized hornblende in discontinuous mesostasis of quartz

Tsgg **Granodiorite and granite (Miocene)—**Medium-grained hypidiomorphic granular to porphyritic granophyric granodiorite and granite (Erikson, 1969, p. 2221). Mostly with biotite. CI of 1-5, rarely to 10. Normative composition is mostly granodiorite (Erikson, 1969, appendix 2), but with considerably more quartz than northern and southern phases. Includes most of Erikson's informally named Preacher Mountain quartz monzonite

Tstn **Tonalite and granodiorite, northern phase (Miocene and Oligocene)—**Biotite-hornblende granodiorite and tonalite, medium grained, mostly equigranular, with hypidiomorphic texture; locally with clinopyroxene. CI = 9-24. Mostly light-colored, coarsely jointed rock. Description adapted from Erikson (1969, p. 2218-2219). On Three Queens (peak) [12], rock is characterized by graphic intergrowth of K-feldspar and quartz. Considerable sulphide is associated with tonalite in Mineral Creek

Tsm **Mafic diorite and gabbro (Miocene and Oligocene)—**Biotite-hornblende diorite and gabbro, including mafic pyroxene-bearing tonalite and quartz diorite. CI = 20-40 (Erikson, 1969, p. 2217). On Pratt River, mafic quartz diorite is associated with considerable amounts of thermally metamorphosed porphyritic andesite and andesite breccia

Tcr **Carbon River stock (Miocene)—**Hypidiomorphic-granular biotite pyroxene granodiorite in main body and subordinate sills. Locally, main body has microtonalite border phase. Main phase approximately 40 to 50 percent euhedral to subhedral phenocrystic plagioclase with twinning and oscillatory zoning, 20 percent slightly elongate interstitial orthoclase, 20 to 25 percent equant interstitial quartz, 5 percent biotite which that is generally present as small grains in the groundmass, and 5 to 10 percent euhedral pyroxene or uralite. Description adapted from Fischer (1970, p. 137-150). Pyroxene crystals are mostly uralitized; scarce primary hornblende is interstitial

Intrusive rocks (Miocene and Oligocene)—Divided into:

Tip **Pyroxene andesite porphyry**--Gray to green hypersthene and (or) clinopyroxene andesite with hyalocrystalline to intergranular groundmass. Generally partially altered with glass replaced by smectite. Fresh rocks of unit ,mostly in area underlain by, Fifes Peak Formation, are black with unaltered brown glass. Vine (1969, p. 32-34) described parts of unit as slightly altered, mostly clinopyroxene-bearing porphyritic rocks intrusive into Puget Group

Tit **Tonalite**--Uralitic pyroxene tonalite, mostly with hypersthene and clinopyroxene grading to rare granodiorite or quartz diorite. Most bodies are plagioclase-pyroxene phyric and have fine-grained hypidiomorphic granular texture; quartz is interstitial and commonly mesostasic. Some bodies are texturally transitional to pyroxene andesite porphyry (**Tip**). Intrusion north of Blowout Mountain [22] ranges to quartz gabbro (Stout, 1964, p. 331). Small intrusions on Dalles Ridge, Amabilis Mountain, and west of Tacoma Pass are quartz-bearing olivine-pyroxene gabbro. Many small tonalite masses may be satellitic to the Snoqualmie or Tatoosh batholiths. Small masses in Cedar River area are rich in sulphides, mostly pyrite (Hammond, 1963, p. 200). Tonalite bodies may also grade into unit **Tidp**. Some areas mapped as tonalite may be made up of closely spaced dikes

Tiap **Altered porphyry**--Highly altered brown to green hornblende and pyroxene plagioclase phyric andesite with holocrystalline to intersertal groundmass, locally trachytoid. Includes some dacite with groundmass quartz. Commonly altered to smectite and zeolite

Tidp **Dacite porphyry**--Gray hornblende and (or) pyroxene dacite and rhyodacite porphyry with fine-grained to microgranular holocrystalline or devitrified groundmass. Contains clinopyroxene and hypersthene where fresh. Generally, mafic minerals and groundmass are partially altered to smectites and calcite. Includes some highly altered quartz-bearing volcanic rocks and some microporphyritic rhyolite on North Fork of Little Naches River

Tf **Fifes Peak Formation (Miocene)—**Basaltic andesite and basalt flows, flow breccia, and interbedded andesite breccia and tuff, mudflow breccia, volcaniclastic sedimentary rocks, and crystal-lithic tuff. Dark-reddish, dark-green to dark-gray or black, porphyritic to microporpyritic andesite contains 20 to 30 percent, generally well-zoned, plagioclase (An_{50} to An_{30}) and 5 to 15 percent hypersthene and clinopyroxene as phenocrysts (Fischer, 1970). Groundmass textures are trachytic to intersertal to intergranular with plagioclase microlites, pyroxene, opaque, or reddish-brown glass with secondary smectites, hematite, calcite, and quartz. Black basalt with plagioclase and pyroxene microphenocrysts in fine-grained holocrystalline or hyalocrystalline, in part, pilotaxitic groundmass; locally contains olivine that has generally been altered to smectite clays (iddingsite). Flow banding is indicated by color bands and layers with different amounts of crystals. Flows exhibit platy jointing, columnar jointing with uniform to splayed orientations, vesicular tops, scoriaceous and amygdaloidal zones, and minor drusy quartz zones. Massive to well-bedded, green, red, and brown polymictic tuff and breccia and less colorful monolithologic tuff and breccia contain angular to well-rounded porphyritic andesite clasts; breccia matrix is commonly rich in feldspar crystals. Breccia may predominate locally, but is not as easily seen as flows. Minor volcanic sand-

