DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

m **Man-modified land (Holocene)**—Gravel or diamicton as fill, or extensively graded areas

Landslide deposits (Holocene and Pleistocene)—Divided into:

Ql **Landslide**—Diamicton of angular clasts of bedrock and surficial deposits derived from upslope. Many shown with no letter symbol; arrows denote downslope direction of movement. Includes areas of irregular, hummocky topography; apparently underlain by locally derived rock fragments (shown by map unit symbol Ql?)

Qib **Incipient blockslide**—Large unrotated mass of bedrock extensively crevassed by slight movement toward free faces. Shown with broken arrow in downslope direction

Qra **Rock-avalanche deposits**—Huge angular boulders on or at base of steep slope

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

Qt **Talus deposits (Holocene and Pleistocene)**—Angular-gravel diamicton. At lower altitudes, gradational with unit Qa. At higher altitudes, includes deposits of some Holocene moraines, rock glaciers, and protalus ramparts, small rock avalanches. Generally not vegetated

Qa **Alluvium (Holocene and Pleistocene)**—Moderately sorted pebble-to-cobble gravel along rivers to poorly sorted gravelly sand on small-tributary fans; some fan material similar to that included in unit Qt

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

DEPOSITS RELATED TO ALPINE GLACIERS

Qgp **Glacial and protalus deposits (Holocene and Pleistocene)**—Material similar to unit Qt but having distinct morainal form that indicates deposition at terminus of small glacier or permanent snowfield

Qag **Alpine-glacier deposits (Pleistocene)**—Ranges from till upvalley and in uplands to gravelly outwash on broad valley floors; includes areas mostly veneered with drift but having small areas of protruding bedrock or overlying small fans, colluvium, or other discontinuous deposits. Grades into unit Qgp in headward reaches of alpine valleys

DEPOSITS RELATED TO CORDILLERAN ICE SHEET

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. Largely plane-bedded outwash and foreset deltaic deposits in lowlands, but includes fine-grained deposits of ice-dammed lakes in major west-draining alpine valleys and at low altitudes along Snoqualmie and Skykomish River valleys. Includes parts of ice-marginal embankments, kame terraces, and glaciolacustrine deltaic deposits

Qgvl **Glaciolacustrine deposits**—Bedded silt and clay containing sand lenses and sparse dropstones; present in mountain valleys. Distinguished on map from other Vashon-age deposits (mainly unit Qvr) only where continuous and thick

Qgt **Till**—Mainly compact diamicton with subangular to rounded clasts, glacially transported and deposited. Includes minor stratified fluvial sand and gravel. Contact with unit Qvr is gradational and is approximately located in ice-marginal areas or where covered by thin layer of recessional outwash

Qva **Advance outwash deposits**—Well-bedded gravelly sand to fine-grained sand, generally unoxidized, deposited in proglacial streams

OTHER DEPOSITS

Qpf **Glacial and nonglacial deposits of pre-Fraser glaciation age (Pleistocene)**—Compact gray clay and deeply weathered stratified sand and gravel or clay-rich diamicton. Clay is in contact with or grades into fine sand assigned to unit Qva. Other deposits mapped herein as pre-Fraser deposits show evidence of strong in-situ weathering throughout depth of exposure, including oxidation of matrix and deeply weathered clasts. May include some early Fraser-age lacustrine sediments

Qbf **Basalt flows and cones (Pleistocene)**—Olivine basalt either as massive, poorly vesicular rocks or as massive to stratified scoriaceous bombs and lapilli. Rocks are solidified lava flows, generally on valley floors and having low-relief, near-level surfaces. Weakly agglutinated scoria forms partly degraded cones on sides and floors of valleys excavated in bedrock

TERTIARY BEDROCK

Volcanic rocks of Cady Ridge (Pliocene and Miocene)—Divided into:

Tcd **Dacite dikes**—Numerous dacite dikes from 1 to 5 m thick intruding altered gneiss. Dikes are composed mostly of gray porphyritic biotite-hornblende-hypersthene dacite and locally, resorbed quartz phenocrysts. Considerable pyrite in dikes and in country rock

Tcp **Dacite plugs**—Small plugs composed of hornblende-hypersthene dacite similar to that forming dacite dikes. Well-developed columnar jointing common

Tcb **Breccia and flows**—Porphyritic hornblende-hypersthene andesite and (or) dacite in flows and breccias. Rocks commonly highly altered to smectite

Tivb **Intrusive volcanic breccia (Miocene)**—Unit as mapped includes Conglomerate Point Breccia of Yeats (1958b), which consists of rhyolitic to basaltic breccia containing clasts of granitoid rocks near its margins. Clasts of angular to subangular, greenish-gray altered pyroxene andesite porphyry, altered basalt porphyry, and flow-banded rhyolite are set in dacite tuff matrix containing angular quartz fragments and plagioclase. Matrix and clasts considerably altered to chlorite, calcite, and epidote. Breccia in Silver Creek valley contains rounded clasts of heterogeneous volcanic rocks and rare clasts of sulfide ore in fine-grained to aphanitic matrix. Locally, breccia is monolithologic, composed of tonalite clasts and matrix and grades into shattered tonalite wallrock

Tts **Tonalite of Silver Creek (Miocene)**—Biotite-hornblende and hornblende-biotite tonalite forming small stocks, plugs, and dikes. Texture is hypidiomorphic to porphyritic granular. Mafic minerals are considerably altered to chlorite and epidote. Small bodies in Silver Creek valley not shown on map

