State of Oregon
Department of Geology and Mineral Industries
Donald A. Hull, State Geologist

GMS-111
Geologic Map of the Summerville Quadrangle,
Union County, Oregon
By M.L. Ferns and I.P. Madin
Text

Geology of the Summerville Quadrangle, Union County, Oregon

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INTRODUCTION

The Summerville quadrangle lies in the north-central Blue Mountains of northeast Oregon, in central Union County, just north of La Grande, Oregon. The quadrangle includes the west escarpment of fault-bounded margin of the Grande Ronde Valley, one of the most prominent structural depressions in northeast Oregon. The escarpment rises nearly 1,000 m above the valley floor; elevations in the quadrangle range from about 1,800 m at the top of Mount Emily to just over 800 m in the lowest part of the valley in the southeast corner of the quadrangle. Much of the area in higher elevations is heavily timbered, while the valley floor is intensely cultivated. Most of the northwestern part of the quadrangle is part of the Wallowa Whitman National Forest, administered by the USDA Forest Service.

The map area (Figure 1) lies in the south-central part of the La Grande 30 × 60 minute quadrangle, which has been targeted for detailed geologic mapping under the U.S. Geological Survey STATEMAP program. The Summerville quadrangle itself encompasses one of the most spectacular and youthful rangefront fault systems in northeast Oregon. Most recent workers in the La Grande area (Barrash and others, 1980; Gehrels, 1981) have concentrated on these large Quaternary faults in attempts to determine the tectonic origin of the valley. Some water resource data were collected during an early study by Hampton and Brown (1964). More recent regional studies (Swanson and others, 1981; Reidel and others, 1989; Bailey , 1990; Hooper and Swanson, 1990) have established a volcanic stratigraphy in the Columbia River Basalt Group, using geochemical analyses and paleomagnetic polarity measurements to define mappable units.

We use whole-rock chemical data to classify volcanic rocks, as many are too fine grained and glassy to be adequately characterized by mineralogical criteria. Simple classifications based on silica abundances, such as those used by Taylor and Ferns (1995), break down in areas that have had a complex volcanic history with eruption of two or more chemically distinctive groups of lavas. In the Summerville quadrangle, the AFM diagram (Figure 2) of Irvine and Barager (1971), which is based on the relative abundance of iron, is a convenient method to show chemical differences between the

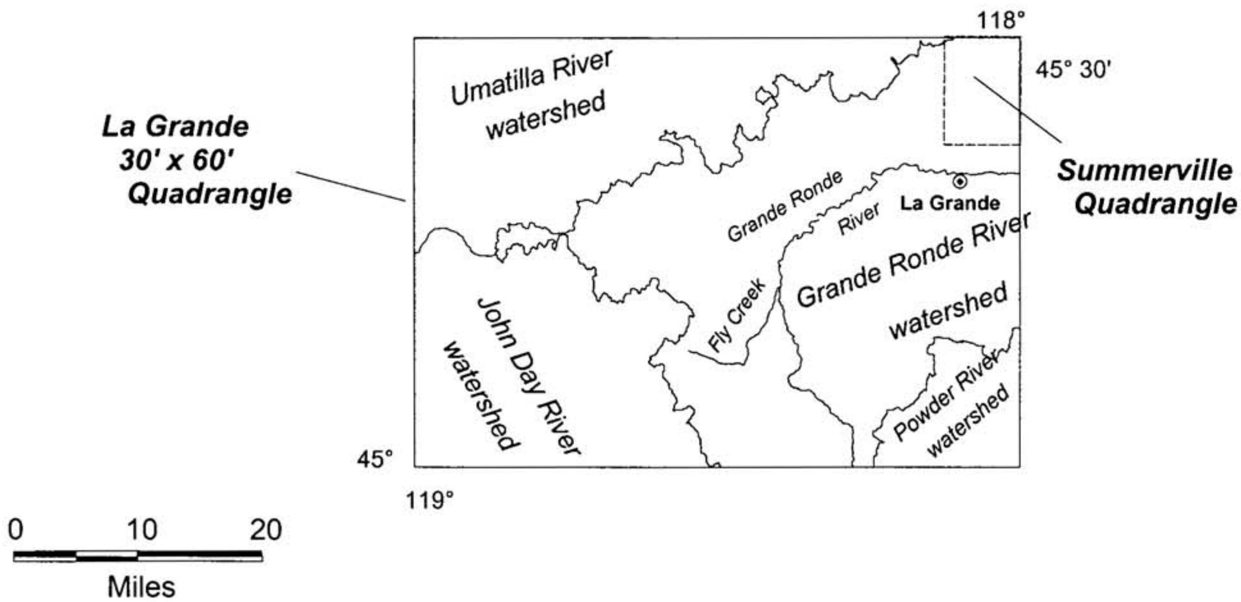

Figure 1. Sketch map of the La Grande 30' × 60' quadrangle. Rectangle marks location of Summerville 7½' quadrangle.