stone, conglomerate, and siltstone, dacite, and mudflow breccia. Well-bedded greenish volcanic conglomerate, and fine-grained silty layers, locally rich in organic materials, contains leaf fossils. Quartz-bearing, crystal-rich, lithic ash-flow and air-fall tuff interbeds are locally prominent. According to Hartman (1973, p. 39-48), andesite flows and breccia of Fifes Peak Formation in the Snoqualmie Pass quadrangle were only slightly affected by "low-grade metamorphism" (primarily heulandite-clay-(chlorite)-quartz). Rocks of Fifes Peak Formation in this quadrangle were described in part by Hammond (1963, p. 144-152, 169-178), Fischer (1970, p. 54-81), and Hartman (1973, p. 21-25). Locally, divided into:

Tfv **Volcaniclastic rocks**--Well-bedded andesitic breccia, tuff, and volcanic sandstone, cropping out in vincinity of Maggie Creek. Porphyritic andesite breccia clasts commonly multicolored. In part, pebbly volcanic sandstone. Cut-and-fill structures and graded bedding present in some exposures. Thin pumice-bearing white ash layers and leaf fossils present but uncommon. Interbedded with unit flows of Fifes Peak Formation

Tfb **Andesite and basalt megabreccia**--Megabreccia containing blocks as large as 4 m across. Clasts of andesite similar to unit **Tf**, and including very fine grained, sugary to coarse-grained andesite porphyry. Interbedded and gradational with flows of Fifes Peak Formation

Tfc **Crystal-lithic tuff**--White to gray tuff containing crystals of plagioclase, pyroxene, and quartz, and clasts of pumice and volcanic rocks in brownish matix of devitrified glass. At Boulder Creek, grades upward into diamictite consisting of a matrix similar to tuff studded with andesite and basalt blocks

Rhyolite unit of Clear West Peak--Divided into:

Tfci **Intracaldera rhyolite**--Mostly gray to purple, sparsely plagioclase phyric devitrified rhyolite. Equivalent in part to the informally named Clear West complex of Fischer, 1972; see also 1970). Local exposures of ash-flow tuff with vitroclastic and eutaxitic textures (McCulla, 1986, p. 65-68). Most rocks highly altered but Fischer (1970, p. 102-113) described black vitrophyre containing plagioclase, augite and hypersthene phenocrysts, and abundant crystallites of hornblende. Many of the altered rocks have pseudomorphs of smectite clays after hornblende(?). Rocks are conspicuously banded perpendicular to columnar joints and commonly subhorizontally arrayed, suggesting steep and variable flow layering or multiple dikes. McCulla (1986, p. 68) suggested that intrusions are concentrated near south margin of caldera. Mass is locally intruded by andesite dikes and also includes some andesite xenoliths. See Fischer (1970, p. 93-114) and McCulla (1986, p. 66-70) for detailed descriptions, modes, and chemical analyses

Tfce **Extracaldera rhyolite tuff**--Gray to white devitrified, mostly banded rhyolite with rare black welded vitrophyre and local basal unwelded pumice-perlite tuff (reported by Fischer 1970, p. 98). Mineralogy and chemistry (Fischer, 1970, p. 93-113) are similar to intracaldera rhyolite (**Tfci**), but flattened shards and local folded flow bands are more prominent. Locally, rare beds of rhyolitic sandstone, siltstone, and coal. Rhyolite tuff near unnamed hill [20] north and locally south of White River is considerably altered, mostly to conspicuously massive white silica and hematite. McCulla (1986, p. 108-174, plate 2) described replacement silica cap over

argillitic, iron oxide-rich zone with local quartz, kaolinite, alunite, and pyrite veining. Silicified rhyolite is shown with diagonal line pattern and may include some silicified andesite

Tfrt **Rhyodacite tuff**--Predominately tan, locally light-green, in part flow banded, crystal-lithic ash-flow tuff with vitroclastic texture. Rounded, resorbed quartz, euhedral to rounded feldspar, clinopyroxene, and volcanic lithic clasts (as large as 1.5 cm) in matrix of mostly undeformed glass shards and glass dust

Tfst **Sun Top unit**--Rhyodacite ash-flow tuff and well-bedded volcaniclastic sedimentary rocks. Equivalent to informally named Sun Top tuff of Vance and others (1987). Typically light gray or tan, locally reddish tan or light green. Vitric to crystal-lithic tuff and interbedded air-fall tuff, volcanic sandstone, conglomerate, and siltstone. Rhyodacite ash-flow tuff generally contains abundant euhedral to subrounded plagioclase, clinopyroxene, hornblende, hypersthene, and biotite, rounded and embayed quartz, pumice and felsic to mafic volcanic rock fragments in generally highly altered matrix of glass shards and dust and very fine grained minerals. Alteration minerals include smectites, chlorite, and calcite. Alteration is locally so pervasive that original grain types and textures are not discernable, but rocks are generally less altered than dacite tuff in Ohanapecosh Formation. Locally welded and with crude columns. Gray to tan, in part greenish, well-bedded polymictic volcanic sandstone, conglomerate, siltstone, and tuff locally exhibit sedimentary structures such as cross-bedding and ripple marks. Includes rare mudflow breccia. Rocks in quadrangle are in part described by Fischer (1970, p. 34-53), Hartman (1973, p. 15-21, tables 6, 7), and Vance and others (1987)

