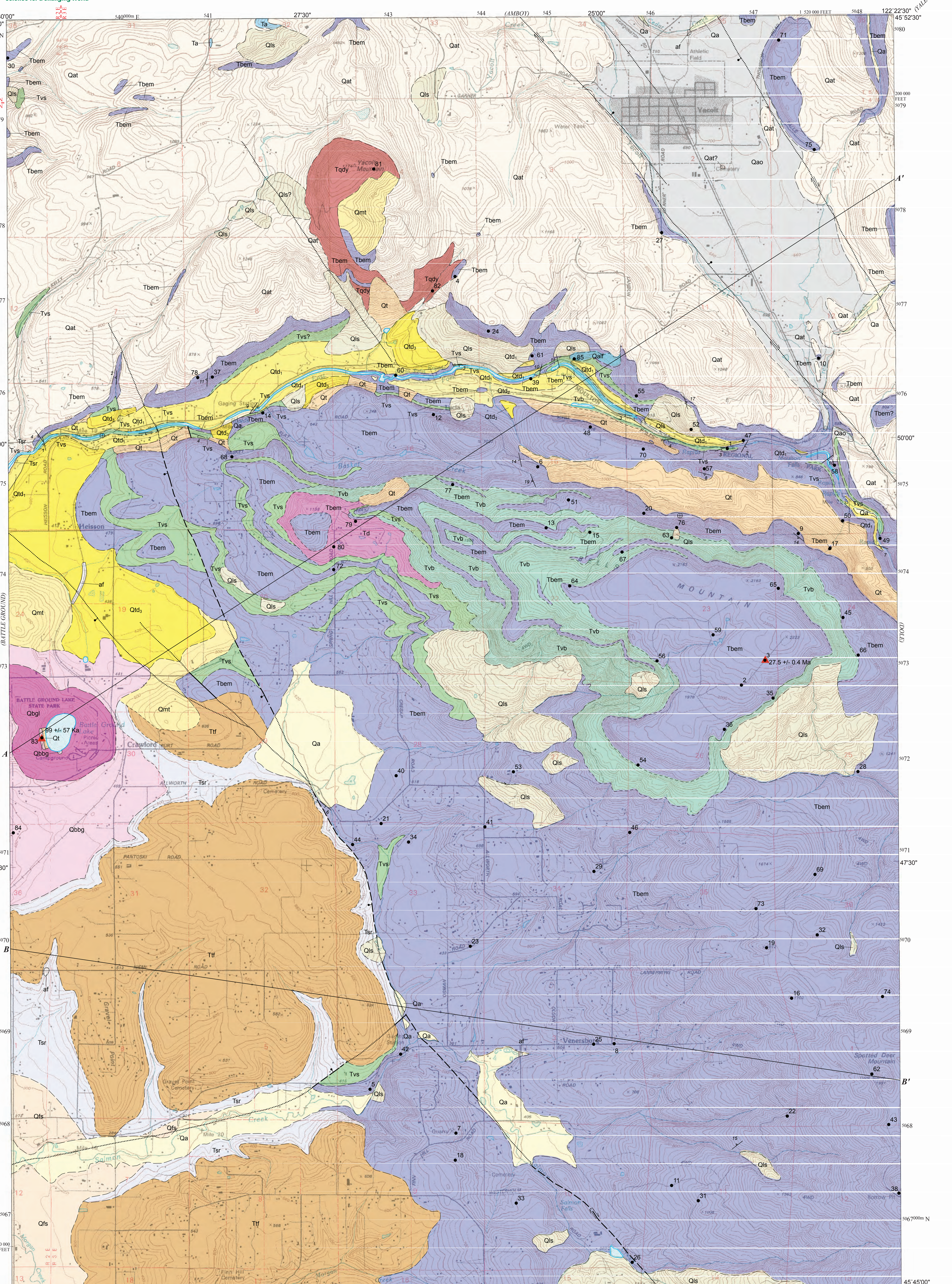
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



Base from U.S. Geological Survey, Yacolt, Wash., 1990.
Universal Transverse Mercator projection, zone 10

