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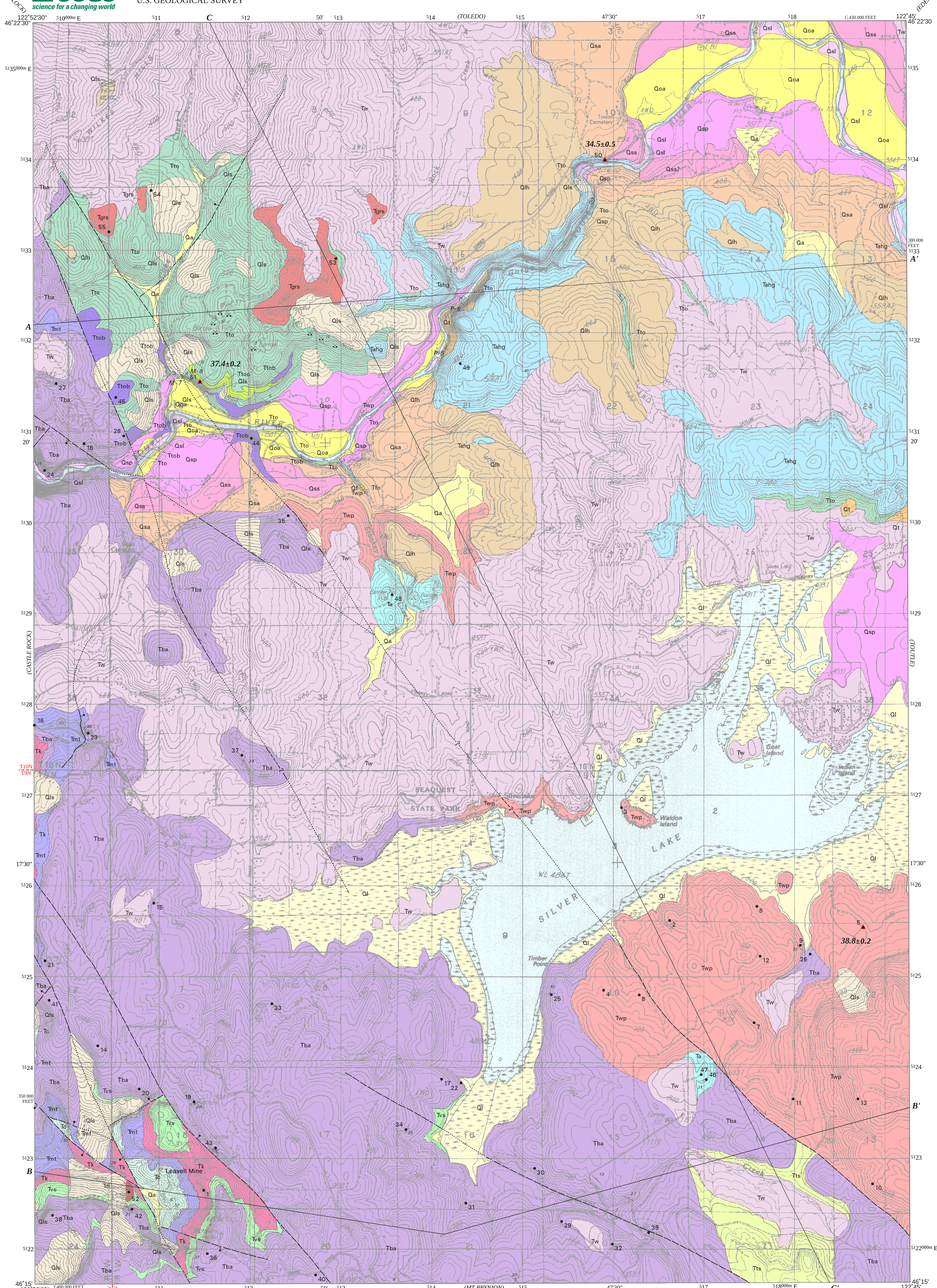


Base from U.S. Geological Survey, Silver Lake, 1985.
Universal Transverse Mercator projection, zone 10

