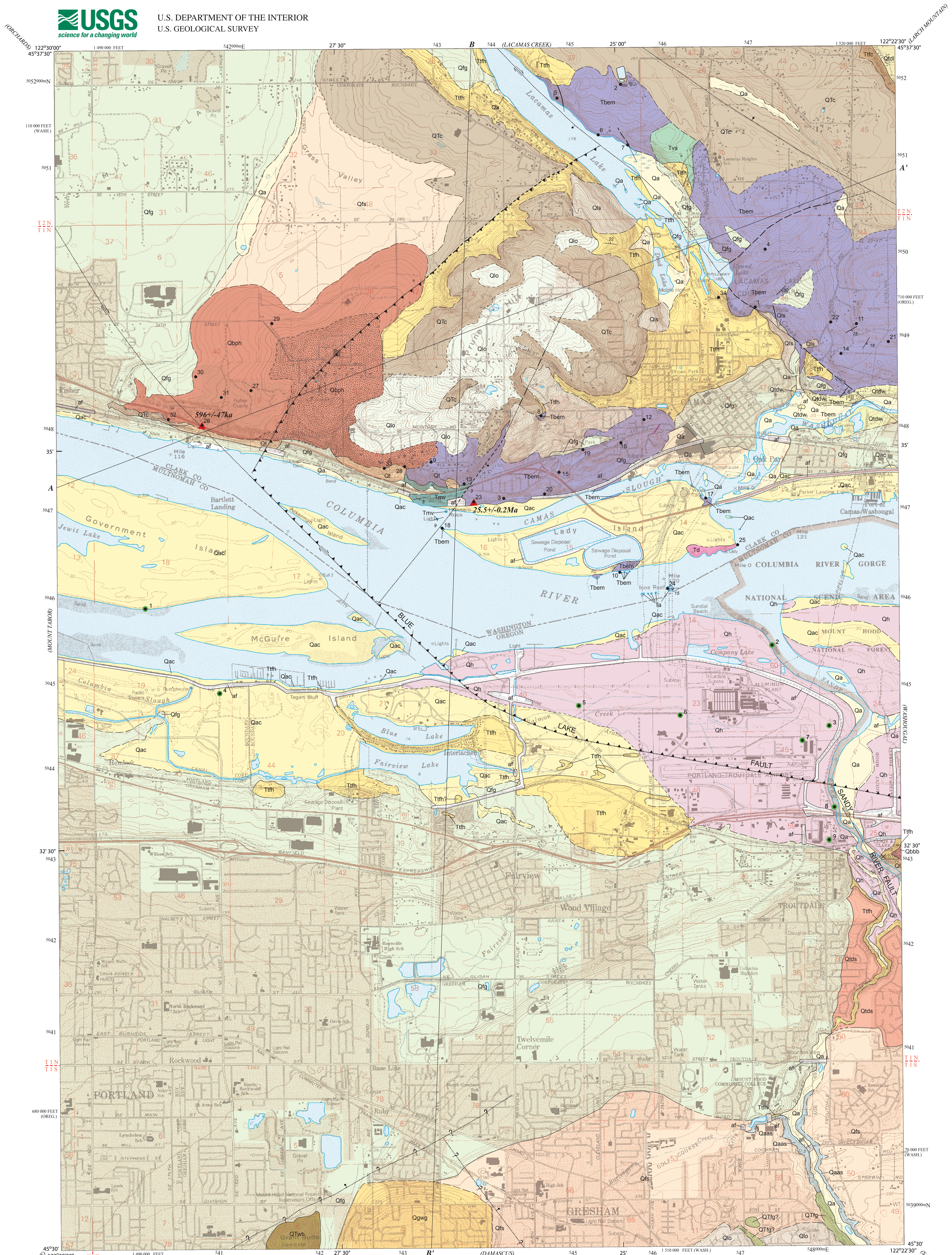


Base from U.S. Geological Survey, Camas, WA-OR, 1993
Universal Transverse Mercator projection, zone 10

