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Preliminary Geologic Map of the Lebanon and Onehorse Slough 7.5' Quadrangles, Linn County, Oregon

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Preliminary Geologic Map of the Lebanon and Onehorse Slough 7.5' Quadrangles, Linn County, Oregon

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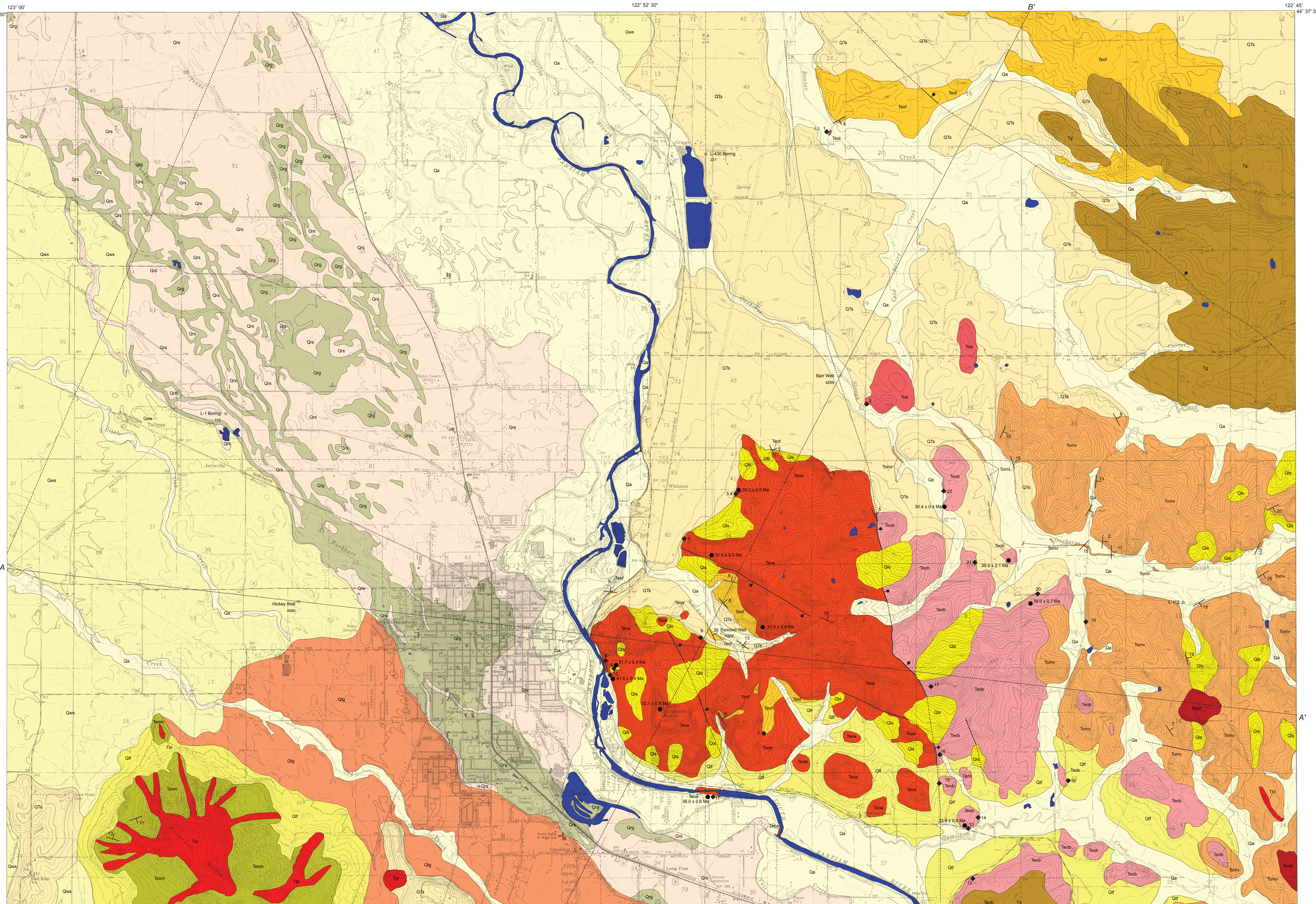

Base map by U.S. Geological Survey

Geology by Mark L. Ferns and Jason D. McClaughry, Oregon Department of Geology and Mineral Industries

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Digital cartography by Jason D. McClaughry
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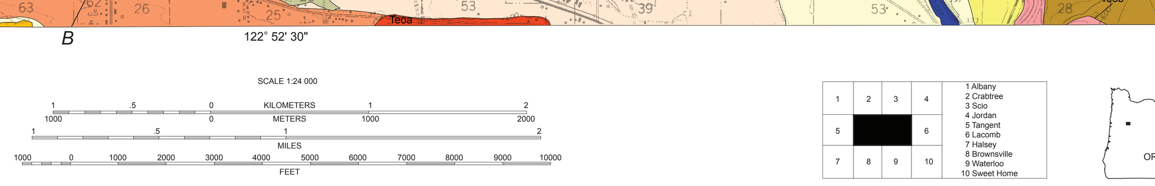