APPROXIMATE MEAN DECLINATION, 1995

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP LOCATION

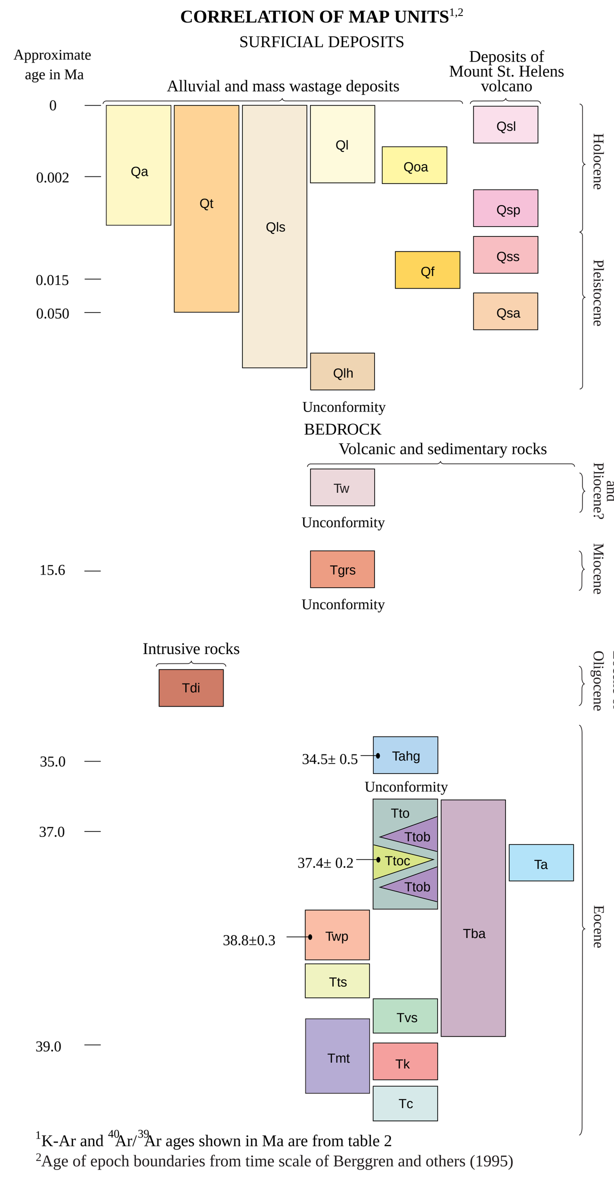
Geology mapped by R.C. Evarts, 1993-1995 and 1997-1999; assisted by B.H. Reid, 1998

Digital database by C.B. DuRoss.

Edited by T. Iki

Manuscript approved for publication June 25, 2001

CORRELATION OF MAP UNITS[1,2]



[1]K-Ar and $^{40}Ar/^{39}Ar$ ages shown in Ma are from table 2
[2]Age of epoch boundaries from time scale of Berggren and others (1995)

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Alluvial and mass wastage deposits

Qa **Alluvium (Holocene)**—Unconsolidated, poorly to moderately well sorted deposits of mud, silt, sand, and fine gravel in valley bottoms of small active streams

Qt **Talus deposits (Holocene and Pleistocene)**—Unsorted accumulations of loose, angular blocks, some as large as 10 m across, lying beneath cliffs of porphyritic andesite (unit Tahg) in Hollywood Gorge reach of Toutle River and near northeast end of Silver Lake. Produced by rockfall, rockslide, and topple events triggered by erosion or failure of nonresistant subjacent volcaniclastic sedimentary rocks of the Toutle Formation (unit Tto)

Qls **Landslide deposits (Holocene and Pleistocene)**—Diamictons composed of surficial material and (or) bedrock debris transported downslope. Mapped slides predominantly deep-seated failures ranging from more-or-less coherent slumps to internally disrupted rock-avalanche deposits. Large landslide immediately west of Hollywood Gorge has well-developed hummocky surface littered with blocks of Grande Ronde Basalt (unit Tgrs) as large as 10 m across. Most slides result from failure of weathered or poorly consolidated sedimentary rocks (units Tvs, Tto, Tc, and Tmt). Unmapped small or shallow-seated landslides may exist in some areas, particularly those underlain by the Wilkes Formation

Ql **Lake deposits (Holocene)**—Organic-rich sand, silt, and clay deposits peripheral to Silver Lake

Qoa **Older alluvium (Holocene)**—Unconsolidated, stratified, poorly to moderately well sorted deposits of silt, sand, and gravel, that forms low terrace remnants with surfaces 3 to 8 m above active alluvium of Toutle River; older than active alluvium (Qa). Dominated by well-rounded clasts of Mount St. Helens-derived dacite, basalt, and andesite but locally contain significant proportion of Tertiary rocks. Presence of mafic clasts indicates deposition during or after Castle Creek eruptive period (Crandell, 1987); terraces may reflect aggradation in response to influx of volcaniclastic debris upstream during Castle Creek and (or) Kalama eruptive periods. Locally veneered with 1980 lahar deposit

Qf **Cataclysmic flood deposits (Pleistocene)**—Approximately 0.5 m-thick deposit of unconsolidated, massive, light-brown silt overlying Ape Canyon-age alluvium in lower Stankey Creek at elevation of approximately 230 ft (70 m). Composed largely of quartz, feldspar, and conspicuous muscovite, indicative of a Columbia River provenance. Interpreted as slackwater deposits of colossal jökulhlaups initiated by failure of ice dam at Pleistocene Lake Missoula in Idaho and Montana (Bretz, 1925, 1969; Allison, 1978; Baker and Bunker, 1985; Waitt, 1985, 1994; Allen and others, 1986; O'Connor and Baker, 1992). Sediment-laden floodwaters pouring down the Columbia River washed up into lower Cowlitz River valley and its tributaries and deposited suspended sediment load before receding (Waitt, 1985; Scott, 1989). Radiocarbon ages and tephrochronologic data indicate floods occurred between about 15.5 and 12.7 ka (Waitt, 1994)

