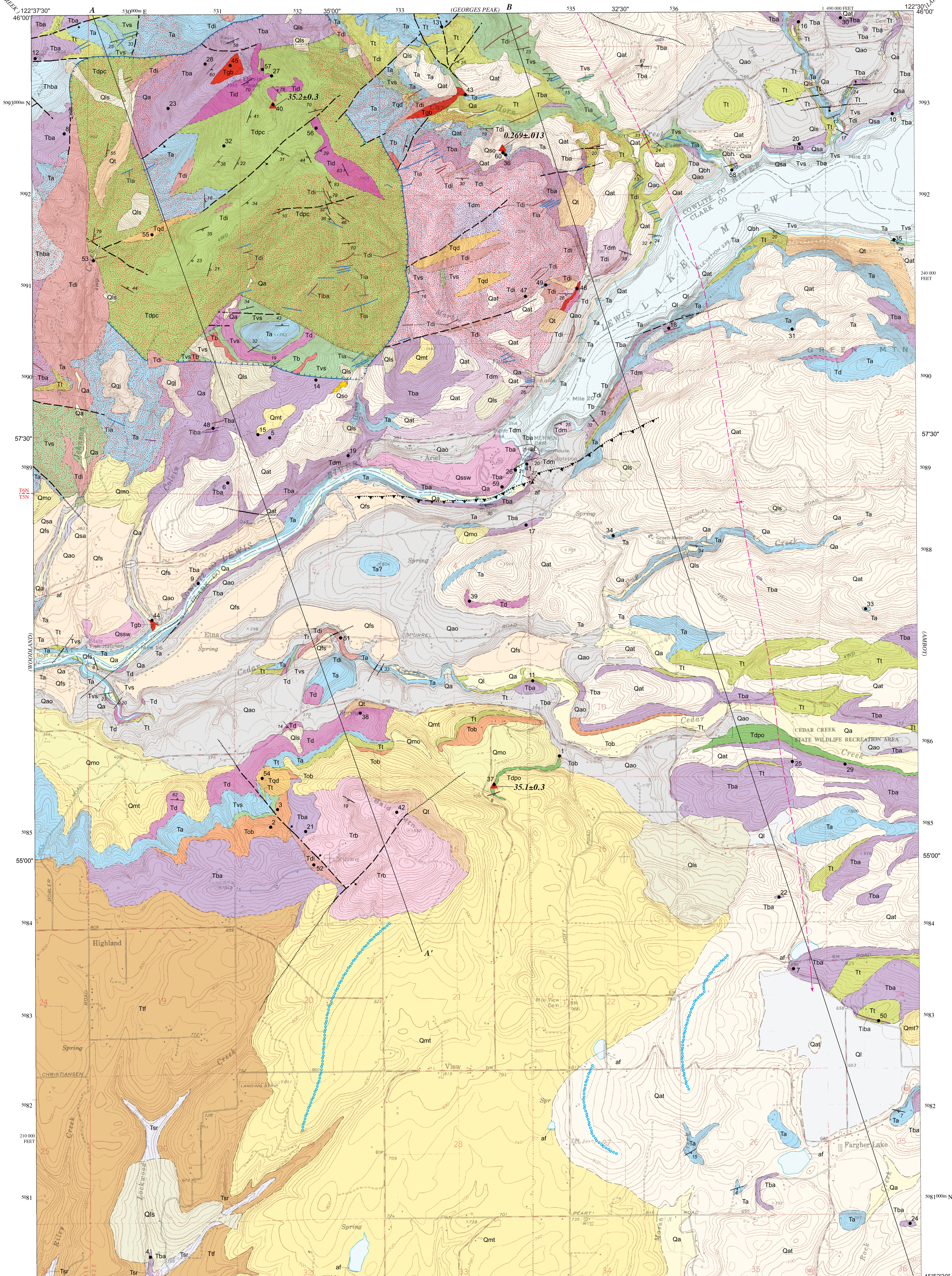
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP 2826
Pamphlet accompanies map



Base from U.S. Geological Survey, Ariel, 1971.
Universal Transverse Mercator projection, zone 10