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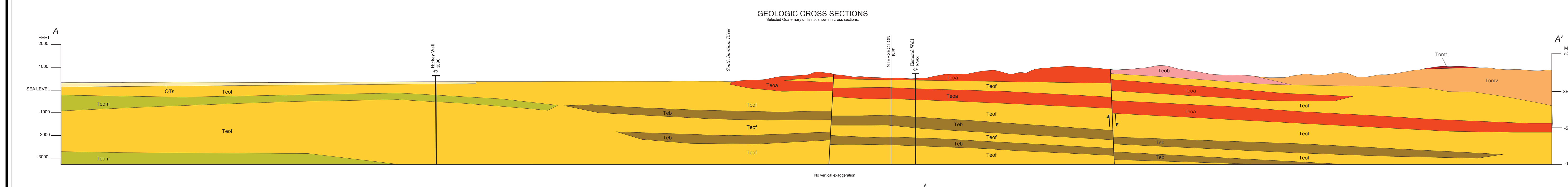
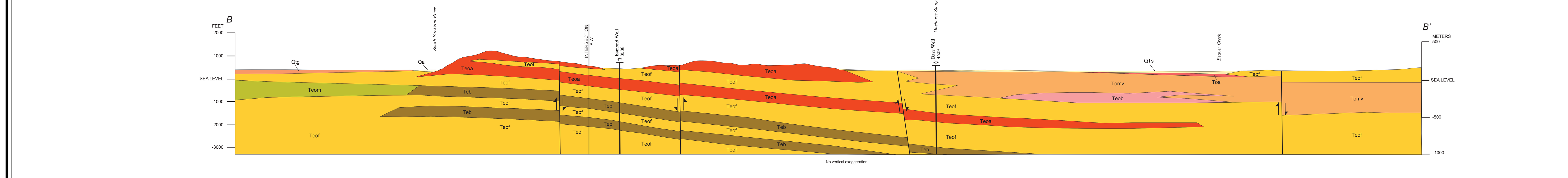
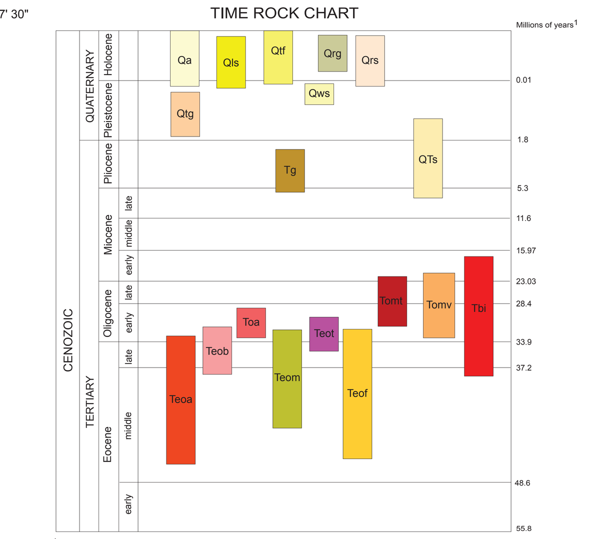




TIME ROCK CHART



MAP SYMBOLS

Contact - approximately located

Fault - Dashed where approximately located; dotted where concealed; ball and bar on downthrown side

Inclined bedding - showing strike and dip, measured or estimated

7 ◆ Location of whole-rock XRF geochemical analysis sample - see Table 1

39.2 ± 0.5 Ma ● Location of radiometric age sample - see Table 2

L-430 221 ○ Location of geotechnical boring showing operator number and total depth (in feet)

Barr Well 4259 Location of drill hole showing operator number and total depth (in feet). Show of gas. See Table 1 for geochemical analyses from drill holes.

Water - includes streams, lakes, and small ponds

INTRODUCTION

The Lebanon and Onehorse Slough 7.5' quadrangles are located in the Willamette Valley of Oregon at the western edge of the Western Cascades physiographic province (Figure 1). Geology depicted on the 1:24,000-scale Lebanon and Onehorse Slough 7.5' quadrangles is based partly on previous 1:62,500-scale mapping by Allison and Felts (1956) and Beaulieu and others (1974). The area was remapped at a larger scale as part of a regional effort to construct a geologic framework for the middle and southern Willamette Valley (Figure 1; Hladky and McCaslin, 2006; Madin and Murray, 2006; Madin and others, 2006; Murray and Madin, 2006; Wiley, 2008). New mapping conducted during the 2007 field season, augmented by numerous geochemical analyses and compiled radiometric age determinations, now ties poorly exposed, discontinuous bedrock outcrops to lithologic, geochemical, and fossil data extracted from engineering bore holes (Shannon and Wilson, Inc., 1974; Niem and others, 1987) and oil and gas exploration wells (Newton, 1969; McKeel, 1985). Overall, bedrock interpretations of the present map differ little from those of Allison and Felts (1956) and Beaulieu and others (1974); substantive differences are attributable to the identification of mappable, geochemically distinct lava flow packages, faults discerned from the correlation of oil and gas exploration well logs, and the addition of surficial deposits modified from National Resources Conservation Service (NRCS) soil maps.

The map is released as an interim open-file report and has not been peer reviewed. The United States Government is authorized to reproduce and distribute reprints for governmental use. Geologic data were collected at the 1:24,000 scale and combine new mapping with published and unpublished data from air photos, orthophotoquads, and digital shaded relief images derived from USGS 10-m DEM (digital elevation model) grids. The map and cross sections also incorporate lithologic interpretations of water well logs available through the Oregon Water Resources Department GRID system. The mapped distribution of surficial deposits is modified from soils maps and descriptions published by the U.S. Department of Agriculture (Langridge, 1987; NRCS, 2006). Open water bodies were digitized from circa 2005 air photo coverage and, when compared to the soils maps and 1993 topographic base maps, show how stream channel locations changed as a result of the 1996 and 1997 Willamette Valley floods. Geologic mapping was supplemented with x-ray fluorescence (XRF) geochemical analyses from Franklin and Marshall College, Lancaster, Pennsylvania. Results of chemical analyses shown in Table 1 have been normalized on a volatile-free basis and recalculated with total iron expressed as FeO*. Descriptive rock unit names are based upon analyses plotted on the total alkalis versus silica diagram (TAS) of Le Bas and others (1986) and Le Maitre and others (1989) (Figure 2). K-Ar radiometric age determinations were compiled from Shannon and Wilson, Inc. (1974), Sutter (1978), and Sloan and others (2003) (Table 2).

GEOLOGY

Bedrock units in the map area include Paleogene marine and nonmarine tuffaceous sandstone, mafic lava flows, volcaniclastic conglomerate and breccia, and dacite and rhyolite ash-flow tuff. Tuffaceous sandstones of the Eugene and Fisher Formations of late Eocene and early Oligocene age are the oldest units exposed in the quadrangles. Arkosic and micaceous sandstones and siltstones exposed at Peterson Butte and observed in cuttings from oil and gas wells are considered to be part of the Eugene Formation as defined by Smith (1924). From mega and microfossils identified from Peterson Butte (Washburne, 1914; Allison and Felts, 1956) and from cuttings from the Hickey oil and gas well, rocks of the Eugene Formation are interpreted as marine deposits (McKeel, 1985). Near Eugene, Retallack and others (2004) and Murray (2006) used the 40.1 ± 0.6 Ma ($^{40}Ar/^{39}Ar$) tuff of Fox Hollow to mark the base of the Eugene Formation. Marine sedimentary rocks stratigraphically beneath the tuff of Fox Hollow are considered to be part of the Spencer Formation (Retallack and others, 2004). The transition between the Eugene Formation and underlying units in the Lebanon and Onehorse Slough area is not exposed. Tuffaceous sandstone, pebble conglomerate, and siltstone intertonguing with the Eugene Formation are considered to be part of the Fisher Formation as defined by Schenck (1927). Rocks of the Fisher Formation are interpreted as nonmarine deposits on the basis of an absence of marine fossils and the presence of local coal layers and subarially derived plant debris. The Eugene and Fisher Formations may be as old as late Eocene and, in the case of the Eugene Formation, contain Refugian and late Narizian Stage marine microfossils. The interfingered contact relationship between the Eugene and Fisher Formations is thought to reflect local transgression and regression of the Paleogene shoreline (Wiley, 2006).