Qlh **Logan Hill Formation (Pleistocene)**—Unconsolidated, crudely bedded, deeply weathered, yellowish- to reddish-brown, moderately sorted to well-sorted pebble and cobble gravels and minor sand. Found as patchy erosional remnants at elevations below about 650 ft (200 m) on low-relief surface north of Silver Lake and east of Stankey Creek, and locally caps ridges in Wilkes Hills. Overlies dissected surfaces of Paleogene bedrock or Wilkes Formation; may be as much as 30 m thick in this quadrangle. Composed of subrounded to well-rounded clasts of Tertiary volcanic and plutonic rocks, but most clasts thoroughly weathered to kaolinitic clay; typically only a lag of resistant clasts such as felsite, granodiorite, hornfels, vein quartz, and tourmalinite remains to indicate protolith. All clast lithologies are known to crop out upstream in Cowlitz and Toutle River valleys. Probably glaciofluvial sediments (Snavely and others, 1958; Roberts, 1958). Weathering characteristics and topographic position indicate an early Pleistocene age (Crandell and Miller, 1974; Easterbrook, 1986; Dethier, 1988); may be correlative with the Orting Drift in the Puget Lowland, deposited between 1.87 and 2.48 Ma (Easterbrook, 1994). As mapped, unit may locally include younger outwash possibly correlative with the Wingate Hill Drift of Crandell and Miller (1974)

Deposits of Mount St. Helens volcano

Qsl **Deposits of 1980 lahars (Holocene)**—Flat-surfaced, unconsolidated, light-gray to light-brown, crudely stratified to unstratified, unsorted to poorly sorted, matrix-supported volcanic diamicton deposited during afternoon of May 18, 1980 by lahar generated on debris avalanche in North Fork Toutle River. Generally less than 2 m thick. Consist of angular to subangular pebbles dispersed in abundant matrix of silt and sand. Diverse clast composition includes basalt, andesite, dacite, and pumice from pre-eruption edifice, well-rounded clasts of pre-lahar alluvium incorporated during transport, and less than 2 percent of juvenile, blue-gray, microvesicular blast dacite (Scott, 1988b). Locally underlain by 0.5 m or less of crudely stratified sand, silt, and granules deposited by lahar-runout phase of lahar generated in South Fork Toutle River in morning of May 18, 1980 (Scott, 1988b). In most places, deposits have been thoroughly reworked by post-eruption fluvial processes; shown on this map is their distribution in June, 1980

Qsp **Deposits of Pine Creek eruptive period of the Spirit Lake eruptive stage (Holocene)**—Sequence of light- to medium-gray, unconsolidated, generally unstratified, moderately well sorted to unsorted lahar and lahar-runout deposits that form prominent terraces with surface elevations between about 200 and 340 ft (60 and 100 m) along Toutle River; similar deposits underlie relatively undissected surface at east end of Silver Lake. As much as 15 m thick in broad valley segment northeast of Hollywood Gorge. Lahar deposits consist of subangular to well-rounded pebbles and cobbles dispersed in a matrix of silty sand; compared to lahar deposits, lahar-runout deposits are finer grained, better sorted, and may be crudely stratified (Scott, 1988b). The well-rounded nature of many clasts indicates the lahars grew by incorporating alluvium as they traveled beyond the volcano flanks (Scott, 1988a, b, 1989). Most clasts are Mount St. Helens-erupted dacites, including abundant light-gray to pink, coarsely porphyritic, hypersthene-hornblende dacite of the type characteristic of Pine Creek-age lithic pyroclastic-flow deposits (Crandell and Mullineaux, 1973; Mullineaux, 1996; M.A. Clynne, oral commun., 1999). Pumice clasts (as large as 30 cm) of similar mineralogy and clasts of Tertiary volcanic rocks also common, but mafic rocks of the kind erupted at Mount St. Helens during the Castle Creek eruptive period are absent. Unit comprises deposits of four lahars emplaced in rapid succession about 2,500 radiocarbon yrs b.p., near the end of the Pine Creek eruptive period (Scott, 1989). The first of these (PC 1) was the largest lahar in the history of the Toutle River watershed. This lahar, initiated by failure of a debris dam at Spirit Lake, moved down the North Fork Toutle River, backed up behind a constricted reach of the river at Coalbank Rapids, and dammed Outlet Creek, thus forming Silver Lake (Crandell, 1987; Scott, 1988a, 1989). A characteristic constituent of PC 1 deposits are megaclasts of brecciated, hydrothermally-altered dacite eroded from the debris dam (Scott, 1988a). Along the Toutle River, PC 1 contains subangular blocks, commonly 2 to 5 m across, of black porphyritic andesite (unit Tahg) that were incorporated into the lahar from landslide and talus deposits at Coalbank Rapids and in Hollywood Gorge. Lower parts of some terraces mapped as this unit may include older deposits emplaced during Swift Creek and Cougar eruptive stages