Tfcr **Chenuis Ridge unit--**Light-greenish-gray rhyodacitic ash-flow tuff, breccia, and minor interbedded volcaniclastic sedimentary rocks. Similar to Sun Top unit. Near Carbon River stock (fig. 2), rocks are locally hornfelsic

Teg **Volcanic rocks of Eagle Gorge (Miocene and Oligocene)—**Basaltic andesite and basalt flows, breccia, and minor well-bedded tuff and volcanic sedimentary rocks. Predominantly dark-green to black andesitic flows and flow breccia. Flows variously exhibit platy or columnar jointing, vesicular tops, scoriaceous or amygdaloidal zones, and minor drusy quartz zones. Breccia generally monolithologic. Plagioclase, clinopyroxene, and lesser hypershtene and hornblende phyric andesite exhibit intersertal and intergranular texture; with secondary smectites, hematite, calcite, and quartz. Minor well-bedded multicolored tuff and breccia; volcanic sandstone, conglomerate, siltstone, and dacite; rare mudflow breccia

Volcanic rocks of Mount Daniel (Oligocene)—Divided into:

Tdv **Andesite, dacite, and rhyolite volcanic rocks**--Predominantly clinopyroxene and clinopyroxene-hypersthene andesite and dacite tuff, breccia, and subordinate flows. Breccia beds as thick as 25 m. Commonly highly altered to calcite and smectites. Some thinly bedded (water-laid?) tuff and volcanic sandstone. Detailed descriptions in Ellis (1959, p. 65-70) and, for rocks north of Snoqualmie Pass quadrangle, in Simonson (1981)

Tdgr **Granophyre and rhyolite porphyry**--Intrusive rocks east of Waptus River grade, from medium-grained hornblende granite to fine-grained porphyritic granophyre. Highly altered to chlorite, epidote, sericite, and prehnite. West of

river, plagioclase and quartz phyric rhyolite with devitrified groundmass. On Cle Elum River, intrusive rhyolite porphyry breccia is filled with inclusions of country rock and broken phenocrysts of quartz, plagioclase, and K-feldspar. These rocks are closely associated with tonalite dikes and they are thermally metamorphosed

Tdrd **Rhyodacite tuff**--Vitric crystal-lithic dacite tuff, commonly containing plagioclase, resorbed quartz and silicic to intermediate volcanic fragments in devitrified glassy matrix. Probably of ash-flow origin. Similar to the member of Lake Keechelus (**Tolk**), but with more quartz phenocrysts

Tdb **Breccia**--Monolithologic breccia composed of angular sandstone clasts as large as 3 m across derived from Swauk Formation. Rare volcanic clasts. Further descriptions in Ellis (1959, p. 66-67) and Simonson (1981, p. 40-41)

Tdr **Rhyolite**--Quartz and plagioclase phyric devitrified rhyolite. Mostly tuff and breccia rich in devitrified shards, locally eutaxitic. Rhyolite on Cone Mountain [13] may be intrusion

To **Ohanapecosh Formation (Oligocene)—**Well-bedded, multicolored, volcanic- and crystal-lithic andesitic tuff and breccia and volcaniclastic sedimentary rocks alternating with massive tuff breccia, subordinate basalt and andesite flows and flow breccia, and minor rhyolite tuff. Characteristically light green, but also pistachio-green, light-bluish green, purplish, black, brown, or white. Mixed volcanic lithic, in part pumice-rich or feldspar-rich tuff, lapilli, and breccia. Massive to well-bedded, mono- and polymictic breccias contain red, yellow, brown, green, or blue-green clasts of andesite porphyry and basalt in feldspar crystal-rich matrix. Clasts generally about 2 to 6 cm in diameter, but as large as 2 m. Well-bedded volcanic sandstone and comglomerate are rich in plagioclase crystals and contain variety of volcanic rock fragments and rare chert and granitoid clasts. Volcanic argillite is, in part, rich in organic material and contains leaf impressions. Minor fresh to mostly highly altered andesite and basalt flows, flow breccia, and mudflow breccia are locally present, particularly in basal parts of unit on the northeast and east side of outcrop area. Dark-green, brown or black, weathering to light-green or brown, one- and two-pyroxene andesite porphyry contains phenocrysts or glomerocrysts of plagioclase or plagioclase and pyroxene. Commonly trachytic with groundmass composed of plagioclase microlites, clinopyroxene, opaque minerals, and alteration products. Flows locally exhibit platy jointing, columns, and vesicular tops. Dark basalt with small plagioclase, clinopyroxene, and olivine phenocrysts set in groundmass of plagioclase, opaque, clinopyroxene, and alteration minerals. Plagioclase locally replaced by calcite, and pyroxene by smectite. Other alteration minerals include quartz, zeolite, calcite, chalcedony, smectite, clays, and chlorite that replace minerals, lithic grains, or fill vugs. Hartman (1973, p. 38-48, fig.8) reported minerals indicative of "low-grade metamorphism" (laumontite-chlorite-quartz and epidote-prehnite-chlorite-quartz assemblages), but added that rocks were not pervasively altered and that alteration likely had hydrothermal origin. Minor crystal-rich dacite and rhyolite ash-flow tuff generally contains plagioclase and partially embayed quartz crystals as well as volcanic rock fragments, pumice, or altered glass shards in generally altered matrix, which may contain potassium feldspar. In part, with clinopyroxene microphenocrysts that in general are at least partially altered to smectite clays. On south side of Huckleberry Mountain,