The Eugene and Fisher Formations are succeeded upward in the map area by the Little Butte Volcanic Series, a succession of Oligocene volcaniclastic sedimentary rocks, silicic tuffs, and interbedded basalt, basaltic andesite, and andesite lava flows. The term Little Butte Volcanics was originally used in reference to the post-Colestin volcanic rocks of Oligocene age exposed in the Medford quadrangle (Wells, 1956). Subsequently, Peck and others applied the term Little Butte Volcanic Series to all Oligocene and early Miocene volcanic and terrestrial rocks of the Western Cascades. As such, the unit includes the Mehama Formation of Smith (1958) and Mehama Volcanics of Thayer (1939). In the map area, Beaulieu and others (1974) called these rocks the Little Butte Formation and found that the middle and lower parts of the formation were interbedded with marine sandstone equivalent to the Eugene Formation. These workers also correlated these rocks with the Mehama Volcanics of Thayer (1939) and the Little Butte Volcanic Series of Peck and others (1964). The base of the Little Butte Volcanic Series is defined by Peck and others (1964) by the tuff of Bond Creek (Smith and others, 1980), which forms a prominent stratigraphic marker south of Eugene. Retallack and others (2004) reported an age of 34.8 ± 0.2 Ma ($^{40}Ar/^{39}Ar$) for the tuff of Bond Creek at Eugene, where the tuff is interbedded with marine sedimentary rocks of the Eugene Formation. At Eugene, Retallack and others (2004) considered the base of the Little Butte Volcanics to be marked by an unnamed 30.06 ± 0.2 Ma ($^{40}Ar/^{39}Ar$) ash-flow tuff. In the map area, an upper age to the Mehama Volcanics is defined by overlying mafic lava flows on the east at Green Mountain that have a radiometric age determination of 22.6 ± 0.30 (K-Ar; Walker and Duncan, 1989).

Paleogene deposits in the map area are unconformably overlain by Quaternary and late Tertiary fluvial sedimentary rocks that blanket much of the northern half of the field area. Inverted topography in the form of low-standing, gravel-capped ridges in the eastern part of the map area are underlain by the Lacomb Gravel of Allison (1953), which is herein interpreted as late Miocene to early Pliocene fluvial channel deposits. The southernmost exposures of gravels are part of an ancestral South Santiam River channel that was subsequently filled farther south at Sweet Home by the 4.5 ± 0.3 Ma (K-Ar) basalt of Marks Ridge (Walker and Duncan, 1989). Paleogene deposits elsewhere in the map area are unconformably overlain by poorly consolidated, clay-rich Pliocene and Pleistocene deposits. Low terraces along Crabtree Creek and Beaver Creek that form the Leffler Gravel of Thayer (1939) are underlain by fine-grained silt and clay, deeply weathered gravels, and deeply weathered Paleogene bedrock. From engineering drill holes and water well logs from within the Willamette Valley proper, fine-grained, commonly blue-colored, silty and sandy clays with interbedded sand and fine gravel lenses form the Calapooia clay of Niem and others (1987), a sequence of largely fine-grained sediments as much as 100 m thick that unconformably overlies weathered Paleogene units. Contacts between Neogene fluvial-lacustrine clay deposits and weathered-to-clay Paleogene bedrock are ill-defined and largely interpretative.

In the uplands, late Quaternary surficial deposits include stream and floodplain alluvium, landslide deposits, fan deposits, and colluvium. At Lebanon, low terraces formed by coarse gravel and sand are part of the Santiam River fan, a large alluvial fan that extends northwest from Lebanon to the Willamette River at Albany. The Santiam River fan is one of a series of broad, coalescing, alluvial fans that extend across tributary streams at the eastern margin of the Willamette Valley (Piper, 1942; Gannett and Caldwell, 1998).

Older parts of the fan surface are mantled by the 5- to 7-m-thick blanket of Pleistocene silt and sand known as the Willamette Silt. The Willamette Silt was, with ice-rafted glacial erratics (Allison, 1935), deposited by catastrophic Missoula floods. Between Lebanon and Albany, receding flood waters eroded through the silt, revealing an ancestral channel to the South Santiam River that once joined the Willamette River at Albany.

EXPLANATION OF MAP UNITS

Upper Cenozoic Surficial and Valley-Fill Deposits

Qa — **Alluvium (Holocene and upper Pleistocene) –** Unconsolidated gravel, sand, and silt deposited in modern stream channels and on adjoining flood plains. The unit includes the Qal and Qau units of O'Connor and others (2001) and Qal, Qng, Qns, Qyg, and Qys units of Wiley (2006). The unit also includes hill-slope colluvium marginal to upland streams. Mapped distribution corresponds in part to areas mapped as Camas, Newberg, Wapato, Chapman, and Chehalis soils (Langridge, 1987). Balster and Parsons (1969) recognize two erosional surfaces within this unit, an older Ingram surface that includes channels 6 or more meters above the modern flood plain and a younger Horseshoe erosional surface that corresponds to the modern flood plain. Balster and Parson (1969) report the upper age of the older Ingram surface to be 3,290 years B.P.

Qtf — **Gravel, sand, silt, and clay (Holocene and Pleistocene) –** Slope wash, alluvial fan, and colluvial deposits found along modern upland tributary streams. The unit forms part of the modern erosional surface downslope of bedrock highs at Peterson Butte and east of Ridgeway Butte. The mapped distribution of the unit corresponds in part to areas mapped as Hazelair, Dixonville, Chapman, Philomath, Bashaw, Chehyulpum, and Wetzel soils by Langridge (1987).