Tib **Intrusive breccia (Miocene)**—Sericitized and silicified fragments of hornfels in matrix of calcite and sulfides (Ream, 1972, p. 10). Breccia has poorly defined subhorizontal bedding and grades abruptly into country-rock hornfels

Tte **Eagle Tuff of Yeats (1977) (Miocene)**—Brown to gray-brown rhyolitic to dacitic tuff, ash-flow tuff, and breccia. Conspicuous quartz phenocrysts are set in clastic matrix of plagioclase and silicic volcanic rock; some glassy shards. Abundant fragments of pre-Tertiary country rock present in unit. Poor sorting. Bedding inconspicuously shown by flattened pumice clasts and local thin layers of tuff

Tbk **Breccia of Kyes Peak (Miocene)**—Mostly andesite and dacite breccia beds with abundant clasts of schist, gneiss, and granitoid rocks. Rare two-pyroxene andesite, dacite, and rhyolite flows. Monolithologic breccias consist predominantly of fine-grained mica schist or granodiorite clasts. Clasts as long as 200 m. Breccia beds range from a few centimeters to more than 50 m in thickness. Thin volcanic to volcanic-lithic-subquartzose-sandstone beds locally near base. Heath (1971, p. 124-125) described probable primary garnets in rhyodacite and dacite flows. Alteration minerals are chlorite, sericite, and epidote. Some rocks, especially those east of Glacier Creek, are thermally metamorphosed and enriched in magnetite, actinolite, and albite(?)

Rocks of the Snoqualmie batholith—Divided into:

Tst **Tonalite and granodiorite (Miocene and Oligocene)**—Biotite-hornblende tonalite and granodiorite, medium-grained, mostly equigranular, with hypidiomorphic texture; locally contains clinopyroxene. Mostly light-colored (CI 9-24), coarsely jointed rock. Description adapted from Erikson (1969, p. 2218-2219)

Tsg **Granodiorite and granite (Miocene and Oligocene)**—Medium-grained, hypidiomorphic-granular to porphyritic granophyric granodiorite and granite (Erikson 1969, p. 2221). Most contain biotite; CI 1-5, rarely to 10

Tsh **Granite of Mount Hinman (Miocene and Oligocene)**—Hornblende-biotite and two-pyroxene granite; CI 6-15. Generally medium grained, hypidiomorphic granular, but commonly has mesostasic quartz or micrographic texture between larger grains. Rocks commonly altered, containing chlorite and epidote. Description modified from Erikson (1969, p. 2222)

Tsb **Breccia (Miocene and Oligocene)**—Fine- to medium-grained mafic biotite and hornblende-biotite tonalite containing numerous mafic inclusions.

Tsm **Mafic diorite and gabbro (Miocene and Oligocene)**—Biotite-hornblende diorite and gabbro; includes some mafic pyroxene-bearing tonalite and quartz diorite. CI 20-40 (Erikson, 1969, p. 2217)

Rocks of the Grotto batholith—Divided into:

Tgg **Biotite-hornblende granodiorite and granite (Miocene and Oligocene)**—Medium-grained hypidiomorphic-granular granodiorite and granite with subhedral to euhedral, oscillatorily zoned plagioclase in matrix of optically continuous quartz or anhedral quartz and perthite; some granopyhric textures. CI 10-20. Relic pyroxene in uralitic pale-green hornblende. Many rocks extensively altered to chlorite, epidote, and sphene; some crosscutting fractures filled with alteration minerals. Fine-grained mafic inclusions common. Includes some areas underlain by rocks similar to the granite of San Juan Creek. North end of pluton and smaller stocks in Monte Cristo area are more mafic and mostly granodiorite and tonalite

Tgs **Granite of San Juan Creek (Miocene and Oligocene)**—Mostly biotite granite to granophyric porphyry, CI about 5; graphic intergrowths of potassium feldspar and quartz are common

Tggb **Gabbro, quartz gabbro, and pyroxene porphyry (Miocene and Oligocene)**—Fine-grained to porphyritic pyroxene-hornblende gabbro, quartz gabbro, and porphyry. Normally zoned labradorite-oligoclase crystals with euhedral oscillations set in sparse matrix of granophyric potassium feldspar and quartz or uralitic hornblende. For detailed descriptions and modes see Yeats (1958a, p. 190-192)

Tgb **Contact breccia (Miocene and Oligocene)**—Heterogeneous, fine- and medium-grained, locally porphyritic tonalite contact breccia containing numerous dark inclusions of hornfels; includes metavolcanic rocks and metachert. Tonalite has clinopyroxene and micrographic intergrowths of quartz and sodic plagioclase. Similar rocks on Crosby

Mountain [10] lack inclusions and form anastomosing dikelets (unmapped) in country rocks

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

Tdd **Dacite, andesite, and rhyolite**—Clinopyroxene and hypersthene-clinopyroxene dacite, andesite, and rhyolite in flows, breccia, tuff, dikes, and sills. Rocks commonly highly altered to smectites and (or) calcite on the south and epidote, chlorite, and locally prehnite on the north. Bedding obscure; welded tuff locally shows flattening, and tuff is locally interbedded with volcanic sandstone and siltstone. For further descriptions, see McDougall (1980, p. 54-55) and Simonson (1981)

