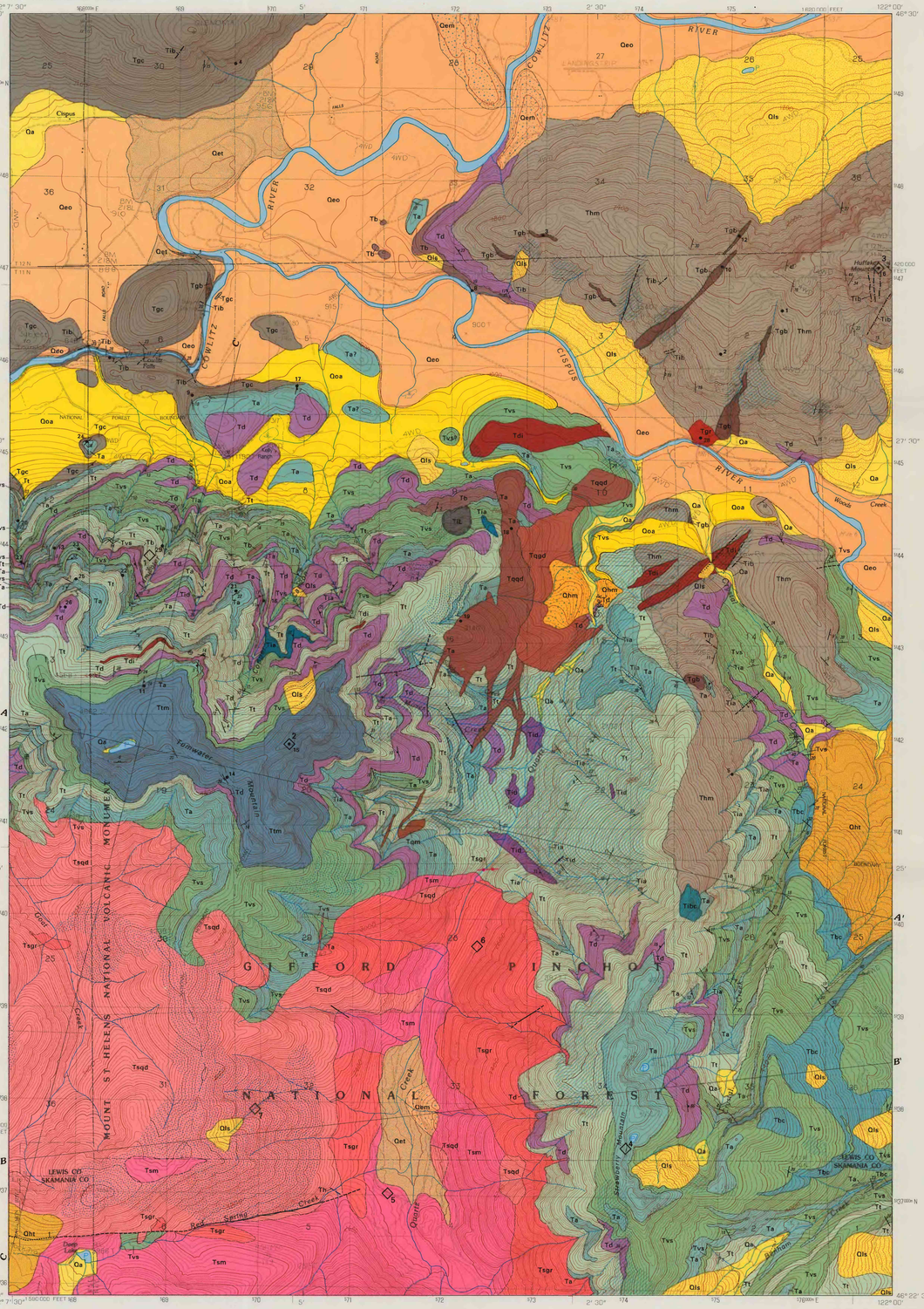
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
WASHINGTON DEPARTMENT OF NATURAL RESOURCES
GEOLOGY AND EARTH RESOURCES DIVISION

GEOLOGIC QUADRANGLE MAP
COWLITZ FALLS QUADRANGLE, WASHINGTON
GQ–1682

Explanatory pamphlet accompanies map



Base from U.S. Geological Survey, Provisional Edition, 1983
10,000-foot grid based on Washington coordinate system, South zone
1000-meter Universal Transverse Mercator grid zone 10
Lambert Conformal Conic projection

APPROXIMATE MEAN DECLINATION, 1993

SCALE 1:24 000
1 ½ 0 1 MILE
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

