Preliminary Digital Compilation Map of the Greater Portland Urban Area

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Description of Units

Qaf artificial fill (Holocene)—Sand silt and clay fills with subordinate amounts of gravel, debris and local concentrations of sawdust and mill ends. Unit Qaf is mapped only where fill has eliminated lakes, sloughs marshes or gullies depicted on the 1898 USGS topographic map of Portland. Some lake and marsh areas may have been drained rather than filled.

Qal alluvium (Quaternary)—River and stream deposits in channels and floodplains of modern streams and rivers. In the Columbia and Willamette Rivers, predominantly sand, silt, clay and organic material reaching a maximum thickness of 60 m in the Columbia beneath Government Island. Gravel is subordinate in the Columbia and Willamette, with the notable exception of Ross Island on the Willamette, where alluvial gravel is approximately 40 m thick. Deposits of Mazama Ash (ca 6700 ka) are commonly encountered at depths of 10-15 m beneath the modern surface, suggesting that much of the alluvium in the Columbia and Willamette is mid-late Holocene in age. Alluvium in the Tualatin River is predominantly silt and clay, with the exception of the last few km before the mouth, where coarse gravel is common. Alluvium in the Clackamas River is predominantly pebble to cobble gravel with some sand, mostly derived form intermediate volcanic rocks of the Cascade Range. Alluvium in the Sandy River is largely pebble to cobble gravel composed of intermediate volcanics from the Cascade Range, but also includes abundant fine to coarse sand derived from Holocene lahars originating on Mt. Hood. Alluvium in minor streams is variable in thickness and proportions of clay, silt, sand, gravel and organic material.

Qls landslide deposits (Quaternary)—Chaotic deposits of mixed rock, soil and colluvium formed in slumps, rockfalls and debris flows. In the Tualatin Mountains, large historical slides have occurred near Washington Park and the Portland Zoo. These slides are probably parts of larger prehistoric slides, and their exact extent is the subject of much study and debate. The slide areas depicted on the map are those for which there is wide agreement, the actual area may be larger. Large slides are also common along Tickle and Deep Creeks in the Sandy and Estacada quadrangles, and occur in the Troutdale Formation where sandstone and conglomerate overlie mudstone. Spectacular rockfall deposits occur near Carver, where Clackamas River has undermined cliffs of Boring lava overlying Springwater Formation conglomerate and Troutdale Formation mudstone. One such slide at Hardscrabble quarry consists of jumbled blocks of lava up to 10 m (33 ft) covering about 33 ha (90 acres). The landowner reports an extensive talus cave system within the rockfall debris.

Qe eolian deposits (Quaternary)—Silt, and locally sand deposited by wind. Primarily quartzo-feldspathic silt (Lentz, 1977, 1981) that mantles the Tualatin Mountains, and to a lesser degree Bull and Cooper Mountains and the Boring Hills. Loess up to 12 m thick mantles most slopes, but is not shown as a separate unit in the Tualatin Mountains or Bull or Cooper Mountains, though it may comprise much of unit QTs locally. Lentz (1981) suggested that loess was deposited between 34 ka and 700 ka B.P. based on correlations of paleosols to glacial advances and stratigraphic relations with Boring Lava and catastrophic flood deposits. In the Boring Hills, loess mantles northern slopes up to 15 m thick, and a few deposits of cross-bedded eolian sand occur. The sand deposits are depicted on the map, the loess mantle is not.

Catastrophic flood deposits (Pleistocene) - Boulder to pebble gravel, sandy gravel, sand and silt containing high percentages of Columbia River basalt clasts and representing high-energy, subfluvial deposition during catastrophic floods caused by the repeated failure of the glacial ice dam that impounded glacial Lake Missoula (Bretz and others, 1956; Baker and Nummedal, 1978; Waitt, 1985; Allen and others, 1986). Date of most recent catastrophic flood is estimated to be 15,500 to 13,000 years B.P. (Mullineaux and others, 1978; Waitt, 1987). Within map area, flood sediments are subdivided into three facies listed below.