between strands of the White River Fault, unit includes variety of atypical rocks, including dacite ash-flow tuffs similar to unit **Tfst** and poorly consolidated tuffaceous shales that may be much younger than unit **To**. Locally, includes:

Tolk **Tuff member of Lake Keechelus**--Dacite crystal-vitric tuff and breccia consisting of plagioclase (20 to 25 percent), quartz (7 to 11 percent), and pyroxene (trace to 4 percent, altered to smectite) phenocrysts in groundmass of quartz, plagioclase, potassium feldspar, and devitrified glass. Light greenish, weathering to light pink or salmon. Bedding locally defined by flattened pumice. Breccia blocks as large as1 m. Rocks of unit described in detail by Hammond (1963, p. 123-144)

Tv **Volcanic rocks (Oligocene)—**Mostly andesite with minor dacite and rhyolite in coarse breccia, tuff, ash flow-tuff, and rare flows. Mostly highly recrystallized by thermal metamorphism; many rocks are hornblende-biotite hornfels. As mapped, may include some rocks belonging to underlying Naches Formation

ROCKS WEST OF THE STRAIGHT CREEK FAULT

Tdg **Diabase, gabbro, and basalt (Oligocene? and Eocene)—**In Puget Lowlands, consists of dark-gray porphyritic calcic andesite and may include minor basalt or dacite (Vine, 1969, p. 32-34). Euhedral to subhedral phenocrysts of andesine and augite dominate; variously altered to smectite clays, calcite, and chlorite. Occures mostly as sills or sill-like bodies less than 10 m thick, but some as thick as 50 m, and one about 125 m

Green River-Cabin Creek block

Tn **Naches Formation (early Oligocene? to middle Eocene)—**Rhyolite, andesite, and basalt flows, tuff, and breccia with interbeds of feldspathic subquartzose sandstone and siltstone as well as rare coal. Well-bedded andesite and basalt flows and breccia are nondescript, porphyritic to aphyric, dark-green to black rocks, weathering to brown. In part amygdaloidal, with columns, or with brecciated and vesicular tops. Rhyolite forms mostly flow-banded flows or domes and minor ash-flow tuffs. Interbedded sedimentary rocks are white to light-tan or gray, coarse-grained micaceous feldspathic sandstones, exhibiting crossbeds and graded bedding, and black argillite and laminated siltstone. Both volcanic and sedimentary rocks are thermally metamorphosed adjacent to Miocene stocks and plutons. Ort and others (1983) presented chemistry of volcanic rocks. Locally, divided into:

Tnmc **Mount Catherine Rhyolite Member (late and middle Eocene)—**Commonly flow-banded, platy jointed, black, welded, crystal-lithic ash-flow tuff containing highly flattened pumice lapilli, some volcanic breccia, and minor thin feldspathic sandstone and shale interbeds. Unusual hardness and apparent freshness probably are due to recrystallization during intrusion of Snoqualmie batholith. Unit described by Foster (1960, p. 114), Hammond (1963, p. 50-54), and Tabor and others (1984)

Tnr **Rhyolite (late and middle Eocene)—**Mostly white to gray, flow-banded, platy-jointed flows or domes with ash-flow tuff containing flattened pumice fragments. In beds meters to hundreds of meters thick. Includes some probably intrusive rhyolite, especially near Rampart Ridge north of Keechelus Lake.

Mainly aphyric or with minor plagioclase or quartz phenocrysts; completely devitrified to white spherulitic masses. Contains minor interbeds of basaltic tuffs and flows and feldspathic sandstone

Tns **Feldspathic sandstone and volcanic rocks (late and middle Eocene)—**Well-bedded, medium- to coarse-grained, tan to gray, predominantly micaceous feldspathic to feldspatholithic subquartzose sandstone and interbedded siltstone and shale, with conspicuous rhyolite, andesite, and basalt flows, tuff, and breccia. Contains interbeds of coal-bearing shale and rare volcanic clast-rich pebble conglomerate and quartz-pebble grit. Leaf fossils locally common. Volcanic clasts constitute only about 28 percent of framework grains in sandstone (Frizzell, 1979, p. 47)

Tnbg **Glomeroporphyritic basalt (late and middle Eocene)—**Mostly basalt and glomeroporphyritic basalt with interbeds of andesite and rare feldspathic sandstone and siltstone. Thick flows, in part with vesicular tops, some of which contain tabular plagioclase phenocrysts as large as 2 cm across, that in some flows are strongly flow aligned. Described in some detail by Foster (1967, p. 39, 40)