APPROXIMATE MEAN DECLINATION, 2004

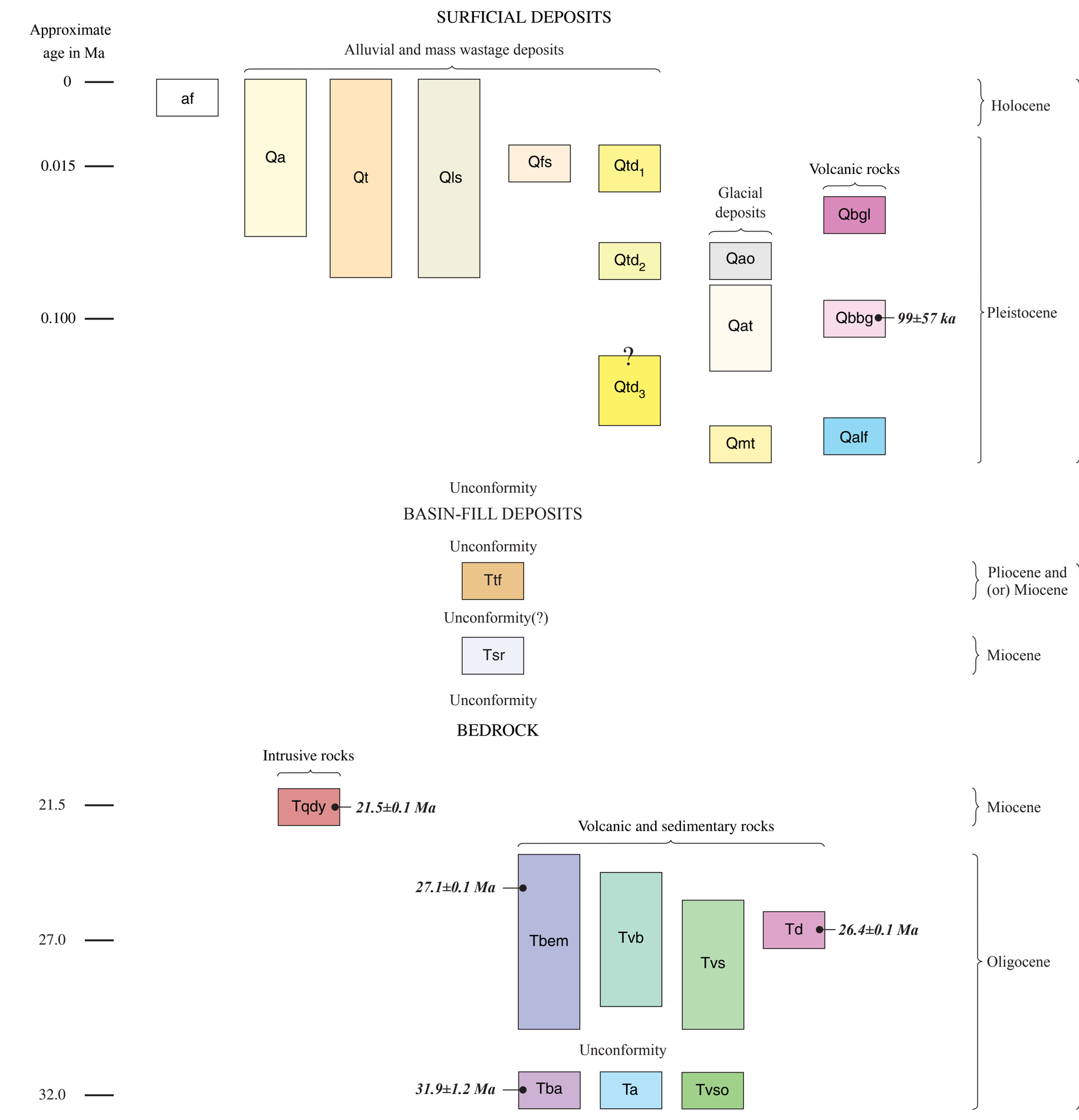
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP LOCATION

Geology mapped by K.A. Howard, 1998-1999 and R.C. Evarts, 2000-2003
Digital database by P.A. Dinterman
Edited by Theresa Iki
Manuscript approved for publication September 14, 2005

CORRELATION OF MAP UNITS*



*Age of epoch boundaries from time scale of Berggren and others (1995). Ages from table 2.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial fill (Holocene)**—Unconsolidated soil, sand, gravel, and crushed rock used to construct road and railroad beds and small dams

Alluvial and mass wastage deposits

Qa **Alluvium (Holocene and Pleistocene)**—Unconsolidated silt, sand, and gravel along active streams; poorly sorted to well sorted, crudely stratified to well laminated, locally cross-stratified. Includes small alluvial fan east of Crawford that may be coeval with drift of Mason Creek (Qmt)