Qls — **Landslide deposits (Holocene and Pleistocene) –** Unconsolidated, poorly sorted, and unstratified chaotic mixtures of soil and rock deposited by gravity-driven mass-wasting processes (i.e., slumps, slides, and debris flows). The unit includes rockfall and colluvial deposits. Most landslide deposits in the map area are inferred on the basis of geomorphology and are derived from the Little Butte Volcanic Series (Peck and others, 1964; Beaulieu and others, 1974). The surfaces of landslide deposits are typically irregular and hummocky. More recent slides can be traced upslope to steep, headwall bedrock escarpments, and the distal toes of these deposits retain a fan-shaped morphology. In water well logs, landslide deposits are typically referred to as clay and rock and clay. On the basis of relatively subdued geomorphic expression, most of the deposits are considered to be old and inactive and have been modified by secondary erosional processes. Some landslide deposits on steeper slopes, such as those near Ridgeway Butte, ultimately stem from failure along contacts between competent basalt flows and underlying, less competent sedimentary units. Mapped only where deposits cover underlying strata. Thickness of the landslide deposits is highly varied; maximum thickness is several tens of meters.

Qrs — **Reworked silt (Holocene and Pleistocene) –** Unconsolidated deposits of silt and sand with subordinate amounts of gravel that form a low terrace along the South Santiam River between Lebanon and Albany. Equivalent in part to the Linn Gravels (Qli) of Allison and Felts (1956) and unit Qt1 of O'Connor and others (2001). Considered by Wiley (2006) to be fine-grained fluvial deposits that developed during reworking of the Willamette Silt (Qws) by the South Santiam River. As such, the silt and sand are considered to have been derived largely from Willamette Silt (Qws). The mapped distribution of the unit is based on silty and sandy soils such as the Malabon, Silton, Bashaw, Coburg, Conser, and Salem soils that were mapped by Langridge (1987). The surface of the unit is part of the Winkle erosional surface; reportedly, the unit includes admixed Mazama ash (Langridge, 1987).

Qrg — **Reworked gravel (Holocene) –** Unconsolidated deposits of gravel, with subordinate amounts of sand and silt that form a low terrace along the South Santiam River between Lebanon and Albany. Equivalent in part to the Linn Gravels (Qli) of Allison and Felts (1956) and unit Qt1 of O'Connor and others (2001). The surface of the unit defines part of the Winkle erosional surface, which reportedly includes admixed Mazama ash (Langridge, 1987). The unit is an important gravel aggregate source and generally corresponds to areas overlain by the Clackamas gravelly soil as mapped by Langridge (1987). Allison and Felts (1956) interpreted these deposits to define an older channel of the South Santiam River that once joined the Willamette River at Albany. Gravels are, in part, reworked Albany fan gravels (Piper, 1942) (Qtg) that had been exposed through stripping of the overlying Willamette Silt (Qws) by the South Santiam River.

Qws — **Willamette Silt (upper Pleistocene) –** Unconsolidated silt, clay, and sand interpreted as upper Pleistocene Missoula flood deposits. The unit includes thin- to medium-bedded rhythmites of light gray to light brown silts, sandy silt, and silty clay that contain abundant grains of quartz and feldspar. Individual rhythmites range from 0.1 to 1 m thick (O'Connor and others, 2001). The upper limit of the flood deposits in the map area is defined by ice-rafted granite erratics deposited northeast of Lebanon, which form a strand land at an elevation of 375 ft (Allison, 1935). From water well logs, the unit is no more than 6 m thick in the map area. The mapped distribution generally corresponds with areas overlain by Willamette, Dayton, Malabon, Holcomb, Woodburn, Amity, and Coburg soils as mapped by Langridge (1987). In the map area, water well drillers generally describe the Willamette Silt as brown or gray clay or silt in their well logs.

Quaternary and Upper Tertiary Sedimentary Deposits

Qtg — **Gravel, sand, and silt (Pleistocene) –** Unconsolidated to semi-consolidated deposits of gravel, sand, silt, and clay. The unit is generally mantled by unit Qws and is equivalent to the Qli unit of Wiley (2006), the middle sedimentary unit of Conlon and others (2005), and the Qau and parts of the Qt2 and QTt units of O'Connor and others (2001). The unit forms the Calapooia erosional surface of Balster and Parson (1968) and is part of the Albany fan of Piper (1942) and Gannett and Caldwell (1998). Equivalent in part to the Linn and Leffler gravels of Allison (1953) and Allison and Felts (1956) as well as the Linn member of the Rowland Formation of Balster and Parsons (1969). The unit is as much as 20 m thick, thinning to the west, into the Willamette Valley. In the map area, water well drillers generally describe the unit as gravel or sand and gravel in their well logs. Deposits in the map area are interpreted as part of a large, incised alluvial fan and upland terrace complex formed by the South Santiam River and tributary streams.

QTs — **Clay, silt, sand, and gravel (Pleistocene, Pliocene, and upper Miocene?) –** Unconsolidated to semi-consolidated deposits of green-blue and blue clay, silt, and sand and gravel dominated by volcanic lithic grains and clasts. Sands and gravels typically contain white and gray volcanic rock fragments; sands are primarily composed of plagioclase, pyroxene, and magnetite grains. The unit includes finely laminated brown and dark blue-gray clays that retain root fragments. The unit is equivalent to the Calapooia clay of Niem and others (1987) and in part is equivalent to the Leffler gravel of Allison and Felts (1956), the middle terrace deposits of Beaulieu and others (1974), and the lower sedimentary unit of Conlon and others (2005). The southernmost exposures of the volcanic-clast gravel in the map area, near Peterson Butte, are deeply weathered; volcanic clasts are largely altered to clay and can be easily cut by a knife. Water well drillers commonly describe the unit as clay or gravel and clay in their well logs.

Tg — **Gravel, clay, and sand (Pilocene to upper Miocene) –** Semi-consolidated conglomerate interbedded with clay and silt. The conglomerate is composed of rounded, gray, cobble-sized, porphyritic andesite up to as much as 0.20 m in length, as well as white, tuffaceous sandstone pebbles. Where fresh, the conglomerate matrix includes sand-sized grains of plagioclase, pyroxene, magnetite, and silicic volcanic rock fragments. The unit generally corresponds to the Lacomb Gravel of Allison (1953) and upper terrace deposits of Beaulieu and others (1974). Typically overlain by Salkum, Willakenzie, and Siever soils as mapped by Langridge (1987). The unit forms part of the Dolph erosional surface of Balster and Parson (1968). From well logs, the unit is highly irregular in thickness, ranging from 3 m to more than 50 m east of the map near Lacomb. Although elsewhere the unit is interpreted as high-standing terrace gravels related to the North Santiam River (Allison, 1953; Beaulieu and others, 1974), herein the unit is interpreted as a channel gravels that mark an older stream system. The eroded top of unit stands about 60 m above the modern drainage system. Pliocene to late Miocene age based correlation with the channel-filling gravels that underlie a 4.5 ± 0.3 Ma (K-Ar; Walker and Duncan, 1989) basalt flow at Marks Ridge near Sweet Home, 5 km to the south.

