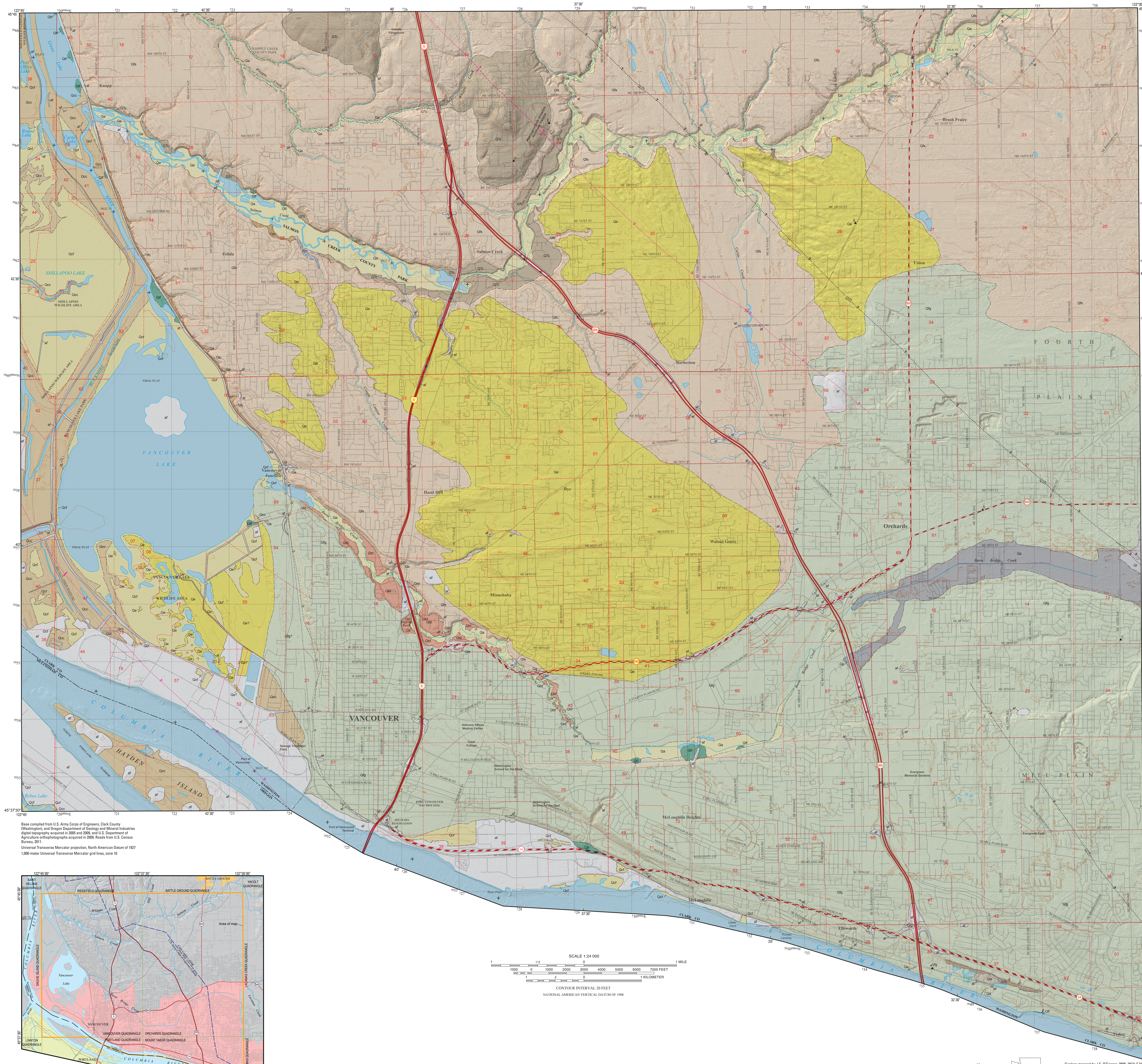
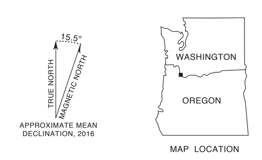