Qff fine-grained facies (Pleistocene) - Coarse sand to silt deposited by catastrophic floods. The finer sediments are predominantly quartz and feldspar and also contain white mica. The coarser sediments are predominantly Columbia River basalt fragments. Poorly defined beds 0.3 to 1 m (1 to 3 ft) thick are observed in outcrop. Locally, beds are separated by accumulations of brown clay and iron oxide 1 to 6 cm thick, which are probably paleosols. Soil development commonly introduces significant clay into the upper 2-3 m (5-10 ft) of the deposits. The fine sediments are up to 30 m (100 ft) thick and mantle slopes up to an elevation of 122 m (400 ft).

Qfc coarse-grained facies (Pleistocene) - Pebble to boulder gravel with silt and coarse sand matrix. The coarse sediments are poorly sorted and sub-rounded to well rounded and range from openwork gravel to gravel with considerable fine-grained matrix material. Clasts are largely basalt, but other lithologies may dominate downstream from bedrock exposures. The coarse flood sediments are up to 60 m (200 ft) thick in the map area.

Qfch channel facies (Pleistocene)—Complexly interlayered and variable silt, sand and gravel deposited in major flood channel. Channel is cut in earlier and/or contemporaneous fine and coarse flood sediments (units Qff, Qfc) and retains much of the original morphology. Irregular post flood surface of these deposits has been locally filled by bog or pond sediments and minor stream alluvium. Channel deposits typically 5 to 15 m thick.

Strath Terraces (Quaternary) - Strath terraces cut by the Clackamas River into bedrock units. The planed bedrock surfaces are typically capped by sandy cobble gravel deposits up to 30 ft (9m) thick. The gravel is typically composed of basalt, andesite and dacite lava with feldspathic-lithic sand matrix. Four distinct terraces are differentiated based on height above the current floodplain on a profile perpendicular to the gross modern channel trend. The four terraces probably represent four ages of terrace formation related to Pleistocene glaciation in the Cascade Range or changes in downstream base level associated with Pleistocene catastrophic flood events.

Qst4 Strath Terrace (Pleistocene)---Surface elevation typically 15 m (50 ft) above the modern floodplain. Scattered remnants preserved largely along the north side of the Clackamas River. Mapped as Quaternary alluvium or Quaternary terrace deposits by Trimble (1963).

Qst3 Strath Terrace (Pleistocene)-- Surface elevation typically 24 m (80 ft) above the modern floodplain. Well preserved along both sides of the Clackamas River and up major tributaries. Underlies the broad flats near Barton and along Springwater Road southeast of Carver. Trimble (1963) mapped this unit mostly as Late Pleistocene Estacada Formation, partly as Quaternary terrace deposits.

Qst2 Strath Terrace (Pleistocene)-- Terrace surface typically 39 to 45 m (130 to 150 ft) above modern floodplain. Terraces preserved only along the south side of the Clackamas within the map area. Mapped by Trimble (1963) as Late Pleistocene Gresham Formation.

Qst1 Strath Terrace (Pleistocene)--Oldest terrace, surface elevation approximately 52 to 58m (170 to 190 ft) above modern floodplain. Scattered remnants occur north and south of the Clackamas River. Mapped by Trimble (1963) as Gresham Formation.

Boring Lava (Pliocene to Pleistocene)--Light-gray to gray, diktytaxitic, olivine- (less commonly plagioclase-) phyric basalt and basaltic andesite flows and associated scoria erupted from a series of local vents. Boring Lava flows typically display blocky to columnar jointing, and if preserved, vesicular flow tops. Contact relations are rarely observed but channel filling is clearly common. Madin (1994) describes twelve chemically distinct Boring Lava flows or groups of flows in the Boring Hills, which are described separately below.