Tertiary Volcanic and Sedimentary Rocks

Little Butte Volcanic Series (lower Miocene to Eocene?) – Basalt, basaltic andesite, and andesite lava flows, silicic tuffs, and volcaniclastic sedimentary rocks. The term Little Butte Volcanics was originally used in reference to the post-Colestin volcanic rocks of Oligocene age exposed in the Medford quadrangle (Wells, 1956). Subsequently, Peck and others (1964) applied the term Little Butte Volcanic Series to all Oligocene and early Miocene volcanic and terrestrial rocks of the Western Cascades. As such, the unit includes the Mehama Formation of Smith (1958) (Mehama Volcanics of Thayer [1939]). In the map area, Beaulieu and others (1974) identified these rocks as the Little Butte Formation and found that the middle and lower parts of the formation were interbedded with marine sandstone equivalent to the Eugene Formation. On the basis of lithology, the unit is subdivided in the map area into:

Tomv — **Mehama Formation (lower Miocene and Oligocene) –** Gray-orange, green, yellow-brown, and white volcaniclastic conglomerate, sandstone, breccia, and lithic tuff, with subordinate amounts of intercalated andesite, basaltic andesite, and basaltic trachyandesite flows. The unit includes tuffaceous conglomerate, sandstone, and matrix-supported breccia that contain abundant pumice clasts in addition to volcanic rock and tuffaceous sandstone fragments. Both the matrix and clasts are commonly altered to clay and often described as clay or claystone in water well logs. Volcaniclastic conglomerate and sandstone are more common in the topographically lower, westernmost exposures, while andesitic and dacitic lithic tuff and breccia become more abundant upsection and to the east. More coherent conglomerates contain woody debris; clasts are rimmed by black oxides (manganese?) and cemented by zeolite and calcite. The unit includes a green-gray dacitic lithic tuff (sample 19, Table 1) that contains abundant aphyric volcanic rock fragments set in fine matrix cut by zeolite and calcite veinlets. Strata mapped as the Mehama Formation (Smith, 1958) were first referred to as the Mehama Volcanics by Thayer (1939) for exposures along the North Santiam River near the hamlet of Mehama. Allison and Felts (1956) extended the terminology "Mehama Volcanics" southward into the Lebanon area. Beaulieu and others (1974) consider the Mehama Volcanics to be correlative to their Little Butte Formation and the Little Butte Volcanic Series of Peck and others (1964). The unit is also equivalent to the clastic sedimentary rocks unit (Tus) of Walker and Duncan (1989). Radiometric age determinations from lava flows interbedded with volcaniclastic rocks farther to the east range from 22.6 ± 0.3 to 28.5 ± 0.4 Ma (K-Ar; Walker and Duncan, 1989). The unit both overlies and grades westward into volcaniclastic sandstones and conglomerates of the Fisher Formation (Teof).

Tomt — **Dacite lithic ash-flow tuff (lower Miocene and Oligocene) –** White, red-purple, and red dacitic lithic ash-flow tuff that is mapped only where it forms a ridge-capping succession on the east side of the Onehorse Slough quadrangle. The base of the tuff in the adjoining Lacomb quadrangle overlies a fine-grained, gray-white air-fall tuff that contains carbonized fossil leaves. The tuff is typically heavily altered and marked by conspicuous red-purple and red iron-stained fractures. An analyzed sample of heavily oxidized, silicic lithic tuff in the adjoining Lacomb 7.5' quadrangle (sample 37 MWJ 07) is marked by low niobium (9.5 ppm Nb) and rubidium (6.2 ppm Rb) with moderate amounts of strontium (321 ppm Sr) and barium (288 ppm Ba).

Teof — **Fisher Formation undivided (lower Oligocene and middle Eocene) –** Poorly exposed, light gray, gray-brown, brown, and pale brown to pale yellow feldspathic sandstone and pebbly tuffaceous sandstone. Sedimentary units include massive sandstone, finely laminated fine-grained sandstone and siltstone that contain wood debris, bentonitic claystone, and minor coal beds. These deposits are equivalent to the coal-bearing, nonmarine volcanic sandstones and tuff identified by McKeel (1985) in the upper 3,000-ft interval of the Hickey oil and gas well. Fisher Formation sandstones are commonly described as gray sandstone in water well logs. The Fisher Formation grades upward and eastward into volcaniclastic deposits of the Mehama Formation. In the map area the Fisher Formation also includes interbedded mafic lava flows and silicic ash-flow tuff. A high-titanium basalt recovered from the 5,800-ft depth in the Esmond well (sample E-5800; Table 1) somewhat resembles the high-titanium basalts of the volcanics of Scravel Hill (Albany 7.5' quadrangle), which (Wiley, 2006) considers to be equivalent to the Fisher Formation. Wiley (2006) interprets the volcanics of Scravel Hill to mark the contact between the Eugene Formation and underlying Spencer Formation. Volcanic units of the Fisher Formation mapped separately in the Lebanon and Onehorse Slough 7.5' quadrangles include:

Teot — **Rhyolite ash-flow tuff (lower Oligocene and upper Eocene) –** Light gray, crystal-vitric ash-flow tuff. The tuff is plagioclase-phyric and contains embayed quartz phenocrysts set in a gray, glassy matrix. Minor silicic lithic fragments are interspersed in the matrix. Fractures in the tuff are stained by black oxides. Chemically the tuff is a peraluminous rhyolite (sample 1; Table 1) that contains 71.15 weight percent SiO_2 and 15.57 weight percent Al_2O_3. The rhyolite is characterized by low niobium (18.2 ppm Nb) and rubidium (16.4 ppm Rb) abundances, with moderate amounts of yttrium (56.5 ppm Y), barium (354 ppm Ba) and strontium (212 ppm Sr). Contact relationships are unclear, but the tuff is interpreted to be interbedded with feldspathic sandstones of the Fisher Formation (Teof).