Base compiled from U.S. Army Corps of Engineers, Clark County (Washington), and Oregon Department of Geology and Mineral Industries digital topography acquired in 2005 and 2009, and U.S. Department of Agriculture orthophotographs acquired in 2009. Roads from U.S. Census Bureau, 2011.
Universal Transverse Mercator projection, North American Datum of 1927
1,000-meter Universal Transverse Mercator grid ticks, zone 10

SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 20 FEET
NATIONAL AMERICAN VERTICAL DATUM OF 1988

INDEX MAP SHOWING GEOGRAPHIC AND CULTURAL FEATURES OF MAPPING AREA (ORANGE OUTLINE) AND VICINITY ON HILLSHADE IMAGE DERIVED FROM LIDAR DATA. DASHED BLUE LINE SHOWS BOUNDARY BETWEEN U.S. ARMY CORPS OF ENGINEERS AND CLARK COUNTY LIDAR DATA USED TO CREATE BASE TOPOGRAPHY

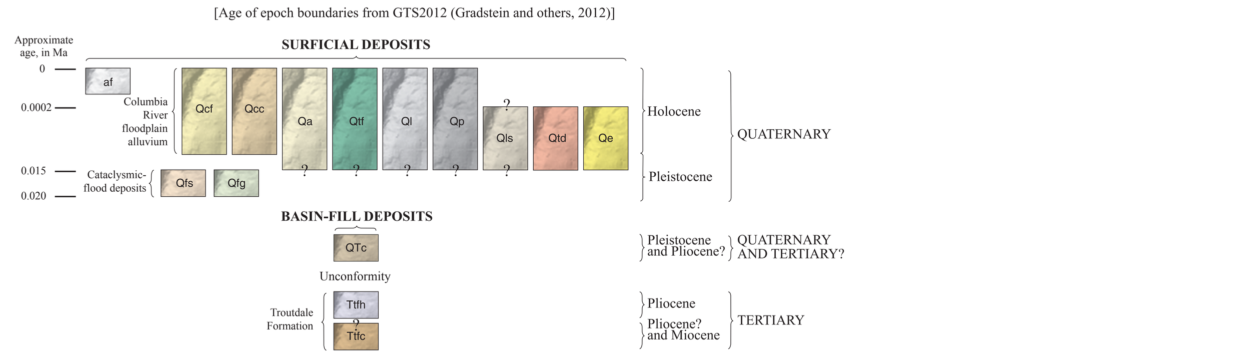


APPROXIMATE MEAN DECLINATION, 2016
MAP LOCATION

Geology mapped by J.E. O'Connor, 2008–2012; C.M. Cannon, 2010–2012; R.C. Evarts, 2004–2012; and J.F. Mangano, 2010–2012
Digital cartography by J.F. Mangano
Edited by Katherine Jacques and Regan Austin
Manuscript approved for publication May 26, 2016

CORRELATION OF MAP UNITS

[Age of epoch boundaries from GTS2012 (Gradstein and others, 2012)]



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial fill (Holocene)**—Unconsolidated soil, sand, and gravel that underlie industrialized floodplain areas of Vancouver and Hayden Island; includes mounds of sand and minor gravel from channel dredging, and earth and crushed rock used for levees, railroad beds, and highways, particularly Interstate Routes 5 and 205 (I-5, I-205)

Columbia River floodplain alluvium (Holocene)—Unconsolidated sediment of modern floodplain, islands and bars of the Columbia River at elevations mostly less than 30 ft (10 m) above sea level (altitudes referenced to National Geodetic Vertical Datum of 1988); largely composed of quartz, feldspar, and conspicuous muscovite, indicating Columbia River provenance. Upper elevation limit of deposits approaches maximum extent of historical flooding before 20th-century river regulation and floodplain diking; the 1894 flood attained a maximum stage of 39.8 ft (12 m) above sea level at Vancouver. Most deposits above typical low-water river level are younger than 2,000 years (Evarts and O'Connor, 2008; Evarts and others, 2009a). Mostly corresponds to Sauvie Series soils (McGee, 1972), and Trimble's (1963) alluvium (Qal). Well logs and seismic-reflection profiles show that fine-grained valley fill beneath historic floodplain locally reaches 210–250 ft (65–75 m) below sea level and in and near the map area (Gates, 1994; Pratt and others, 2001; Peterson and others, 2011, 2013). Deposited from river aggradation since the last glacial sea-level low stand at about 16 ka (Baker and others, 2010); deposits at 210 ft (64 m) below sea level at the I-5 crossing are 11.32–11.33 ka (Peterson and others, 2011); in the same core, the 7.7 ka Mazama tephra is at 122 ft (37.2 m) below sea level (Peterson and others, 2013). Silt and clay facies mapped separately from predominantly sand facies