QTvu Undifferentiated Boring Lava (Pleistocene) - Basalt flows that have not been separated as map units on the basis of age or chemistry. Some undifferentiated outcrops have been dated. A thick flow at Rocky Butte has an $^{40}Ar/^{39}Ar$ age of 125 +/- 40 ka (Fleck and others, 2002) . A series of vents and flows occurs along the crest of the Tualatin Mountains north of Sylvan. Flows in this area have $^{40}Ar/^{39}Ar$ ages of 120 +/- 15, 1160 +/- 935 and 1022 +/- 67 ka (Fleck and others, 2002). Flows near Estacada have $^{40}Ar/^{39}Ar$ ages of 1070 +/- 50 and 2700 +/- 70 ka (George Priest, Personal Communication, 1997). Mt. Sylvania is a small stratovolcano, with poor exposures that have not been dated. Small outcrops south and west of Mt. Sylvania may be related. Isolated flows occur at Cooks Butte and Kelly Butte, where a single thin flow is draped over QTs gravels. A small cinder cone and associated flow occur along the north side of Mt. Tabor, but have not been analyzed for chemistry or radiometric age.

QTvb Basalt of Borges Road (Pleistocene) - Flow or flows of basalt and associated scoria restricted to the hill just north of Borges Road in section 29, T. 2S., R. 3E.. Maximum thickness penetrated in water wells is at least 145 m (475 ft), but this section may be deformed. Magnetic polarity is normal; the radiometric age is 510 +/- 8 ka (Personal Communication, R. Duncan, Oregon State University) from the only exposure located on Wooded Hills Road near the center of Section 29, T. 3E., R. 1S. The vent may be located on the west flank of the hill described above, where there is a strong positive aeromagnetic anomaly.

QTvr Basalt of Rodlun Rd. (Pleistocene) - Flow or series of flows up to 50m (170 ft) thick covering large regions in the hills just south of Gresham. All measured outcrops have normal magnetic polarity. The radiometric age is 544 +/- 25 ka (Personal Communication, R. Duncan, Oregon State University) from a sample taken from a roadcut in the northwest corner of the southeast quarter of section 22, T. 1S., R. 3E.. A possible vent may be located at the small conical hill in the southwest corner of the northwest quarter of Section 27 T. 1S., R. 3E, which is associated with a strong positive aeromagnetic anomaly.

QTvh Basalt of Hardscrabble (Pleistocene) - Flow or series of flows forming a broad plateau south and southeast of Damascus. All measured outcrops have normal magnetic polarity. Excellent exposures in Hardscrabble quarry (section 17, T. 2S., R. 3E.) indicate that one flow was at least 45 m (150 ft) thick. The radiometric age is 612 +/- 23 ka (Personal Communication, R.. Duncan, Oregon State University) at Hardscrabble quarry. One likely vent for these flows is a small conical hill in the northwest corner of section 15, T. 2S., R. 3E. which is associated with a strong positive aeromagnetic anomaly.

QTvw Basalt of Winston Road (Pleistocene) - Flow or flows with associated scoria located to the west and north of Damascus, up to 110 m (360 ft) thick. The radiometric age is 646 +/- 27 ka (Personal Communication, R. Duncan, Oregon State University) from a cut on Winston Road just east of Foster Road. All measured outcrops have normal magnetic polarity. The likely vent is located in the southwest corner of the northeast corner of section 28, T. 1S., R. 3E.. A water well at this site penetrated over 30 m (100 feet) of unit QTvw scoria. The unit is associated with a moderate positive aeromagnetic anomaly.

QTvt Basalt of Tong Road (Pleistocene) - Flow or flows of basaltic andesite or andesite forming a small body north of the Clackamas River and west of Tong Road (sections 8 and 18, T. 2S., R. 3E.). The basalt may be as much as 61 m (200 ft) thick, but only covers about 60 ha (160 acres). The chemistry is significantly different from other analyzed Boring lava units with relatively high A_2l0_3 and SiO_2 and low TiO_2 and MgO. There is no obvious vent and no strong aeromagnetic signature.