Toa — **Andesite (lower Oligocene) –** Gray, aphyric andesite that is exposed in low hills north of Beaver Creek. The andesite is very fine grained and has pronounced platy jointing. The unit appears to lie stratigraphically above flows of unit Teb and is interbedded with sandstones of the Fisher Formation (Teof). Chemically, the unit is an andesite, with 59.32 weight percent SiO_2; 1.83 weight percent TiO_2; and 2.00 weight percent MgO (sample 2; Table 1).

Teob — **Basalt (lower Oligocene and middle Eocene) –** Brown and red-weathering aphyric to sparsely microporphyritic basalt lava flows. Flows are gray to dark blue-gray in color, generally are very fine grained, and typically do not contain discrete phenocrysts. Some flows contain microphenocrysts of plagioclase and pyroxene as much as 2 mm in length. The unit is typically poorly exposed, with deeply weathered road-cut exposures marked by red weathering rinds and occasionally cored by well-developed columnar joints. Chemically, the unit has a basalt composition (samples 12, 13, 14, 15, 16, 17, 18, and 20, 21, 22, 23, 24; Table 1) with 49.69 to 51.25 weight percent SiO_2; 0.75 to 1.16 weight percent TiO_2; and 4.98 to 10.65 weight percent MgO. From water well logs, individual flows are separated by thin interbeds of volcaniclastic sandstone and conglomerate of the Fisher Formation (Teof). The unit appears to lie at or near the transition between underlying, predominantly epiclastic sandstones of the Fisher Formation and overlying, tuffaceous conglomerates and breccias of the Mehama Formation. An upper Eocene to lower Oligocene age is assigned on the basis of radiometric age determinations that range from 30.4 ± 0.4 Ma to 39.0 ± 0.7 Ma (Table 2; Shannon and Wilson, Inc., 1974; Sloan and others, 2003). However, stratigraphic position indicates the basalt flows are most likely lower Oligocene in age.

Teoa — **Andesite, basaltic andesite, basalt (lower Oligocene and Eocene) –** Dark blue-gray, gray, and brown-gray basaltic andesite and andesite lava flows. Lava flows are generally porphyritic and contain about 5 percent phenocrysts of plagioclase, pyroxene, and olivine that are as much as 3 mm in length. The top of the exposed section near Ridgeway Butte includes a fine-grained, blue-gray, aphyric basaltic andesite (sample 11, Table 1). Where exposed in rock quarries, interiors to the flows are marked by thick, irregularly oriented columns. Where stripped of overlying cover, such as along the South Santiam River at Lebanon Dam, vesiculated flow tops form uneven, undulating surfaces that resemble tumuli. From water well logs, the unit as mapped locally includes interbedded tuffaceous sandstone lenses. Unit includes two flows cut by the Esmond well (samples E-660 and E-870; Table 1). Lava flow package has a regional apparent dip to the northeast. Chemically, the unit consists mostly of basaltic andesite and andesite (samples 2, 3, 4 and 6, 7, 8, 9, 10, 11; Table 1) but does include a microporphyritic basalt flow exposed north of Lebanon (sample 5; Table 1). Basaltic andesite and andesite in composition, with 53.43 to 59.19 weight percent SiO_2,1.15 to 1.80 weight percent TiO_2; and 2.06 to 4.93 weight percent MgO. Whole-rock K-Ar age determinations range from 32.1 ± 0.8 to 41.5 ± 0.9 Ma (Table 2; Shannon and Wilson, Inc., 1974; Sloan and others, 2003). Verplanck (1985) reports a 31.7 ± 0.4 Ma ($^{40}Ar/^{39}Ar$) radiometric age determination from a rock quarry east of Lebanon; reported by Lux (1982) and Walker and Duncan (1989) to have yielded a whole rock K-Ar age of 41.5 ± 0.9 Ma.

Teb — **Basaltic andesite (lower Eocene) (cross section only) –** Gray-black, porphyritic basaltic andesite lava flows. These flows are not exposed at the surface and are known only from cuttings from the Esmond and Barr exploration wells. The unit includes at least three separate flows that are separated by variable thicknesses of tuffaceous shale, sandstone, and conglomerate. Chip samples contain chalky white plagioclase phenocrysts and are cut by thin calcite and zeolite veins. In the Esmond well, the unit includes all lava flows within the 1,410-ft to 2,635-ft depth interval. In the Barr well, the unit includes all lava flows within the 3,320-ft to 4160-ft depth interval. Although all analyzed samples (samples B-3350 through B-4100 and E-1420 through E-2560; Table 1) are altered, as evidenced by high loss on ignition (LOI) values, strong similarities in major elements such as aluminum (> 20 weight percent Al_2O_3) and titanium (1.55 to 2.18 weight percent TiO_2), indicate that the Barr and Esmond flows are arguably correlative flow packages.

Teom — **Eugene Formation (lower Oligocene and middle Eocene) –** Light gray, gray-brown, brown, and pale brown to pale yellow arkosic and tuffaceous marine sandstone and siltstone. Unit includes pebbly, tuffaceous sandstone interbeds. Sandstones are typically poorly exposed. Placement of the exposures at Peterson Butte in the Eugene Formation is based on marine fossils reported by Allison and Felts (1956). The contact between the Fisher Formation and Eugene Formation is poorly constrained and is interpreted from the transition from marine (glauconite-bearing sandstones) to nonmarine (coal-bearing sandstones). In cross sections A-A' and B-B', marine (Eugene Formation) to nonmarine (Fisher Formation) transitions are based on identification of marine microfossils in the Hickey exploration well by McKeel (1985) and seismic interpretations by Yeats and others (1996). Although the top of the underlying middle to late Eocene Spencer Formation is placed by Yeats and others at elevations of 457 m (1,499 ft) below mean sea level in the Hickey well, McKeel (1985) does not report age-diagnostic marine microfossils at elevations less than 987 m (3,238 ft) below mean sea level. The benthic Narizian foraminera *Cibicides natlandi* occurs within the 3,570- to 3,900-ft depth interval. Wiley (2006) places the faunal assemblage of benthic foraminera Cibicides natlandi and planktic foraminers *Globigerinatheka index* and *Globigernitheka tropicalis* (McKeel, 1985) in the nearby Wolverton well at the base of the Eugene Formation which, in the Albany 7.5' quadrangle, is marked by high-titanium basalt lava flows of the volcanics of Scravel Hill. The similar high-titanium lava flow present at 5800-ft depth in the Esmond well (sample E-5800; Table 1) somewhat resembles the Scravel Hill flows (Wiley, 2006). Marine strata of the Eugene Formation completely enclose the ~35 Ma Tuff of Bond Creek south of Autzen Stadium in Eugene.