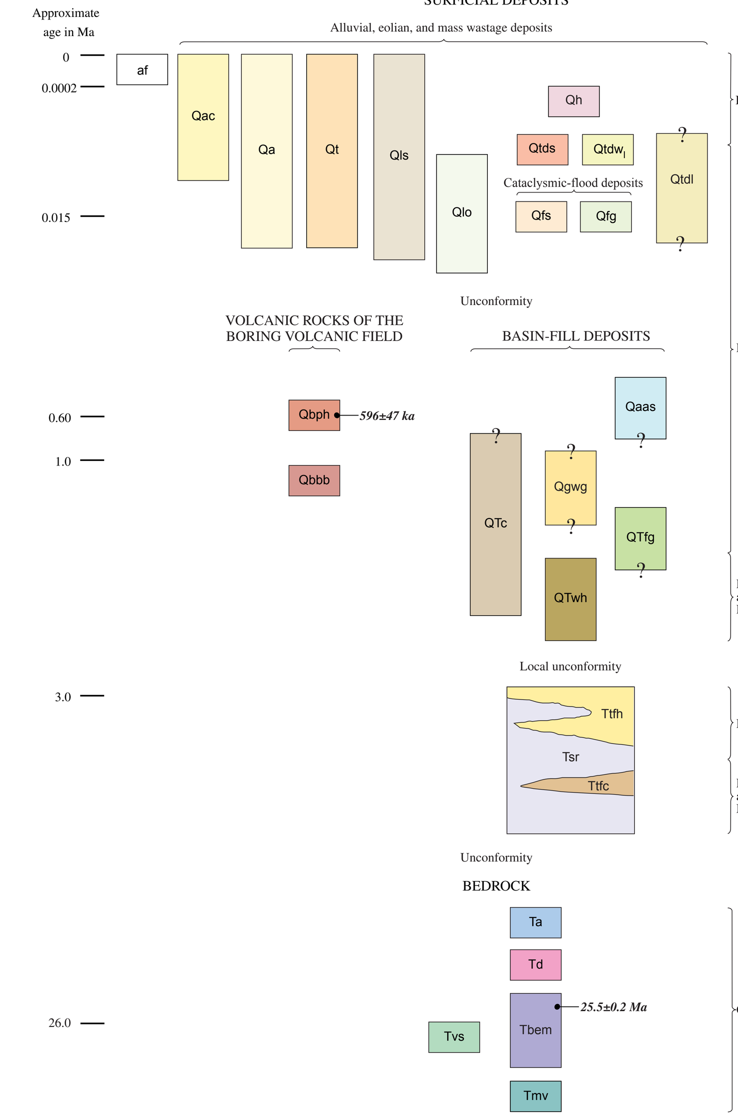
SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC DATUM OF 1929

MAP LOCATION

Geology mapped by R.C. Evarts, 1999, 2001-2006 and J.E. O'Connor, 2003-2006; assisted by P.A. Dinterman, 2002
Digital cartography by P.A. Dinterman and K.L. Wheeler
Edited by T. Iki
Manuscript approved for publication 04/21/2008

CORRELATION OF MAP UNITS



$^{40}Ar/^{39}Ar$ ages shown are from table 2

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af — **Artificial fill (Holocene)**—Unconsolidated soil, sand, gravel, and crushed rock used for highway and railroad beds and levees

Alluvial, eolian, and mass wastage deposits

Qac — **Alluvium of Columbia River floodplain and channel (Holocene and Pleistocene)**—Unconsolidated fine sand, silt, and clay that underlies historic floodplain, islands, and bars of the Columbia River at elevations less than 30 ft (10 m); composed largely of quartz, feldspar, and conspicuous muscovite. Sections exposed in banks, excavations, and drill-core samples commonly show sand-silt couplets up to 30 cm thick; basal sands locally display ripple cross lamination, planar lamination, and tabular foresets; capping silt and clay beds generally massive and bioturbated; couplets interpreted as deposits of large annual Columbia River freshets before substantial 20th century river regulation and floodplain diking. Unit includes local diatomaceous beds and layers of organic-rich sediment that probably formed in floodplain marshes, ponds, and lakes, as well as thin (less than 2 cm) tephra beds from Holocene eruptions of Mount St. Helens. Regionally, most deposits above modern low-water river level (3 ft (1 m) above sea level in map area) are younger than 2000 years old and most deposits forming Government Island are younger than 500 yr B.P. (table 3). Well logs and seismic reflection profiles show that fine-grained valley fill beneath the historic floodplain, presumably representing river aggradation since the last-glacial sea level low stand of about 15,000 yr B.P. (Baker, 2002), locally extends to 300 ft (90 m) below sea level in the map area (Hoffstetter, 1984; Hartford and McFarland, 1989; Gates, 1994; Pratt and others, 2001; Rapp, 2005). Near Blue Lake, deposits contain fluvially concentrated 7.7-ka Mazama tephra (Gates, 1994) at 45 ft (14 m) below sea level. Near tributary mouths, unit includes rare lenses of cobble to pebble gravel composed largely of andesite and dacite clasts; also includes local unmapped areas of dredge spoils and other fills, and possibly eolian deposits

Qa — **Alluvium (Holocene and Pleistocene)**— Unconsolidated sand, gravel, and organic-rich mud along rivers and creeks, in seasonally inundated depressions, and along shore of Lacamas Lake. Deposits along the Washougal and Sandy Rivers consist mostly of stratified sand and cobble to pebble gravel; deposits along smaller watercourses are more variable

Qt — **Talus deposits (Holocene and Pleistocene)**— Unsorted accumulations of angular basalt blocks and scoria below cliffs on south slope of Prune Hill; includes deposits of both natural and anthropogenic origins

Qls — **Landslide deposits (Holocene and Pleistocene)**— Diamictons of unsorted, angular bedrock and 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 at Camas possibly triggered by late Pleistocene cataclysmic flooding