QTvc Basalt of Carver (Pleistocene) - Basalt flows, scoria and at least one dike form a small volcanic edifice north of the Clackamas River at Carver. The dike intrudes volcaniclastic sandstone and scoria conglomerate (unit QTvcs) which is capped by unit QTvc flows. Most exposures are too deeply weathered for radiometric dating. Samples of the dike were dated at 427 +/- 26 ka (Personal Communication, R. Duncan, Oregon State University). The vent for was probably in the modern Clackamas channel just upstream of Carver. There is a moderately strong positive magnetic anomaly associated with this unit.

QTvcs Volcanic sandstone and conglomerate (Pleistocene) - Well-lithified crudely-bedded tuffaceous siltstone, sandstone and pebble conglomerate. Restricted to the area immediately around the QTvc vent at Carver. Massive to well bedded, composed largely of vitric silt and sand, angular to sub-rounded pebbles and cobbles of scoria, basalt and rare quartzite, and feldspathic and lithic sand with some mica.

QTvj Basalt of Jenne (Pleistocene) - Basaltic scoria and at least one flow making up the hill south of the communities of Jenne and Linneman. The flow or flows are up to 18 m (60 ft) thick. At the eastern foot of the hill in section 24, T. 1S. R. 2E., a flow directly overlies a flow of Basalt of Mount Scott. The flow is normally magnetically polarized, and has a radiometric age of 832 +/- 128 ka (Personal Communication, R. Duncan, Oregon State University). The vent is probably the bowl-shaped depression in the southeast corner of section 18, T. 1S R. 3E. The vent area is associated with a modest positive aeromagnetic anomaly.

QTvz Basalt of Zion Hill (Pleistocene) - Flow or flows of basalt and associated scoria mantling the hills immediately north of Boring and in the subsurface along the eastern edge of Sunshine Valley. The basalt is up to 61m (200 feet) thick. Magnetic polarity measured on one poor outcrop was normal. No samples were sufficiently fresh for radiometric dating. There is a significant negative magnetic anomaly associated with this basalt.

QTvs Basalt of Mount Scott (Pleistocene) - Mt Scott. is a small stratovolcano with a clear summit crater, and some of the flows from the volcano and its surroundings have been analyzed. One flow directly underlies a flow of Basalt of Jenne on the eastern flank of the hill in section 24, T. 1S., R. 2E. and has a K/Ar radiometric age of 711 +/- 20 ka (Personal Communication, R. Duncan, Oregon State University). An $^{40}Ar/^{39}Ar$ age of 1230 +/- 390 was reported from the western edge of the volcano by Fleck and others (2002). Outcrops have both normal and reversed magnetic polarity.

QTvm Basalt of Mt. Talbert (Pleistocene) - Flow or flows of basalt and associated scoria exposed in Rock Creek in section 6, T. 2S., R. 3E.. These exposures are the eastern edge of a thin sheet that extends in the subsurface to the west for about 2 miles. The western edge of the unit is marked by Mt. Talbert, a conical hill composed of this basalt. Most of the measured outcrops have reversed magnetic polarity. The radiometric age of the unit is 1,590 +/- 170 ka (Personal Communication, R. Conrey, Washington State University) from a sample taken from a roadcut in the southwest corner of the northwest corner of section 11, , T. 2S.,R. 2E. The unit has no clear aeromagnetic signature. Mt. Talbert is the likely vent.

QTvp Basalt of Powell Butte (Pleistocene) - Flow or flows of basalt mantle the northwest slopes of Powell Butte. The only measurable outcrop has reversed magnetic polarity.

QTvo Basalt of Outlook (Pliocene) - A flow or series of flows up to 60 m (200 ft) thick which underlies a broad plateau south of the Clackamas River and west of Carver. The radiometric age of 3,146 +/- 62 ka (Personal Communication, R. Duncan, Oregon State University) from a sample taken from the cliff immediately south of Bakers Bridge at Carver. All measured outcrops of the unit had reversed magnetic polarity. A likely vent for these flows is the hill just south of the community of Outlook.