tholeiitic Columbia River Basalt Group and the calc-alkaline rocks of the Powder River Volcanic Field (Bailey, 1990). We suggest that names be based on chemical analyses recalculated to a 100-percent total without volatile and with all iron calculated as Fe+2. Rock names used herein are:

	Calc-alkaline group	Tholeiitic group
Silica < 53 weight percent =	Basalt	Basalt
Silica ≥ 53 and < 58 percent =	Basaltic andesite	Ferro-basaltic andesite
Silica ≥ 58 and < 63 percent =	Andesite	Ferroandesite
Silica ≥ 63 and < 68 percent =	Dacite	Ferrodacite

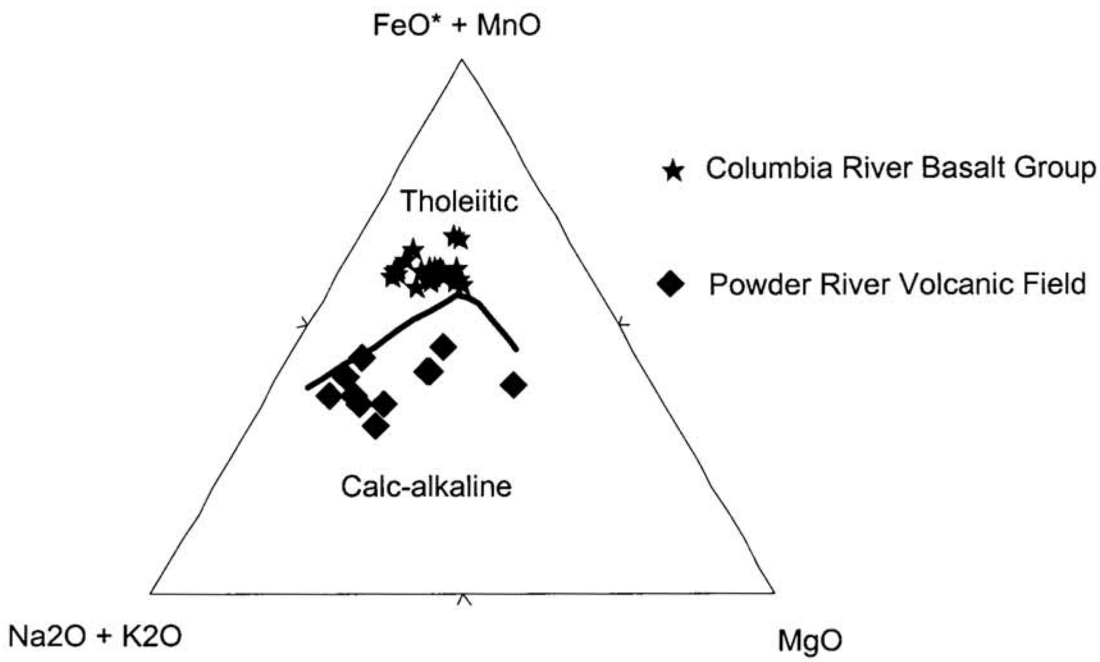

Figure 2. AFM diagram of samples from the Summerville and adjacent quadrangles.

EXPLANATION

Surficial Deposits

Qa **Loess and distal air-fall deposits (Holocene)**—Yellow-brown to tan, very fine grained accumulation of loess and ash that mantles some landslide, terrace, valley-floor, and alluvial-fan surfaces. Although this unit is locally admixed with colluvium and landslide debris, it is mapped separately only along constructional terraces in stream canyons upslope from alluvial fans on the east flank of Mount Emily

Qds **Debris-avalanche deposits (Holocene)**—Unconsolidated mixtures of rock and soil produced by debris avalanches along the east slope of Mount Emily. Mapped only where the deposits form hummocky, lobate masses on alluvial fans at the foot of Mount Emily. Comprised mainly of blocks of dacite as large as 3 m in diameter that mantle the alluvial fans up to 2 km from the foot of the escarpment. Holocene age indicated by absence of Mazama ash (unit Qa) on debris-flow surfaces