Qt **Talus deposits (Holocene and Pleistocene)**—Unsorted accumulations of angular bedrock blocks below steep slopes in East Fork Lewis River valley. Chiefly rockfall and rock-avalanche deposits but in places includes much colluvium

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. Most slides, including large ones on Bells Mountain, generated by failure of deeply weathered, clay-rich, volcanic breccia (Tvb) beds; those north and west of Yacolt Mountain are mostly shallow-seated slides derived from till (Qat)

Qfs **Cataclysmic-flood deposits, sand and silt facies (Pleistocene)**—Unconsolidated silt and fine sand mantling paleosurfaces below about 300 ft (90 m) near southwest corner of quadrangle. Rarely exposed; distribution inferred largely from well logs, which indicate thickness of unit in map area ranges from 0 to about 15 m. Contains abundant quartz, potassium feldspar, and muscovite grains, indicating deposition by Columbia River rather than by local streams. Interpreted as slackwater deposits of colossal glacier-outburst floods initiated by repeated failure of ice dam at Glacial Lake Missoula in Idaho and Montana during the late Pleistocene (Bretz, 1925, 1959; Baker and Bunker, 1985; Waitt, 1985, 1994, 1996; Atwater, 1986; O'Connor and Baker, 1992; Benito and O'Connor, 2003). Hydraulically dammed floodwaters temporarily ponded in Portland Basin and deposited suspended sediment load (Trimble, 1963). Radiocarbon and tephrochronologic data from outside the map area indicate depositional ages between about 17,000 and 13,000 ^{14}C years B.P. (Waitt, 1985, 1994; Atwater, 1986; Clague and others, 2003)

Terrace deposits (Pleistocene)—Fluvial gravel and sand forming sets of terraces along East Fork Lewis River; clasts consist of Tertiary volcanic and granitic rocks eroded from Cascade Range. Divided into three units based on differences in tread elevations and weathering characteristics

Qtd_1 **Terrace deposits 1**—Deposits forming terraces with tread elevations about 10–15 m above East Fork Lewis River; exposed along both banks of river downstream from Moulton Falls. Large surface of unit west of Lucia Falls preserves surface morphology of old river channels. About 10–12 m thick, composed chiefly of weakly indurated, crudely stratified, and poorly sorted cobble and boulder gravel with subrounded blocks as large as 2 m across; locally includes beds of coarse-grained sand or grit. In several places, lowest exposed bed in unit is a diamicton, inferred to be a landslide-induced debris-flow deposit, which contains rounded and angular volcanic clasts to 25 cm across in a matrix of compact brown silt. Deposits characterized by weakly developed soils and clasts with little or no weathering rinds. Corresponds in part to terrace deposits (Qt) and older alluvium (Qoa) mapped by Howard (2002) in adjacent Battle Ground quadrangle

Qtd_2 **Terrace deposits 2**—Deposits forming terrace along the south side of East Fork Lewis River upstream from Lucia Falls with tread elevations between 25 and 30 m above East Fork Lewis River. Approximately 15–20 m thick; consist of poorly sorted bouldery cobble gravel with well rounded to subrounded clasts as large as 1 m across in a matrix of coarse oxidized sand. Weathering rinds on volcanic clasts 1 to 2 mm thick. Probably downstream equivalents of Amboy-age outwash (Qao) beneath Yacolt

Qtd_3 **Terrace deposits 3**—Deposits forming terraces with tread elevations between 40 and 50 m above East Fork Lewis River; underlies broad area south of river at Heisson and several smaller areas upstream. Up to 30 m thick. Predominantly bouldery cobble and pebble gravel with sand matrix; well sorted to poorly sorted and clast-supported; contains well rounded to subrounded clasts as large as 2 m across. Terraces commonly capped by several meters of sand and silt with thick soil profile; weathering rinds on aphanitic andesitic clasts typically 2 to 5 mm thick. Near Heisson, upper 1 m of unit contains tephra bed mineralogically similar to tephra set C of Mount St. Helens, so must be older than 35 ka (Mullineaux, 1996) and possibly as old as 300 ka (Evarts and others, 2003). Terrace surfaces grade upstream to elevation higher than that of Amboy Drift outwash deposits (Qao) north of Moulton Falls; contiguous at west edge of quadrangle with deposits mapped as alluvial fan member of Troutdale Formation (QTta) and glacial drift (Qd) by Howard (2002)