Tdia **Intrusive andesite**—Porphyritic pyroxene andesite containing large plagioclase phenocrysts and glomerocrysts in felty to intersertal matrix. Augite is common, and hypersthene (or psuedomorphs of smectites after hypersthene) is rare

Tdb **Sandstone breccia**—Monolithologic breccia composed of angular sandstone clasts as much as 10 m across, derived from the Swauk Formation (Gualtieri and others, 1973). Rare volcanic clasts. East of Spade Lake, breccia is locally highly sheared and altered. Simonson (1981, p. 40-41) and Ellis (1959, p. 66-67) describe basal sandstone breccia with lapilli tuff matrix

Tv **Volcanic rocks (Oligocene)**—On Garfield Mountain. Mostly dacite and minor andesite and rhyolite in breccia, tuffs, ash-flow tuffs, and rare flows. Most are highly recrystallized by thermal metamorphism; many are hornblende-biotite hornfels

Tm **Metaporphyry of Troublesome Mountain (Oligocene)**—Dark, recrystallized clinopyroxene-plagioclase porphyry; abundant poikiloblastic phenocrysts set in a crystalloblastic matrix of plagioclase, quartz, biotite, hornblende, and opaque minerals. Pyroxene partially or completely replaced by green hornblende. Plagioclase has relict euhedral oscillatory zoning

Rocks of the Index batholith—Divided into:

Tig **Granodiorite and tonalite (Oligocene)**—Mostly biotite-hornblende and hornblende-biotite granodiorite and tonalite but locally ranges from quartz diorite and quartz monzonite to rare granite; CI 2-30. Medium-grained hypidiomorphic-granular texture; granofelsic, mostly anhedral quartz is interstitial to subhedral and euhedrally oscillatorily zoned from labradorite or andesine to oligoclase (see Yeats, 1958a, p. 202-203; Griffis, 1977, p. 85). Pyroxene is rare and mostly present as tiny rounded inclusions in plagioclase. On North Fork of Tolt River, unit includes granodiorite with clinopyroxene, uralitic hornblende, and some micrographic texture. Stock on Youngs Creek has uralitic hornblende and relict clinopyroxene

Tigg **Granodiorite of the Goblin Creek stock (Oligocene)**—Mostly dark-colored, medium-grained pyroxene-biotite-hornblende granodiorite and granite; CI 13-35. Pyroxene mostly uralitized; quartz commonly forms optically continuous mesostasis between plagioclase crystals. Some granophyric texture. Cut by chloritic shears; highly altered to chlorite, epidote, calcite, and prehnite

Tigs **Granodiorite and granite of the Sunday Creek stock (Oligocene)**—Granodiorite and granite similar to unit Tig but highly altered to sericite, epidote, and chlorite. Bethel (1951, p. 147) reported some micrographic and local granoblastic textures. Locally cataclastic. Contact breccias along margin are rich in clasts of unit Tpa

Tus **Unnamed sandstone (Oligocene)**—Sandy pebble conglomerate to very fine grained sandstone, moderately to deeply weathered. Coarser beds contain high percentage of quartzose pebbles; finer beds contain considerable mica and lignite. Deeply weathered exposures usually distinquished from old glacial outwash materials by manganese staining on joint planes, quartzose or pebble lithology, and presence of organic matter

Naches Formation (Oligocene? and late Eocene)—Divided into:

Tnv **Volcanic rocks and minor sandstone**—Well-bedded basaltic to andesitic flows, tuff, and breccia interbedded with feldspathic subquartzose sandstone and siltstone. Flows and breccia are somewhat nondescript porphyritic to aphyric, dark-green to black rocks, weathering to brown. In part amygdaloidal, with columns or with brecciated and vesicular tops. Interbedded sedimentary rocks are white, coarse-grained feldspathic sandstone, exhibiting crossbeds and graded bedding and black argillite and laminated siltstone. Both volcanic and sedimentary rocks are thermally metamorphosed

Tnr **Rhyolite**—White to gray, flow-banded rhyolite containing flattened pumice fragments; well recrystallized by thermal metamorphism

Volcanic rocks of Mount Persis (late Eocene)—Divided into:

Tpa **Andesite flows, tuffs, and breccia, containing minor dacite and basalt, and minor volcaniclastic sandstone, conglomerate, and siltstone**—Massive, dark-green to black, plagioclase-porphyritic two-pyroxene andesite and andesitic breccia and tuff. Phenocrysts and glomerocrysts of plagioclase, clinopyroxene, hypersthene, mostly greatly altered in an intersertal to holocrystalline groundmass of mainly clinopyroxene, plagioclase, and opaque minerals. Black basalt is aphyric to microporphyritic, commonly trachytoid, and locally with altered olivine. Upper part of unit includes rare interbedded, dark-gray to brownish volcanic sandstone and siltstone. Danner (1957, p. 471-472) reports andesite conglomerate interbeds in Youngs Creek. Generally poorly indurated volcanic sandstone contains angular to rounded clasts of volcanic rocks, altered glass, and plagioclase crystals; also contains clasts of chert, sandstone, and siltstone. Variably altered to smectites, epidote, and calcite. Locally hornfelsic near Tertiary plutons, most extensively south of Youngs Creek stock. Near Calligan Lake, unit includes andesite and dacite porphyry dike swarm