Qls **Landslide deposits (Holocene and upper Pleistocene)**—Unconsolidated mixtures of soil and rock formed by downslope movement typically involving bedrock. Includes debris flow and large block slides or slumps. Also includes rockfall, talus, and debris-avalanche deposits at the base of Mount Emily. Holocene avalanche deposits that form lobate masses of large dacite blocks on alluvial fans at the mouth of tributary canyons on the east flank of Mount Emily (e.g., Indian Creek Canyon) are mapped separately as unit Qds. Surfaces of landslides are typified by a hummocky landsurface marked by numerous springs. Slides in the quadrangle commonly originate along the contact between the dacite of Mount Emily (unit Tpd) and underlying olivine basalt (unit Tpb) or on sediments beneath the olivine basalt (unit Tpb)

Qal **Alluvium (Holocene and upper Pleistocene)**—Unconsolidated silt, sand, and gravel along modern flood plains adjacent to Mill and Willow Creeks. Includes channel gravel, sand, and silt deposits. Forms Catherine soils (Dyksterhuis and High, 1985)

Qaf **Alluvial-colluvial fan deposits (Holocene and upper Pleistocene)**—Unconsolidated, poorly sorted accumulations of boulders and cobble gravel deposited at the break-in-slope at the foot of Mount Emily. Water-well logs indicate that the fan gravels are generally 30–70 m thick and overlie older, finer grained sand and gravel deposits. Well defined fans are present at the mouths of most canyons and merge into a bajada dowsnlope. Unit adjacent to the range front away from canyons is dominantly colluvial. Overlying soil series generally coarsen upslope, from Conley soils at the toe of the fans to Emily and Hall Ranch soils at the foot of Mount Emily (Dyksterhuis and High, 1985)

Qf **Grande Ronde River fan gravel (Pleistocene)**—Unconsolidated gravel and sand deposited in an alluvial fan by the Grande Ronde River at the point where the Grande Ronde River enters the Grande Ronde Valley. Most of the fan, which comprises an area of approximately 22 mi^2 (Hampton and Brown, 1964; Schlicker and Deacon, 1971) lies in the northern part of the La Grande quadrangle. Unit is as much as 70 m thick in the quadrangle. Fan gravel is made up of well-rounded volcanic, metamorphic, and plutonic clasts derived from the upper Grande Ronde River drainage and is generally overlain by thin flood-plain silt deposits

QTal **Fluviatile and lacustrine sediments (Pleistocene, Pliocene, and upper Miocene?)**—Unconsolidated to poorly consolidated sand, silt, clay, and pebble-gravel deposits. Locally grades upward into thin terrace gravels on the fringe of the valley. Overlain by the mixed loess and ash-fall deposits in the eastern part of the quadrangle that form the Alicel, Hot Lake, and Palouse soils (Dyksterhuis and High, 1985). According to water-well drill logs, unit is as much as 350 m thick in the quadrangle and more than 650 m thick elsewhere in the Grande Ronde Valley. Cuttings collected from a well completed in 1998 (SE¼SE¼ sec. 11, T. 2 S., R. 38 E.) were predominantly fluvial sand and silt deposits with some thin pebble gravel layers and organic-clayey silt beds

POWDER RIVER VOLCANIC FIELD

Powder River Volcanic Field (middle Miocene)—The youngest volcanic rocks exposed in the quadrangle are calc-alkaline dacite, andesite, and high-alumina olivine basalt lava flows that make up part of the Powder River Volcanic Field of Bailey (1990). Although these lavas are coeval with eruptions of later phases of Columbia River Basalt Group lavas, their chemistry and petrography differ significantly from the tholeiitic Columbia River Basalt Group lavas. In the quadrangle, units include the following:

Tpa **Andesite (middle Miocene)**—Gray, light-brown-weathering, massive- to platy andesite flows. Unit includes chemically distinctive, widely separated flows exposed at the summit of Mount Emily and in the Grande Ronde valley in secs. 26 and 35, T. 1 S., R. 38 E. Flow on Mount Emily is about 20 m thick and consists of a calc-alkaline andesite with ~ 58 percent SiO_2 (Table 1, map nos. 17 and 44). Determination of age as middle Miocene based on stratigraphic position immediately above the dacite of Mount Emily (unit Tpd). Andesite flow exposed in valley floor may be continuous with sequence of similar andesite flows that underlie dacite in a water well east of the quadrangle near Alicel (unpublished data, DOGAMI Baker City field office)