Qcf **Silt and clay facies**—Silt, clay, and minor sand deposited on low-lying areas of the Columbia River floodplain less than 10 ft (3 m) above sea level. Includes area of drained Shillapoo Lake. Bank exposures, auger holes, and trenches show silt, clay, and organic materials in horizontal laminae 0.04–0.8 in (1–20 mm) thick. Probably formed from this overbank deposition during floods, and local deposition and in-situ accumulation of organic materials in marshes, ponds, and lakes

Qcc **Sand facies**—Sand and silt commonly as much as 30 ft (9 m) above sea level forming crevasse splays and natural levees along floodplain channels. Exposed stratigraphy outside map area shows stratified fine to medium sand in layers as thick as 1 ft (30 cm), alternating with silty sand. Subhorizontal and inclined beds indicate deposition by both vertical and lateral accretion

Qa **Alluvium of small streams and creeks (Holocene and Pleistocene?)**—Unconsolidated sand, gravel, and organic-rich mud of modern channels and floodplains, excluding the Columbia River floodplain. May include late Pleistocene terrace deposits, especially in upstream parts of Salmon Creek where valley-bottom morphology is poorly resolved from available topography. Most extensive along Salmon Creek and Burnt Bridge Creek

Qff **Fan deposits (Holocene and Pleistocene?)**—Unconsolidated silt, sand, and gravel in small fan-shaped accumulations at mouths of small and steep drainages. Mostly Holocene, inferred from relation to 20–1 ka cataclysmic-flood deposits and Columbia River floodplain deposits. Not exposed, but likely composed of sand and gravel diamicts deposited by debris flows and stratified sediment deposited by streamflow. Includes areas of debris flow deposits shown in Burns and others (2012)

Ql **Lake deposits (Holocene and Pleistocene?)**—Black to gray silt, mud, and organic material underlying valley of Burnt Bridge Creek east of I-205; contiguous to large area underlying Lacamas Creek valley east of map area. Distinguished from alluvium of small streams and creeks (Qa) and peat and organic-rich alluvium (Qp) by extent of Cove Series soils (McGee, 1972). Mostly Holocene, inferred from relation to 20–15 ka cataclysmic-flood deposits

Qp **Peat and organic-rich alluvium (Holocene and Pleistocene?)**—Organic-rich fine alluvium and peat underlying poorly drained valley bottom along Burnt Bridge Creek east of I-205. Mostly Holocene, inferred from relation to 20–15 ka cataclysmic-flood deposits. Map extent similar to Trimble's (1963) bog deposits (Qb), and the Semiahmoo and Tisch Series of organic and clayey soils composed of peat and diatomaceous earth that underlie depressions and former marsh and lake basins (McGee, 1972)

Qls **Landslide deposit (Holocene? or Pleistocene?)**—Diamict of unsorted debris transported downslope en masse. Single occurrence in map area involved unnamed conglomerate (QTc) along Columbia valley slope east of I-205. Position and morphology indicate this landslide formed after the late Pleistocene cataclysmic floods of 20–15 ka

Qtd **Terrace alluvium (Holocene and Pleistocene)**—Unconsolidated silt, sand, and gravel that form benches along Burnt Bridge Creek. Not exposed at surface in map area. Likely formed of stratified alluvium as Burnt Bridge Creek incised through and reworked cataclysmic flood deposits during late Pleistocene and Holocene