Tng **Guye Sedimentary Member (late and middle Eocene)—**Light to dark gray feldspathic sandstone, black slaty shale, and hard chert-pebble conglomerates; rare volcanic interbeds. Argillite is leaf bearing. Locally hornfelsic. Discussed by Foster (1960, p. 111-113), Hammond (1963, p. 45-48), and Tabor and others (1984)

Tnb **Basalt (late and middle Eocene)—**Mostly basalt flows and breccia with interbedded feldspathic sandstone and siltstone. Basalt forms nondescript, porphyritic to aphyric, dark-green to black rocks that weather brown. Holocrystalline to intersertal microporphyritic rocks contain plagioclase, clinopyroxene, opaques, glass, and alteration minerals. Many are so highly altered to smectite or calcite that identification of original textures and minerals is difficult

Tp **Puget Group**--Micaceous feldspathic subquartzose sandstone, siltstone, claystone, and coal. Rocks in the Green River area (described in detail by Vine, 1969, p. 6-13) are white, very fine grained to gritty sandstone with subangular to rounded grains consisting of about 40 to 60 percent quartz, 30 to 50 percent feldspar, and about 5 percent lithic clasts (Frizzell, 1979, appendix III). Tabular beds of sandstone are massive to cross bedded and occasionally exhibit channel cut-and-fill structures. Light to dark siltstones form poor outcrops, are commonly thinly laminated, and contain organic matter. Coal beds are as thick as 5 m and are described in detail by Beikman and others (1961).
In northwest corner of map area, near Tiger Mountain, unit consists of interbedded nonmarine sandstone and volcanic breccia belonging to undivided Tiger Mountain and Tukwila Formations, which were previously separated by Vine (1969). Immediately north of Green Valley along Cedar River and along western edge of map area. north of Enumclaw, rocks (**Tp?**) may be nonmarine sandstones of the Puget(?) Group that are in contact with unit **To**; Walsh (1984) and Phillips (1984) provide more details in Tiger Mountain and Green River areas. In Snoqualmie Pass quadrangle, divided into:

Tpr **Renton Formation (late and middle Eocene)—**Fine- to coarse-grained feldspathic to lithofeldspathic subquartzose sandstone with interbedded siltstone,

claystone, and coal. The fluvial to nearshore marine rocks, (Vine, 1969, p. 23-26), attain at least 670 m thickness near Taylor Mountain [2]. Contains 30 to 45 percent quartz, 40 to 50 percent feldspar, and 10 to 20 percent lithic grains (Frizzell, 1979, Appendix III)

Tpt **Tukwila Formation (late and middle Eocene)—**Volcanic breccia, conglomerate, sandstone, and flows with intercalated feldspathic sandstone and impure coal beds. Tuff and breccia with clasts of porphyritic andesite and dacite and polymictic volcanic conglomerate appear to predominate, but flow rocks (in part sills or dikes?) form resistant layers (Vine, 1969, p. 19-23) On Lookout Mountain, north of Cedar River, unit includes massive, columnar jointed flows *unlike* flows in most Tukwila Formation. These rocks were previously mapped as unamed volcanic rocks by Vine (1969) and Walsh (1984; written commun., 1994)

Tptm **Tiger Mountain Formation (middle Eocene)—**Light-colored, medium-grained, micaceous feldspathic subquartzose sandstone interbedded with siltstone, minor pebble conglomerate, and coal beds. Vine (1969, p. 16-19) and Johnson (in press) describe the Tiger Mountain Formation

Tmp **Volcanic rocks of Mount Persis (late? Eocene)—**Mostly gray to black, locally reddish, porphyritic two-pyroxene andesite lava and breccia. Phenocrysts and glomerocrysts of plagioclase, clinopyroxene, hypersthene, and opaque minerals in devitrified groundmass. Mostly highly altered. Massive to blocky joints. Flow layering obscure

Trr **Raging River Formation (middle Eocene)—**Shallow marine and alluvial, volcanic-rich sandstone, siltstone, and shale. Locally highly fossiliferous; plant remains common Minor conglomerate predominantly consists of volcanic clasts, but locally contains chert pebbles. For detailed descriptions see Vine (1969, p. 13-16) and Johnson (1992)

ROCKS EAST OF THE STRAIGHT CREEK FAULT

Teanaway River Block

Roslyn Formation (late and middle Eocene)—Divided into:

Tru **Upper member (late Eocene)—**Medium- to fine-grained, nonmarine, white, weathering to yellow, micaceous lithofeldspathic sandstone, some with calcite cement. Dark olive-gray to greenish-yellow siltstone, predominantly quartz and feldspar; thin-bedded to laminated. Subordinate 0.6- to 6-m-thick seams of well-jointed, banded bituminous coal. See "Coal Measures" of Bressler (1951, p. 31)

Trm **Middle member (late and middle Eocene)—**Similar to upper member (**Tru**) but contains only minor stringers of coal

Trl **Lower member (middle Eocene)—**Mostly white, weathering to yellowish and pale orange, nonmarine, medium- to coarse-grained, micaceous, lithic, feldspathic, and lithofeldspathic sandstone. Beds to 15 cm thick with crossbedding, pebble stringers, and cut-and-fill structures. In part zeolitic; Pongsapich (1970, p. 54, table 6) reported laumontite in eight samples and

clinoptilolite in one. Calcite cement locally abundant. Abundant conglomerate and pebbly sandstone with rounded pebbles of granitic and aphanitic extrusive or hypabyssal rock. Includes Bressler's (1951, p. 35) basal beds of red to red-brown, fine-grained sandstone with minor angular clasts of quartz, metamorphic rock fragments, some feldspar, and other rock types