Glacial deposits

Amboy Drift (Pleistocene)—Moderately weathered till and glaciofluvial deposits (Mundorff, 1984) characterized by weathering profiles about 2 m thick and by development of weathering rinds 1 to 2 mm thick on aphanitic andesitic clasts from upper part of weathered zone; unoxidized till light brownish- to bluish-gray. Clasts composed of diverse volcanic rocks similar to Tertiary rocks of the western Cascade Range. 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; estimates range from about 50 ka to greater than 300 ka (Crandell and Miller, 1974; Crandell, 1987; Colman and Pierce, 1981; Dethier, 1988, Grigg and Whitlock, 2002, Evarts and others, 2003; Evarts, 2004b, 2005). As mapped, may include deposits of more than one glacial advance

Qao **Outwash**—Poorly consolidated pebbly to cobbly gravel and sand that forms south-sloping valley fill of basin in which Yacolt is situated. As thick as 42 m beneath Yacolt, according to well logs. Deposits moderately weathered, 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). Interpreted as glaciofluvial deposits of the Amboy Drift (Mundorff, 1984) deposited during retreat of Lewis River glacier in late Pleistocene time

Qat **Till**—Unconsolidated to compact, massive diamicton mantling much of terrain north of East Fork Lewis River to elevations as high as 1400 ft (425 m). As much as 15 m thick; in several places observed to rest on glacially smoothed and striated bedrock surface. Consists of angular to rounded clasts up to boulder size, some grooved or striated, dispersed in matrix of sand, silt, and clay; locally includes postglacial colluvium; east of Yacolt includes alluvium deposited in glacier-margin stream. Some till north and west of Yacolt Mountain is atypically clay-rich (Mundorff, 1984), and deposits mapped as Amboy Drift in that area may locally include a more deeply weathered older drift

Qmt **Drift of Mason Creek (Pleistocene)**—Deeply weathered, dark-brown, moderately compact cobbly till on east side of Yacolt Mountain between 1400 to 1670 ft (425-510 m) elevation and stratified drift(?) on hills north and east of Battle Ground Lake. Distinguished from Amboy Drift (Qat and Qao) by more pervasive weathering and thicker weathering rinds (3 mm to 12 mm thick) on aphanitic andesitic clasts; resembles drift of Mason Creek of Evarts (2004b) in Ariel quadrangle and deeply weathered till described by Crandell (1987) in Battle Ground quadrangle (Howard, 2002). Hills near Battle Ground Lake, each about 640 ft (195 m) high, may be eroded end-moraine remnants; roadside ditch about 0.7 km northeast of Crawford exposes poorly sorted, limonite-cemented gravel composed of subrounded volcanic cobbles to 25 cm across. Crandell (1987) interpreted deeply weathered till in adjacent Battle Ground quadrangle to be 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; underlies basalt of Battle Ground (Qbbg)

Volcanic rocks

Qbgl **Basalt of Battle Ground Lake (Pleistocene)**—Basaltic pyroclastic deposits forming maar occupied by Battle Ground Lake. Deeply weathered and poorly exposed deposits consist of red-orange basaltic ash and scoriaceous lapilli; include abundant angular cobbles of nonvesicular olivine-phyric basalt apparently ripped from older lava flow (Qbbg), now exposed in crater wall, during phreatomagmatic eruption that formed maar; sparse exotic clasts including quartzite pebbles and blocks of Tertiary volcanic rocks also present. Age unknown but must be younger than about 100 ka (age of disrupted lava flow) and older than 20 ka (oldest radiocarbon age obtained from lake sediments by Barnosky, 1985)

Qbbg **Basalt of Battle Ground (Pleistocene)**—Two or more flows of light to medium gray, diktytaxitic, olivine-phyric basalt with highly vesicular flow tops; equivalent to basalt of Battle Ground of Howard (2002). Underlies gently sloping surfaces around base of Battle Ground Lake maar; also locally exposed in crater walls as thick as 40 m. Probably erupted from cinder cone(s) in adjacent Battle Ground quadrangle (Howard, 2002). Contains phenocrysts of olivine (11–12 percent; as large as 3 mm across; enclosing abundant chromian spinel inclusions) and sparse microphenocrysts of greenish augite in an intergranular to trachytic groundmass. Whole-rock $^{40}Ar/^{39}Ar$ age of basalt flow exposed in west crater wall of Battle Ground Lake maar is 99±57 ka (table 2); age of chemically similar basalt in Battle Ground quadrangle is 108±21 ka (R.J. Fleck, written commun., 2002)