Qh — **Deposits derived from Mount Hood volcano (Holocene)**—Unconsolidated, stratified sand and gravel and diamictons composed of volcanic debris transported down Sandy River from Mount Hood; underlie an extensive lowland north of Troutdale informally known as the Sandy River delta as well as terraces with treads as high as 40 ft (12 m) above the Sandy River; as thick as 9 m in borings and 6.5 m in riverbank outcrops (Rapp, 2005); locally contain interbeds of Columbia River overbank deposits, and almost everywhere overlain by more recent Columbia River floodplain deposits up to 1 m thick; also includes local areas of artificial fill. Sand and gravel form planar or cross-stratified beds that typically fine upwards; gray except for fine sand beds, which are locally reddish to pinkish gray. Gravel clasts are dominantly fresh, porphyritic, pyroxene and hornblende andesites; sand composed mostly of angular to sub-rounded, gray to red, lithic (andesite) fragments, 5–20 percent clear plagioclase fragments, and 2–10 percent equant hornblende crystals. Diamictons are brown to brownish gray, massive to weakly stratified beds, 0.5 to 5 m thick, composed of 30–50 percent angular andesite fragments up to 10 cm diameter in matrix of sand, silt, and clay (Rapp, 2005). Stratified sand and gravel interpreted to represent fluvial aggradation triggered by highly increased sediment supply following Mount Hood eruptions. Diamictons are interpreted as deposits of Mount Hood lahars. Numerous radiocarbon ages (table 3) and regional stratigraphic relations show that these deposits are younger than 1600 yr B.P. and were produced during and after the Timberline and Old Maid eruptive episodes of Crandell (1980); most are older than 1200 yr B.P. and are related to the Timberline period (Rapp, 2005). Old Maid-age sediment forms several channel-fill deposits, as thick as 5 m, in the Sandy River delta and aggraded in the lower Sandy River valley to elevations as high as or higher than the Timberline-age deposits (Rapp, 2005)

Qtds — **Terrace deposits of Sandy River (Holocene and (or) Pleistocene)**—Poorly exposed, unconsolidated, sandy cobble to boulder gravel forming distinct bench with surface elevation between 170 and 190 ft (48 and 58 m) along Sandy River and Beaver Creek. Consist of subhorizontal gravel sheets, 0.5–5 m thick, locally separated by thin sand lenses; poorly sorted, locally imbricated, and texture varies from compact with sand matrix to loose open-work; clasts subangular to well rounded, include common large (up to 1 m diameter) boulders of hornblende andesite; deposit contains at least one 1-m-thick bed of silty lithic-rich sand inferred to be the distal facies of a Mount Hood lahar. Exhibits weakly developed soil profile and weathering rinds on fine-grain volcanic clasts less than 1 mm thick, suggesting relative youth; absence of cover by cataclysmic (Missoula)-flood deposits indicate that unit postdates flooding; may reflect deposition behind the immense Missoula-flood bar extending southwestward from Broughton Bluff that temporarily blocked the Sandy River at its confluence with the Columbia River. Equivalent in part to Estacada Formation of Trimble (1963)

$Qtdw_l$ — **Terrace deposits of lower Washougal River (Holocene and (or) Pleistocene)**—Unconsolidated sandy gravel and sand underlying small terraces along Washougal River; generally less than 10 m thick. Gravel is poorly sorted, locally imbricated, and texture varies from compact with sand matrix to loose openwork. Clasts subangular to well rounded, derived from Tertiary volcanic and granitic rocks of Cascade Range, Columbia River Basalt Group, and Troutdale Formation. Deposits are below 50 ft (15 m) elevation and minimally weathered; inferred to represent aggradation behind coarse-grained Missoula Flood bar that now constricts mouth of Washougal River

Qtdl — **Terrace deposits of Little Washougal River (Holocene and (or) Pleistocene)**—Unconsolidated gravel and sand flanking Little Washougal River near northeastern corner of map area; about 2–5 m thick. Gravel is poorly sorted, composed of subangular to well rounded clasts derived from Tertiary volcanic and granitic rocks of Cascade Range, Columbia River Basalt Group, and Troutdale Formation. Minimal soil development. Formed by aggradation behind downriver landslide complex in adjacent Washougal quadrangle (R.C. Evarts and J.E. O'Connor, unpub. mapping)

Qlo — **Loess (Pleistocene)**—Massive unconsolidated deposits of light-gray to buff, micaceous, quartzofeldspathic eolian silt and fine sand; commonly contains isolated granules and small pebbles; generally capped with strongly developed red soils. Forms widespread mantle on uplands of map area but mapped only where thick (about 3 to 25 m) and extensive enough to obscure underlying units. Overlies 596-ka basaltic andesite of Prune Hill, but probably deposited during several episodes throughout late Quaternary time. Below about 300 ft (90 m) elevation, may include slack-water cataclysmic-flood deposits (Qfs)