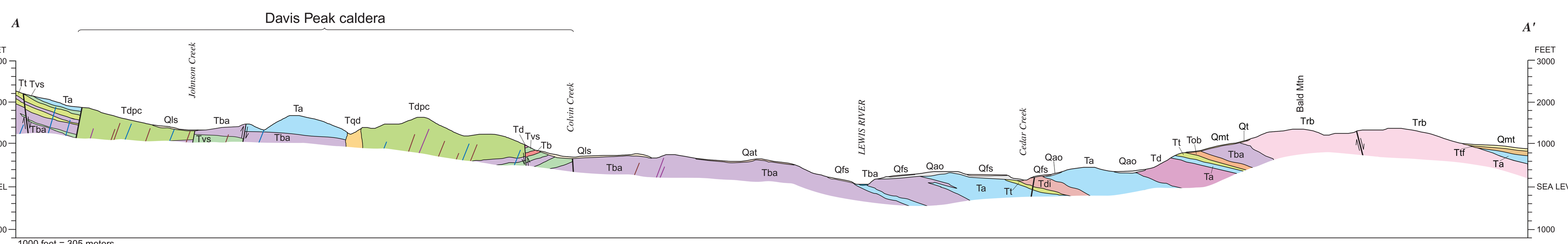
APPROXIMATE MEAN DECLINATION, 2004

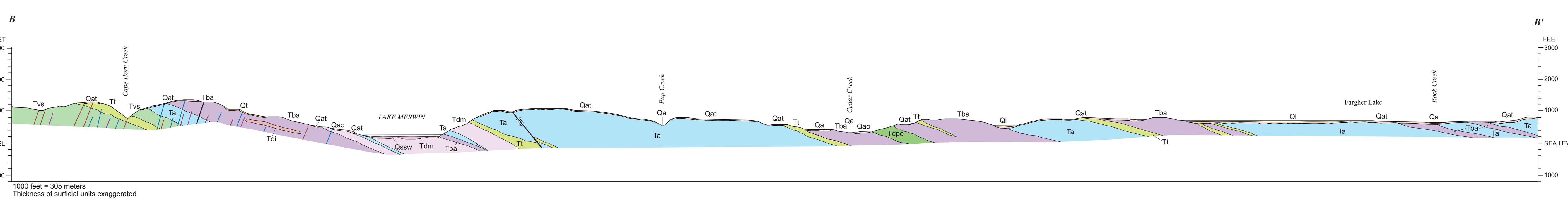
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

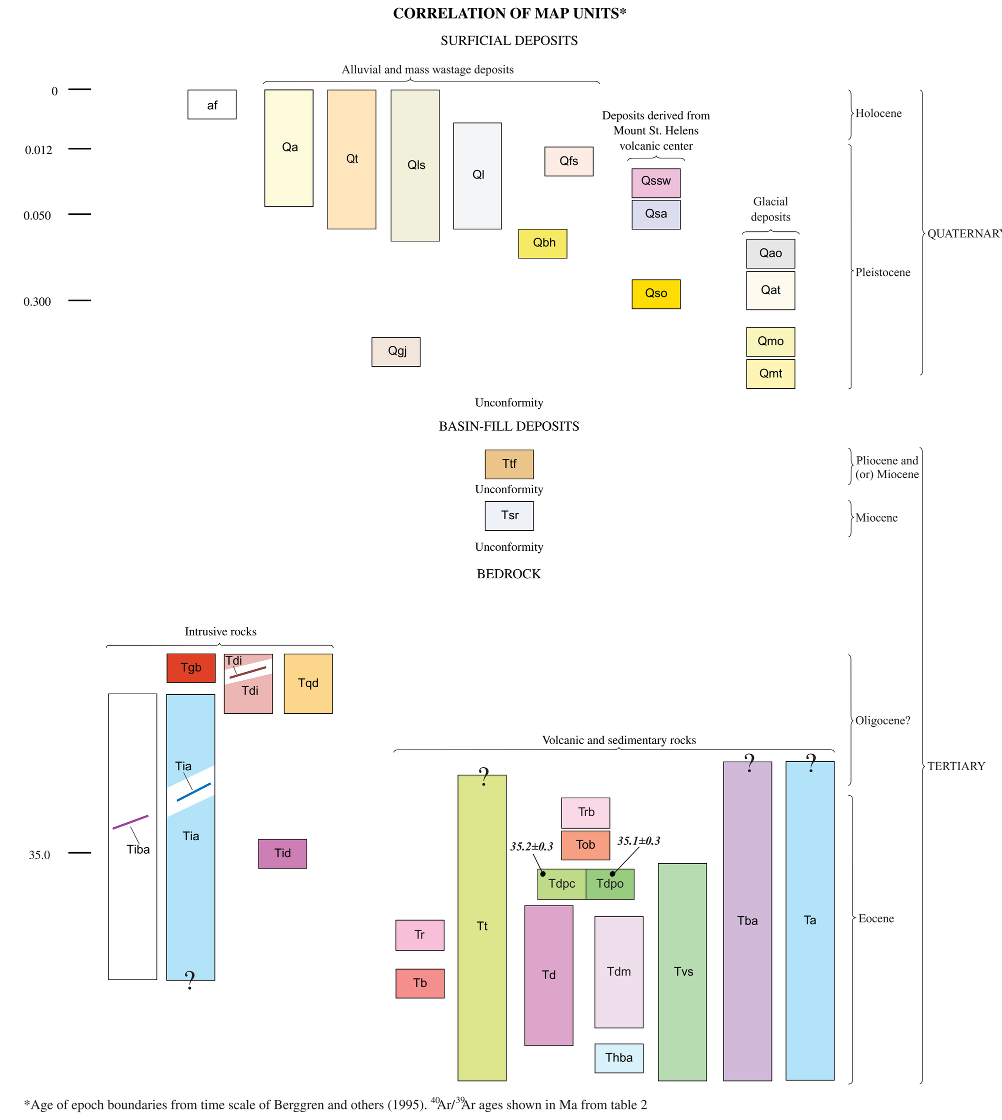
MAP LOCATION

Geology mapped by R.C. Evarts, 1997-2000; assisted by K. Anderson, 1997; B.H. Reid, 1998; C.B. DuRoss, 2000
Digital database by P.A. Dinterman
Edited by Theresa Iki
Manuscript approved for publication March 18, 2004





CORRELATION OF MAP UNITS*



*Age of epoch boundaries from time scale of Berggren and others (1995). $^{40}Ar/^{39}Ar$ ages shown in Ma from table 2

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial fill (Holocene)**—Unconsolidated soil, sand, gravel, and crushed rock used to construct roadbed of State Route 503 and dams that impound small streams; also includes concrete of Merwin Dam