Qalf **Andesite of Lucia Falls Road (Pleistocene?)**—Light- to medium-gray, typically microvesicular, aphyric andesite. Small remnant of eroded flow crops out at elevation of about 550 to 900 ft (165 to 275 m) on north wall of East Fork Lewis River valley between Lucia Falls and Moulton Falls. Trachytic, flow-banded; composed of plagioclase, augite, hypersthene, and Fe-Ti oxide. Young age inferred from lack of vesicle fillings

BASIN-FILL DEPOSITS

Ttf **Troutdale Formation (Pliocene and (or) Miocene)**—Semi-consolidated, massive to crudely stratified, pebbly and cobbly conglomerate with sparse lenses of friable sandstone; moderately to well sorted and clast supported, with sandstone matrix. Underlies broad, southwest-sloping surfaces between about 500 and 650 ft (150 to 200 m) elevation 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 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 underlying Sandy River Mudstone (Tsr). These rock types indicate dominant source areas east of the Cascade Range and deposition by the ancestral Columbia River. Sedimentary structures observed west of map area are consistent with deposition during floods in a gravel-dominated braided river system. In most places, upper several meters weathered to reddish-brown clayey soil, and presence of scattered quartzite pebbles in soil is only indicator of conglomeratic parent material. Water-well logs indicate unit is generally less than 30 m thick in quadrangle. Basal contact with Sandy River Mudstone is low-relief disconformity. Equivalent to upper member of Troutdale Formation of Mundorff (1964) and to quartzite-clast member of Troutdale Formation of Howard (2002). Pliocene and (or) Late Miocene age inferred from stratigraphic relations outside of this quadrangle (Tolan and Beeson, 1984)

Tsr **Sandy River Mudstone (Miocene)**—Semiconsolidated, well-bedded sandstone, siltstone, claystone, and minor quartzite-bearing pebble conglomerate, pumice-lapilli tuff, and lignite. Poorly exposed beneath Troutdale Formation (Ttf) in creek valleys east of Gravel Point. Water-well logs indicate unit is at least 140 m thick southeast of Crawford. Sandy and silty beds are bluish gray in fresh exposures, weather to light brown; commonly limonite-cemented. Sandstones range from lithic to arkosic, contain subangular grains of quartz, feldspar, various rock fragments, muscovite and minor biotite, tourmaline, magnetite, hornblende. Thin claystone beds varicolored, commonly carbonaceous, tuffaceous in part. Better outcrops west of quadrangle reveal sedimentary structures that indicate a fluvial depositional environment (Howard, 2002; Evarts, 2004c). Equivalent to lower member of Troutdale Formation of Mundorff (1964) and to fine-grained member of Troutdale Formation of Howard (2002). Age poorly constrained. Plant fossils from near top of unit at localities outside of quadrangle assigned Pliocene or Late Miocene ages (Trimble, 1963; Mundorff, 1964; Tolan and Beeson, 1984)

BEDROCK

Intrusive rocks

Tqdy **Quartz diorite of Yacolt Mountain (Miocene)**—Light- to medium-gray, fine- to medium-grained, pyroxene quartz diorite underlying Yacolt Mountain. Seriate to hypidiomorphic granular; composed of plagioclase, (65 percent; as long as 4 mm), augite (6 percent; 1 to 3 mm across; locally replaced by brown hornblende), hypersthene (11 percent; 1 to 2 mm across), olivine (<1 percent; about 1 mm across; totally altered to smectite; surrounded by fine-grained granular orthopyroxene + magnetite), Fe-Ti oxide (2 percent; <0.5 mm across), complexly intergrown quartz and potassium feldspar (about 12 percent), and minor fine-grained hornblende, biotite, apatite, and interstitial clay. Miarolitic cavities filled with quartz and stilbite. Local slight to moderate deuteric alteration to stilbite, calcite, and clay minerals. As mapped, includes dark porphyritic rock containing abundant interstitial devitrified glass and clay that crops out in creek valley southeast of Yacolt Mountain; this rock is chemically similar to the diorite on Yacolt Mountain (table 1, nos. 81 and 82; fig. 2) and is interpreted as a chilled border phase of the intrusion; plagioclase from this rock gave an $^{40}Ar/^{39}Ar$ age of 21.5±0.1 Ma (table 2)