Qe **Eolian deposits (Holocene and Pleistocene)**—Unconsolidated massive sand and silt broadly covering upland areas. Forms undulating, apparently wind-fluted topography, locally shaped into parabolic dunes. Mapped only where undulating surfaces imply thick accumulations, but most upland surfaces are covered by variable thicknesses of eolian silt and sand. Mostly quartzofeldspathic sand containing muscovite and minor lithic fragments; in places difficult to distinguish from sand and silt facies of the cataclysmic-flood deposits (Qfs). Uncertain extent south of Vancouver Lake where undulating topography and higher benches may also be partly underlain by cataclysmic-flood deposits. Commonly mapped as Hillsboro loam soils (McGee, 1972); shown mostly as sandy phase, lacustrine deposits (Qlc) by Trimble (1963). Likely formed by easterly winds entraining cataclysmic-flood deposits and Columbia River beach and bar sand. Historically inactive but position atop cataclysmic-flood deposits requires late Pleistocene or Holocene age. Radiocarbon ages from eolian silt on uplands east of map area, show episodic deposition through the Holocene (Punke and others, 2011)

Cataclysmic-flood deposits (Pleistocene)—Sediment deposited by colossal glacier-outburst floods caused by repeated breaching of ice dam that impounded Pleistocene Lake Missoula in western Montana (Bretz, 1925, 1959; Allison, 1978; Waitt, 1980, 1985; Hanson and others, 2012). Largest floods achieved stages of 400 ft (120 m) above sea level as they spread over the eastern Portland Basin. Flow velocity slowed northwestward across map area, from a maximum of 115 ft/s (35 m/s) at peak discharge (Benito and O'Connor, 2003) in the western Columbia River Gorge. Slackening currents deposited coarse bedload in huge bars and plains in eastern part of map area, and finer suspended sediment to the west and north (Trimble, 1963; Mundorff, 1964). Radiocarbon and tephrochronologic data outside the map area indicate depositional ages between about 20 and 15 ka (Waitt, 1985, 1994; Atwater, 1986; Benito and O'Connor, 2003; Clague and others, 2003; O'Connor and Benito, 2009). 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. May be 200 ft (60 m) thick near Felida, south of the Salmon Creek valley; thins toward upper mappable extent at 310 ft (95 m) above sea level in map area. Upper elevation limit only approximately placed on basis of topography owing to difficulty in distinguishing from loess and clayey soils that cover most upland surfaces. Most exposures obscure, but rare fresh exposures show multiple, 0.82–4.9 ft (0.25–1.5 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, indicating Columbia River provenance. Coarser sand beds contain abundant dark volcanic rock fragments. Map extent similar to the "sandy" and the "silty and clayey" phases of Trimble's (1963) lacustrine deposits (Qls and Qlc). Interpreted as slack-water sediment settled from slowing floodwater. May locally include compositionally similar 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 and Fourth Plains (Bretz, 1925; Allison, 1978; Minervini and others, 2003; Evarts and others, 2009a; Peterson and others, 2011). On uplands of Mill Plain and Fourth Plains in the eastern map area, several quarries show more than 49 ft (15 m) of crudely stratified and poorly sorted coarse gravel and sand, commonly deposited in tall (locally > 16 ft [5 m]), steeply dipping (as much as 35°) foresets; former exposures to west showed similar features (Mundorff, 1964). In east part of map area, many rounded boulders exceed 3 ft (1 m) diameter. Many active and historic quarry exposures in upland areas reveal fining westward, and away, from the Columbia River. Poorly to moderately sorted, locally separated in part by discontinuous bedding unconformities visible in large, fresh exposures likely separate deposits of individual floods (Benito and O'Connor, 2003). Texturally and compositionally variable; most clasts derived from Columbia River Basalt Group but includes blocks of Troutdale Formation and Pliocene to Quaternary volcanic rocks, all probably entrained in the western Columbia River Gorge. On uplands, deposits overlie older basin-fill deposits, but cataclysmic-flood gravel bars step down into the Columbia River valley and locally thicken to the south and west, perhaps to as much as 200 ft (60 m) thick along I-5 through Vancouver (Peterson and others, 2011). West of Vancouver, a possibly inset bench may have been deposited by later, smaller floods. Beneath Holocene Columbia River floodplain deposits, cataclysmic-flood gravel coats and partly fills the late-glacial valley, a valley bottom incised at least 230 ft (70 m) below sea level (Hartford and McFarland, 1989; Pratt and others, 2001; Peterson and others, 2011). Mostly corresponds to Trimble's (1963) gravelly phase lacustrine deposits (Qlg), and Lauren Series gravelly loam soils (McGee, 1972)