Qss **Deposits of Swift Creek eruptive stage (Pleistocene)**—Stratigraphically complex section of unconsolidated pebbly to bouldery lahar, lahar-runout, and alluvial deposits forming variably dissected terraces along Toutle River with surface elevations between about 240 to 360 ft (75 to 110 m), about 12 m higher than Pine Creek terraces. Deposits contain rare pumice clasts bearing small phenocrysts of hornblende, hypersthene, and augite, consistent with tephra set Jg, erupted sometime between 10,500 and 12,000 radiocarbon years ago (Mullineaux, 1996), and exhibit pronounced soil development in upper 1 m; both features indicate a Swift Creek age (Scott, 1989). May locally include deposits of the Cougar and Spirit Lake eruptive stages, especially downstream from Hollywood Gorge

Qsa **Deposits of Ape Canyon eruptive stage (Pleistocene)**—Poorly exposed, moderately weathered, unconsolidated laharic and alluvial deposits forming dissected terrace remnants along Toutle River with surface elevations ranging from about 300 to 450 ft (90 to 140 m). Include light colored sand and fine gravel containing lithic and pumiceous clasts as large as 10 cm across of light-gray, light brownish-gray, and white, coarsely porphyritic quartz- and biotite-phyric dacite lithologically similar to eruptive products of the Ape Canyon eruptive stage of Mount St. Helens (Crandell, 1987; Scott, 1989; Mullineaux, 1996). As mapped, unit also includes pebble and cobble gravels composed chiefly of Tertiary volcanic clasts but in which biotite-bearing dacite forms a minor but persistent component; these beds may be outwash deposits of the Hayden Creek Drift of Crandell and Miller (1974) and predate the main period of Ape Canyon activity (about 50 to 36 ka) inferred from radiocarbon ages obtained near Mount St. Helens (Crandell, 1987; Scott, 1989). Alternatively, the biotite-bearing dacite may have come from Goat Mountain, a glaciated plug-dome immediately west of Mount St. Helens (Evarts and Ashley, 1990b), which has been dated by the K-Ar technique at 296 ± 7 ka (M.A. Clynne, written commun., 2000)

BEDROCK

Intrusive rocks

Tdi **Diorite (Eocene or Oligocene)**—Aphanitic intergranular pyroxene diorite form small intrusive body of unknown configuration near southwest corner of quadrangle. Composed of plagioclase (63 percent, 1 mm across), augite (20 percent, 0.5 to 1 mm across), hypersthene (9 percent; 1 mm across), Fe-Ti oxide (1.5 percent; 0.5 mm across) and interstitial smectite with trace brown hornblende. Chemistry does not resemble that of any extrusive rock in quadrangle

Volcanic and sedimentary rocks

Tw **Wilkes Formation (Miocene and Pliocene?)**—Varicolored, thick-bedded to finely laminated, semiconsolidated, nonmarine, tuffaceous claystone, siltstone, and sandstone, with minor pebble conglomerate, lignite, and airfall tuff. Unoxidized strata are pale green to bluish gray; weathers white to pale yellow to dark brown; commonly mottled and limonite stained. Owing to weakly lithified character, poorly exposed except in fresh roadcuts. Sandy beds generally poorly sorted, clayey, commonly crossbedded; originally ash-rich beds converted to plastic smectitic or kaolinitic clay. Claystone and siltstone commonly carbonaceous with abundant plant debris. Conglomerates contain well-rounded pebbles of aphyric and porphyritic intermediate to felsic volcanic rocks in a sandy matrix. Typical sandstone composed of volcanic rock fragments, plagioclase, quartz, magnetite, hornblende, and minor biotite and augite; some sandstone micaceous and arkosic, possibly comprising material reworked from Cowlitz Formation. Unconformably mantles Paleogene bedrock and Grande Ronde Basalt. Up to 230 m thick in Wilkes Hills (Roberts, 1958); thins to the south and east and present only as isolated patches south of Silver Lake. Sedimentary structures indicate deposition in low-relief fluvial, lacustrine, and swamp environments. A fossil flora collected from Wilkes Formation and correlative strata north of the Silver Lake quadrangle were assigned a late Miocene age by R.W. Brown (cited as personal commun. in Roberts, 1958) and assigned to the middle to upper Miocene Homerian megaflora stage by J.A. Wolfe (cited as personal commun. in Phillips, 1987)