WASHINGTON
QUADRANGLE LOCATION

Geology mapped by R.C. Evarts, 1978–1987, R.P. Ashley, 1977–1979 and 1984–1987, and N.G. Banks, 1977; assisted by W. Avramenko, K.R. Bishop, M. Covey, M. Evarts, J. Infeld, M. Lukk, S. Petersen, C. Peterson, and J. Schmidt
Edited by Carol Ostergren; cartographic design by Kevin Ghequiere
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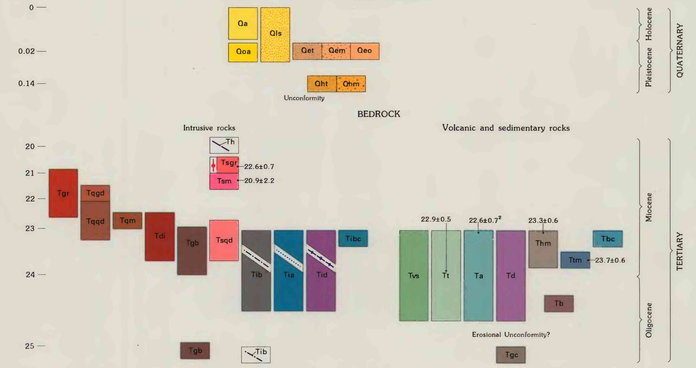
GEOLOGIC MAP OF THE COWLITZ FALLS QUADRANGLE, LEWIS AND SKAMANIA COUNTIES, WASHINGTON

By
Russell C. Evarts and Roger P. Ashley
1993

CORRELATION OF MAP UNITS[1]

SURFICIAL DEPOSITS



[1]K-Ar, $^{40}Ar/^{39}Ar$, and fission-track ages shown in Ma are those considered most reliable; see table 1
[2]Partially reset, minimum age

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qa **Alluvium (Holocene and Pleistocene)**—Unconsolidated, poorly to moderately sorted deposits of silt, sand, and gravel in valleys of active streams. Locally includes colluvium, talus, and thick accumulations of reworked tephra derived from Mount St. Helens; also locally includes drift, especially in small basins above 3800 ft in southern part of quadrangle

Qoa **Older alluvium (Pleistocene)**—Unconsolidated, poorly to moderately sorted and moderately weathered sand and gravel deposits on lower valley walls south of Cowlitz and Cispus Rivers. Includes isolated deposits of glacier-marginal streams (Crandell and Miller, 1974)[1] perched at elevations of 900 to 1500 ft and debris-flow deposits forming alluvial cones along lower reaches of high-gradient streams draining north slope of Tumwater Mountain; lower parts of these alluvial cones are overlain by, or merge with, glacial outwash-terrace gravels of the Evans Creek Drift (Qeo). Locally includes minor postglacial alluvium and colluvium

Qls **Landslide deposits (Holocene and Pleistocene)**—Diamicton of unsorted, angular, mixed bedrock and surficial material transported downslope *en masse*. Includes large, hummocky-surfaced rockslides on flanks of Huffaker Mountain (overlain by glacial outwash terrace gravels of the Evans Creek Drift (Qeo) and therefore of Evans Creek age or older), active slides near Benham Creek at east edge of quadrangle, and slumps, earthflow, and debris-avalanche deposits elsewhere. Most slides head at theatre-shaped scars and exhibit subhorizontal tops, bulbous toes, and hummocky surfaces

Evans Creek Drift (Pleistocene)—Divided into:

Qet **Till deposits**—Unsorted, unstratified diamicton along upper Quartz Creek; composed of angular to rounded clasts as much as 2 m across in a compact matrix of sand, silt, and clay; locally includes glaciofluvial sand and gravel deposits, postglacial colluvium, and areas of modern alluvium too small to map. Till is oxidized to depth of 1 m and contains volcanic clasts that lack discernible weathering rinds, both features characteristic of the Evans Creek Drift, which was deposited during the Fraser Glaciation, the last major glaciation in western Washington (Crandell and Miller, 1974; Colman and Pierce, 1981). Age approximately 17 to 25 ka (Barnosky, 1984; Crandell, 1987)

Qem **Moraine deposits**—Deposits lithologically similar to those of Evans Creek till deposits (Qet) forming terminal moraines in Cowlitz River valley near west end of Huffaker Mountain (Crandell and Miller, 1974) and in upper Quartz Creek

Qeo **Outwash deposits**—Unconsolidated, stratified, moderately to well-sorted deposits of silt, sand, and gravel forming terraces along Cowlitz and Cispus Rivers; typically unweathered but oxidized to depths of less than 1 m. Considered to be of Evans Creek age based on correlation with outwash terraces of equivalent position downvalley as described by Dethier (1988), but some terrace deposits north-northwest of Cowlitz Falls show weathering profiles suggesting a Hayden Creek age (Crandell and Miller, 1974; D.R. Crandell, written commun., 1989). Locally includes minor till and postglacial alluvium