Alluvial and mass wastage deposits

Qa **Alluvium (Holocene and Pleistocene)**—Unconsolidated silt, sand, and gravel along Lewis River, Cedar Creek, and small tributary streams; poorly sorted to well-sorted, crudely stratified to well-laminated, locally cross-stratified. Deposits inset against, and hence postdate, cataclysmic flood deposits (Qfs). Some sediments along Lewis River consist chiefly of clasts of Mount St. Helens-derived dacitic rocks reworked from penecontemporaneous lahar deposits upstream

Qt **Talus deposits (Holocene and Pleistocene)**—Unsorted accumulations of angular bedrock blocks below cliffs. Chiefly rockfall and rock-avalanche deposits. Largest deposits are in upper Johnson Creek and at north base of Green Mountain

Qls **Landslide deposits (Holocene and Pleistocene)**—Diamictons of angular bedrock and(or) surficial material transported down slope en masse. Chiefly deep-seated, semi-coherent slumps and internally disrupted rockslide, earthflow, and debris-flow deposits. Many mapped slides head at arcuate scars and exhibit subhorizontal tops, bulbous toes, and hummocky, poorly drained surfaces. Slides involving bedrock are most abundant in steep, unglaciated terrain in northwestern part of quadrangle. Most slides caused by failure of weathered, clayey rocks such as volcaniclastic strata of units Tvs and Tt, thin, unmapped, sedimentary intervals in flow-dominated units, or hydrothermally altered rock. Large landslide located 3 km northwest of Fargher Lake generated by slumping of unconsolidated drift

Ql **Lake deposits (Holocene and Pleistocene)**—Thin-bedded to finely laminated clay, silt, and fine-grained sand; dark-gray to black, locally contain abundant organic material. Deposits beneath bed of drained Fargher Lake are at least 11 m thick, include peat, gyttja, and several tephra layers recording eruptions at Mount St. Helens (Rigg, 1958; Mundorff, 1964; Heusser and Heusser, 1980; Doh and Steele, 1983); tephrochronology, radiocarbon ages, and pollen analysis indicate deposits range from about 20,000 to at least 55,000 years old (Grigg and Whitlock, 2002). Along Cedar Creek, deformed deposit of dark-gray, rhythmically laminated silt and clay at least 12 m thick underlies limonite-cemented gravel of probable outwash origin (too small to show on map). Small outcrops of unmapped lake beds locally present along shore of Lake Merwin

Qfs **Cataclysmic-flood deposits, sand and silt facies (Pleistocene)**—Unconsolidated silt and clay as much as 5 m thick beneath terrace surfaces as high as 300 ft (90 m) along Lewis River and lower Cedar Creek. Overlie Mount St. Helens-derived alluvium and glacial outwash. Fresh exposures in small slump scarps reveal blue-gray rhythmites, each bed several cm thick, but in more typical weathered exposures silt is oxidized light brown and bedding is inconspicuous. Composed largely of quartz, feldspar, and conspicuous muscovite, indicating upper Columbia River Basin provenance. Interpreted as slack-water deposits of colossal jökulhlaups initiated by repeated failure of ice dam at Pleistocene Lake Missoula in Idaho and Montana during the late Pleistocene (Bretz, 1925, 1929, 1969; Allison, 1978; Baker and Bunker, 1985; Waitt, 1985). Radiocarbon and tephrochronologic data for the slackwater deposits (Waitt, 1994; Clague and others, 2003) indicate depositional ages between about 17,000 and 13,000 ^{14}C B.P.

Qbh **Basaltic hyaloclastite deposits (Pleistocene)**—Weakly cemented basaltic sand and grit. Form north-thickening wedge-shaped deposit as much as 10 m thick along north shore of Lake Merwin near mouth of Cape Horn Creek and small terrace on opposite lakeshore to south. Dark greenish to yellowish-brown, poorly sorted, crudely stratified. Composed predominantly of angular clasts as large as 1 cm across of black (pale brown in thin section), partially palagonitized, moderately vesicular to nonvesicular, olivine- and plagioclase-phyric basalt; contain dispersed foreign clasts, including rounded clasts of Tertiary bedrock and rip-up clasts of subjacent glaciofluvial deposits; interbedded with fluvial cobble gravel. Unconformably overlie Amboy Drift till (Qat) and underlie Ape Canyon-age alluvial and lahar deposits (Qsa). Chemical composition of basaltic clasts (A.M. Sarna- Wojcicki, written commun., 2000) dissimilar to those of known Quaternary basalts exposed nearby (Evarts and Ashley, 1990a, 1991). Beds near Cape Horn Creek dip variably (20-70°) to south. Deposits appear to constitute eroded remains of apron or delta generated by phreatomagmatic eruptions from an unexposed source vent located to north

Qgj **Gravel of Johnson Creek (Pleistocene)**—Highly weathered deposits of weakly consolidated, poorly sorted, crudely bedded, cobbly pebble gravel, sand, and clayey silt that cap interfluves between Johnson and Colvin Creeks at elevations between about 800 and 1000 ft (260 to 305 m); at least 7 m thick. Subrounded to angular clasts, some as large as 15 cm across, consist entirely of locally derived rock types; most clasts smaller than 7 cm are thoroughly weathered to clay. Gravel generally clast supported; locally possesses abundant matrix of coarse-grained sand and texturally resembles deposits of hyperconcentrated flood flows (Smith, 1986). Interpreted as sediment deposited when lower parts of Johnson and Colvin Creeks were blocked by a glacier occupying the Lewis River valley