Tbi — **Mafic intrusions (lower Miocene, Oligocene, and middle Eocene) –** Irregular plug and array of radiating and branching dikes of basalt that intrude sandstones of the Eugene Formation at Peterson Butte. The unit consists of a medium-grained, dark gray, holocrystalline basalt containing abundant phenocrysts of augite, olivine, and plagioclase as much as 2 to 4 mm in diameter (Allison and Felts, 1956). Outcrops near the summit of Peterson Butte form distinct knobs underlain by relatively fresh basalt characterized by irregular horizontal columns and mantled by boulder fields. Lower parts of the basalt section near the contact with the Eugene Formation are characterized by brown-weathering spheroidal basalt. Lux (1982) reports a date of 32.1 Ma from a similar (?) basaltic andesite intrusion at Saddle Butte, to the southwest.

STRUCTURE

Geologic structures in the map area are inferred largely on the basis of topographic expression and geophysical data, including multi-channel seismic reflection lines from a 1977-1978 study by Mobil Oil (Figure 3; Graven, 1991). Older Paleogene sedimentary rocks generally dip to the northeast, forming a surface that is overlain by easterly dipping Paleogene volcaniclastic rocks. Northwest-trending faults depicted on the map are inferred on the basis of topographic lineaments and apparent offsets in resistant lava flows. The northeast trend to the Ridgeway Butte Fault (Graven, 1991; Yeats and others, 1996) is based on apparent dips from structures inferred from 1977-1978 seismic lines 716-77-34 and 716-77-29. The fault trend follows large-scale gravity and aeromagnetic anomalies. The northwest-trending Beaver Creek Fault (Graven, 1991; Yeats and others, 1996) is inferred from topographic lineaments and seismic line 716-77-W11. The inferred trace follows a large-scale aeromagnetic anomaly. The Golden Valley Fault (Bromery, 1962) is based in part on the spatial distribution of basaltic andesite (Teoa) and olivine basalt flows (Teob) north of Hamilton Creek. The basalt outcrops, many of which were mapped as intrusions by Allison and Felts (1956), form a northwest-trending belt of rocks that butt up against a band of older basaltic andesite flows. The fault is marked by apparent east side-down offset between the Teb lava flows in the Esmond and Barr oil and gas wells. The northern trace of the Golden Valley Fault is not readily imaged by either the 716-77-W11 or 716-77-W7 seismic lines. Bromery (1962) originally defined the Golden Valley Fault on the basis of a strong northwest-trending aeromagnetic anomaly. From geochemical data from the Crabtree 7.5' quadrangle to the north, it appears that the Golden Valley Fault has a more northerly trend and runs parallel to the prominent east-side-down faults mapped by Tolan and others (2000) along the east side of the Salem Hills.

Table 2. Radiometric age determinations, Lebanon and Onehorse Slough 7.5′ Quadrangles, Linn County, Oregon.

Field and Laboratory No.	Quadrangle	UTM Coordinates	Lithology	Map Unit	Age (Ma)	Method
77113†	Lebanon	4930880N 509260E	andesite	Teoa	41.5 ± 0.9	K-Ar
78BL42†	Onehorse Slough	4933720N 511240E	basalt	Teoa	39.2 ± 0.5	K-Ar
77110†	Onehorse Slough	4931500N 510640E	basaltic andesite	Teoa	32.9 ± 0.4	K-Ar
77112†	Onehorse Slough	4928520N 514750E	basalt	Teob	33.9 ± 0.8	K-Ar
GWW-15-83†	Lebanon	4930980N 509320E	andesite	Teoa	31.7 ± 0.4	K-Ar
1*	Onehorse Slough	4932650N 515400E	basalt	Teob	39.9 ± 2.1	K-Ar
2*	Onehorse Slough	4931980N 515790E	basalt	Teob	39.0 ± 0.7	K-Ar
3*	Onehorse Slough	4930380N 510050E	basalt	Teoa	32.1 ± 0.8	K-Ar
4*	Onehorse Slough	4929070N 510870E	basalt	Teoa	36.0 ± 0.6	K-Ar
5*	Onehorse Slough	4933470N 514470E	basalt	Teob	30.4 ± 0.4	K-Ar
6*	Onehorse Slough	4932700N 514470E	basalt	Teoa	31.4 ± 0.3	K-Ar

†Analyses from Sloan and others (2003); *Shannon and Wilson, Inc. (1974).

Table 1. Whole-rock XRF (x-ray fluorescence) analyses, Lebanon and Onehorse Slough 7.5′ quadrangles, Linn County, Oregon.