Tphb **Hornblende dacite breccia**—Light-green hornblende dacite breccia composed mainly of andesitic clasts, euhedral plagioclase (in part altered to epidote), tan to olive-green hornblende, clinopyroxene altered to smectites, resorbed quartz, and opaque mineral grains in altered partially devitrified glassy matrix

Tpp **Pyroxene andesite**—Pyroxene andesite porphyry containing phenocrysts of plagioclase, clinopyroxene, and rare brown hornblende (mostly altered to chlorite) and mixed clots of plagioclase and clinopyroxene in highly altered, groundmass of microlites of plagioclase and opaque minerals

Barlow Pass Volcanics of Vance (1957b) (late and middle Eocene)—In this area divided into:

Tbv **Volcanic rocks**—Basalt, rhyolite, and andesite flows, breccia, and tuff interbedded with minor bedded tuffaceous to feldspathic sandstone and argillite. Andesite and basalt generally dark-green to gray, massive, and dense. Light-green to white rhyolite. Rocks are mostly highly altered to a dense mat of chlorite, epidote, calcite, and sericite; porphyritic and trachytoid textures are relict. Most bedding in volcanic members is obscure. Many rocks recrystallized by thermal metamorphism near Tertiary plutons, reaching pyroxene-hornfels facies adjacent to unfaulted contacts with plutons. Further descriptions in Heath (1971, p. 116-118) and, for the Barlow Pass unit north of mapped area, in Vance (1957a, p. 275-286).

South of Skykomish, rocks that we mapped as Barlow Pass(?) Volcanics are mostly heterogeneous, light-tan to dark-gray-green, rhyolitic to andesitic breccia and feldspar porphyry. Rocks identified as andesite in the field generally contain at least trace amounts of quartz in thin section. Crystal-rich andesite and dacite breccia contains andesite, dacite, and rhyolite clasts, sandstone, metasedimentary rocks, chert, siltstone, quartz, foliated polycrystalline quartz, potassium feldspar, and plagioclase. Crystal-rich greenish rhyodacite breccia has platy cleavage. Amygdaloidal andesite(?) and andesite(?) porphyry, in part having crude columns, are also present. Plagioclase is commonly altered to calcite and chlorite. Pyrite is locally present. Further details given by Yeats (1958a, p. 152-161). Includes probable intrusive rhyolite porphyry on Money Creek. Many volcanic rocks in the Barlow Pass(?) Volcanics are partly to strongly recrystallized by nearby Tertiary plutons

Tbs **Sandstone**—Fluviatile, light-colored, fine- to medium-grained feldspathic subquartzose sandstone and conglomerate with interbeds of siltstone and shale. Bedding is thick to very thick but obscure near Tertiary plutons except where revealed by pebble trains and changes in grain size. Along Silver and lower Trout Creeks, framework grains are composed of subequal amounts of quartz, plagioclase, and chert. Near Crosby Mountain, our unit Tbs(?) includes plane bedded to crossbedded quartz-rich sandstone and quartz-pebble to cobble conglomerate

Puget Group (Eocene)—In this area, consists of:

Tt **Tukwila Formation (late and middle Eocene**)—Andesitic flows, breccia, conglomerate, and sandstone with subordinate intercalated feldspathic sandstone and impure coal beds. Tuff and breccia contain clasts of porphyritic andesite and dacite and polymictic volcanic conglomerate predominate, but flow rocks (in part sills or dikes?) form resistant layers. As mapped, includes some sandstone belonging to Tiger Mountain Formation

Ttm **Tiger Mountain Formation (middle and early Eocene)**—Light-colored, medium-grained, micaceous feldspathic subquartzose sandstone interbedded with siltstone, minor pebble conglomerate, and coal beds

Trr **Raging River Formation (middle Eocene)**—Marine sandstone, siltstone, shale, and minor conglomerate. Sandstone pre-dominantly volcanic subquartzose. Described in detail by Vine (1969, p. 13-16)

Tfm **Fuller Mountain plug (early Eocene)**—Gray, highly jointed, hornblende-biotite-clinopyroxene granodiorite. Clinopyroxene rimmed with hornblende; intergranular quartz and potassium feldspar graphically intergrown(?)

Swauk Formation (early Eocene)—Divided into:

Tss **Sandstone and conglomerate**—Predominantly feldspathic subquartzose sandstone and conglomerate, fluviatile, light-colored, medium-grained, and minor interbeds of siltstone and shale. Bedding thin to very thick. Compositions reported by McDougall (1980, p. 39-45) for Swauk on southern Tonga Ridge

Tssp **Silver Pass Volcanic Member**—As mapped on Summit Chief and in upper Waptus River area [28] includes mostly sandstone with interbeds of dacitic breccia and thin-bedded silicic tuff and ash-flow tuff

Tssc **Sandstone and conglomerate**—Similar to unit Tss, but conglomerate is more conspicuous and rich in granitic clasts. Upper contact shown as mapped by McDougall (1980)