Deposits derived from the Mount St. Helens volcanic center

Qssw **Deposits of Swift Creek eruptive stage (Pleistocene)**—Unconsolidated sand and gravel along north valley wall of Lewis River directly west of Merwin Dam and near mouth of Colvin Creek. Clast population of most beds dominated by light-colored, porphyritic dacites like those erupted from the ancestral volcanic center at Mount St. Helens. Chiefly alluvium but include fine-grained lahar and lahar-runout deposits and, at river level near Merwin Dam, a diamict with dacite boulders of hornblende-hypersthene dacite as large as 3 m across. Composition of clasts in diamict indicates deposition during the Swift Creek eruptive stage (M.A. Clynne, written commun., 2002), approximately 21,000 to 10,000 ^{14}C years B.P. (Crandell, 1987). Upper part of unit near Merwin Dam includes younger slope-mantling deposits according to Major and Scott (1988)

Qsa **Deposits of Ape Canyon eruptive stage (Pleistocene)**—Unconsolidated, stratified sand and gravel composed predominantly of light-colored dacitic debris from ancestral Mount St. Helens; beds poorly to well sorted, typically massive; include pebbly to bouldery lahar and lahar-runout deposits as well as alluvium formed by reworking of lahar deposits. Exposed locally along north shore of Lake Merwin east of Cape Horn Creek and in valley walls about 1.5 km above mouth of Johnson Creek; in both places unconformably overlie Amboy Drift (Qao and Qat); locally as thick as 12 m. Nearly all clasts are distinctive coarsely porphyritic quartz + biotite ± cummingtonite-bearing dacite of the kind erupted from Mount St. Helens during the Ape Canyon eruptive stage (approximately 50,000 to 36,000 ^{14}C years B.P. according to Crandell, 1987); clasts of younger eruptive stages are absent (M.A. Clynne, oral commun., 2003)

Qso **Older Mount St. Helens-derived deposits (Pleistocene)**—Small scattered outcrops of unconsolidated, poorly sorted to well-sorted, massive to laminated sediments composed predominantly of quartz + biotite ± cummingtonite-phyric dacitic rocks similar to those erupted from the Mount St. Helens volcanic center during its earliest period of activity (Ape Canyon eruptive stage of Crandell, 1987). Overlie Amboy till high above valley floors in Cape Horn Creek, Husky Creek, and Pup Creek. Largest deposit, at 1500 ft (460 m) elevation in Cape Horn Creek, is 9-m-thick section of well-bedded clay, silt, sand, and gravel; includes probable lahar deposits, light-gray, feldspar-rich sandy layers, beds of pale yellow to orange-brown, weathered pumiceous tephra, and varved clay and silt. Character of sediments and position well above valley floors suggests deposition was triggered by eruptions at Mount St. Helens and occurred in glacier-margin lakes at time when a glacier occupied Lewis River valley (Evarts and others, 2003). $^{40}Ar/^{39}Ar$ age of plagioclase extracted from bed of slightly reworked pumice lapilli in Cape Horn Creek outcrop is 269±13 ka (table 2), considerably older than other known products of the Mount St. Helens center

Glacial deposits

Amboy Drift (Pleistocene)—Moderately weathered till and glaciofluvial deposits (Mundorff, 1984) characterized by weathering profiles about 2 m thick, development of weathering rinds 1-2 mm thick on aphanitic andesitic clasts in upper part, and widespread presence of quartz-, biotite-, and cummingtonite-bearing dacite clasts derived from the ancestral volcanic center at Mount St. Helens. Based on weathering characteristics, Amboy Drift is correlative with Hayden Creek Drift, which Crandell and Miller (1974) interpreted to be the product of the penultimate glaciation in the Washington Cascade Range. Age poorly known; Grigg and Whitlock (2002) suggest age of about 55 ka for periglacial deposits near Fargher Lake but reworked synglacial tephra in Cape Horn Creek (Qso) has age of 269±13 ka (table 2)

Qao **Outwash**—Poorly consolidated pebbly to cobbly gravel and sand forming complex assemblage of terraces along Lewis River and Cedar Creek. Deposits crudely stratified, moderately to well sorted; commonly weakly cemented by limonite or clay. Composed mostly of well-rounded clasts of diverse volcanic rocks, some with grooved or striated surfaces, similar to those in associated till (Qat). Light-gray, feldspar-rich sandy beds dominated by ancestral Mount St. Helens rocks locally interbedded with gravel. Interpreted as glaciofluvial deposits deposited during retreat of Lewis River glacier in late Pleistocene time; may locally include older outwash. Elevations of terrace surfaces that are underlain by outwash in Lewis River valley range from about 700 ft (215 m) near northeast corner of quadrangle to 300 ft (90 m) or less near mouth of Cedar Creek; semi-continuous outwash-terrace surface along Cedar Creek declines in elevation from 450 ft (135 m) in east to about 300 ft (105 m) west of creek mouth. In many places, most conspicuously at Etna, multiple terrace surfaces are evident; lower terraces may be erosional surfaces cut into older outwash deposits or may reflect younger pulses of aggradation during the Amboy glaciation. All terrace surfaces below 300 ft (90 m) elevation coated with cataclysmic flood deposits (Qfs)