Cataclysmic-flood deposits (Pleistocene)—Sediment deposited by colossal glacier-outburst floods caused by repeated failure of ice dam across Clark Fork River that formed Pleistocene Lake Missoula in western Montana (Bretz, 1925, 1959; Bretz and others, 1956; Trimble, 1963; Allison, 1978; Baker and Bunker, 1985; Waitt, 1985, 1994, 1996; Atwater, 1986; O'Connor and Baker, 1992; Benito and O'Connor, 2003). The Missoula floods achieved stages of 400–500 ft (120–150 m) as they spread and slowed over the eastern Portland Basin after exiting the western Columbia River Gorge with velocities of 35 m/s at peak discharge (Benito and O'Connor, 2003) and deposited coarse traction load in series of large bars and plains, the Portland delta of Bretz (1925). 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; Benito and O'Connor, 2003; Clague and others, 2003). Coarse bedload deposits and fine slack-water deposits mapped separately

Qfs — **Sand and silt facies**—Unconsolidated light brown to light gray silt, clay, and fine to medium sand. Up to 20 m thick at low elevations in the region but thins toward upper mappable extent at 300–350 ft (90–105 m) elevation in the map area. Upper map limit only approximately placed on basis of topography owing to the difficulty in distinguishing from similar loess and clayey soils that cover most upland surfaces. Most exposures obscure, but rare fresh exposures show multiple, 0.25-to-1.5-m thick, fining-up sequences of ripple cross-stratified very fine sand grading up to massive bioturbated clayey silt. Sand composed of quartz, feldspar, and conspicuous muscovite, indicative of a Columbia River provenance. Coarser sand facies contain abundant dark volcanic rock fragments. Interpreted as slack-water sediment settled from temporarily ponded floodwater. May locally include compositionally identical loess

Qfg — **Gravel facies**—Unconsolidated, gray, stratified, bouldery to cobbly gravel and sand deposited in thick sheets over older basin-fill deposits on upland areas flanking the Columbia River; organized into prominent large bar and channel complexes on Mill Plain in the northwest part of map area and much of east Portland, Fairview, and Troutdale south of the river (Allison, 1978; Minervini and others, 2003). Beneath Holocene floodplain deposits (Qac) northeast of Blue Lake, flood gravel occupies buried late glacial channel; channel floor is at least 230 ft (70 m) below sea level (Hartford and McFarland, 1989; Pratt and others, 2001). Locally, as along southern edge of the historic Columbia River floodplain and in the Lacamas Lake trough, Missoula-flood deposits form thin (<2 m) and discontinuous mantle on older basin-fill and bedrock units. Numerous active and historic quarry exposures in upland areas reveal more than 15 m of crudely stratified and poorly sorted coarse gravel and sand, commonly deposited in tall (locally >5 m), steeply dipping (up to 35º) foresets. Deposits generally fine westward and away from the Columbia River; in some places, contain immense boulders, some exceeding 4 m in long diameter, particularly near Troutdale and along southwest side of Prune Hill. Texturally and compositionally variable; most clasts derived from Columbia River Basalt Group but includes blocks of Troutdale Formation and Pliocene–Quaternary Cascadian basalt, all probably entrained in the western Columbia River Gorge; locally, such as southwest of Prune Hill, consists of large, angular-to-subangular blocks eroded from nearby valley walls. Sweeping unconformities visible in large fresh exposures likely reflect multiple flood events (Benito and O'Connor, 2003). Unit includes local sand accumulations below 200 ft (60 m) elevation, some of them mapped as sand and silt deposits (Qs) by Trimble (1963), that were probably deposited by smaller late-episode floods confined to the narrow Columbia River valley of late Pleistocene time

VOLCANIC ROCKS OF THE BORING VOLCANIC FIELD

Qbph — **Basaltic andesite of Prune Hill (Pleistocene)**—Light- to medium-gray, microvesicular, olivine-phyric, calc-alkaline basaltic andesite (54–55 wt percent SiO_2) that underlies area directly west of Prune Hill; well developed platy and columnar jointing; up to 65 m thick in Fisher Quarry, where complex jointing patterns and contacts with scoriaceous flow breccia indicate multiple flow lobes. Contains phenocrysts of olivine (3–7 percent; about 0.5 mm, locally to 1 mm across; with minute chromian spinel inclusions), plagioclase (0.1 percent; 0.5–1 mm long), and augite (0.1 percent) in trachytic to intergranular, locally microvesicular groundmass of plagioclase, pyroxene, Fe-Ti oxide, and dark-brown interstitial glass; distinguished by presence of prismatic hypersthene microlites. Some samples contain corroded and sieved plagioclase xenocrysts about 1 mm across. Vent located east of Fisher Quarry in area underlain by scoria deposits (stipple pattern) and coincident with a strong positive aeromagnetic anomaly (Snyder and others, 1993). Well sorted to poorly sorted scoria beds consist of black to brick-red, variably vesicular clasts as large as 1 m across that are petrographically and chemically similar to associated lava flows; also commonly contain well-rounded pebbles and cobbles of Columbia River Basalt Group and quartzite derived from basin-fill sediments. Normal magnetic polarity (J.T. Hagstrum, written commun., 2000). $^{40}Ar/^{39}Ar$ age of 596±47 ka (table 2) is indistinguishable from K-Ar age of 590±50 ka reported by Conrey and others (1996a)