PRE-TERTIARY BEDROCK

ROCKS WEST OF THE STRAIGHT CREEK FAULT

gb **Gabbro (age uncertain)**—On Money Creek, hypersthene-clinopyroxene gabbro, medium-grained, subophitic to locally uralitic. Commonly layered containing well-aligned calcic plagioclase. On Palmer Mountain, medium-grained uralitic gabbro and quartz gabbro composed of tightly packed calcic plagioclase with uralite patches and uralite pseudomorphous after subophitic pyroxene(?). On Middle Fork of Snoqualmie River, heterogeneous, uralitized pyroxene gabbro to mafic biotite-hornblende tonalite; strongly thermally metamorphosed

bm **Bald Mountain pluton (age uncertain)**—Medium- to coarse-grained, hypidiomorphic biotite granodiorite and granite, in part gneissic near the margins. Accessory cordierite, mostly altered to pinite, and rare garnet. Locally cataclastic. Clinopyroxene rimmed with hornblende; integranular quartz and potassium feldspar graphically intergrown

Rocks of the western melange belt (early Tertiary to mid-Cretaceous)—Consist of:

TKwa **Argillite and graywacke**—Pervasively sheared, scaley matrix of mostly argillite containing steep-sided, outcrop- to mountain-sized phacoids of purplish, reddish, gray, and black, fine- to coarse-grained and pebbly, lithofeldspathic, volcanolithic, and subquartzose sandstone interbedded with black argillite. Sandstone has clasts mostly of plagioclase, chert, volcanic rocks, and quartz. Also abundant are grains of sandstone, siltstone, phyllite, biotite, muscovite, and epidote. Where more strongly deformed, unstable grains are broken down into anastomosing shear zones or smeared out into indistinct chloritic matrix. Alteration minerals are calcite, chlorite, sericite, limonite, epidote, and prehnite. Near Tertiary plutons the rocks have become hornfelsic, commonly with conspicuous biotite. Sedimentary features such as graded bedding and load casts are locally well preserved. Unit includes minor chert, polymictic and quartz-pebble conglomerate, and shale-chip breccia; also very minor chert, limestone, metavolcanic rocks, metagabbro, and metatonalite. Locally cut by greenstone (metadiabase) dikes

TKwk **Potassium-feldspar-bearing sandstone**—Lithologically similar to sandstone of unit TKwa but having 2-20 percent potassium-feldspar clasts and commonly more plagioclase, muscovite, and biotite

TKwv **Metavolcanic rocks**—Greenstone and metadiabase, with minor metagabbro, argillite, and sandstone. Greenstone and metadiabase contain relict plagioclase and clinopyroxene locally having intersertal to diabasic textures. Amygdaloidal texture and pillow structures locally preserved. Boudins of metamorphosed quartz-porphyry dikes(?) in faintly foliate greenstone breccia on Little Si. Outcrops north of Sultan River are cut by numerous faults, of various orientations, that outline streamlined blocks of metavolcanic, metaplutonic, and sedimentary rocks

TKwg **Metagabbro, minor gneissic amphibolite, and rare gabbro flaser gneiss**—Massive to foliated, fine- to medium-grained metagabbro. Many outcrops sheared on all scales. In massive rocks, euhedral, mottled, locally crushed plagioclase, intergranular to euhedral uralitized clinopyroxene, and opaque minerals are common. Mafic metagabbro on Woods Creek bears relicts of hypersthene and clinopyroxene. Sheared rocks range from flaser gabbro with plagioclase cataclasts in schistose, chloritic matrix to well-recrystallized greenstone, greenschist, or amphibolite, locally banded. Most metamorphic minerals are uralite, chlorite, epidote, sphene, carbonate, prehnite, and pumpellyite in metagabbro and metadiabase. Unit includes minor hornblende metatonalite, metaquartz diorite, and minor feldspathic hornblendite. Vance and others (1980) discuss trace-element chemistry of metagabbro of Woods Creek area

TKwd **Metadiabase**—Metadiabase composed of plagioclase, uralite, chlorite, epidote, and opaque minerals; secondary blebs or veinlets of quartz. Rare relict clinopyroxene. Relict intergranular to diabasic texture. Most rocks highly thermally metamorphosed and similar to those of unit TKed. North of Money Creek, unit includes many hornfelsic Tertiary dikes and some volcanic breccia containing clasts of metadiabase in hornfelsic tuffaceous matrix

TKwt **Metatonalite**—Fine- to coarse-grained porphyroclastic metatonalite, locally sheared into light-colored cataclastic chlorite gneiss. Predominantly composed of plagioclase and quartz (in part secondary) with actinolitic hornblende, epidote, and chlorite. Occurs mostly as small bodies generally associated with metagabbro

TKwc **Chert**—Maroon, reddish, and white chert and metachert, in part with shaley interbeds. Undeformed to contorted bedding. Occurs as streamlined pods with scaley margins

TKwm **Marble**—Black to bluish-gray marble and, in part, interbedded chert and shale occurring as steeply dipping pods and lenticular beds. Thin, green tuffaceous chert beds crop out in marble at Haystack quarry on Proctor Creek. Further description in Danner (1966, p. 343-358). Asterisk indicates pod too small to show at map scale

TKws **Slate, phyllite, and semischist**—Rocks similar in composition to those of unit TKwa, but with well-developed schistosity commonly parallel to bedding. New metamorphic minerals in semischist include sericite, chlorite, albite, calcite, sodic plagioclase, and opaque minerals; hornfels near contacts with Tertiary plutons. Contact with unit TKev is based on more abundant metavolcanic rocks, chert, and ultramafic rocks in unit TKev

TKwp **Phyllitic greenstone**—Mostly metabasalt and mafic tuff. Includes volcanic-clast-rich, foliated sandstone