Hayden Creek Drift (Pleistocene)—Divided into:

Qht **Till deposits**—Compact, unsorted, unstratified diamicton composed of angular to rounded clasts as much as 2 m across in a matrix of sand, silt, and clay. Forms veneer as much as several meters thick on upland surface in southwestern corner of quadrangle and on flat area immediately east of Crystal Creek; small unmapped patches of similar till present on Huffaker Mountain. Till is typically intensely weathered to depth of 0.5 to 1 m, oxidized to depth of 3 m, and, in upper part of weathering profile, contains clasts of volcanic rocks that display weathering rinds 1–2 mm thick; these features indicate age equivalence to the Hayden Creek Drift of Mount Rainier region (Crandell and Miller, 1974; Colman and Pierce, 1981). Age of the Hayden Creek Drift is controversial; it may be as young as about 60 ka (Crandell and Miller, 1974; Crandell, 1987) or greater than 300 ka (Dethier, 1988); 140 ka is age preferred by Colman and Pierce (1981) on basis of weathering-rind thickness. Areas mapped as Hayden Creek till deposits may locally include older or younger drift

Qhm **Moraine deposits**—Deposits lithologically similar to those mapped as Hayden Creek till deposits (Qht) in lower Quartz Creek. Poorly exposed till and compact laminated clay deposited in temporary lake impounded by lateral moraine of glacier occupying Cispus River valley; incised by Quartz Creek

BEDROCK

Intrusive rocks

Th **Hornblende dacite (Miocene)**—Dike of medium-gray porphyritic dacite in quartz diorite phase of Spirit Lake pluton near mouth of Red Spring Creek. Consists of 10–15 percent blocky white plagioclase phenocrysts (as long as 4 mm) and 10–15 percent blocky to acicular phenocrysts of green hornblende (0.5 to 1 mm long; a few as long as 5 mm) in a microporphyritic groundmass of quartz, feldspar, and Fe-Ti oxide. Almost totally altered to assemblage of calcite, montmorillonite, quartz, albite, K-feldspar, and chlorite

Spirit Lake pluton (Miocene)—Divided into:

Tsgr **Granite phase**—Light-gray to pale-pinkish-gray, fine- to medium-grained, porphyritic and commonly miarolitic two-pyroxene granite, hornblende-pyroxene granite, biotite-hornblende granite, and alaskite (Evarts and others, 1987) forming irregular continuous body along eastern margin (top) of pluton on west flank of Strawberry Mountain and smaller elongate bodies farther west; thin alaskitic dikes are found throughout pluton. Forms about 20 percent of pluton exposed in this quadrangle, but only 8 percent of entire pluton. Consists of many individual subphases or "surges" (Cobbing and Pitcher, 1972); contacts between subphases range from sharp to gradational and are commonly geometrically complex (Evarts and others, 1987). Contacts with main phase (Tsm) locally gradational, but generally sharp and marked locally by granite apophyses and intrusion breccia. Consists of phenocrysts of plagioclase (5–30 percent; as long as 8 mm), augite (<5 percent; as long as 4 mm), hypersthene (<5 percent; as long as 4 mm), and Fe-Ti oxide (1–2 percent; as much as 2 mm across) in a groundmass of predominantly quartz and alkali feldspar (average grain size 1 mm); subhedral to anhedral green hornblende and brown biotite present locally in amounts less than 5 percent. Groundmass textures range from micrographic to spherulitic to microgranular to aplitic. Deuteric alteration pervasive; primary mafic phases generally uralitized or chloritized, and plagioclase variably replaced by albite, epidote, sericite, chlorite, K-feldspar, and kaolinite. Clots and veinlets of fine-grained black tourmaline are widespread. Zircon fission-track ages from granite phase (table 1; Evarts and Ashley, 1993b) are, within limits of error, essentially identical to those from main phase (about 21 Ma)