BASIN-FILL DEPOSITS

QTc **Unnamed conglomerate (Pleistocene and Pliocene?)**—Unconsolidated to semi-consolidated, round-cobble conglomerate. Underlies Fourth Plains and Mill Plain beneath 30–70 ft (10–20 m) of cataclysmic-flood gravel, where it is commonly exposed near bottom of gravel pits. Also locally exposed along Columbia valley edge east of I-205 and along Salmon Creek valley, where it forms straths following Holocene-age creek incision of overlying cataclysmic-flood deposits. A distinctly higher, and possibly older, component underlies hills 330–390 ft (100–120 m) high in northwest part of map area. Exploratory borings along the I-5 corridor indicate this unit extends 64 m below sea level beneath the Columbia River, where it is inferred to overlie Troutdale Formation (Peterson and others, 2011). Isolated exposures at construction sites and along Salmon Creek show round-cobble gravel in a matrix of micaceous quartzofeldspathic sand. Maximum clast diameter about 1 ft (30 cm). Deposited in subhorizontal layers 0.7–6.6 ft (0.2–2 m) thick, locally separated by discontinuous sand lenses as much as 10 ft (3 m) thick. Exposures along Salmon and Mill Creeks locally capped by as much as 10 ft (3 m) of compact, laminated sandy silt containing abundant mica. Cobble clast lithologies are diverse and include basaltic rocks of the Columbia River Basalt Group, granitic rocks and quartzite from the interior Columbia River basin, and olivine-bearing volcanic rocks probably derived from Pliocene to Quaternary flows of the Cascade Range. Many fine-grained volcanic clasts in the surficial oxidized zone have weathering rinds 0.1–0.2 in (2–4 mm) thick; more weathered clasts are found on higher elevation surfaces in northwest part of map area. No age information in map area, but radiocarbon dates to the east show uppermost deposits are older than 40 ka (Peterson and others, 2011). Optical luminescence ages from quarries near Scappoose indicate a late Quaternary age of 80–15 ka for the upper 26 ft (8 m) of this gravel (Evarts and others, 2016); deeper gravel may be much older. Equivalent gravel is locally overlain east of the map area by 653±3 ka basalt andesite of Prune Hill (Evarts and O'Connor, 2008; Fleck and others, 2014). Previously grouped with Troutdale Formation (Trimble, 1963; Mundorff, 1964) but is generally coarser, more poorly sorted, and contains clasts derived from of late Pliocene and Pleistocene olivine basalt from the Cascade Range. Aggradation of coarse sediment possibly resulted from episodes of Columbia basin glaciation and downstream valley aggradation from Lewis River glacial outwash (Evarts and others, 2009a)

Troutdale Formation (Pliocene and Miocene)—Semi-consolidated to well consolidated conglomerate and sandstone. Few exposures in map area, but regionally divided into two informal members locally separated by an unconformity

Tth **Hyaloclastic sandstone member (Pliocene)**—Indurated, coarse fluvial sandstone composed of abundant grains of basaltic glass containing crystals of olivine and plagioclase. Exposed only near confluence of Cougar Canyon and Salmon Creek 1 km east of Felida, where it apparently underlies the unnamed Conglomerate (QTc). Equivalent to vitric sandstone of Troutdale Formation of Trimble (1963) and Tolan and Beeson (1984). Possibly correlates to vitric sandstone identified at 240–260 ft (75–80 m) below sea level in borings along the I-5, and at 200 ft (60 m) below sea level in City of Vancouver water wells (Peterson and others, 2011). More extensively exposed east of map area (Evarts and O'Connor, 2008; Evarts and others, 2013), but no known exposures to the west and north. Hyaloclastic sandstone largely consists of angular to subrounded fragments, as much as 0.24 in (6 mm) across, of black basalt containing sparse phenocrysts of olivine (0.02–0.08 in; 0.5–2 mm) and plagioclase (0.04–0.12 in; 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. Sandstone ranges from poorly sorted to well sorted; typically thick-bedded in lenticular crossbeds containing dispersed pebbles and cobbles of olivine-bearing basalt. Angular, dense, and glassy basalt fragments in hyaloclastic sandstone beds interpreted as debris generated by basalt-water interaction in the Columbia River Gorge and rapidly transported downstream and deposited in Portland Basin (Trimble, 1963; Swanson, 1986, 1988; Evarts and others, 2009a,b). Vitric clasts and associated basalt cobbles have a low-potassium-tholeiite composition (Swanson, 1986, 1988; Lite, 1992; A.W. Sarna-Wojcicki, U.S. Geological Survey, written commun., 2005), rocks likely derived from compositionally similar late Pliocene (3.5–3.0 Ma) basalt flows east of map area (Tolan and Beeson, 1984; Swanson, 1986, 1988; Evarts and others, 2009b; Fleck and others, 2014)