Qbbb — **Basaltic andesite of Broughton Bluff (Pleistocene)**—Light-gray, olivine-phyric, calc-alkaline basaltic andesite flow (52–53 wt percent SiO_2) (R.C. Evarts and R.M. Conrey, unpub. data); flow caps Broughton Bluff and has well developed columnar jointing; probably erupted from vent at Chamberlain Hill about 3 km to east. Contains phenocrysts and microphenocrysts of olivine (about 9 percent; mostly 0.5 to 1 mm but a few as large as 3 mm across; with inclusions of chromian spinel; locally replaced by iddingsite) in a trachytic to subophitic groundmass of plagioclase, augite, and Fe-Ti oxide. Reversed magnetic polarity (J.T. Hagstrum, written commun., 2002). An $^{40}Ar/^{39}Ar$ age of 1.282±0.014 Ma was obtained from a sample collected just east of the map area (R.J. Fleck, written commun., 2008)

BASIN-FILL DEPOSITS

Qaas — **Alluvium of ancestral Sandy River (Pleistocene)**—Unconsolidated to well-cemented sandy gravel underlying uplands west of the Sandy River. Poorly exposed along Beaver Creek, but well exposed beneath 12 to 18 m of cataclysmic-flood gravel (Qfg) in gravel pit 1 km north of Grant Butte; likely underlies flood gravel (Qfg) and loess (Qlo) throughout most of terrain south of Interstate 84. Gravel crudely stratified and well sorted, contains abundant well-rounded clasts up to 20 cm across of basaltic and andesitic rocks derived from Cascade Range (including Mount Hood volcano) and sparse clasts of Columbia River Basalt Group and quartzite. Sand lenses, generally less than 1 m thick and 10 m long, composed chiefly of volcanic lithic grains; lack quartz and muscovite. Along Beaver Creek, unit includes poorly sorted debris-flow deposits that contain subrounded Mount Hood-derived pyroxene and hornblende andesite clasts as large as 1 m diameter. Unit at least 50 m thick in gravel pit north of Grant Butte; upper 11 to 15 m is distinctly lighter colored than the more oxidized and cemented dark gray sandy gravel composing lowermost 35 m; surface of upper gravel descends to north and west, indicating northwesterly transport, consistent with clast imbrication. Distribution, sedimentary texture and composition of unit indicate deposition during major, glacially induced(?), aggradational episodes of the ancestral Sandy River, producing a broad fan or braidplain extending north and west into the eastern Portland Basin. Interbedded debris-flow deposits record lahars associated with eruptive activity at Mount Hood. Age poorly constrained; overlies weathered surfaces on the hyaloclastic sandstone member of the Troutdale Formation (Ttfh); weak soil development indicates probable middle-to-late Pleistocene age

QTc — **Conglomerate (Pleistocene and Pliocene?)**—Unconsolidated to cemented, thick bedded, pebble to boulder conglomerate with minor beds (<2 m thick) and lenses of basaltic and quartzofeldspathic sandstone; up to 90 m thick. Conglomerate varies from well sorted, clast-supported, imbricated and crossbedded deposits composed largely of well rounded clasts of Columbia River Basalt Group and quartzite to poorly sorted deposits dominated by subangular to subrounded clasts of volcanic rocks eroded from Cascade Range. Deeply weathered except east of Lacamas Lake where top was removed by Missoula floods. Age poorly constrained; gradationally to unconformably overlies hyaloclastic sandstone member of Troutdale Formation (Ttfh); probably of latest Pliocene or early Pleistocene age

Qgwg — **Gravel west of Gresham (Pleistocene)**—Unconsolidated sandy gravel underlying low hill between Gresham and Grant Butte. Consists of well rounded to subrounded pebbles and cobbles (up to 20 cm diameter) of volcanic rocks, chiefly andesites, derived from Cascade Range to the east, in oxidized silty matrix. Clasts minimally weathered and weathering rinds on fine-grained volcanic clasts are less than 5 mm thick, indicating a Pleistocene age. Topographic position suggests this unit is older than the uppermost gravel of the ancestral Sandy River alluvium (Qaas) exposed in excavation immediately to northwest, but it may be an erosional remnant correlative with the lithologically similar deeper gravel