Tgrs **Grande Ronde Basalt, member of Sentinel Bluffs (Miocene)**—Light- to dark-gray, hackly-fractured to blocky- or columnar-jointed, vesicular to microvesicular and commonly diktytaxitic, aphyric to microphyric tholeiitic basalt and minor flow breccia. Found as four erosional remnants that rest unconformably on Toutle Formation (unit Tto) at elevations above about 400 ft (120 m) in Cline Creek area. Maximum thickness approximately 50 m. Locally contains sparse plagioclase microphenocrysts less than 1 mm long in an intersertal to intergranular groundmass of lathlike plagioclase, granular clinopyroxene, skeletal Fe-Ti oxide crystals, and scarce equant olivine grains in abundant dark glass. Textures essentially identical to those described by Long and Wood (1986) for basalt flows on the Columbia Plateau. Chemical compositions (table 1) are typical of low-TiO_2 basaltic andesites of the Grande Ronde Formation of the Columbia River Basalt Group (Mangan and others, 1986; Beeson and others, 1989; Reidel and others, 1989); differences are within normal intraflow variation (Mangan and others, 1986), suggesting that all outcrops in this quadrangle are remnants of a single flow. The relatively high MgO contents (about 4.4 wt percent) and normal magnetic polarity (J.T. Hagstrum, oral commun., 1999) indicate flow belongs to the informal Sentinel Bluffs unit of Reidel and others (1989). $^{40}Ar/^{39}Ar$ age determinations by Long and Duncan (1982, cited as personal commun. in Reidel and others, 1989) from this unit on Columbia Plateau indicate age of 15.6±0.2 Ma

Tahg **Andesite of Hollywood Gorge (Eocene)**—Flow or shallow sill of dark-gray to black, platy to columnar-jointed, coarsely porphyritic, hypersthene-augite andesite in northeast quadrant of quadrangle. Forms near-vertical cliffs as high as 60 m along Toutle River at Hollywood Gorge and can be traced east of quadrangle to confluence of North and South Forks of Toutle River near village of Toutle. Consists of phenocrysts of plagioclase (25-35 percent, 2 to 6 mm long), augite (6-8 percent, 1 to 6 mm across), and hypersthene (5-7 percent, 1 to 5 mm long) and Fe-Ti oxide (1-2 percent; ≤0.5 mm across) in hyalopilitic to cryptocrystalline groundmass. Unconformably overlies Toutle Formation; contact relations indicate unit in much of this quadrangle is a thick invasive flow that burrowed into unconsolidated Toutle Formation sediments. Considered by Roberts (1958) to be Miocene in age; however, a plagioclase K-Ar age of 34.5±0.5 Ma was obtained by Phillips and others (1986) on a sample collected near Hollywood Gorge, and an $^{40}Ar/^{39}Ar$ age of 35.2±0.3 Ma was obtained from plagioclase separated from this unit near village of Toutle (R. Fleck, oral commun., 1999, confirming a late Eocene age)

Tto **Toutle Formation (Eocene)**—Heterogeneous volcaniclastic unit composed of light-green to dark-olive-brown, well-bedded, poorly sorted volcanic sandstone, siltstone, and claystone, pebble to cobble conglomerate, tuff, lapilli tuff, tuff breccia, and coal mapped as Toutle Formation by Roberts (1958). As much as 175 m of volcaniclastic sedimentary rocks are exposed in roadcuts in valley of Cline Creek and in nearby banks of Toutle River. Lower part of Cline Creek section consists largely of texturally and compositionally immature sandstone and conglomerate composed chiefly of volcanic lithic clasts petrographically similar to interbedded lava flows; sandstone framework grains also include plagioclase, Fe-Ti oxide, and pyroxene crystals, pumice, vitric ash, rare quartz, and sparse plant remains; a few sandstone beds contain a poorly preserved shallow-marine molluscan megafauna (Roberts, 1958; May, 1980); massive, green, poorly sorted lapilli tuff beds within the lowest part of formation well exposed in banks of Toutle River near Tower Road bridge. Upper part of Cline Creek section consists of generally finer grained deposits representing fluvial, lacustrine, and paludal environments; uppermost 50 m of this section contains beds of dark-bluish-gray, white- to yellowish-gray- to pale-brown-weathering, high-alumina clay with nodules and seams of siderite, interbedded with lignite seams as much as 2 m thick. Galvinian marine fauna from Cline Creek area and Kummerian fossil flora from localities in this and adjacent quadrangles are consistent with a late Eocene age (Roberts, 1958; May, 1980; Wolfe, 1981). Locally includes:

Ttob **Basaltic andesite flows**— Isolated flows of basaltic andesite similar to those of unit Tba