Tsm **Main phase**—Dark- to light-gray to pale-pinkish-gray, medium- to coarse-grained, pyroxene-bearing quartz diorite, quartz monzodiorite, granodiorite, monzogranite, and granite; average composition is granodiorite (Evarts and others, 1987). Makes up roughly 77 percent of pluton overall, but only about 25 percent of exposures in this quadrangle. In detail, consists of myriad texturally and chemically heterogeneous subphases that have subtle and often gradational contacts. Average grain size 2–3 mm. Consists of blocky to prismatic plagioclase (40–60 percent; as long as 10 mm), augite (2–10 percent; as long as 6 mm), hypersthene (0.5–5 percent; as long as 5 mm), and subequant Fe-Ti oxide (0.5–3 percent; as much as 1 mm across) in a groundmass of equant anhedral to micrographic quartz (12–20 percent; as much as 2 mm across) and K-feldspar (8–20 percent; as much as 2 mm in diameter). Late-magmatic brown hornblende (0–2 percent; as much as 1 mm across) and biotite (0–7 percent; as much as 1 mm across) present sporadically in interstices or partially replacing pyroxene. Plagioclase in many samples is dark gray owing to abundant, minute, unidentified inclusions. Rock texture varies from coarsely porphyritic to hypidiomorphic granular depending on shapes and grain sizes of late-stage quartz and K-feldspar; fine-grained micrographic intergrowths, and resultant porphyritic textures, more common in eastern (upper) part of pluton. Deuteric alteration similar to that in granite phase (Tsgr) is widespread but generally less intense. K-Ar and fission-track determinations indicate a crystallization age of about 21 Ma (table 1; Evarts and others, 1987; in press)

Tsqd **Quartz diorite phase**—Dark- to medium-gray, fine- to medium- grained, porphyritic to seriate two-pyroxene and hornblende-pyroxene quartz diorite and granodiorite. Forms about 15 percent of pluton overall, but roughly 55 percent of pluton exposures in this quadrangle. Large body south of Tumwater Mountain composed of multiple dikes and irregular small intrusions with screens of thoroughly recrystallized volcanic country rock. Contacts with main and granite phases (Tsm and Tsgr) are sharp; and inclusions of quartz diorite phase in these units are common near contacts. Contains phenocrysts of plagioclase (20–35 percent; as long as 7 mm), pyroxene (25–30 percent; 1 to 2 mm across), and hornblende (<5 percent; 1 to 2 mm long) in intergranular to hypidiomorphic-granular groundmass (average 1 mm) of plagioclase, pyroxene, quartz, Fe-Ti oxide, with or without alkali feldspar, hornblende, and (or) biotite. Deuteric alteration generally more intense than in main (Tsm) and granite (Tsgr) phases. Much of this unit pervasively silicified or argillized (K-Ar age of alteration 23.2±0.4 Ma; table 1)

Tgr **Granite (Miocene)**—Pink to light-gray, fine-grained porphyritic granite present as small equidimensional intrusion about 250 m across along north bank of Cispus River. Contains phenocrysts of plagioclase (8 percent; 1 to 3 mm long), partly uralitized pyroxene (1 percent; 1 to 3 mm across), and greenish-brown hornblende (2 percent; 0.5 to 1 mm long) in an equigranular groundmass of quartz, K-feldspar, plagioclase, and Fe-Ti oxide. Similar to granite phase of Spirit Lake pluton (Tsgr)

Quartz Creek stock (Miocene)—Divided into:

Tgqd **Granodiorite**—Light- to medium-gray pyroxene granodiorite to quartz monzodiorite forming most of eastern half of stock on west bank of Quartz Creek. Texturally variable but composed mostly of relatively coarse-grained porphyritic rock consisting of plagioclase (60 percent; as much as 7 mm), augite (10 percent; as long as 5 mm), hypersthene (5 percent; 1 to 2 mm long), quartz (12 percent), K-feldspar (10 percent), Fe-Ti oxide (2 percent), and minor brown hornblende; quartz and K-feldspar form fine-grained feathery to micrographic intergrowths; resembles main phase of Spirit Lake pluton (Tsm) and may be connected to it at depth. Variable deuteric alteration similar to that in Spirit Lake pluton

Tqgd **Quartz diorite**—Dark-gray to pale-greenish-gray, porphyritic to seriate pyroxene quartz diorite. Forms an elongate multiphase intrusion that consists largely of north-south-trending dikes between Cispus River and Sulphur Creek and a smaller equant body near mouth of Quartz Creek. Typically composed of phenocrysts of plagioclase (as much as 6 mm), augite (as long as 3 mm; locally to 7 mm), hypersthene (0.5 to 2 mm across), and Fe-Ti oxide (<1 mm diameter) in a hypidiomorphic groundmass of same minerals plus intergrown quartz (>5 percent), alkali feldspar (generally <5 percent), and apatite; some samples contain traces of brown hornblende. Amygdules or miarolitic cavities common but rarely abundant. Petrographically similar to quartz diorite phase of Spirit Lake pluton (Tsqd)