QTfg — **Unnamed fan gravel (Pleistocene and Pliocene?)**—Deeply weathered unconsolidated sand and cobbly gravel poorly exposed along Beaver Creek valley near southern map boundary; underlies extensive northwest sloping piedmont surface south of the map area and west of Sandy River. Clasts consist chiefly of andesite and other Cascade Range rock types; weathering rinds on clasts exceed 1 cm thick. Locally includes diamicts, interpreted as lahar and lahar-runout deposits, that contain 1-m-diameter clasts of pyroxene and hornblende andesite. Capped by as much as (25 m) of strongly oxidized and pedogenically altered micaceous silt, inferred to be loess (Qlo). Morphology and composition of unit indicate deposition in broad fan by an ancient Sandy River draining Cascade Range. Topographic position, degree of weathering, and thick overlying loess mantle imply substantial age, probably early Pleistocene or late Pliocene. Lahar deposits derived from an ancient volcanic center, possibly the Sandy Glacier volcano (Wise, 1969; Sherrod and Scott, 1995) located in the Mount Hood area. Mapped as Springwater Formation by Trimble (1963), but geomorphic relations outside the map area indicate that it is probably younger than deposits in the type area near Springwater, about 30 km south of map area

QTwh — **Walters Hill Formation (Pleistocene and (or) Pliocene)**—Semiconsolidated, deeply weathered, poorly exposed fluvial gravel forming Grant Butte. Consists of well-rounded to subrounded cobbles and pebbles of volcanic rocks, predominantly porphyritic andesites derived from Cascade Range to the east; matrix is coarse to fine volcaniclastic sand. Age unknown; topographic position suggests unit is younger than Troutdale Formation (Ttfh) and older than other gravel units (QTc, QTfg, Qgwg, Qaas) in map area

Troutdale Formation (Pliocene and Miocene)—Semiconsolidated to well consolidated conglomerate and sandstone. Divided into two informal members separated by an unconformity

Ttfh — **Hyaloclastic sandstone member (Pliocene)**—Fluvial sedimentary strata distinguished by indurated, coarse sandstone composed of abundant grains of glassy, olivine+plagioclase-phyric basalt and conglomerate that contains olivine-bearing basalt clasts; overlies and intertongues with micaceous, arkosic sandstone, siltstone, and claystone of the Sandy River Mudstone (Tsr). Well exposed in valley of Lacamas Creek, on west shore of Lacamas Lake, and along Sandy River east of Troutdale. Hyaloclastic sandstone (equivalent to vitric sandstone of Trimble (1963) and Tolan and Beeson (1984)) consists largely to entirely of angular to subrounded fragments, 2 to 6 mm across, of black, generally nonvesicular basalt that contains phenocrysts of olivine (0.5–2 mm) and plagioclase (1–3 mm) in a glassy (sideromelane) to intergranular groundmass; sideromelane partly to completely altered to palagonite, which cements sandstone and imparts a distinctive yellowish-brown color to the originally dark-green rock; many beds contain minor admixed nonvolcanic debris such as quartz, muscovite, hornblende, and potassium feldspar. Sandstone ranges from poorly sorted to well sorted; typically thick-bedded, commonly lenticular, crossbedded, and contains dispersed pebbles and cobbles of olivine-bearing basalt. Interbedded conglomerate mostly well-sorted and clast supported; consists of well rounded to subrounded pebbles and cobbles of variably vesicular, olivine+plagioclase-phyric basalt, basaltic rocks of Columbia River Basalt Group, and generally minor amounts of quartzite and other rock types; some conglomerate beds poorly sorted, with subangular basalt boulders as large as 1 m across. Angular nonvesicular vitric clasts in hyaloclastic sandstone beds interpreted as debris generated by basalt-water interaction in the Columbia River Gorge and rapidly transported downstream and deposited in eastern Portland Basin (Trimble, 1963; Swanson, 1986, 1988). Vitric clasts and associated basalt cobbles exhibit a low-potassium-tholeiite composition (Swanson, 1986, 1988; Lite; 1992; A.W. Sarna-Wojcicki, written commun., 2005; table 1, no. 34), indicating probable derivation from compositionally similar middle Pliocene basalt flows east of map area (Tolan and Beeson, 1984; Swanson, 1986, 1988; R.C. Evarts and R.M. Conrey, unpub. mapping). Leaf fossils from fine-grained interval within unit below Broughton Bluff date as early Pliocene (Trimble, 1963). Approximately equivalent to informal upper member of Troutdale Formation of Tolan and Beeson (1984)

Ttfc — **Conglomerate member (Pliocene? and Miocene)**—Indurated, well-sorted, clast-supported, pebble and cobble conglomerate exposed on steep valley wall of Little Washougal River near northeast corner of map area. Composed largely of well-rounded clasts of Columbia River Basalt Group with minor but persistent quartzite and granitic and felsic metamorphic rocks. Sparse interbeds of micaceous quartzofeldspathic sandstone. Equivalent in part to upper member of Troutdale Formation of Mundorff (1964); correlative with lower member of Troutdale Formation of Tolan and Beeson (1984) and with quartzite-clast member of Troutdale Formation of Howard (2002) (see fig. 5). Late Miocene to early Pliocene age inferred from stratigraphic relations east of quadrangle (Tolan and Beeson, 1984)