Ttoc **Cline Creek Tuff Member**—Massive dacitic pumice-lapilli tuff composed of angular, equant, pale-yellow pumice lapilli as large as 6 cm across in martix of light-gray ash. Bed as thick as 16 m forms cliffy outcrops about 60 m above base of formation east of mouth of Cline Creek. Indurated but not welded; angular to rounded lithic clasts as large as 20 cm concentrated in lower meter of tuff but otherwise sparse. Vitric material exhibits partial replacement by amorphous clay and calcite, but unit is exceptional in that glass has not been pervasively altered to green smectite as in most tuffaceous rocks of area. Pumice clasts contain about 5 percent of blocky, commonly broken, plagioclase phenocrysts 1 to 2 mm across and less than 1 percent each augite and hypersthene crystals 0.5 to 1 mm across. Roberts (1958) considered unit water-laid but its poorly sorted texture resembles subaerially emplaced pumice-flow deposits. Plagioclase from tuff yielded an incremental-heating $^{40}Ar/^{39}Ar$ age of 37.4±0.2 Ma (table 2)

Tba **Basaltic andesite (Eocene)**—Massive to platy flows and flow-breccia of medium- to dark-gray, aphyric, porphyritic, and seriate basaltic andesite and minor basalt; also includes volcaniclastic strata too thin or poorly exposed to map. Sparsely to abundantly phyric flows contain phenocrysts of plagioclase (as much as 25 percent; 1 to 3, rarely to 8 mm long) and, in most samples, augite (mostly ≤ 1 percent; 0.5 to 2 mm across; may exhibit sector-zoning), with or without olivine (≤1 percent; 0.5 to 2 mm across; replaced by smectite or carbonate; commonly partly resorbed and rimmed by fine-grained granular pyroxene±magnetite; may contain minute chromite inclusions); hypersthene phenocrysts (<1 percent; 0.5 mm long) are rare. Groundmass textures are intergranular, microphyric, or (rarely) intersertal, commonly display strongly flow-aligned feldspar and streaky zones of interstitial glass (altered to smectite); some flows have a dark, nearly cryptocrystalline groundmass with abundant very fine grained Fe-Ti oxide. Flows in this unit have relatively high TiO_2 contents (>1.80 wt percent) compared to most basaltic andesite flows in the southern Washington Cascade Range

Ta **Andesite (Eocene)**—Minor flows and flow breccia of medium- to dark-gray, platy, sparsely phyric andesite; found only in Stankey Creek and north of Sucker Creek. Contains phenocrysts of plagioclase (<3 percent; generally ≤ 1mm long but as long as 3 mm in some flows), augite (<1 percent; ≤0.5 mm across), FeTi-oxide (trace; ≤0.5 mm across), and locally olivine (trace; ≤0.5 mm across; altered to smectite) in strongly flow-foliated intergranular groundmass of feldspar, augite, FeTi-oxides, and interstitial glass (altered to smectite)

Twp **Basalt of Wolf Point (Eocene)**—Massive to platy, medium- to dark-gray, orange- to red-weathering, porphyritic to seriate, locally vesicular or diktytaxitic basalt and basaltic andesite flows and flow breccia containing conspicuous olivine as the only or most abundant phenocryst phase. Individual flows generally about 4 to 7 m thick; maximum total thickness in this quadrangle at least 190 m. Olivine phenocrysts (commonly 5 to 15 percent; mostly ≤1mm but a few as large as 3 mm) show minor to total replacement by smectite±hematite; many contain minute euhedral chromite inclusions. Some flows also contain augite and (or) rare plagioclase phenocrysts; augite grains (as much as 6 percent; ≤1 mm) are typically anhedral to subhedral, display compositional and sector zoning, and commonly form multigrain clots; plagioclase (as much as 7 percent; average 1 mm) commonly forms glomerocrysts and in some flows is probably xenocrystic. Flow-foliated, fine- to medium-grained, intergranular groundmass consists of plagioclase, augite, Fe-Ti oxide (may be subpoikilitic), and minor interstitial glass replaced by pale-green smectite; some flows contain subpoikilitic hypersthene grains whereas others have traces of fine-grained interstitial phlogopite. Unit as used here is equivalent to the olivine basalt sequence of Roberts' (1958) Hatchet Mountain Formation. Evarts and Ashley (1991, 1992) mapped similar rocks to the east as olivine-phyric basaltic andesite in the Elk Mountain quadrangle and basaltic andesite of Indian George Creek in the Lakeview Peak quadrangle. A whole-rock incremental-heating $^{40}Ar/^{39}Ar$ age of 38.8±0.3 Ma was obtained from basalt flow south of Silver Lake (table 2)

Tts **Pumice-lapilli tuff of Sucker Creek (Eocene)**—Massive, dacitic pumice-lapilli tuff composed of angular, equant, pale-yellow pumice lapilli as large as 6 cm across in martix of light-gray ash. Crops out sporadically beneath Basalt of Wolf Point in upper Sucker Creek drainage southeast of Silver Lake. Lithologically similar to Cline Creek Tuff Member of Toutle Formation, but lacks hypersthene and contains higher proportion of lithic clasts