Qat **Till**—Unconsolidated to compact, massive diamicton that blankets much of terrain south of Lake Merwin and forms discontinuous cover north of Lewis River to elevations as high as 1750 ft (530 m). As much as 15 m thick; generally shown only where thick and extensive enough to obscure bedrock. Consists of angular to rounded clasts up to boulder size, some grooved or striated, dispersed in matrix of sand, silt, and clay; locally includes stratified drift, ice-contact deposits, outwash, lake deposits, loess, and postglacial colluvium. Fresh till typically light brownish to bluish gray. Composed chiefly of diverse volcanic rocks similar to Tertiary rocks of the western Cascade Range, but commonly contains clasts similar to middle Pleistocene olivine-phyric basalts and basaltic andesites erupted from monogenetic vents in the Lewis River drainage upstream from map area (Evarts and Ashley, 1990a, 1991); clasts of quartzite and basalt reworked from Troutdale Formation rare to absent; conspicuous light-colored clasts of coarsely porphyritic quartz-, cummingtonite-, and biotite-bearing dacite of the type erupted from the ancestral Mount St. Helens volcanic center (Crandell, 1987) are a minor but widespread component in some till, especially north of Lewis River

Drift of Mason Creek (Pleistocene)—Deeply weathered drift. Mapped as Amboy Drift by Mundorff (1984) but more intensely weathered, with weathering rinds on aphanitic andesitic clasts ranging from 2 to 10 mm thick and averaging about 5 mm thick. Lacks quartz- and biotite-bearing dacitic clasts derived from Mount St. Helens. Interpreted by Crandell (1987) to record a glacial episode correlative with or older than the Wingate Hill Drift of the Mount Rainier region (Crandell and Miller, 1974), estimated by Colman and Pierce (1981) and Dethier (1988) to have occurred between 300 and 600 ka

Qmo **Outwash**—Semi-consolidated, generally limonite-cemented gravel, sand, and silt forming dissected terrace remnants with surface elevations between about 400 and 700 ft (120 and 215 m) in valleys of Cedar Creek and Lewis River. Most beds moderately to well sorted. Typically composed of well-rounded cobbles and pebbles lithologically similar to clasts in older till (Qmt). Comprises probable glaciofluvial deposits related to one or more episodes of pre-Amboy glaciation; as mapped, may also include minor deposits of Amboy age

Qmt **Till**—Dark-brown, unconsolidated to moderately compact diamicton. As much as 30 m thick. Distinguished from Amboy Drift by more intensely weathered condition; distinguished from Troutdale Formation by texture and an abundance of Cascade-derived volcanic clasts; locally contains scarce clasts of olivine-phyric basalt or basaltic andesite probably eroded from middle Pleistocene volcanic centers in the Lewis River drainage upstream from quadrangle (Evarts and Ashley, 1990a, 1991). Overlies Troutdale Formation in area beyond Amboy-age moraines west of Fargher Lake; also present in patchy exposures in Lewis River valley at higher elevations than Amboy Drift. A similar deposit northeast of Fargher Lake also tentatively assigned to this unit. May include deposits of more than one glacial advance. Best exposed in valley of Mason Creek in Battle Ground quadrangle to south (Howard, 2002)

BASIN-FILL DEPOSITS

Ttf **Troutdale Formation (Pliocene and (or) Miocene)**—Semi-consolidated pebble and cobble conglomerate with sparse lenses of friable sandstone; massive, poorly sorted to well-sorted and clast-supported, with openwork fabric or sandstone matrix. Underlies broad, south- to southwest-sloping surface in southwestern part of quadrangle, part of the Troutdale bench of Mundorff (1964). Clasts well rounded; clast population dominated by cobbles of basalt from the Columbia River Basalt Group but typically includes some light-colored granitic and quartzofeldspathic metamorphic rocks, and distinctive, white to light-gray, iron-oxide stained quartzite; clasts of volcanic rocks eroded from Cascade Range are scarce. Sandstone interbeds and matrix of conglomerate range from basaltic grit to micaceous arkose compositionally similar to sandy beds of Sandy River Mudstone (Tsr). Clasts in sandstone and conglomerate are of rock types foreign to the Portland Basin; indicates dominant source areas east of the Cascade Range and deposition by the ancestral Columbia River. In most places, upper several meters are weathered to reddish-brown clayey soil; in such areas, presence of scattered, iron-stained, brown to yellow quartzite pebbles in soil is the only indicator of protolith. Water wells in area south of Highland penetrate as much as 70 m of conglomerate and show that weathering extends to depths exceeding 30 m (Mundorff, 1964; Swanson and others, 1993)

Tsr **Sandy River Mudstone (Miocene)**—Light grayish-green to pale-brown, poorly indurated arkosic, tuffaceous and carbonaceous claystone, siltstone, sandstone, and minor pebble conglomerate. Poorly exposed in valleys of Riley and Lockwood Creeks near southwest corner of map area. Planar and trough cross-beds and cut-and-fill structures common in sandy beds indicate fluvial depositional environment; fine-grained deposits with thin lignite interbeds probably represent overbank settings on broad floodplain. Equivalent to lower member of Troutdale Formation of Mundorff (1964) and fine-grained member of Troutdale Formation of Howard (2002). Age is poorly constrained. Plant fossils from near top of unit at localities outside of quadrangle were assigned late Miocene or Pliocene ages (Trimble, 1963; Mundorff, 1964; Tolan and Beeson, 1984), and unit is generally considered to postdate Columbia River Basalt Group (Trimble, 1963; Swanson and others, 1993). Near Woodland, however, (Evarts, 2004), flows of the Grande Ronde Basalt overlie, are banked against, or invade this unit, so base must be as old as late early Miocene