Tsr — **Sandy River Mudstone (Pliocene and Miocene)**—Shown in cross sections only. Semiconsolidated, well-bedded, fluvial and lacustrine sandstone, siltstone, claystone, and minor quartzite-bearing conglomerate, pumice-lapilli tuff, and lignite; not exposed in map area but water-well logs indicate this unit may be more than 300 m thick near western edge of quadrangle (Hartford and McFarland, 1989; Swanson and others, 1993). Approximately equivalent to informal lower member of Troutdale Formation as defined by Mundorff (1964). Age poorly known but probably ranges from middle Miocene to middle Pliocene; upper part underlies or interbedded with lower part of hyaloclastic sandstone member of Troutdale Formation, inferred to be about 3 to 4 m.y. old; plant fossils from localities near top of unit along Sandy River to southeast of quadrangle assigned an early Pliocene age (Chaney, 1944; Treasher, 1942; Trimble, 1963; Tolan and Beeson, 1984)

BEDROCK

Ta — **Andesite (Oligocene)**—Platy porphyritic to seriate andesite forming Ione Reef in Columbia River. Contains phenocrysts of plagioclase (18 percent; 1–2 mm long) and sparse microphenocrysts of orthopyroxene and Fe-Ti oxide in an intergranular groundmass of plagioclase, pyroxene, Fe-Ti oxide, and minor interstitial brown smectite. Age unknown but overlies basaltic andesite of Elkhorn Mountain (Tbem)

Td — **Dacite (Oligocene)**—Sparsely plagioclase-phyric dacite flow and flow breccia exposed at east end of Lady Island; exhibits pronounced platy parting with widely variable orientation. Contains phenocrysts of plagioclase (1 percent; 0.5–1 mm long), olivine (0.5–1 mm across; 0.1 percent), and clinopyroxene (0.5–1 mm across; 0.1 percent) and microphenocrysts of Fe-Ti oxide and apatite in a pilotaxitic groundmass. Age unknown but overlies basaltic andesite of Elkhorn Mountain (Tbem)

Tbem — **Basaltic andesite of Elkhorn Mountain (Oligocene)**—Sequence of lava flows and flow breccia composed of dark-gray to brown, porphyritic to seriate to aphyric tholeiitic basaltic andesite and basalt; individual flows generally about 5 to 8 m thick, exhibit platy to blocky to columnar jointing; unit locally includes minor volcaniclastic rocks too thin or poorly exposed to map. Typical flows contain phenocrysts and glomerocrysts of weakly zoned plagioclase (0–40 percent; 1–6 mm, rarely more than 10 mm long; variably replaced by zeolites and (or) clay) and olivine (<2 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; almost invariably replaced by some combination of smectite, hematite, carbonate, serpentine, quartz and kaolinite). Some flows also contain phenocrysts of augite (<1 percent; 0.5 to 1 mm across) and microphenocrysts of Fe-Ti oxide. Groundmass consists of plagioclase, augite, Fe-Ti oxide, and minor to abundant interstitial glass (largely devitrified or replaced by smectite, quartz, or calcite); groundmass textures chiefly intergranular to trachytic, less commonly subophitic or microphyric. All flows in unit are tholeiitic, and many are exceptionally rich in Fe (FeO* as high as 13.3 wt percent) and poor in Sr (<320 ppm) compared to mafic rocks elsewhere in southern Washington Cascade Range (du Bray and others, 2006; R.C. Evarts, unpub. data). $^{40}Ar/^{39}Ar$ age of 25.5±0.2 Ma obtained for sample near top of unit north of Camas Slough

Tvs — **Volcaniclastic sedimentary rocks (Oligocene)**—Section of weathered, poorly exposed volcaniclastic rocks interbedded with basaltic andesite flows (Tbem) east of Lacamas Creek; approximately 30 m thick. Primarily massive, light-green to dark-brown, lithic lapilli tuff composed of angular to subrounded volcanic lithic and pumice clasts to 5 cm across in sandy to silty matrix; pervasively altered to smectite, kaolinite, and zeolites. Abundance, variety, and subrounded character of lithic clasts suggests unit consists largely of debris-flow rather than primary pyroclastic-flow deposits

Tmv — **Mafic volcaniclastic rocks (Oligocene)**—Indurated, olive-brown, mafic tuff breccia, lapilli tuff, and minor tuff; distinct decimeter-scale stratification defined by gradational variations in grain size; moderately well sorted to poorly sorted; composed largely of angular fragments as large as 60 cm across of texturally variable, lithic to scoriaceous, basalt and basaltic andesite. Unit locally contains rounded lithic clasts and blackened wood fragments; one exposure displays matrix-poor, talus-like deposit of angular blocks to 2 m across; cemented by clay, zeolites, calcite

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

Fault—Dashed where inferred; dotted where concealed, queried where existence or extent uncertain. Ball and bar on downthrown side. Arrows show relative horizontal movement.