Tvs **Volcaniclastic sedimentary rocks (Eocene)**—Poorly exposed sections of volcanic sandstone, siltstone, conglomerate, and lapilli tuff in southwestern part of quadrangle; lithologically similar to sedimentary rocks of the Toutle Formation. Interpreted as debris eroded from older and penecontemporaneous volcanoes and deposited by normal fluvial and lacustrine processes in medial to distal volcanic settings. Minor, unmappable volcaniclastic interbeds are scattered throughout flow-dominated area south of Toutle River

Tmt **Mafic tuff (Eocene)**—Massive to bedded, moderately to poorly sorted, well-indurated mafic tuff and lapilli tuff associated with basalt and basaltic andesite flows in southwestern part of quadrangle. Weathers to characteristic yellowish-brown color. Texturally variable; some beds are monolithologic and consist almost entirely of zeolitized scoria, whereas others are heterogeneous and contain a variety of angular, variably phyric, nonvesicular to scoriaceous mafic clasts. Persistent traces of quartz, green hornblende, and muscovite, presumably derived from underlying arkosic sand of the Cowlitz Formation, suggests the tuffs are hyaloclastites formed by mixing of quenched basaltic magma with water-saturated sand during phreatomagmatic eruptions. Some tuff beds are vesicular, also consistent with a phreatomagmatic origin (Lorenz, 1974). Vesicles and pore spaces filled by zeolites (most commonly heulandite), clay minerals, and carbonate

Tk **Basalt of Kalama River (Eocene)**—Flows and zeolitic flow breccia of variably vesicular, coarsely porphyritic to glomerophyric, olivine+plagioclase±augite-phyric basalt. Crops out near west boundary of quadrangle south of State Route 504. Composed of blocky, weakly zoned plagioclase (10-25 percent; 2 to 6 mm long), olivine (2-4 percent; 1 to 3 mm across), and, rarely, augite (≤2 percent; 0.5 mm across) phenocrysts in an intergranular, commonly diktytaxitic groundmass of the same minerals plus Fe-Ti oxide. Chemically these basalts are low-potassium tholeiites similar to mid-ocean-ridge basalt. Presumably they are distal parts of flows originating from the east where this unit is much thicker (Evarts and Ashley, 1990a, 1991, 1992; Evarts and Swanson, 1994)

Tc **Cowlitz Formation (Eocene)**—Bluish-gray, yellowish-gray-weathering, friable, thin-bedded to massive, commonly crossbedded, moderately to poorly sorted, fine- to medium-grained nonmarine micaceous arkosic sandstone and siltstone; interbedded with lesser volcaniclastic and (or) carbonaceous sandstone and siltstone and local thin beds of low-rank coal. Poorly exposed beneath volcanogenic rocks in small area near southwestern corner of quadrangle, but about 800 m of formation crops out immediately west of quadrangle boundary (Roberts, 1958). Arkosic beds consist of angular grains of quartz, plagioclase, potassium-feldspar, Fe-Ti oxide, muscovite, carbonaceous matter, and fine-grained granitic and metamorphic rock; heavy mineral suite includes biotite, green and brown hornblende, epidote, zircon, apatite, garnet, tourmaline, titanite, augite, and kyanite. Cemented by calcite or limonite. Inferred source areas for arkosic sandstones are pre-Tertiary plutonic and metamorphic terranes in Idaho and northern Washington (Heller and others, 1987; Vance, 1989; Brandon and Vance, 1992). Grades westward into beds containing late Eocene marine faunas (Roberts, 1958; Payne, 1998)

Contact—Dashed where approximately located; short-dashed where inferred; dotted where concealed

Fault—Dashed where approximately located; short-dashed where inferred; dotted where concealed; queried where very uncertain. Ball and bar on downthrown side. Arrows show relative horizontal movement

Strike and dip of beds
10 **Inclined**
Horizontal

12 **Strike and dip of compaction foliation in pumiceous lapilli tuff**

21 **Strike and dip of platy parting in lava flows**

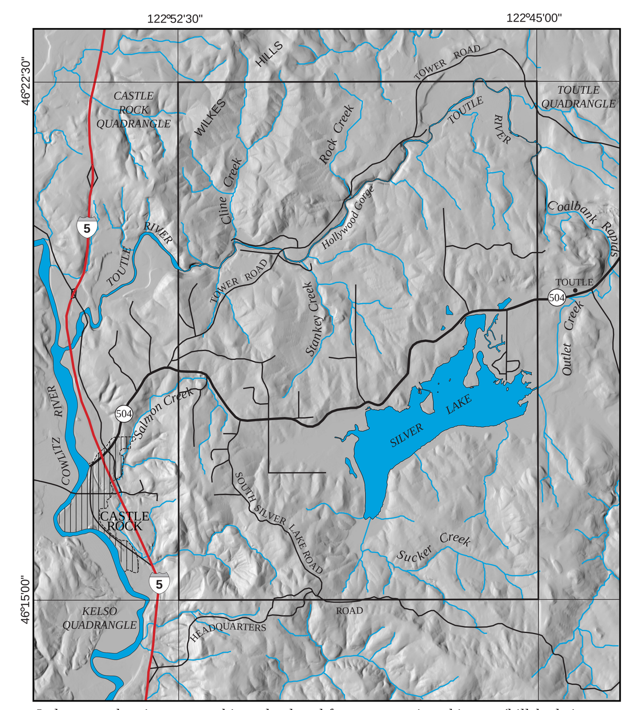
33 **Sample locality for chemical analysis**—See table 1