TKwu **Ultramafic rocks**—Serpentinized peridotite; X indicates pod too small to show at map scale

Rocks of the eastern melange belt (early Tertiary to mid-Cretaceous)—Consist of:

TKev **Mafic metavolcanicrocks, chert, argillite, and gray-wacke**—Greenstone, greenschist (metabasalt and meta-andesite), metagraywacke, chert-rich metagrit, and metaconglomerate, mostly massive and rarely bedded. Original sedimentary and volcanic textures largely obscured by penetrative deformation, low-grade regional metamorphism, and static thermal metamorphism. Contact metamorphism by Tertiary plutons has destroyed original textures and structures as well as earlier formed greenschist-facies minerals; many rocks are now pyroxene hornfels. Detailed description of rocks in Skykomish River area in Yeats (1964, p. 555-558; see also 1958a, p. 106-115)

TKec **Chert and metachert**—Intensely folded, white to cream or gray, ribbon chert and medium- to fine-grained banded quartzite (metachert); alternating with thin to thick, dark-brown to black layers of calcareous argillite grading to phyllitic slate. Tectonically thinned and thickened into discontinuous stringers

TKeg **Migmatitic gneiss**—Fine-grained schistose amphibolite to medium- and coarse-grained massive quartz diorite with layered hornblende gneiss, gneissose quartz diorite, trondhjemite, and replacement breccia and minor serpentinized ultramafite. Amphibolite is crystalloblastic with xenoblastic unzoned and untwinned andesine, brown to brownish-green xenoblastic hornblende, and accessory sphene, apatite, magnetite, ilmenite, and zircon. Rocks grade through hornblende gneiss to gneissose quartz diorite; commonly mafic and less mafic rocks in irregular, intimately mixed layers. All exposures cut by anastomosing shear zones; rocks cataclastically deformed prior to late static recrystallization. Description modified from Yeats (1958a, p. 83-99; 1964, p. 552-555)

TKed **Metadiabase**—Altered and thermally metamorphosed, fine-grained ophitic to subophitic metadiabase and metagabbro. Euhedral plagioclase and mostly uralitized subhedral clinopyroxene, rare hypersthene (Plummer, 1964, p. 53). Newly grown reddish biotite and mesostasis of quartz present adjacent to Tertiary plutons. For further descriptions see Danner (1957, p. 513-517) and Plummer (1964, p. 52-54)

TKet **Metatonalite**—Altered medium-grained metatonalite. Subhedral plagioclase, mostly anhedral and intergranular mosaics of quartz and small amounts of altered green hornblende and perthitic potassium feldspar. Locally cataclastic

TKem **Marble**—Lenticular beds and pods of banded, white to grayish, medium- to fine-grained crystalline marble intercalated with metachert and greenstone; in part, shaly laminations or graphitic impurities mark bedding planes. Silicified replacement masses (Danner, 1966, p. 374; Yeats, 1958a, p. 103). Asterisk indicates pod too small to show at map scale

TKeu **Ultramafic rocks**—Highly altered pods of pyroxenite, peridotite, and serpentinized dunite are tectonically intercalated with argillite and ribbon chert near Merchant Peak [22]. See Yeats (1958a, p. 116-119) for further discussion of that area. Schistose ultramafite east of Weden Creek [12] consists of foresterite in mesh of antigorite. Olivine is locally converted to phlogopite near Tertiary plutons. In Sultan Basin area Dungan (1974, p. 40-41) describes peridotite hornfels on Red Mountain with assemblage of forsterite-talc-tremolite±chlorite within 2.5 km of contact with Index batholith. North of quadrangle, ultramafic rocks on strike with this layer are serpentinized cumulus peridotite with relict olivine and orthopyroxene associated locally with layered gabbro (Dungan, 1974, p. 48-62). X indicates pod too small to show at map scale

Easton terrane

Easton Metamorphic Suite (Early Cretaceous)—In this area, consists of:

Ked **Darrington Phyllite**—Black sericite-quartz phyllite with abundant quartz segregation veinlets and lenses. Abundant graphite and albitic plagioclase; accessory minerals include chlorite, iron oxide, apatite, tourmaline, and sphene. Mostly thermally metamorphosed to biotite phyllite and locally pyroxene hornfels close to Tertiary intrusive rocks. Description taken from Heath (1971, p. 81-87)

ROCKS EAST OF THE STRAIGHT CREEK FAULT

Rocks of the Mount Stuart batholith (Late Cretaceous)—Divided into:

Ksw **Tonalite and granodiorite of the western pluton**—Predominantly medium-grained, hypidiomorphic-granular hornblende-biotite tonalite and subordinate granodiorite. CI 4-15, based on normative mineral data from Erikson (1977b and written commun., 1978). Hornblende locally uralitic around clinopyroxene relicts; potassium feldspar crystallized late and replaces plagioclase with some myrmekite developed. Massive to gneissic near margins. See Erikson (1977b) for modal and chemical analyses. As mapped includes:

Kswh **Tonalite of Harding Mountain**—Fine- to medium-grained biotite-hornblende tonalite, commonly with crystalloblastic patches of actinolitic hornblende and biotite; CI 12-18. Hypidiomorphic-granular, rich in matrix quartz. Local cummulate layering of hornblende and plagioclase. Outcrops tend to be highly jointed and disintegrate into 10- to 20-cm blocks in extensive talus