Tt **Teanaway Formation (middle Eocene)—**Basalt, basaltic tuff, and breccia with minor andesite, dacite, and rhyolite. Black, generally dense to glassy nonporphyritic pyroxene and rare olivine basalt, weathering red brown to yellow. Commonly fine-grained intersertal groundmass with plagioclase laths and clinopyroxene; interstices of brown glass or alteration products (Clayton, 1973, p. 18-19). Blocky to columnar-jointed flows characterized by large chalcedony and calcite amygdules. Tuff and breccia commonly altered to clays. Silicic varieties including welded tuff are white, purple, and highly altered but contain relict phenocrysts of quartz, plagioclase, and rare K-feldspar. Contains minor feldspathic sedimentary rock (Clayton, 1973, p. 35-36). Teanaway dike swarm composed of dark-green and brown to black basalt and diabase dikes that weather reddish brown. Includes pale, dull holocrystalline dikes containing plagioclase laths and granular clinopyroxene in intergranular texture. Interstices are filled with quartz, plagioclase, zeolite, and clays (Southwick, 1966, p. 9). Waxy, partly glassy dikes with andesine, clinopyroxene, and minor olivine; altered to chlorophaeite and devitrified glass (Southwick 1966, p. 10-11). Percent of area underlain by dikes shown by density of symbols

Tdg **Diabase, gabbro, and basalt (Eocene)—**Fine- to medium-grained black diabase and gabbro dikes and plugs that weather to brown and reddish brown. Contains labradorite, clinopyroxene, rare olivine, and opaque ores. Subophitic to ophitic texture; variously altered to smectite clays, calcite, and chlorite (Stout, 1961, p. 350)

Swauk Formation (middle and early Eocene)—Divided into:

Tss **Sandstone**--Predominantly fluvial, gray-weathering to tan, zeolitic, locally carbonate-cemented, medium-grained, micaceous feldspathic to lithofeldspathic subquartzose sandstone averaging 40, 48, and 12 percent quartz, feldspar, and lithic clasts, respectively, and containing 40 to 80 percent quartz, 20 to 50 percent feldspar, and 5 to 15 percent lithics in map area (Frizzell, 1979). In part contains laumontite, clinoptilolite, and prehnite (Pongsapich, 1970). Basal beds resting on Easton Metamorphic Suite consist of pebbly sandstone containing quartz and phyllite clasts, which rapidly grade up section into more feldspathic sandstone. Thin to very thick bedded, poorly sorted, locally crossbedded, and with lesser interbeds of carbonaceous siltstone and shale, pebbly sandstone, and conglomerate. Pattern indicates zone of sheared rocks

Tsc **Conglomerate facies (middle and early Eocene)—**20 to 50 percent conglomerate and conglomeratic sandstone interbeds in feldspathic and lithofeldspathic sandstone, siltstone, and shale. Boulders to pebbles of quartzite, chert, argillite, granite, phyllite, and serpentinite in matrix of micaceous feldspathic and lithofeldspathic sandstone. Locally exhibits crossbedding and cut-and-fill structures

Tssp **Silver Pass Volcanic Member (early Eocene)—**Mostly dacite and andesite flows and pyroclastic rocks, but compositions range from rhyolite to basalt (Ort and others, 1983). Light-tan to dark-green-gray andesite and feldspar porphyry with phenocrysts, microphenocrysts, and glomerocrysts of plagioclase-hypersthene and plagoclase-clinopyroxene in groundmass of plagioclase microlites, pyroxene, opaques, and alteration minerals. Commonly highly altered with plagioclase altered to calcite and chlorite and pyroxene altered to smectite. Locally contains zeolite-filled amygdules. Altered rhyolite or dacite ash-flow tuff and tuff breccia contain plagioclase and quartz crystals, volcanic clasts, and flattened shards and pumice. Described in greater detail by Lofgren (1974, p. 25-34)

Tsi **Ironstone (early Eocene)—**Iron-rich sandstone, shale, and conglomerate, locally well bedded. Conglomerate locally composed of peridotite and serpentinized peridotite clasts in an iron-rich matrix consisting of limonite, hematite, magnetite, and serpentenite. Most deposits are rich in nickel (Lamey, 1950)

Manastash River Block

Tbf **Basalt of Frost Mountain (middle Eocene)—**Dense black microporphyritic olivine basalt; microphenocrysts of plagioclase, clinopyroxene, and olivine in intersertal groundmass of plagioclase, clinopyroxene, opaque minerals, and brown glass. Weathers red and is locally columnar jointed. Locally altered to siliceous white rock. Locally, divided into:

Tbfb **Basalt breccia and tuff**--Brown to red oxidized basaltic breccia and tuff with thin basalt flows. Crudely bedded

Tta **Taneum Formation (early Eocene)—**Mostly gray to green and brown, generally highly altered porphyritic to nonporphyritic andesite, dacite, and rhyolite flows, tuff, and breccia; greenish-blue, purple, and white altered ash-flow tuff, commonly welded, with quartz and plagioclase phenocrysts and flattened pumice lapilli