38.8±0.2 **Sample locality for radiometric age determination and age in Ma (±1-σ error)**—See table 2

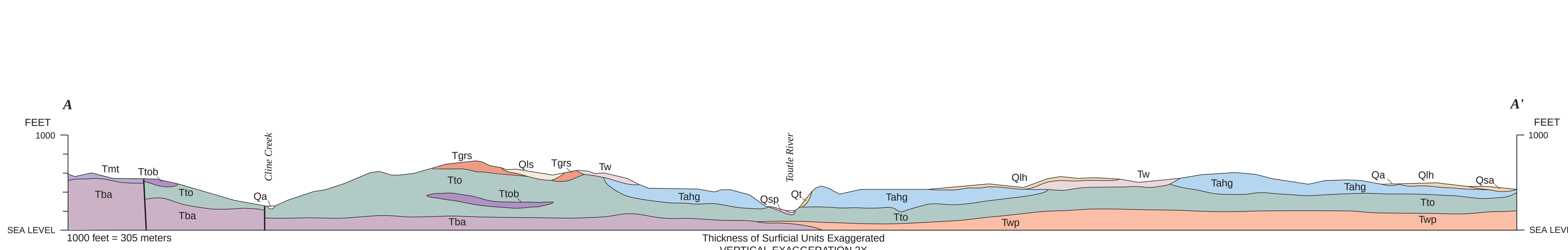
M-7 **Megafauna (*M*) and plant fossil (*P*) localities from Roberts (1958)**

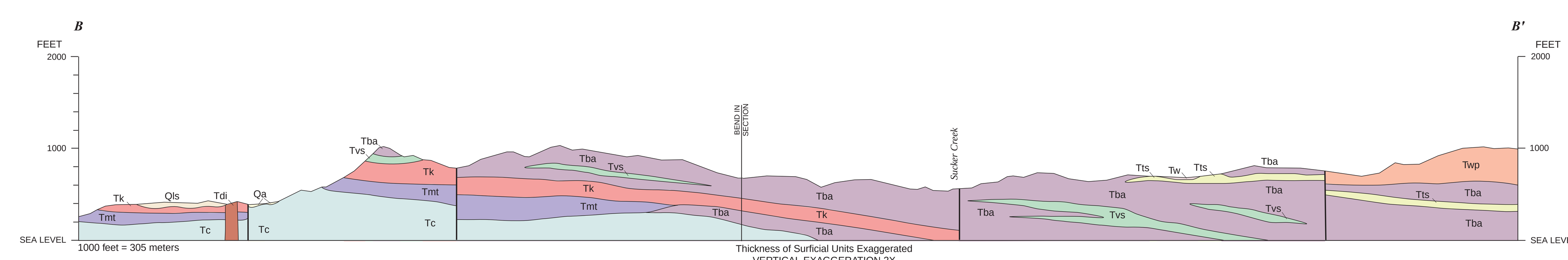
Clay pit in Toutle Formation

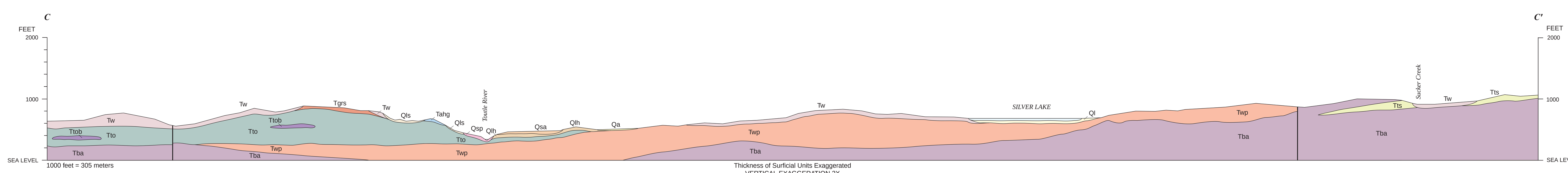
Site of coal mine or prospect in Cowlitz Formation, approximately located



Index map showing geographic and cultural features mentioned in text (hillshade image derived from 10-m DEM of the Silver Lake 7.5' quadrangle and vicinity)







GEOLOGIC MAP OF THE SILVER LAKE QUADRANGLE, COWLITZ COUNTY, WASHINGTON

By

Russell C. Evarts

2001

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, 1-888-ASK-USGS

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