Kse **Tonalite and granodiorite of the eastern pluton**—Predominantly medium-grained, hypidiomorphic-granular hornblende-biotite tonalite and subordinate granodiorite. Similar to unit Ksw, although parts of the eastern pluton are somewhat more mafic than western pluton. CI 3-30, based on normative minerals and modal analyses by Erikson (1977b and written commun., 1978)

Ksb **Granodiorite of the Beckler Peak stocks**—Biotite granodiorite, hypidiomorphic granular to xenomorphic with microcline microperthite. Mostly CI 5-9, but Yeats (1958a, p. 75) reports some rocks with as much as 18 percent mafic minerals. Stocks are commonly highly sheared and cataclastic. See Yeats (1958a, p. 74-77) for further description

Ksm **Metagabbro and metadiorite**—Medium-grained biotite-hornblende metagabbro and metadiorite; minor metatonalite characterized by uralitic hornblende and actinolitic hornblende mats between subhedral to euhedral, well-aligned plagioclase prisms. Some rocks exhibit mosaic of granoblastic plagioclase between clots of mafic minerals

Ksc **Tonalite gneiss of the Sloan Creek plutons (Late Cretaceous)**—Biotite-hornblende tonalite gneiss, flaser gneiss, and local gneissic tonalite; medium-grained, homogeneous, crystalloblastic gneissose to strongly flaseroid; locally strongly mylonitic. Plagioclase normally zoned, or unzoned and strongly stress-twinned but has relict patchy zoning and faint oscillatory zoning and synneusis twins (Heath, 1971, p. 62). Retrogressive alteration is pronounced but somewhat sporadic; epidote minerals and sericite commonly fill plagioclase cores; mafic minerals are altered to chlorite, sphene, and prehnite. See Heath (1971, p. 57-59) for modes and further description

Kt **Tonalite gneiss and tonalite of the Tenpeak Mountain pluton (Late Cretaceous**)—Hornblende-biotite and biotite-hornblende tonalite gneiss and tonalite, medium-grained, hypidiomorphic to crystalloblastic with interstitial quartz, broken and healed sodic andesine with relict euhedral oscillatory zoning and rare synneusis twins. Hornblende commonly euhedral. Euhedral epidote and clinozoisite locally have pseudomyrmekitic intergrowths of quartz. Common sphene, allenite; rare garnet. CI 20-40. Plagioclase porphyroclasts filled with euhedral epidote minerals and some muscovite

Tonga Formation of Yeats (1958b) (Late Cretaceous)—Divided into:

Ktp **Phyllite, semischist, schist, and biotite-hornblende gneiss and amphibolite**—South of Tye River, mostly graphitic chlorite-sericite-quartz phyllite and high-rank semischist. To the north, mostly fine-grained graphitic garnet-staurolite-biotite schist, fine-grained biotite-hornblende gneiss, and local metaconglomerate and metaporphyry (fine-grained two-mica gneiss). In many outcrops from Jack Pass [19] south, relict bedding and other sedimentary structures in metapelite and metasandstone are prominent despite well-developed penetrative foliation. Northward and northeastward from Jack Pass, schistose texture and recrystallization increase until recrystallization has produced fine-grained staurolite-garnet-mica schist, and sandstone is recrystallized to fine-grained hornblende-biotite schist and gneiss, locally with randomly oriented or sheaflike poikiloblastic amphibole blades (garbenschiefer); cummingtonite is locally intergrown with hornblende. Staurolite and garnet are usually porphyroblastic; biotite is porphyroblastic to strongly aligned. Many of the higher grade rocks show some degree of retrogression: garnet altered to chlorite, staurolite to sericite. Grade and coarseness of recrystallization increase markedly adjacent to gneissic granodiorite of the Beckler Peak stocks, but hornfelsic textures are not developed. Rocks are recrystallized to pyroxene hornfels near the Goblin Creek stock. For detailed descriptions see Yeats (1958a, p. 42-64)

Ktg **Greenschist and fine-grained amphibolite**—Fine-grained greenschist on Tonga Ridge, but outcrops north of Tye River are fine-grained actinolitic hornblende schist or biotite amphibolite

Ktu **Ultramafic rocks**—Serpentine and serpentinized peridotite associated with fault bounding the Tonga Formation on west

Kgt **Gneissic tonalite of Excelsior Mountain (Late Cretaceous)**—Light-colored biotite-tonalite gneiss and flaser gneiss, locally massive; contains minor hornblende, muscovite, and clinozoisite and rare garnet and opaque ores. Subhedral to euhedral plagioclase with faint patches of relict euhedral oscillatory zoning and patchy zoning set in mylonitic matrix of quartz, biotite, hornblende, and clinozoisite

Nason terrane

Chiwaukum Schist (Late Cretaceous)—Divided into:

Kcb **Biotite schist**—Graphitic garnet-biotite-quartz schist, mostly fine- to medium-grained, well-laminated, locally with cordierite, andalusite, staurolite, and (or) kyanite and rare sillimanite. Contains very minor schistose amphibolite. Commonly isoclinally folded on outcrop and microscopic scales, with contorted quartz segregations and veins. Locally has thick veins of quartz and local dikes and sills of foliated, light-colored tonalite. Grades into unit Kca