Tqm **Quartz monzodiorite (Miocene)**—Light-gray to tan pyroxene quartz monzodiorite forming two dikelike intrusions just north of Spirit Lake pluton on east slope of Tumwater Mountain. Medium-grained porphyritic rock containing phenocrysts of plagioclase (65 percent; as long as 5 mm), augite (10 percent; as long as 4 mm), hypersthene (5–10 percent; 2 mm long), and Fe-Ti oxide (1–2 percent; 0.5 mm across) in a groundmass of fine-grained plagioclase, quartz (5–10 percent), and K-feldspar (5–10 percent). Metamorphosed to albite-epidote hornfels

Tdi **Diorite (Miocene)**—Dark-gray to grayish-green, fine- to medium-grained, porphyritic to seriate to hypidiomorphic-granular pyroxene diorite. Present as thick northeast-striking dikes and irregular stock on south side of Cispus River valley and two thin sills on upper north flank of Tumwater Mountain. Consists of plagioclase (1 to 3 mm long), augite (1 to 2 mm across), hypersthene (0.5 to 2 mm long), and Fe-Ti oxide (0.3 mm diameter) with minor quartz and interstitial clay minerals; amygdules or miarolitic cavities common and locally abundant. Nearly ubiquitous alteration to pyrite-bearing propylitic assemblages including epidote, chlorite, calcite, dolomite, albite, titanite, and secondary quartz

Tpb **Gabbro (Miocene and Oligocene)**—Black to light-greenish-gray, medium-grained, porphyritic to seriate olivine gabbro occurring chiefly as sills and northeast-trending dikes on Huffaker Mountain. Plagioclase (65–80 percent; as long as 5 mm) and augite (8–30 percent; as much as 2 mm across) are chief constituents; also contains olivine (1–3 percent; as much as 2 mm across), Fe-Ti oxide (1–3 percent; as much as 0.5 mm across), traces of interstitial quartz and altered glass, and, in some samples, minor orthopyroxene; locally contains as much as 10 percent clay-filled vesicles. Dikes interpreted as feeders for mafic flows erupted from fissures on flanks of basaltic volcanos (see units Thm and Tgc)

Tib **Intrusive basalt (Miocene and Oligocene)**—Cylindrical plug of dark-gray porphyritic basalt on lower northeast flank of Tumwater Mountain and small dikes and sills in north half of quadrangle. Petrographically similar to and probably feeders for basalt flows (Tb, Thm, and Tgc)

Tia **Intrusive andesite and basaltic andesite (Miocene and Oligocene)**—Widely scattered dikes, sills, and plugs of aphyric to porphyritic andesite and basaltic andesite. Petrographically similar to andesite flows (Ta) and considered to be subvolcanic intrusions related to them. Thick sill in Copper Canyon is coarsely porphyritic, columnar-jointed rock similar to basaltic andesite flows (Ttm) on top of Tumwater Mountain

Tid **Intrusive dacite and rhyolite (Miocene and Oligocene)**—Widely scattered dikes, sills, and plugs of light-gray, pink, or buff, essentially aphyric and generally strongly flow-banded dacite and minor rhyolite; petrographically similar to, and probably feeders for, silicic flows (Td). Common in thick section of pyroclastic rocks (Tt) in Quartz Creek

Tibc **Intrusive andesite of Benham Creek (Miocene)**—Cylindrical plug about 300 m in diameter exposed on ridge north of crest of Strawberry Mountain. Black, sparsely phyric silicic andesite petrographically identical to andesite flows exposed in Benham Creek (Tbc) and probably feeder for these flows

Volcanic and sedimentary rocks

Tvs **Volcaniclastic sedimentary rocks (Miocene and Oligocene)**— Diverse assemblage of varicolored continental volcaniclastic rocks of inferred epiclastic origin. Consists of siltstone, sandstone, conglomerate, and abundant breccia, all composed entirely of volcanic debris. Locally includes thin beds of pumiceous pyroclastic rocks and lava flows too small or poorly exposed to map separately. Typically light green to olive green or greenish gray but also white, tan, brown, or maroon. Virtually all lithic clasts are volcanic rocks petrographically identical to interbedded basalt, andesite, and dacite; minor components include plagioclase, pyroxene, and Fe-Ti oxide crystals, pumice, fine-grained plutonic rocks, and plant remains; coaly beds a few centimeters thick are present locally. Includes strata ranging from thin-bedded, relatively fine grained fluvial and lacustrine deposits to thick, massive, unsorted, very coarse grained breccia probably deposited by lahars and debris flows. Origin of many volcanic diamictites unknown, and unit doubtless includes explosion (vent) breccia, block-and-ash flows, landslide deposits, and talus breccia. Metamorphic recrystallization and hydrothermal alteration generally more thorough than in associated lava flows; zeolite and clay-carbonate assemblages are common