QTh Hillsboro Formation (upper Miocene-Pleistocene)—claystone, siltstone and sandstone deposited in fluvial and lacustrine conditions over the Columbia River Basalt west of the crest of the Tualatin Mountains. Includes units QTs of Beeson and others, 1989, 1991, and Sandy River Mudstone Equivalent of Madin 1990. Locally interbedded with loess (unit Qe) and QTvu in the Tualatin Mountains. Wilson (1997, 1998) formally named the unit, and described a 263m thick section from a corehole at the Hillsboro airport that included 75m of upper Miocene to Pliocene strata with the remainder Pleistocene in age.

QTs Springwater Formation (Pliocene to Pleistocene)- Fluvial conglomerate, volcaniclastic sandstone, siltstone, and debris flows derived from the Cascade Range. The conglomerate is moderately indurated and typically consists of well-rounded pebbles, cobbles and boulders of basalt, andesite and dacite with rare exotic metamorphic and plutonic rocks. The sand and silt conglomerate matrix contains varying amounts of feldspathic and volcanic lithic and vitric sediment. The conglomerate is commonly massive and profoundly weathered. Weathered conglomerates are strongly vari-colored in reds, browns, gray-greens and oranges. Fresh material is more typically gray and brown. Debris flows consist of angular to rounded clasts of basalt, andesite and dacite lava, scoria and pumice in a matrix of clay, ash and sand. Sandstone ranges from fine to coarse and is composed of volcanic lithic, vitric and feldspathic sand, rarely micaceous. Siltstones and mudstones consist of quartzo-feldspathic silt, ash and clay. The basal contact is probably conformable with the underlying Troutdale Formation, and may be gradational. South of the Clackamas River the top of the Springwater Formation appears to be part of a deeply weathered bajada surface which is well developed to the south and east of the Clackamas River and rises eastward to the foothills of the Cascade Range. This surface was originally noted by Trimble (1963). Boring Lava commonly overlies or is interbedded with Springwater Formation rocks. The age of the Springwater is probably Pliocene to Pleistocene, based on its relationships with Boring Lava flows. Near Estacada, a Boring Flow dated at 1070 ka overlies Springwater Formation, and a nearby flow of 2700 ka underlies Springwater. Includes rocks mapped by Trimble (1963) as Gresham, Troutdale and Walters Hill Formations. Some exposures (Mt. Tabor, Kelly Butte, near Lake Oswego) may be a mixture of Troutdale Formation gravel and Springwater Formation gravel, as the Cascade-clast bearing rivers that deposited the Springwater would have emptied into the Columbia River while it was depositing exotic-clast Troutdale formation. In this map, exposures with significant Cascade volcanic component are included with the Springwater.

QTsf Springwater Formation sandstone and mudstone (Pliocene to Pleistocene)— locally it is possible to separate out thick sections of finer grained sedimentary rocks within the Springwater Formation. Sandstone ranges from fine to coarse and is composed of volcanic lithic, vitric and feldspathic sand, rarely micaceous. Siltstones and mudstones consist of quartzo-feldspathic silt, ash and clay

Troutdale Formation (Miocene-Pliocene?) - Moderately to poorly indurated mudstone, siltstone, sandstone and conglomerate. This unit includes coarse and fine-grained fluvial sedimentary rocks with varied provenance, ranging from sediments with exotic origins presumably carried by the ancestral Columbia River, and sediments of local origin. Part of the Troutdale Formation was shown by Tolan and Beeson (1984) to be Miocene to Pliocene age in the Columbia River gorge east of the map area. The age of the unit in the map area is poorly constrained. The stratigraphic and facies relationships between these lithologies are poorly understood but can be divided into the following purely lithologic units.

Ttg   Troutdale Formation conglomerate (Miocene-Pliocene?) - Massive pebble and cobble conglomerate composed largely of well rounded Columbia River Basalt clasts with a significant percentage of metamorphic quartzite, granitoids and schist. Feldspathic and arkosic micaceous sand matrix and interbeds are common. This unit correlates with the Ttug unit of Lite (1992).