Volcanic and sedimentary rocks

Tbem **Basaltic andesite of Elkhorn Mountain (Oligocene)**—Tholeiitic basaltic andesite and basalt flows and flow breccia that constitute most of bedrock in south part of map area. Flows are dark-gray to brown, porphyritic to seriate to aphyric, locally columnar-jointed, commonly weathered into spheroidal blocks 1-3 m across. About 300 m thick in southeast part of map area; top not exposed; basal contact unconformable. Interbedded with thick breccias and other volcaniclastic rocks on Bells Mountain and along East Fork Lewis River, but to the south sedimentary interbeds are too thin or too poorly exposed to map. Individual flows typically about 5-8 m thick, range up to 75 m thick. Typical porphyritic flows contain phenocrysts and glomerocrysts of weakly zoned plagioclase (0–55 percent; 1 to 6 mm, locally more than 10 mm long; variably replaced by zeolites and (or) clay) and olivine (generally <1 percent; locally as much as 5 percent; 0.5 to 3 mm across; commonly partly resorbed and surrounded by rinds of granular pyroxene and (or) magnetite; rarely contain minute chromian spinel inclusions; invariably replaced by some combination of smectite, hematite, carbonate, serpentine, quartz and kaolinite). Some flows also contain phenocrysts of augite (<3 percent; 0.5 to 1 mm, rarely as much as 5 mm across) and microphenocrysts of Fe-Ti oxide; a few contain phenocrysts of hypersthene, (<1 percent; 0.5 to 2 mm long) as well. Groundmass consists of plagioclase, augite, Fe-Ti oxide, and minor to abundant interstitial glass (generally devitrified or replaced by smectite, quartz, or calcite); groundmass textures chiefly intergranular to trachytic, less commonly subophitic, intersertal, or microphyric. Many flows in unit abundantly plagioclase-phyric, reflected in Al_2O_3 contents greater then 19 wt percent, and have probably accumulated excess feldspar. All flows in unit are tholeiitic, and many are exceptionally Fe-rich (FeO^* as high as 12.8 wt percent) and poor in Sr (mostly <320 ppm but higher in plagioclase-accumulative lavas) compared to mafic rocks elsewhere in southern Washington Cascade range (Evarts, 2001, 2002, 2004a, b, 2005, R.C. Evarts, unpub. data). Whole-rock $^{40}Ar/^{39}Ar$ age of 27.1±0.1 Ma (table 2) obtained for sample from summit of Bells Mountain

Td **Dacite (Oligocene)**—Flow of medium- to dark-gray, porphyritic to glomerophyric, mafic dacite exposed on ridge south of Basket Creek. Contains phenocrysts of plagioclase (12–13 percent; 1 to 2 mm long), augite (1–1.5 percent; 0.5 to 1 mm across), hypersthene (1–1.5 percent; 0.5 to 1 mm long), and Fe-Ti oxide (0.5–1.0 percent; <0.5 mm across) in a pilotaxitic groundmass. $^{40}Ar/^{39}Ar$ age of 26.4±0.1 Ma (table 2) obtained for plagioclase from sample collected on Spring Hill Road

Tvs **Volcaniclastic sedimentary rocks (Oligocene)**—Diverse assemblage of continental volcaniclastic rocks inferred to be mostly of epiclastic origin. Consists of thin- to thick-bedded, well to poorly sorted siltstone, sandstone, grit, conglomerate, and clast-supported breccia, all composed of volcanic debris. Locally includes thin lignite beds, diamictites of probable lahar origin and rare pumiceous pyroclastic rocks. Beds dark green and brown where fresh, weather light brown to olive green, greenish gray, tan, or white; locally developed paleosols typically maroon. 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, and fine-grained plutonic rocks. Plant remains, including reed and leaf impressions, locally abundant. Interpreted as debris eroded from older and contemporaneous volcanoes and deposited in fluvial and lacustrine settings in low-lying medial to distal intervolcano environments. Moderate to pervasive alteration to assemblages of clay minerals, zeolites (chiefly heulandite-clinoptilolite), quartz, calcite; weathering generally much more intense than in associated lava flows. Volcaniclastic strata exceptionally well exposed in bed of East Fork Lewis River near the bridge north of Heisson; section includes diamicton with logs as large as 1 m in diameter and 4 to 8 m long

Tvb **Volcanic breccia (Oligocene)**—Thick bedded to massive tuff-breccia and lithic lapilli tuff interfingered with basaltic andesite flows (Tbem) on Bells Mountain; as thick as 200 m. Light brown to olive, poorly sorted to unsorted, polylithologic to (rarely) monolithologic, matrix-supported; interpreted as debris-flow deposits. Composed of mostly angular to subangular clasts of mafic rocks similar to interbedded flows; clasts commonly as large as 1 m across, some as large as 8 m or more. Generally more altered and (or) weathered than interbedded lava flows