Tt **Tuff (Miocene and Oligocene)**—Heterogeneous unit composed of andesitic to rhyolitic tuff, pumiceous lapilli-tuff, and pumice-bearing tuff-breccia; relatively coarse grained deposits predominate; inferred to be mostly of pyroclastic (chiefly ash-flow) origin. Includes all mappable strata that contain abundant pumice lapilli or possess an ash-rich matrix, hence unit contains some slightly to moderately reworked pyroclastic deposits. Also includes sequences of interbedded tuffaceous and pumice-poor epiclastic sedimentary rocks, in which pumice-bearing beds dominate. Mainly shades of green, but locally white, brown, or purple. Proportion of angular volcanic lithic fragments highly variable but commonly exceeds 15 percent. Carbonized wood fragments common in some tuff. Pumice lapilli mostly flattened in lithic-poor tuff but less so where lithic clasts are abundant; flattening in thin-bedded tuff attributed to compaction during burial rather than to welding. Phenocrysts rarely constitute more than 15 percent of juvenile component of tuff and include plagioclase, augite, hypersthene, and Fe-Ti oxide; tuff near top of Tumwater Mountain atypically porphyritic, containing phenocrysts of plagioclase (15–20 percent; 1 to 2 mm long), pyroxene (4–6 percent; 0.5 to 1 mm long), and Fe-Ti oxide (1–2 percent; 0.2 to 0.5 mm across). No quartz, hornblende, or biotite found in any tuff. Original glass ubiquitously devitrified to cryptocrystalline quartz+alkali feldspar or replaced by fine-grained smectites or zeolites. Plagioclase separated from a porphyritic, lithic-poor, pumice-lapilli tuff exposed at elevation of 2560 ft on north face of Tumwater Mountain yielded a $^{40}Ar/^{39}Ar$ laser-fusion age of 22.9±0.5 Ma (table 1). Possible caldera-fill deposits crop out in Quartz Creek adjacent to Spirit Lake pluton (fig. 1), where beds of massive, lithic-rich lapilli tuff and coarse tuff breccia form a sequence as much as several hundred meters thick. Sequence locally displays anomalous westward dips and contains many small dacitic intrusions (Tid); all rocks in this area are highly altered and pyritic

Ta **Andesite and basaltic andesite, undivided (Miocene and Oligocene)**—Petrographically diverse, aphyric to highly porphyritic, black, gray, green, brown, and red flows and flow-breccia of pyroxene andesite and basaltic andesite not assigned to other units. Present as single flows or in stacks of similar-appearing flows with minor intercalated volcaniclastic beds. Individual flows range from 2 to 20 m thick, mostly 6 to 10 m; andesite flows on Tumwater Mountain are as much as 50 m thick and traceable for as far as 3 km. Contacts commonly not exposed, so some units mapped as flows may actually be shallow sills. Porphyritic andesite typically contains phenocrysts of plagioclase (15–25 percent; as long as 6 mm), augite (3-12 percent; as long as 5 mm), hypersthene (0–6 percent; as long as 5 mm), and Fe-Ti oxide (1–2 percent; as much as 1 mm across) in intersertal, pilotaxitic, hyalopilitic, or cryptocrystalline groundmass of same minerals plus glass (normally devitrified or replaced by clay minerals). As much as 5 percent of completely altered olivine phenocrysts (with rinds of granular pyroxene) are common in basaltic andesite, and traces of olivine are present in more felsic andesites as well (table 2). Basaltic andesite is distinguished from basalt by possessing orthopyroxene phenocrysts and a more felsic groundmass. Some flows highly amygdaloidal. Most porphyritic flows massive and blocky jointed; aphyric flows commonly exhibit subhorizontal platy parting; some are flow banded; columnar jointing rare

Td **Dacite and rhyolite (Miocene and Oligocene)**—Widely scattered flows, small domes, and associated breccia of generally flow-banded pyroxene dacite and rhyolite; color ranges from white to green, light-gray, red, brown and purple; locally includes small shallow intrusive bodies. Typically forms lenticular to bulbous flows 5 to 20 m thick; locally over 100 m thick. Dacite on Tumwater Mountain includes striking clast-supported breccia composed of angular slabby blocks as large as 1 m of white, flow-banded dacite in dark-green to purple felsic matrix; these deposits probably represent talus aprons that accumulated at margins of growing domes. Contains sparse phenocrysts or microphenocrysts of plagioclase (as much as 5 percent; 1 to 2 mm long), pyroxene (1–2 percent; 0.5 to 1 mm across), and Fe-Ti oxide (1–2 percent; as much as 0.5 mm across) in a spherulitic, micropoikilitic, or snowflake-textured cryptocrystalline groundmass of quartz, albite, K-feldspar, and Fe-Ti oxide; amphibole and biotite absent. Most outcrops show minor supergene alteration stemming from oxidation of traces of pyrite; a fresh, black, vitreous (but hydrated) flow crops out at about 4000 ft elevation near top of Tumwater Mountain west of Tumwater Creek