Tts Troutdale Formation volcaniclastic sandstone (Miocene Pliocene?) - Massive to well bedded volcanic-lithic and vitric sandstone with some siltstone, locally micaceous.   Correlates to the Ttus unit of Lite (1992).

Ttm Troutdale Formation mudstone and siltstone (Miocene Pliocene?) - Mudstone and siltstone with sandstone, rare conglomerate and water-laid tuff. Predominantly arkosic or feldspathic and micaceous, with some lithic and vitric layers. Blue-green to gray fresh, oxidizing green-green to brown. Typically thin-bedded or laminated in siltstones, sandstone and tuffs. Claystone is typically massive or pervasively cut by anastamosing slickensided shear surfaces. Organic material, wood and logs are locally common. This unit was mapped by Trimble (1963) as the lacustrine Sandy River Mudstone, but ripple, channel and trough cross bedding are common indicating fluvial origin. Correlates with unit Ttl of Lite (1992).

Tr Rhododendron Formation (Miocene-Pliocene)—Trimble (1963) describes the Rhododendron as andesitic mudflow breccia with subordinate andesite flows, conglomerate and sandstone, commonly with uncarbonized wood fragments. Lava blocs up to 2m are common. Flows and lava blocks are hypersthene andesite, and the unit is commonly deeply weathered and capped with a saprolite. Thickness estimated at about 180m. The Rhododendron Formation overlies Columbia River Basalt outside the map area, and is overlain by the mudstone facies of the Troutdale Formation within the map area.

Columbia River Basalt Group (middle Miocene)—Miocene tholeitic flood basalt and basaltic andesite flows that were erupted from long linear fissure system in northeastern Oregon, eastern Washington and western Idaho from approximately 17 to 6 Ma (Swanson and other 1979, Hooper, 1982). Many individual flows were known to be huge in size, often covering thousands to tens of thousands of square kilometers in area, with volumes up to thousands of cubic kilometers (Tolan and others, 1989). These flows entered western Oregon via a wide gap in the northern Oregon Miocene Cascade Range (Beeson and others, 1985); some flows reached the Pacific Ocean (Beeson and others, 1979). Significant differences in the geochemical, paleomagnetic and lithological properties of the Columbia River Basalt Group flows allow their division into five formal formations (Swanson and others, 1979) and allow these formations to be subdivided into numerous mappable members and units. (Swanson and others, 1979; Beeson and others, 1985; Reidel and others, 1989). Members and units belonging to the Wanapum and Grande Ronde Basalts, two of the five formations, are present in the map area and have a collective thickness of as much as 210 m.

Frenchman Springs Member, Wanapum Basalt

Tfsg Basalt of Sentinel Gap (middle Miocene) - Consists of a single, blocky- to columnar-jointed flow within the map area. Fresh exposures are dark gray; weathered surfaces are typically brownish gray to dark gray. Fine- to medium-grained microphyric basalt, with acicular and equant plagioclase laths <0.1 cm in size; generally aphyric but can contain rare plagioclase phenocrysts <1 cm in size. Thickness of unit is variable, ranging from 8 to 15 m. Compositionally similar to older Ginkgo flows but can be differentiated on the basis of stratigraphic position, lithology (lack of abundant plagioclase phenocrysts), and normal paleomagnetic polarity (Beeson and others, 1985)

Tfsh Basalt of Sand Hollow (middle Miocene) - Four flows are present within the map area. Flows typically are blocky to columnar jointed, but occasionally display entablature/colonnade jointing style. Fresh exposures are dark gray to black; weathered surfaces are typically greenish gray to black. The three oldest flows ("+3, +4, and +5" units of Beeson and others [1975]) are fine to coarse grained, occasionally diktytaxitic, and sparsely plagioclase phyric, with phenocrysts <2 cm in size. The youngest Sand Hollow flow is typically diktytaxitic, medium to coarse grained, and plagioclase phyric, with phenocrysts and glomerocrysts that commonly range from 2 to 5 cm in size. Unit thickness is variable, ranging from <15 to >60 m. Sand Hollow flows can be distinguished from both the Sentinel Gap and Ginkgo flows on the combined basis of stratigraphic position, lithology, and composition. Both low- to intermediate-P205 compositional types (Beeson and others, 1985) are present within the map area. Beeson and others (1985) report a K-Ar date of 15.3 Ma for this unit.