Tba **Basaltic andesite (Oligocene)**—Flows and flow breccia of dark, vesicular, plagioclase-phyric, basaltic andesite interbedded with volcaniclastic rocks along East Fork Lewis River between Moulton Falls and Lucia Falls; stratigraphically below unconformity at base of basaltic andesite of Elkhorn Mountain (Tbem). Flow breccia abundant, typically zeolitic. Sample from massive interior of coarsely porphyritic flow gave whole-rock $^{40}Ar/^{39}Ar$ age of 31.9±1.2 Ma (table 2)

Ta **Andesite (Oligocene)**—Andesite flows exposed in isolated outcrops near north edge of map area. Porphyritic flow in eastern outcrop contains phenocrysts of plagioclase (about 15 percent; 1 to 2 mm long) and microphenocrysts of augite, hypersthene, olivine, and Fe-Ti oxide (< 2 percent each) in a pilotaxitic groundmass; sparsely phyric flow to west contains plagioclase phenocrysts (1–2 percent; 0.5–1 mm long) and augite and Fe-Ti oxide microphenocrysts (<1 percent each) in a felty groundmass. Variably altered to quartz, clay minerals and Fe-oxides. Age probably about 32 Ma

Tvso **Older volcaniclastic rocks (Oligocene)**— Volcaniclastic strata exposed in East Fork Lewis River between Lucia Falls and Moulton Falls, below unconformity at base of basaltic andesite of Elkhorn Mountain (Tbem). Similar to volcaniclastic strata elsewhere but locally capped by well developed red paleosol; interbedded with 31.9±1.2-Ma basaltic andesite flow (Tba)

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. ⊙, relative motion toward viewer; ⊗, relative motion away from viewer

Strike and dip of beds

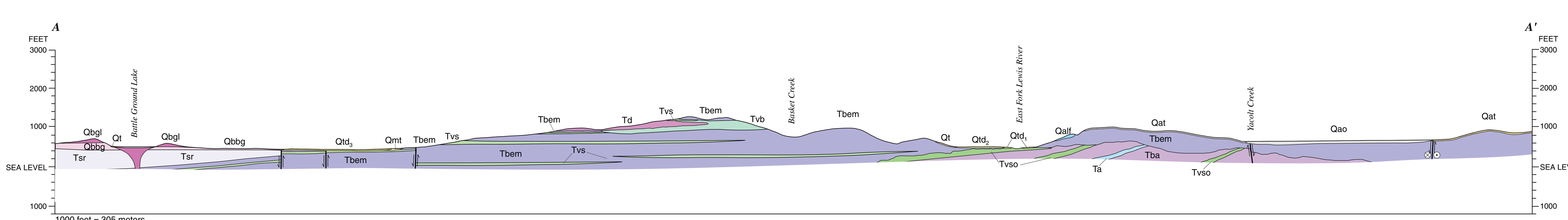
Horizontal

Inclined

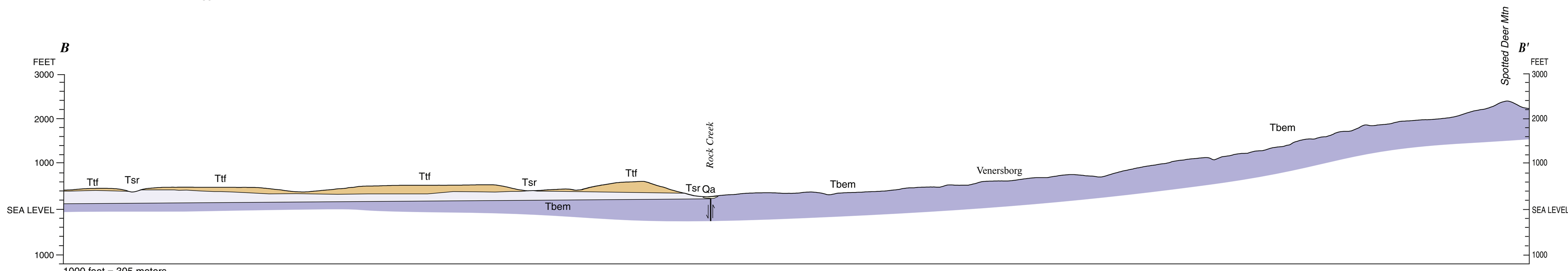
Strike and dip of platy parting in lava flows