Tm **Manastash Formation (early Eocene)—**Nonmarine sandstone, siltstone, and conglomerate. Light-greenish-gray or tan, massive to well-bedded, medium- to coarse-grained feldspathic quartzose to subquartzose sandstone, thin siltstone, and interbeds of conglomerate. Averages 55 to 60 percent quartz and 5 to 10 percent lithic clasts (Frizzell, 1979). Fine to coarse planar and through crossbeds locally present. Minor seams of bituminous coal; fossil leaves locally present

ROCKS SOUTHWEST OF DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

Rocks of the western melange belt (middle Eocene and (or) Late Cretaceous)—Divided into:

TKwa **Argillite and graywacke**--Well-bedded marine sandstone and argillite and subordinate pervasively sheared argillite. Purplish, reddish, gray and black, fine- to coarse-grained and pebbly lithofeldspathic and volcanolithic subquartzose sandstone interbedded with black argillite. Sandstone commonly is mixed type containing clasts of mostly plagioclase, chert, volcanic rocks, and quartz, as well as sandstone, siltstone, phyllite, biotite, muscovite, and epidote. Alteration minerals include calcite, chlorite, sericite, limonite, epidote, and prehnite. Near Tertiary plutons, rocks are hornfelsic, commonly show conspicuous metamorphic biotite. Sedimentary features such as graded bedding and load casts are locally well preserved. Contains highly folded, sheared and recrystallized banded cherts. Unit includes metagabbro, both polymictic and quartz-pebble conglomerate, and shale-chip breccia. East of North Bend, sandstone and argillite are highly sheared, forming outcrops of lenticular sandstone clasts in crudely foliated argillite. This deformational style is typical of western melange belt in exposures north of quadrangle (Tabor and others, 1982b, 1988, 1993; Frizzell and others, 1987). Jett and Heller (1988) described sandstone composition

TKwv **Metavolcanic rocks**--Greenstone, greenstone breccia, and metadiabase with boudinaged metaquartz porphyry dikes

TKwg **Metagabbro**--Massive to foliated, fine- to medium-grained metagabbro. Many outcrops sheared at all scales. In massive rocks, euhedral, mottled, locally crushed plagioclase, intergranular to euhedral uralitized clinopyroxene, and opaque minerals common. Metamorphic minerals include uralite, chlorite, sphene, and calcite. Unit includes rare hornblende metatonalite and well-recrystallized amphibolite

TKwu **Ultramafic rocks**--Serpentinized pyroxenite. Predominantly coarse-grained anhedral and fine-grained subhedral to euhedral clinopyroxene in sea of serpentine minerals with mesh structure

Rocks of the eastern melange belt (middle Eocene and (or) Late Cretaceous)—Divided into:

TKev **Chert, mafic metavolcanic rock, amphibolite, and marble**—Highly deformed chert and medium- to fine-grained banded purplish biotite quartzite (metachert) intimately mixed with tectonized greenstone, greenstone breccia, and marble. Includes hornblende schist and muscovite, biotite quartz schist and dikes of metadiorite and metagabbro. Original sedimentary and volcanic textures largely obscured by penetrative deformation and static thermal metamorphism. Adjacent to Snoqualmie batholith, rocks are greenish pyroxene hornfels. In part described by Chitwood (1976, p. 10-14)

TKem **Marble**—Lenticular beds and pods of banded, white to grayish, medium- to fine-grained crystalline marble that is locally intercalated with metachert, metagabbro, and greenstone. Includes minor fine-grained pale-green silica carbonate replacement masses (Danner, 1966; Mogk, 1978)

pTqm **Quartz Mountain stock (pre-Tertiary)—**Medium-grained hornblende metatonalite and metagranodiorite, locally with biotite and garnet. Hypidiomorphic granular, but with local bent plagioclase and statically recrystallized plagioclase, crystalloblastic growth of sodic plagioclase rims on K-felsdpar and plagioclase, replacement of feldspar cores by clinozoisite, and recrystallization of biotite. Stock and many its many apotheses intruded Lookout Mountain Formation of Stout (1964) with sharp contacts

Lookout Mountain Formation of Stout (1964) (pre-Tertiary)—Divided into:

pTlm **Mica schist**—Black, very fine grained graphitic garnet biotite schist, locally with staurolite, andalusite, and rare cordierite. Relict bedding, graded bedding, and relict clastic grains are common. Includes mafic hornblende metatonalite and gabbro, not mapped separately

pTla **Amphibolite and hornblende tonalite gneiss**--Mostly very fine grained schistose epidote amphibolite with green to blue-green hornblende, locally with biotite. Plagioclase is commonly replaced by microcrystalline pumpellyite(?). Includes some mica schist (see Stout, 1964, p. 319). Also includes small masses of metadiorite and metagabbro. With increasing heterogeneity and increased shearing grades into unit **TKtc**. Goetsch (1978, p. 16-17) describes small bodies of cataclastic hornblende tonalite gneiss

pTlg **Gabbro and metagabbro**--Cataclastically foliated to medium-grained massive gabbro and metagabbro, metatonalite, and metaquartz-diorite. A small mass on south side of Lookout Mountain [24] is mostly hornblendite with relict pyroxene (Goetsch, 1978, p. 28-29)