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

Strike and dip of beds

Strike and dip of platy parting in lava flows

Basaltic andesite dike

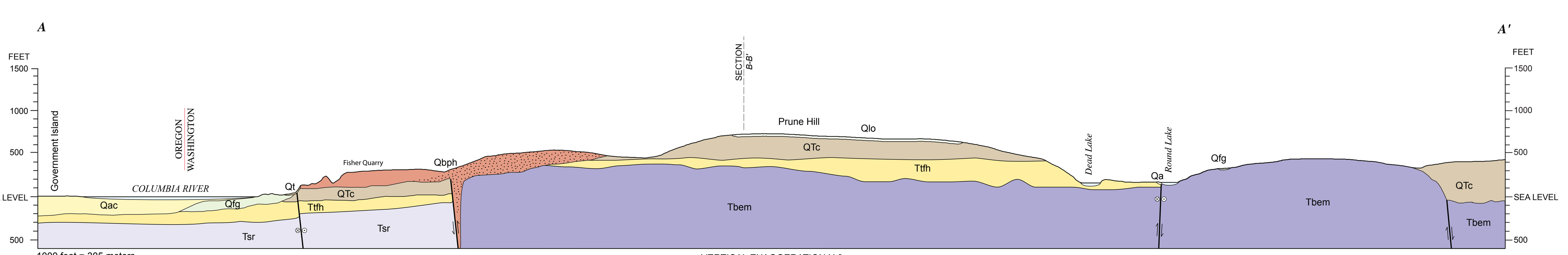
Sample locality for chemical analysis—See table 1

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

Paleoflora locality

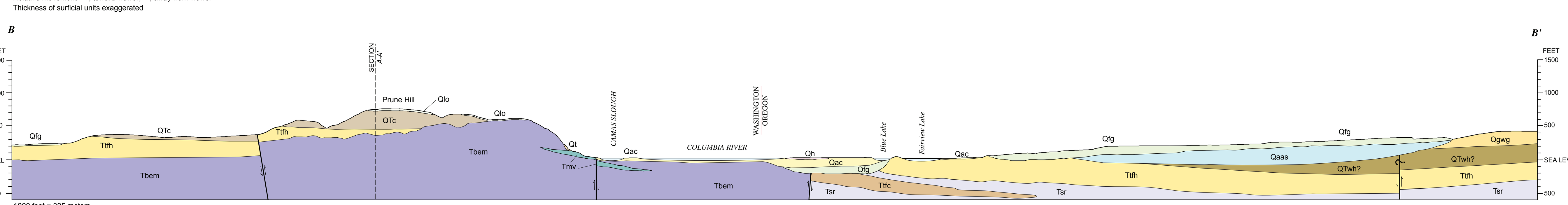
Radiocarbon age locality—See table 3

Cinder cone



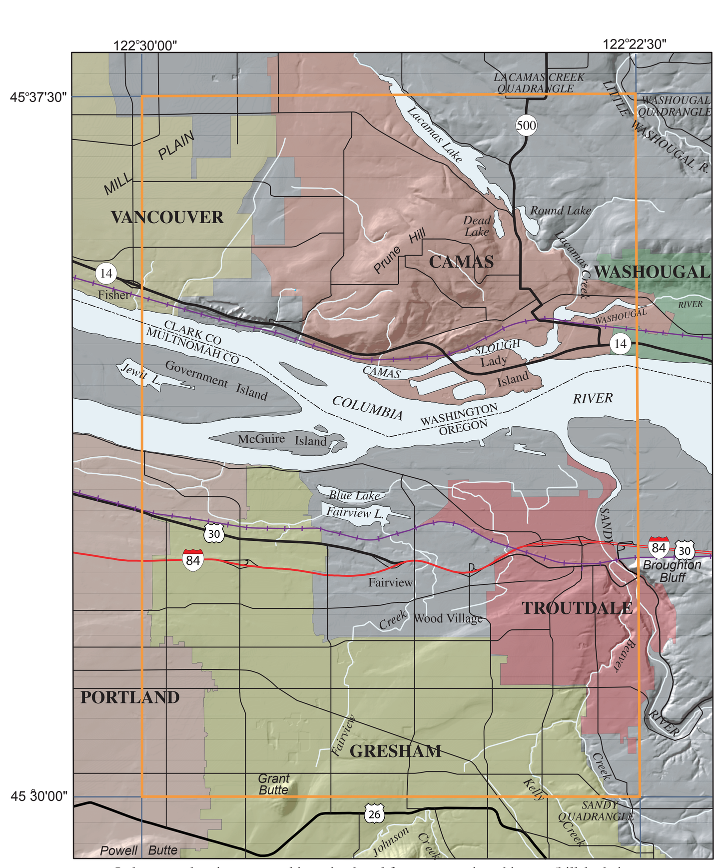
1000 feet = 305 meters
Relative movement - +, toward viewer; •, away from viewer
Thickness of surficial units exaggerated

VERTICAL EXAGGERATION X 2



1000 feet = 305 meters
Artificial fill (unit af) too thin to portray on cross section
Thickness of surficial units exaggerated

VERTICAL EXAGGERATION X 2



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

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Geologic Map of the Camas Quadrangle, Clark County, Washington, and Multnomah County, Oregon

By
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