Tfg Basalt of Ginkgo (middle Miocene) - Two flows are present within the map area. Flows are commonly blocky to columnar jointed, often displaying well-formed prismatic colonnades. Fresh exposures are dark gray to black; weathered surfaces are commonly reddish brown to gray. Both flows are typically medium-grained, plagioclase-microphyric basalt, with laths <0.1 cm in size, and abundantly plagioclase phyric, with phenocrysts and glomerocrysts ranging from 0.3 to 2 cm in size. The upper Ginkgo flow is commonly diktytaxitic. Thickness of this unit varies from 15 to >60 m within the map area. Ginkgo flows can be distinguished from the plagioclase-phyric Sand Hollow flow on the combined basis of stratigraphic position, composition and excursional paleomagnetic polarity (Beeson and others, 1985). This unit commonly overlies a thin (commonly approximately 30 cm-thick), discontinuous, sedimentary interbed that ranges from fluvial arkosic, micaceous sandstone to paleosol. This sediment is equivalent to the Vantage Member of the Ellensburg Formation (Swanson and others, 1979; Beeson and others, 1985) and is not shown here as a separate map unit because of its relative thinness.

Grande Ronde Basalt

Tgsb Sentinel Bluffs unit (middle Miocene) - Within the map area, two flows that were formerly designated as "-1 and -2 flows" of Beeson and Moran (1979) are present. Flows typically display blocky to columnar jointing and rarely display an entablature/colonnade jointing pattern. Fresh exposures are light to dark gray; weathered surfaces are greenish gray to dark gray. The lower flow is typically fine- to medium-grained basalt and sparsely plagioclase phyric, with small (<0.5 cm) tabular plagioclase phenocrysts. The upper flow is fine to medium grained, commonly diktytaxitic, and aphyric. Unit thickness ranges from 8 to 45 m within the map area. Sentinel Bluffs flows are distinguished from both younger Frenchman Springs units and older Grande Ronde units on the basis of stratigraphic position composition, lithology, and normal paleomagnetic polarity (see Reidel and others, 1989; Beeson and others, 1989). Long and Duncan (1982) report a 40Ar/3-'Ar date of approximately 15.6 Ma for the youngest flows of this unit on the Columbia Plateau

Tgww Winter Water unit (middle Miocene) - Within the map area, two flows that were formerly designated as the "-3 flow" of Beeson and others (1975) or "N3 low-MgO flows" of Beeson and Moran (1979) are present. Winter Water flows display a wide range of jointing patterns, from columnar to entablature/colonnade. Fresh exposures are dark gray to black; weathered surfaces are greenish gray to grayish black. Both flows are typically glassy to fine grained and phyric to abundantly phyric, with small (<0.3 cm) plagioclase glomerocrysts that often display a distinctive radial or spoke-shaped habit. Distribution of glomerocrysts is often uneven and tends to be less abundant in the basal portion of the flow. Unit thickness ranges from 8 to 30 m within the map area. Winter Water flows are distinguished from other Grande Ronde units on the basis of lithology, composition, stratigraphic position, and normal paleomagnetic polarity (see Reidel and others, 1989; Beeson and others, 1989).