Sample locality for chemical analysis–See table 1

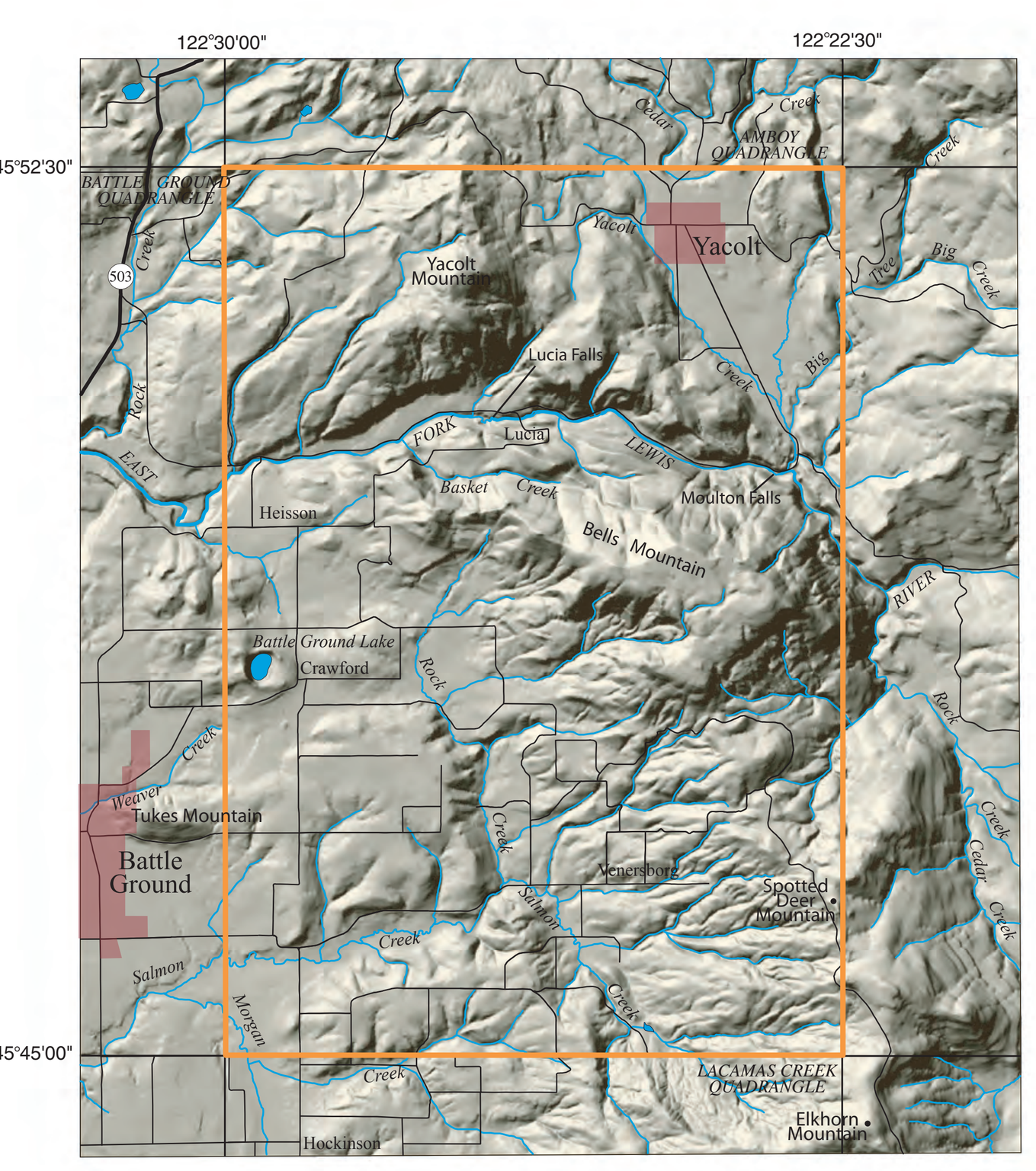
Sample locality for $^{40}Ar/^{39}Ar$ age determination–See table 2



1000 feet = 305 meters
Thickness of surficial units exaggerated



1000 feet = 305 meters
Thickness of surficial units exaggerated



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

Geologic Map of the Yacolt Quadrangle, Clark County, Washington

By

Russell C. Evarts

2006

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