BEDROCK

Intrusive rocks

Tgb **Gabbro (Oligocene?)**—Scattered small intrusions of medium- to coarse-grained, hypidiomorphic granular gabbro; most abundant near Davis Peak. Composed of euhedral to subhedral plagioclase (60-65 percent; 1 to 3 mm long) and olivine (1-7 percent; 1 to 3 mm across), interstitial to subpoikilitic augite (12-30 percent; 1 to 2 mm across) and hypersthene (as much as 14 percent; 1 to 3 mm across), and subhedral to anhedral Fe-Ti oxide (1-2 percent; =0.5 mm across), with as much as 3 percent fine-grained quartz, granophyre, and biotite. Olivine commonly contains chromian spinel inclusions and is enveloped by rinds of granular pyroxene. Moderate to intense deuteric alteration to assemblage of chlorite, epidote, actinolite, montmorillonite, and calcite

Tdi **Diorite (Oligocene?)**—Dikes, sills, and irregular, composite intrusions of medium- to dark-gray, fine- to medium-grained, seriate to hypidiomorphic granular pyroxene diorite. Concentrated near Davis Peak caldera. Composed largely of blocky plagioclase (average 65 percent; 0.5 to 4 mm long), equant augite (5-17 percent; 0.5 to 2 mm across), equant to prismatic hypersthene (7-11 percent; 0.5 to 2 mm across), equant to amoeboid Fe-Ti oxide (<2 percent; <0.5 mm across), and, in some samples, anhedral olivine (as much as 3.5 percent; 0.5 to 2 mm across), accompanied by about 5 to 15 percent interstitial quartz, granophyre, and (or) chloritic clay minerals; some samples contain traces of fine-grained anhedral K-feldspar, biotite, or hornblende; amygdules or miarolitic cavities locally common. Texturally and compositionally gradational to basaltic andesite and quartz diorite. Variable but ubiquitous partial alteration of igneous phases to some combination of albite, quartz, chlorite, epidote, prehnite, actinolite, sericite, smectite, kaolinite, calcite, talc, titanite, pyrite, and hematite

Tqd **Quartz diorite (Oligocene?)**—Dikes and small tabular intrusions of fine- to coarse-grained pyroxene quartz diorite; greenish gray, invariably propylitized. Similar to diorite (Tdi) but contains more quartz and less pyroxene

Tiba **Intrusive basaltic andesite (Oligocene? and Eocene)**—Dikes of sparsely to coarsely porphyritic basaltic andesite. Petrographically similar to basaltic andesite flows (Tba); with increasing grain size grades into diorite (Tdi)

Tia **Intrusive andesite (Oligocene? and Eocene)**—Dikes and small tabular intrusions of aphyric to coarsely porphyritic pyroxene andesite. Petrographically similar to andesite flows (Ta) but commonly more altered; with increasing grain size grades into quartz diorite. Most abundant in zone of N. 75° E. -striking dikes north of Lewis River

Tid **Intrusive dacite (Eocene)**—Dark-gray, platy, sparsely porphyritic pyroxene dacite forming tabular to irregular, commonly composite intrusions that cut caldera-fill deposits near Davis Peak; unit also includes tabular body of porphyritic dacite in Cedar Creek. Intrusions near Davis Peak composed of phenocrysts of plagioclase (3-8 percent; 0.5 to 2 mm long), augite (≤1 percent; 0.5 mm across), hypersthene (≤1 percent; 0.5 mm long), and Fe-Ti oxide microphenocrysts (≤1 percent) in a hyalopilitic to pilotaxitic, vitric to cryptocrystalline groundmass

Volcanic and sedimentary rocks

Tba **Basaltic andesite (Oligocene? and Eocene)**—Flows and flow breccia of dark-gray to brown, variably vesicular, porphyritic to seriate to (rarely) aphyric basaltic andesite; unit locally includes minor andesite and basalt flows and volcaniclastic rocks too small or poorly exposed to map. Typical flows contain phenocrysts of plagioclase (0-40 percent; 1 to 2 mm, rarely to 5 mm long), olivine (as much as 5 percent; 0.5 to 2 mm across; commonly partly resorbed and surrounded by rinds of granular pyroxene and (or) magnetite; almost invariably replaced by some combination of smectite, hematite, carbonate, serpentine, and quartz; commonly contains minute chromian spinel inclusions), and augite (as much as 5 percent; 0.5 to 3 mm across). Some flows lack olivine and (or) augite phenocrysts; many contain microphenocrysts of Fe-Ti oxide and a few contain phenocrysts of hypersthene (as much as 5 percent; 0.5 to 1 mm long). Intergranular to trachytic groundmass consists of the same minerals plus minor altered interstitial glass. Alteration highly variable in intensity and mineralogy, dependent primarily on proximity to intrusions; secondary assemblages include albite, quartz, zeolites (including stilbite and laumontite), chlorite, epidote, prehnite, pumpellyite, actinolite, hornblende, sericite, smectite, kaolinite, calcite, talc, titanite, pyrite, and hematite

Ta **Andesite (Oligocene? and Eocene)**—Flows and flow breccia of medium-to dark-gray, variably vesicular, aphyric to porphyritic pyroxene andesite. Unit locally includes small flows of basaltic andesite and dacite and thin volcaniclastic interbeds. Typically contains phenocrysts of plagioclase (1-25 percent; 1-5 mm long), augite (0-5 percent; <0.5 to 3 mm across), hypersthene (0-3 percent; <0.5 to 3 mm long), Fe-Ti oxide (<0.5 percent; <0.5 mm across), and rare altered olivine (<1 percent; as large as 2 mm across) in an intergranular, intersertal, pilotaxitic, hyalopilitic or cryptocrystalline groundmass; some sparsely porphyritic andesites lack augite or hypersthene or both. Alteration similar in mineralogy and intensity to that described for basaltic andesite (Tba)