Ttfc **Conglomerate member (Pliocene? and Miocene)**—Indurated, well-sorted, clast-supported, pebble and cobble conglomerate exposed along railroad grade on edge of the Columbia valley north of Salmon Creek. Mostly composed of well-rounded clasts of Columbia River Basalt Group, but contains granitic rocks, quartzite, and felsic metamorphic rocks. Sparse interbeds of micaceous quartzofeldspathic sandstone. Extensive correlative deposits likely at depth, mostly more than 200 ft (60 m) below sea level along the Columbia River, where it is separated from overlying unnamed conglomerate (QTc) by arkosic and hyaloclastic sandstone (Evarts and others, 2009a; Peterson and others, 2011). Equivalent in part to upper member of Troutdale Formation of Mundorff (1964); correlative to lower member of Troutdale Formation of Tolan and Beeson (1984) and quartzite-clast member of Troutdale Formation (QTtq) of Howard (2002). Late Miocene to early Pliocene age inferred from stratigraphic relations east of quadrangle (Tolan and Beeson, 1984)

EXPLANATION OF MAP SYMBOLS

Contact—Solid where location is accurate; long-dashed where location is approximate; short-dashed where location is inferred

Fault—Fault locations projected into the map area from adjacent areas. Dotted where location is concealed; queried where existence or extent uncertain. Ball and bar on downthrown block. Arrows show relative horizontal motion

Folds—Dashed where location is inferred; dotted where location is concealed; queried where existence or extent is uncertain

Anticline

Syncline

▲ **Ice-rafted erratic**—Description in table 1

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Table 1. Locations of observed Missoula flood ice-rafted erratics in map area. Locations are relative to North American Datum of 1927 and obtained using global positioning system (GPS) at time of observation. All documented erratics have been moved from their original location.

Station	Date	Latitude	Longitude	Quadrangle	Source	Lithology	Comments
1	3/1/2015	45°39'04"	122°30'17"	Orchards	Nathan Reynolds, electronic commun.	Granitic	On field edge; also 'slaty rock' nearby
2	5/11/2012	45°43'57"	122°37'54"	Vancouver	O'Connor	Granitic	Three >3-ft- (1 m) diameter boulders, derived from single large erratic found during excavation of Washington State University Science building; original location: 45°43'57", 122°38'04"
3	5/11/2012	45°43'36"	122°38'23"	Vancouver	O'Connor	Granitic	
4	7/12/2012	45°35'60"	122°32'50"	Mount Tabor	O'Connor	Granitic	Millstone for Hudson Bay gristmill
5	7/11/2012	45°40'18"	122°32'07"	Orchards	O'Connor	Granitic	About 10 large blocks along sidewalk, as much as 3.9 ft (1.2 m) in diameter
6	7/11/2012	45°42'60"	122°33'48"	Orchards	O'Connor	Granitic	Two 1-m-diameter blocks straddling driveway

Geologic Map of the Vancouver and Orchards Quadrangles and Parts of the Portland and Mount Tabor Quadrangles, Clark County, Washington, and Multnomah County, Oregon

By
Jim E. O'Connor, Charles M. Cannon, Joseph F. Mangano, and Russell C. Evarts
2016

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

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