Thm **Basalt of Huffaker Mountain (Miocene)**—Sequence of basalt and basaltic andesite flows, flow-breccia, and interbedded scoriaceous agglomerate and volcanic conglomerate underlying Huffaker Mountain and an area south of Cispus River near mouth of Crystal Creek; section on Huffaker Mountain is over 2 km thick. Unit includes minor porphyritic two-pyroxene andesite. Flows are black to brown, commonly vesicular, and typically porphyritic to seriate, with phenocrysts of plagioclase (25–50 percent; 1 to 3 mm long; locally to 6 mm) and olivine (2–15 percent; 0.5 to 2 mm across; locally to 5 mm; generally altered to quartz and smectite) in an intergranular groundmass of plagioclase, clinopyroxene, Fe-Ti oxide, and altered interstitial glass; some flows contain a few percent of conspicuous black augite phenocrysts as much as 5 mm across. Plagioclase separated from a flow on top of Huffaker Mountain yielded a K-Ar age of 23.3±0.6 Ma (table 1); another sample collected from lower in section a few meters east of quadrangle gave a virtually identical K-Ar age (Evarts and others, 1987)

Tbc **Andesite of Benham Creek (Miocene)**—Dense, black, silicic andesite flows exposed between Benham and Crystal Creeks. Scarce plagioclase, augite, and Fe-Ti oxide microphenocrysts in a distinctive dark microcrystalline groundmass of feathery plagioclase and granular pyroxene containing abundant fine Fe-Ti oxide and quartz. Most samples contain tiny irregular amygdules of quartz and smectite; some display vague flow-banding

Ttm **Basaltic andesite of Tumwater Mountain (Miocene)**—Black to medium-gray, coarsely porphyritic basaltic andesite and minor andesite flows and flow breccia underlying summit of Tumwater Mountain; as thick as 300 m. Consists of phenocrysts of plagioclase (15–35 percent; 1 to 6 mm long), augite (3–10 percent; 0.5 to 3 mm across), olivine (0–3 percent; 0.5 to 2 mm across), hypersthene (1-7 percent; 0.5 to 3 mm long), and Fe-Ti oxide (1–2 percent; 0.3 to 1 mm across) in an intergranular, intersertal, or pilotaxitic groundmass of plagioclase, pyroxene, Fe-Ti oxide and (generally altered) glass. Age is 23.7±0.6 Ma according to $^{40}Ar/^{39}Ar$ laser-fusion determination on plagioclase (table 1)

Tb **Basalt, undivided (Oligocene)**—Isolated canyon-filling flows on north flank of Tumwater Mountain. Porphyritic to seriate plagioclase- and olivine-phyric basalt petrographically similar to flows in basalt of Goat Creek (Tgc)

Tgc **Basalt of Goat Creek (Oligocene)**— Black to greenish-gray, brown-weathering, commonly vesicular, porphyritic to seriate basalt flows, flow-breccia, and scoria beds exposed at Cowlitz Falls, on nearby hillsides, and on Glenoma Peak in northwestern corner of quadrangle; total stratigraphic thickness in this and adjacent Vanson Peak quadrangle exceeds 2.5 km; probably derived from a volcanic center in Goat Creek about 3 km west of quadrangle (Evarts and Ashley, 1993a). Predominantly porphyritic basalt containing phenocrysts of plagioclase (10–40 percent; 1 to 6 mm long) and altered olivine (2–12 percent; 0.5 to 2 mm across) in an intergranular to intersertal groundmass of plagioclase, pyroxene, Fe-Ti oxide, and altered interstitial glass. Minor associated basaltic andesite flows contains phenocrysts of augite (2–5 percent; 1 mm across) and rare hypersthene (as long as 1 mm) in addition to plagioclase and olivine. K-Ar and $^{40}Ar/^{39}Ar$ ages of about 25 Ma have been obtained from basalt flows west of Glenoma Peak in the Vanson Peak quadrangle (Evarts and Ashley, 1993a)

Contact—Long dashed where approximately located; short dashed where gradational or inferred; dotted where concealed

Fault—Dashed where inferred; dotted where concealed. Ball and bar on downthrown side