Tt **Tuff (Oligocene? and Eocene)**—Heterogeneous unit composed of andesitic to rhyolitic tuff, pumice- and lithic-lapilli tuff, and tuff breccia; very poorly sorted, matrix-supported, relatively coarse-grained deposits predominate; inferred to be mostly of pyroclastic-flow and lahar origin but doubtless includes some air-fall tuff and reworked debris. As mapped, includes sequences of tuffaceous rocks interbedded with and gradational to subordinate pumice-poor epiclastic sedimentary rocks. Generally light colored, ranging from white to light-gray to light greenish and yellowish brown. Carbonized woody debris is present in some lapilli tuff, especially near base of tuff beds. Phenocrysts rarely constitute more than 10 percent of juvenile material in tuff and include plagioclase, augite, hypersthene, and Fe-Ti oxide, but no quartz, hornblende, or biotite. Altered to similar extent as units Tvs, Tba, and Ta

Trb **Rhyolite of Bald Mountain (Eocene)**—Light- to medium-gray, porphyritic hypersthene rhyolite that underlies Bald Mountain; highly jointed and locally platy. Contains phenocrysts of plagioclase (10-15 percent; 1 to 3 mm long) and hypersthene (about 2 percent; 0.5 to 2 mm long), and microphenocrysts of Fe-Ti oxide (≤1 percent; ≤0.3 mm across) in a devitrified cryptocrystalline groundmass of feldspar, quartz, and smectite. Most outcrops are highly weathered, with plagioclase phenocrysts largely replaced by chalky white kaolinite and hypersthene phenocrysts replaced by yellowish smectite. Unit contains no apparent internal flow boundaries or associated fragmental deposits, suggesting it is the eroded core of a dome or shallow plug

Tob **Olivine basalt (Eocene)**—One or more flows and flow breccia of porphyritic to seriate basalt and basaltic andesite; medium- to dark-gray or greenish gray, orange-weathering, commonly diktytaxitic; contains conspicuous, red to orange, variably altered olivine as the sole or dominant phenocryst phase. Exposed in sporadic outcrops between Cedar Creek and Bald Mountain. Olivine phenocrysts (as much as 5 percent; 0.5 to 2 mm across) partly to completely replaced by smectite ± hematite; contain numerous tiny octahedral chromian spinel inclusions. Medium-grained, intergranular to subophitic to trachytic groundmass composed of plagioclase, augite, Fe-Ti oxide, and minor interstitial glass altered to smectite. Smectite and zeolite fill irregular microvesicles

Tvs **Volcaniclastic sedimentary rocks (Eocene)**—Diverse assemblage of continental volcaniclastic rocks of inferred epiclastic origin. Consist of thin- to thick-bedded, well-sorted to poorly sorted siltstone, sandstone, conglomerate, and breccia, all composed mostly of volcanic debris. Locally include thin beds of pumiceous pyroclastic rocks and lava flows too small or poorly exposed to map. Beds are most commonly light green to olive green or greenish gray but some are white, tan, or brown. Texturally and compositionally immature; most abundant clasts are volcanic rocks petrographically similar to interbedded lava flows and tuffs; other components include plagioclase, Fe-Ti oxide, and pyroxene crystals, pumice, vitric ash, fine-grained dioritic rocks, and plant remains. Interpreted as debris eroded from older and penecontemporaneous volcanoes and deposited by normal fluvial and lacustrine processes in low-lying medial to distal intervolcano environments. Typically display intense alteration to assemblages like those in interbedded lava flows of units Ta and Tba

Tuff of Davis Peak (Eocene)—Pyroclastic and associated deposits of Davis Peak caldera

Tdpc **Caldera-fill facies**—Assemblage of complexly interbedded pumiceous tuff and diamictite within Davis Peak caldera. At least 500 m thick. Composed chiefly of olive-green to brown, variably compacted, porphyritic, dacitic pumice-lapilli tuff, intercalated with a variety of poorly sorted lithic breccias interpreted as landslide deposits generated by collapse of unstable caldera walls during paroxysmal eruption; locally includes stratigraphically coherent megaclasts of precaldera rocks tens of meters across (not mapped separately). Proportion and rock type of lithic fragments in lapilli tuff highly variable; angular clasts of mafic to silicic lavas similar to precaldera units are most common. Tuff and breccias are typically propylitized, but strikingly fresh, black, glassy, plagioclase- and pyroxene-phyric, densely welded vitrophyre crops out above 2300 ft (700 m) elevation on south flank of Davis Peak; plagioclase from this tuff yielded an $^{40}Ar/^{39}Ar$ age of 35.2±0.3 Ma (table 2)

Tdpo **Outflow facies**—Bed of porphyritic, densely welded, dacitic tuff exposed east of Bald Mountain. As much as 30 m or more thick. Resembles caldera-fill vitrophyre exposed at Davis Peak (Tdpc) and has analytically indistinguishable $^{40}Ar/^{39}Ar$ age (table 2); interpreted as outflow facies of pyroclastic deposits filling Davis Peak caldera (Tdpc)