Kca **Biotite schist and amphibolite**—Mostly fine- to medium-grained, well-laminated mica schist similar to unit Kcb but with rare to abundant schistose amphibolite, fine-grained hornblende gneiss, and less common calc-silicate schist and marble. Cut by dikes and sills of light-colored biotite tonalite and pegmatite. Unit in Cadet Creek area [16] elaborately described by Heath (1971, p. 12-55). Grades into unit Kbg

Kcm **Marble**—Small, coarsely crystalline gray lenses in schist east of Mill Creek

Banded gneiss (Late Cretaceous)—Consists of:

Kbg **Gneiss, schist, and amphibolite**—Mostly interlayered heterogeneous light-colored tonalite to granodiorite gneiss, mica schist, and amphibolite similar to the Chiwaukum Schist. Kyanite or sillimanite and staurolite locally abundant; sericite pseudomorphs after aluminum silicates common. Predominantly crystalloblastic. Most common is medium-grained biotite gneiss with slightly porphyroblastic appearance due to anastomosing mica layers surrounding larger plagioclase crystals or aggregate grains. Contacts between gneiss and schist are both sharp and gradational along and across strike. Crosscutting sills, dikes, and irregular bodies of light-colored, fine-grained to pegmatitic tonalite and gneiss are also abundant. Locally migmatitic. Most of unit has 10 percent or more light-colored gneiss. Good descriptions in Rosenburg (1961, p. 38-54), Van Diver (1964a, p. 51-67), and Crowder and others (1966)

Kbgg **Gneissic biotite granodiorite**—Nonbanded homogeneous, light-colored, medium-grained gneissic biotite granodiorite with accessory sphene, allanite, zircon, and locally garnet. Relict euhedral oscillatory zoning in cores of subidioblastic plagioclase. Potassium feldspar and quartz are interstitial. Textures mostly granoblastic, but locally blastomylonitic. Contacts with schist layers in unit Kbg are parallel, interlayered, or locally crosscutting

Kbgp **Gneissic pyroxene-biotite tonalite**—Medium- to coarse-grained gneissic tonalite with conspicuous subhedral biotite books as wide as 8 mm. CI 6-15 (Ford and others, 1988, p. 118) Quartz and potassium feldspar intergranular to crystalloblastic; plagioclase with relict euhedral oscillitory zoning, subhedral clinopyroxene, and minor hornblende. Small amounts of zircon and allanite. Interlayers of biotite schist at margins

Kum **Ultramafic rocks (Late Cretaceous)**—Serpentinized orthopyroxenite (metaperidotite) and serpentinite. Coarse-grained enstatite with skeletal relicts of olivine in lens on ridge north of North Fork of Skykomish River; enstatite replaced by serpentine minerals, talc, and tremolite, especially in foliate zones. Small pods are mostly serpentinized pyroxenite(?) or talc-tremolite rocks

Easton terrane

Easton Metamorphic Suite (Early Cretaceous)—Divided into:

Ked **Darrington Phyllite**—Black, graphitic sericite-quartz phyllite with quartz exudation lamellae. Strongly mylonitic with new quartz and quartzofeldspathic layers and boudins; thermally metamorphosed with new red-brown biotite. Ellis (1959, p. 8-12) describes two generations of foliation

Kes **Shuksan Greenschist**—Greenschist, actinolite schist, and rare blue-amphibole schist. Strongly schistose and locally well layered. Actinolitic hornblende locally replaces crossite and glaucophane. Glaucophane rims crossite. Pumpellyite, probable sodic pyroxene, and stilpnomelane are common constituents of some rocks. Descriptions adapted from Yeats (1958a, p. 64-70). Highly recrystallized breccia of metagreenstone tuff, greenschist, and phyllitic clasts crops out in Lower Eagle Creek gorge [25]

Ingalls terrane

Ingalls Tectonic Complex (Early Cretaceous or Late Jurassic)—In this area, divided into:

KJis **Serpentinite and serpentinized metaperidotite**—Metamorphic rocks composed of olivine (forsterite), tremolite or talc, and carbonate minerals and serpentine. Frost (1973, p. 8-12) reports that the original ultramafic rocks in Paddy Go Easy Pass [34] area were lherzolite with olivine, enstatite, diopside, and chromite. Local relict primary layering. Serpentinite, formed prior to intrusion of Mount Stuart batholith, is mostly antigorite with veins of lizardite (Frost, 1973, p. 26). Contact with unit KJim is mapped where subdued topography and gray to bluish-gray serpentinite slopes change to blocky orange outcrops of metaperidotite. In Paddy Go Easy Pass area, contacts are from Frost's (1973, pl. 1 and p. 28-29) serpentine-out isograd. Common foliation in serpentinite not shown on map

KJim **Metaperidotite**—Olivine (forsterite)-talc-tremolite rock with minor late serpentine minerals. Forsterite and enstatite also occur with or without anthophyllite close to Mount Stuart batholith (Frost, 1973, p. 29-34). See Frost (1973) for details of petrology and mineralogy

KJih **Hornfels**—Foliate and nonfoliate metamorphic rocks ranging from hornfels with relict protolith structure to gneissic amphibolite. Includes hornfelsic pillow basalt, gabbro, diorite, quartz diorite, amphibolite, mafic schist, volcaniclastic rocks, argillite, chert, and rodingite. See Frost (1973, p. 16-22, 43-45) for more details