Strike and dip of beds

Inclined

Horizontal

Strike and dip of compaction foliation in pumiceous lapilli tuff

Strike and dip of flow-banding in lava flows, domes, and shallow intrusions

Strike and dip of platy parting in lava flows, domes, and shallow intrusions

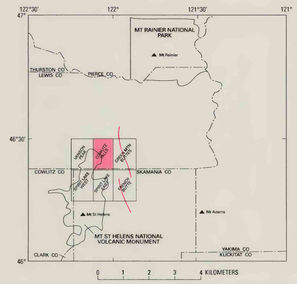
Area of intense hydrothermal alteration

Clay-carbonate, argillic, and pyritic alteration

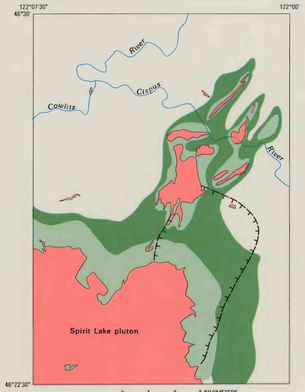
Silicification and advanced argillic alteration

Sample locality for age determination—See table 1

Sample locality for chemical analysis—See table 2



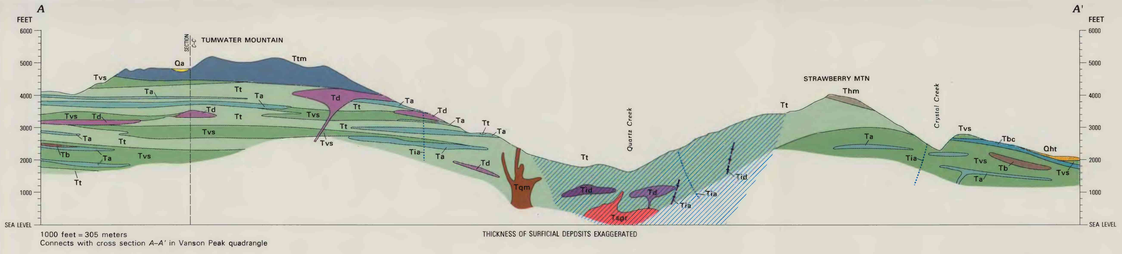
INDEX MAP SHOWING LOCATION OF THE COWLITZ FALLS QUADRANGLE, NEARBY MAPPED QUADRANGLES, MAJOR SYNCLINAL AXES (RED LINES), AND QUATERNARY VOLCANIC CENTERS OF SOUTHERN CASCADE RANGE

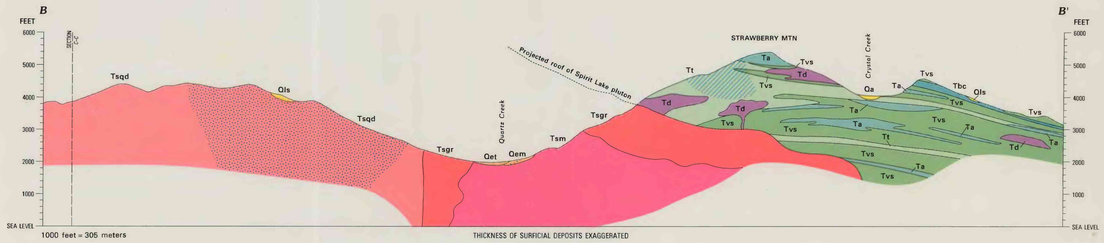


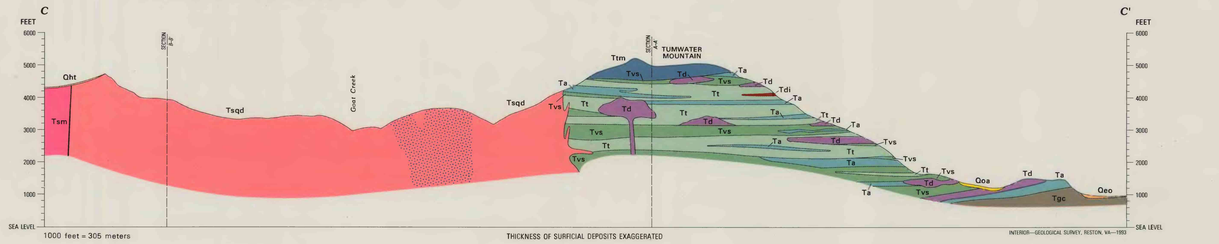
EXPLANATION

Albite-epidote hornfels
Amphibole hornfels
Phaneritic intrusive rock
Approximate margin of inferred caldera

Sketch map showing phaneritic intrusive rocks, approximate distribution of albite-epidote hornfels and amphibole-hornfels contact-metamorphic assemblages, and approximate margin of inferred Miocene caldera in Cowlitz Falls quadrangle







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