Td **Dacite (Eocene)**—Scattered flows and flow breccia of variably porphyritic pyroxene dacite; dark-gray, platy, flow-banded, and locally vesicular. Typically contains phenocrysts of plagioclase (5-25 percent; 1 to 3 mm long), hypersthene (1-2 percent; 0.5 to 1 mm), and, in some samples, augite (≤2 percent; 0.5 to 1 mm), and microphenocrysts of Fe-Ti oxide (<0.5 percent) in a pilotaxitic, hyalopilitic, cryptocrystalline, or spherulitic groundmass. Locally contains as much as 3 percent xenoliths. Exceptionally porphyritic flow in Cedar Creek contains plagioclase (25 percent; 1 to 3 mm long), augite (3-5 percent; 0.5 mm across), and hypersthene (3-5 percent; 0.5 mm across) phenocrysts, Fe-Ti oxide microphenocrysts, and abundant small microdioritic blobs. Dacite commonly exhibits minor to pervasive low-temperature alteration, which imparts greenish, pinkish, and purplish colors; fine-grained alteration assemblages include quartz, calcite, albite, hematite, celadonite, montmorillonite, kaolinite, and titanite

Tr **Rhyolite (Eocene)**—Reddish-orange porphyritic rhyolite, with highly contorted flow banding; crops out in bank of Cedar Creek, about 1 km east of Etna. Contains phenocrysts of plagioclase (5-10 percent; 0.5 to 1 mm long) and microphenocrysts of altered pyroxene (<1 percent) and Fe-Ti oxide (<1 percent) in quartz-rich microcrystalline groundmass

Tdm **Dacite of Marble Creek (Eocene)**— Flows and breccias of porphyritic pyroxene dacite exposed between Cape Horn and Husky Creeks; also present on lower west slope of Green Mountain east of Merwin Dam; light greenish, yellowish, pinkish, and purplish gray to medium gray; commonly platy. Composed of plagioclase (8-15 percent; 1 to 3 mm long) and orthopyroxene (≤2 percent; 0.5 to 1 mm across) phenocrysts and Fe-Ti oxide (≤1 percent; <0.3 mm across) microphenocrysts in a cryptocrystalline, pilotaxitic to hyalopilitic groundmass. In most places pervasively overprinted by hydrothermal alteration and (or) contact metamorphism; plagioclase largely replaced by secondary assemblages including albite, calcite, montmorillonite, heulandite, epidote, sericite, and chlorite; pyroxenes totally replaced by some combination of smectite, quartz, calcite, chlorite, epidote, and pyrite

Tb **Basalt (Eocene)**—Isolated flows of porphyritic plagioclase-phyric basalt in Colvin Creek and Cape Horn Creek drainages. Contains phenocrysts of plagioclase (as much as 15 percent; 1 to 3 mm long; partially altered to albite + smectite), olivine (3-5 percent; 1 to 3 mm across; totally altered to quartz, smectite, and hematite; contains small chromian spinel inclusions), and, in some flows, a few percent augite in intergranular to trachytic groundmass. Some plagioclase crystals embayed and probably xenocrysts

Thba **Hypersthene basaltic andesite (Eocene)**—Flows and flow breccia of dark-gray, densely porphyritic, hypersthene basaltic andesite that crop out on upper west valley wall of Johnson Creek. Part of approximately 225-m-thick sequence exposed in adjacent Woodland quadrangle. Typical flow contains phenocrysts of plagioclase (about 35 percent; 1 to 2 mm long), hypersthene (6-8 percent; 1 to 3 mm long), and augite (<0.5 percent; 1 to 2 mm across) in intergranular to intersertal groundmass of feldspar, pyroxene, Fe-Ti oxide, and local interstitial quartz and smectite

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

Fault—Dashed where inferred; dotted where concealed. Ball and bar on downthrown side. Arrows show relative horizontal movement

Reverse fault—Dashed where inferred, dotted where concealed. Sawteeth on upper plate

Caldera margin of Davis Peak—Approximately located

Buttress unconformity—Approximately located. Hatchures face intracaldera tuff deposited against fault-bounded blocks of pre-caldera rocks within Davis Peak caldera

Syncline—Approximately located, arrow showing direction of plunge

25 **Strike and dip of beds**

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

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

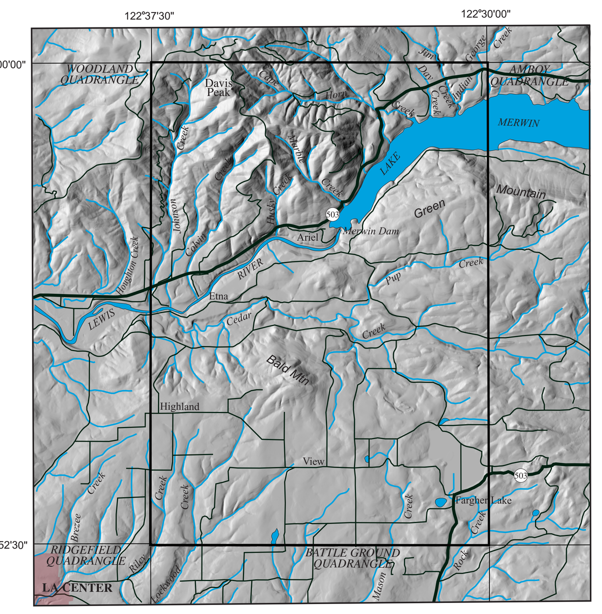
Crest of moraine

•25 **Sample locality for chemical analysis**—See table 1

Sample locality for $^{40}Ar/^{39}Ar$ age determination and age in Ma (±1-σ error)—See table 2

Area of propylitic alteration

Area of tourmalinite alteration



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

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Geologic Map of the Ariel Quadrangle, Clark and Cowlitz Counties, Washington

By
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2004