ROCKS IN DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

TKt **Tectonic complex of Stout (1964) (Tertiary and (or) Cretaceous)—**Cataclastic to blastomylonitic blocks and slivers of predominantly fine-grained schistose amphibolite, as well as phyllite, greenstone and pillowed greenstone, blueschist, tonalite gneiss, leucogreenschist (metatuff), metasandstone, and ultramafic rocks. Stout (1964, p. 323), in addition, reports tectonic breccia, biotite gneiss, slate, and argillite in unit. Locally divided into:

TKtu **Ultramafic rocks**--Mostly serpentinite and serpentinized peridotite. Strongly foliated. Depicted by × where too small to show at map scale

ROCKS NORTHEAST OF DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

Kt **Tonalite (Late Cretaceous)—**Medium-grained hornblende-biotite tonalite exhibiting hypidiomorphic texture exposed in small stock near Fortune Creek

Knp **Metavolcanic rocks of North Peak (Late Cretaceous)—**Greenstone, green to red metamafic to silicic tuff, breccia, metacalcareous tuff, and impure marble. Ashleman (1979, p. 21) reports meta-andesite and rhyodacite. Although volcanic and clastic textures are well preserved, rocks are slightly schistose and contain metamorphic minerals including chlorite, quartz, albite (?), carbonate, pumpellyite, and lawsonite

Easton Metamorphic Suite (Early Cretaceous)—Divided into:

Kes **Shuksan Greenschist**--Very fine grained albite-epidote-chlorite schist with varying amounts of quartz, actinolite, crossite and (or) late glaucophane, pumpellyite, and muscovite. Schist also contains minor sphene, opaques, and calcite. Ashleman (1979, p. 12) reported lawsonite in actinolite schist and described intercalations of ironstone and ferruginous quartzite in greenschist. Locally with layers of phyllite. Most rocks are highly foliated and thoroughly recrystallized with fair mineral segregation, but many rocks south of Little Kachess Lake are texturally undifferentiated and retain relict textures suggesting derivation from porphyritic volcanic rocks, tuffs, and rare mafic intrusive rocks. North of Hicks Butte[23], greenschist retains pillow structures, and in Kachess Lake area, Ashleman (1979, p. 13) also reported possible pillow structures

Ked **Darrington Phyllite**--Mostly black to grey graphitic chlorite-sericite-quartz phyllite with minor albite (?), and opaque minerals. Ashleman (1979, p. 7) reported minor spessartine and stilpnomelane. Phyllite is commonly highly crinkled and contains quartz segregation lenses and veins that are commonly ptygmatically folded. Phyllite predominates and is locally interbedded with greenschist and blueschist

Ktz **Tectonic zone (Early Cretaceous)—**Mostly fine-grained epidote hornblende schist and hornblende pumpellyite(?) schist. Zoisite clearly replaces plagioclase. Rocks are blastomylonitic and porphyroblastic with lenses of coarser mylonitic hornblende gneiss derived from tonalite gneiss (unit **Khb**). Some epidote quartz schist and actinolitic greenschist. Grades into greenschist of (**Kes**). For more complete description see Treat (1987, p. 40-53)

Khb **Tonalite gneiss of Hicks Butte (Early Cretaceous)—**Lineated, medium-grained hornblende tonalite and tonalite gneiss, locally porphyroclastic and mylonitic. In least-deformed rock, green hornblende and labradorite are subhedral with integranular quartz, opaque minerals, and minor biotite. Patchy alteration of plagioclase and hornblende to epidote and late microcrystalline pumpellyite

Kbg **Banded gneiss (Early Cretaceous)—**Very fine grained pyroxene granofelsic gneiss. Locally with replacement veins of poikiloblastic clinozoisite and plagioclase replaced by pumpellyite(?)

Ingalls Tectonic Complex (Early Cretaceous or Late Jurassic)—Divided into:

KJis **Foliated and massive serpentinite and serpentinized metaperidotite**--Southern exposures (with pattern) mostly gray and gray-green to dark-green, commonly foliated and slickensided rubbly serpentinite -- part of Cowan and Miller's (1981; see also Miller, 1985) Navaho Divide Fault Zone. Less serpentinized rock there is harzburgite and dunite. Northern exposures (shown without pattern) partly serpentinized lherzolite and harzburgite, originally described by Frost (1973, p. 8-12) north of Snoqualmie Pass quadrangle where it was named South Peak unit by Miller (1980b, p. 52-69). Includes some mylonitic hornblende peridotite. Detailed descriptions in Miller and Mogk (1987)

KJim **Metabasalt, tuff, and breccia**--Mostly coarse monolithologic pillow breccia; green with red to purple oxidized zones (Miller, 1980b, p. 148-149). Clasts are porphyritic and amygdaloidal; originally plagioclase and augite phyric, intergranular to diabasic. Altered to chlorite, sphene, epidote, opaque minerals and fine-grained unidentified material. Includes minor siliceous argillite and chert

KJid **Diabase and gabbro**--Mostly heterogeneous uralitized pyroxene diabase and gabbro in complex of dikes and irregular intrusive bodies (Miller, 1980b, p. 99-107)

KJia **Amphibolite**--Medium-grained, locally diopside-bearing, layered, polymetamorphic amphibolite, locally with impure metachert and hornblende-biotite schist (Miller, 1980b, p. 221-222)