Map No.	Quadrangle	Field and Laboratory No.	UTM Coordinates	Elev. (ft)	Lithology	Map Unit	SiO_2	Al_2O_3	TiO_2	FeO*	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5
1	Onehorse Slough	26 MWJ 07	4939235N 512680E	290	rhyolite tuff	Teot	71.16	15.57	0.74	3.01	0.02	3.04	0.27	1.04	4.93	0.21
2	Onehorse Slough	32 MWJ 07	4935071N 513231E	365	andesite	Toa	59.32	16.55	1.83	8.93	0.14	5.56	2.00	1.13	4.18	0.36
3	Lebanon	78BL42	4933720N 511240E	430	andesite	Teoa	59.19	15.97	1.44	8.65	0.19	5.88	2.72	1.34	4.30	0.31
4	Onehorse Slough	24 MWJ 07	4933682N 511247E	430	andesite	Teoa	57.78	16.33	1.47	10.21	0.16	6.26	2.06	1.25	4.11	0.36
5	Onehorse Slough	23 MWJ 07	4932930N 510442E	420	basalt	Teoa	50.07	18.16	1.30	11.68	0.25	9.92	4.94	0.62	2.80	0.25
6	Lebanon	2 MWJ 07	4931180N 509245E	380	basaltic andesite	Teoa	55.98	16.35	1.15	9.01	0.16	8.02	4.85	1.16	3.11	0.21
7	Lebanon	GWW-15-83*	4930980N 509320E	600	andesite	Teoa	57.80	15.97	1.37	8.11	0.28	7.78	3.62	1.31	3.51	0.24
8	Lebanon	77113*	4930880N 509260E	400	andesite	Teoa	56.60	16.42	1.22	8.29	0.21	7.64	4.93	1.22	3.26	0.20
9	Onehorse Slough	77110*	4931500N 510640E	450	basaltic andesite	Teoa	54.54	15.37	1.77	11.28	0.24	7.99	4.27	0.80	3.49	0.26
10	Onehorse Slough	22 MWJ 07	[illegible]	380	basaltic andesite	Teoa	55.08	17.46	1.14	9.54	0.22	8.80	3.27	1.14	3.17	0.18
11	Onehorse Slough	1 MWJ 07	[illegible]	420	basaltic andesite	Teoa	53.43	16.05	1.80	12.25	0.19	7.75	4.00	0.78	3.43	0.33
12	Onehorse Slough	77112*	[illegible]	420	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	Onehorse Slough	4 MWJ 07	[illegible]	410	basalt	Teob	49.69	15.36	0.80	9.96	0.16	10.92	10.65	0.31	2.00	0.14
14	Onehorse Slough	49 MWJ 07	[illegible]	440	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	Onehorse Slough	43 MWJ 07	[illegible]	510	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	Onehorse Slough	44 MWJ 07	[illegible]	440	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	Onehorse Slough	49 MWJ 07	[illegible]	440	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	Onehorse Slough	45 MWJ 07	[illegible]	420	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	Onehorse Slough	50 MWJ 07	[illegible]	460	dacite tuff	Tomv	62.95	15.17	1.24	8.86	0.19	6.22	2.72	0.56	1.79	0.30
20	Onehorse Slough	7 MWJ 07	[illegible]	440	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	Onehorse Slough	8 MWJ 07	[illegible]	480	basalt	Teob	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	Onehorse Slough	9 MWJ 07	[illegible]	560	basalt	Teob	51.25	19.07	1.16	9.59	0.18	10.32	4.98	0.36	2.90	0.18
Barr	Onehorse Slough	B-3350	[illegible]	-3010	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Barr	Onehorse Slough	B-3500	[illegible]	-3210	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Barr	Onehorse Slough	B-4100	[illegible]	-3760	[illegible]	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-660	[illegible]	-220	andesite	Teoa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-870	[illegible]	-430	basaltic andesite	Teoa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-1420	[illegible]	-980	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-1630	[illegible]	-1190	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-2230	[illegible]	-1790	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-2560	[illegible]	-2120	basaltic andesite	Teb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-5800	[illegible]	-5360	basalt	unit unknown	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Esmond	Onehorse Slough	E-7330	[illegible]	-6890	basalt	unit unknown	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Trace Elements (parts per million)

Map No.	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th	U	Co	LOI	Fe_2O_3	FeO
1	<1	<1	12	39	354	16.4	212	278	56.5	18.2	19.2	99	119	6	23	54	1.3	1.4	1	3.30	2.73	0.17
2	2	7	31	194	318	25.0	304	258	48.6	16.1	21.8	146	108	4	19	44	2.9	<0.5	24	3.19	5.63	2.74
3–22, Barr, Esmond	[illegible]																					

*Analyses from du Bray and others (2006); n.r = not recorded.

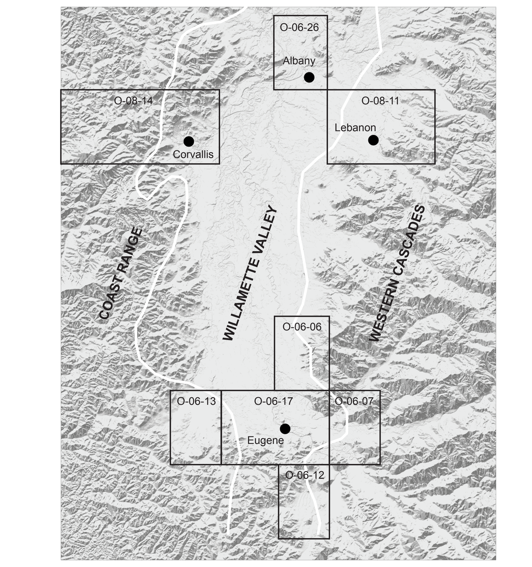


Figure 1. Shaded relief map from digital elevation model (DEM) for the southern Willamette Valley, showing quadrangles mapped between 2002 and 2007 and published as DOGAMI open-file reports under the USGS National Cooperative Geologic Mapping Program. White lines demarcate the approximate boundaries of physiographic provinces.

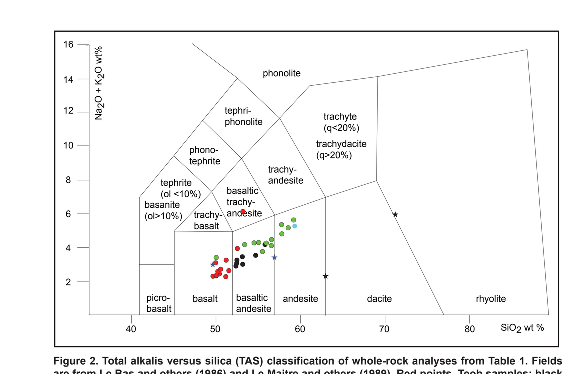


Figure 2. Total alkalis versus silica (TAS) classification of whole-rock analyses from Table 1. Fields are from Le Bas and others (1986) and Le Maitre and others (1989).

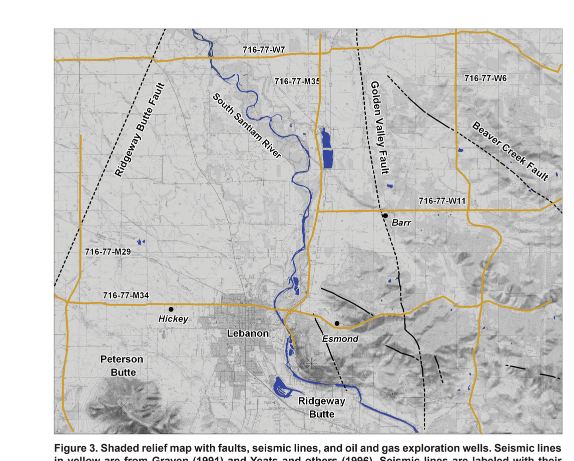


Figure 3. Shaded relief map with faults, seismic lines, and oil and gas exploration wells. Seismic lines are labeled with their corresponding transect numbers.

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