Tgu Umtanum unit (middle Miocene) - Within the map area, two flows that were formerly designated as "N3 low-MgO flows" of Beeson and Moran (1979) are present. Umtanum flows commonly display entablature/colonnade jointing style. Fresh surfaces are dark gray to black; weathered surfaces are gray green to dark gray. Flows are commonly glassy to very fine grained and abundantly plagioclase microphyric, with small (<0.2 cm) acicular microphenocrysts. Umtanum flows are known to interfinger with Ortley flows on the Columbia Plateau (Reidel and others, 1989) but can be distinguished from Ortley flows on the basis of higher TiOg concentrations and the presence of abundant plagioclase microphenocrysts

Tgo Ortley unit (middle Miocene) - Within the map area, four flows formerly designated as "N3 low-MgO flows" of Beeson and Moran (1979) are present. Ortley flows commonly display entablature/colonnade jointing style. Fresh exposures are gray to black; weathered surfaces are greenish gray to dark gray. Flows are commonly glassy to very fine grained and aphyric. Unit thickness ranges from 8 to > 60 m within the map area. Ortley flows are both compositionally and lithologically similar to the older Grouse Creek unit but can be distinguished on the basis of their normal paleomagnetic polarity (see Reidel and others, 1989; Beeson and others, 1989).

Tgr2 R2 Grande Ronde Basalt (middle Miocene) - Consists of approximately six flows that are exposed only in the northern portion of the map area. Flows of this unit are similar to both the Ortley and Umtanum flows in physical, lithological, and compositional characteristics but can easily be distinguished on the basis of their reversed paleomagnetic polarity, (see Reidel and others, 1989; Beeson and others, 1989). Unit thickness varies, ranging from 45 to >120 ft within the map area. Although not differentiated here, this unit contains flows of both the Grouse

Creek and Wapshilla Ridge units of Reidel and others (in press) on the Columbia Plateau.

Ts marine sandstone (Eocene-Miocene?)—Tuffaceous marine sedimentary rocks that underlie the Columbia River Basalt. The Richfield Barber oil well (section 23, T1N, R1W) penetrated 900m of sandstone, shale fossiliferous sandstone, tuffaceous sandstone and shale and volcanic agglomerate beneath the Columbia River Basalt. An excavation on the west flank of the Tualatin Mountains, just NE of the Oatfield Fault exposes well-bedded micaceous quartzo-feldspathic sandstone with tuffaceous sand and silt layers and scattered clam and snail fossils.

Twh Basalt of Waverly Heights and associated undifferentiated sedimentary rocks (Eocene) -Consists of a sequence of subaerial basaltic lava flows and associated sediments that unconformably underlie flows of the Columbia River Basalt Group. The top of unit Twh is typically marked by a deeply weathered zone (probably >10 m thick), except where it has been scoured away either by catastrophic floodwaters or by normal river downcutting. Consequently, the best exposures of this unit are found adjacent to the Willamette River in the Waverly Heights area. Flows of unit Twh are typically blocky to columnar jointed and have well developed vesicular flow tops and bottoms. Vesicles and vugs within flow tops, as well as some joints, are commonly filled with secondary minerals. Flow morphology and the absence of intraflow structures (pillow complexes and hyaloclastites) suggest that the lava flows were emplaced subaerially. Fresh flow surfaces are typically brownish gray to black; weathered surfaces are dark gray to brownish black. In hand sample, the flows are commonly fine to medium grained and range from sparsely to abundantly plagioclase phyric, with phenocrysts and glomerocrysts that are usually <0.5 cm in size. Unit Twh flows are basaltic in composition and are similar in composition to those of the Columbia River Basalt Group (Table 1). However, unit Twh flows can be distinguished from Columbia River Basalt Group flows because they do not precisely match any specific compositional type within the Columbia River Basalt Group. Two flows have yielded K-Ar dates of about 40 Ma (Beeson and others, 1989). Sediments associated with unit Twh flows are not exposed, but borehole data suggest a marine environment of deposition and further suggest that these sediments underlie much of the Tryon Creek area. Thickness of this unit is not known, but it is assumed to extend to considerable depth in the map area. Unit Twh is believed to represent a portion of an oceanic island that was accreted to western Oregon

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