Tpd **Dacite of Mount Emily (middle Miocene)**- Light-gray to gray and black, massive dacite lava flow. Unit is made up of a single, irregularly shaped dacite flow as much as 130 m thick that forms prominent cliffs on the east face of Mount Emily. Includes coarse, matrix-supported breccia at base of flow near Kaleib spring in sec. 7, T. 2 S., R. 36 E. Black vitrophyre is also found near the base of the flow. Locally vesicular in upper, massive part of flow. Often platy jointed in uppermost exposures, commonly weathering to large (1 - to 2-m diameter) blocks that cover contacts with underlying units. Sparsely porphyritic; thin sections typically contain less than 2 percent clinopyroxene and orthopyroxene phenocrysts set in a pilotaxitic groundmass of feldspar crystals. Characterized by approximately 64–66 percent SiO_2; 0.66–0.75 percent TiO_2; ~ 0.300 percent P_2O_5, and FeO*/MgO ratios between 1.5 and 2.6 (Table 1, map nos. 16, 18, 43, 47, and 48). An orthopyroxene-phyric flow protruding through younger alluvial units in sec. 34, T. 1 S., R. 36 E. (Table 1, map no. 43), is considered as part of the unit on the basis of strong similarities in major and trace element geochemistry. Basal contact commonly obscured by landslides and talus. Middle Miocene age based on 13.38 ± 0.24 Ma whole-rock $^{40}Ar/^{39}Ar$ radiometric determination (R.A. Duncan, Oregon State University, College of Atmospheric and Oceanographic Sciences, written communication, 1998)

Tpb **Olivine basalt (middle Miocene)**—Dark-gray, diktytaxitic olivine basalt flows. Unit is made up of one or more medium to coarsely crystalline olivine basalt flows that, in the southern part of the quadrangle, form prominent, 3- to 6-m-thick ledges. Inferred from float, to underlie the dacite of Mount Emily nearly everywhere, outcrops are rare, and much of the contact is marked by talus blocks and landslides. Unit thickens to the south, from 12 m near Indian Rock to about 30 m near the head of Conley Creek. Coarse-grained and equigranular, with 2-mm-diameter olivine crystals set in a groundmass of coarse plagioclase crystals and subophitic clinopyroxene crystals. Analyzed samples (Table 1, map nos. 19 and 45; see also Table 2 *in* Barrash and others, 1980) are typical for a high alumina olivine basalt; ranging from 51.55–51.79 percent SiO_2, 1.19–1.99 percent TiO_2, with FeO*/MgO ratios between 1 and 1.5. Middle Miocene age based on stratigraphic position between the 13.38 ± 0.24 Ma dacite of Mount Emily and the approximately 15.5 Ma uppermost flows of the N2 magnetostratigraphic unit of the Grande Ronde Basalt. Bailey (1990) reports $^{40}Ar/^{39}Ar$ ages of 13.3 ± 0.8, 13.7 ± 0.1, and 14.4 ± 0.2 Ma for similar olivine basalt flows to the east

Tph **Hornblende basaltic andesite (middle Miocene)**—Gray, hackly jointed basaltic andesite flow. Unit is made up of a single hornblende-phyric basaltic andesite flow about 30 m thick that crops out between N2 and R2 Columbia River Basalt Group magnetostratigraphic units of the Grande Ronde Basalt. The flow contains small clinopyroxene crystals and as much as 2 percent euhedral hornblende crystals up to 5 mm in length and set in a trachytic groundmass of feldspar and granular clinopyroxene crystals. The one analyzed sample (Table 1, map no. 23) is a typical calc-alkaline andesite, with 56.61 percent SiO_2, 17.58 percent Al_2O_3, 1.311 percent TiO_2, 0.68 percent P_2O_5 and a FeO*/MgO ratio of ~ 1.8. Middle Miocene age based on stratigraphic position at the top of the R2 magnetostratigraphic unit of the Grande Ronde Basalt is approximately 15.7 ± 0.3 Ma. Although the lava flow lies stratigraphically within the upper part of the Columbia River Basalt Group; the flow's distinctive calc-alkaline geochemistry suggests that it is the earliest calc-alkaline lava flow erupted as part of the Powder River Volcanic Field

COLUMBIA RIVER BASALT GROUP

Columbia River Basalt Group (middle to lower Miocene)—Bluish-black, aphyric to sparsely plagioclase-phyric, glassy to holocrystalline lava flows. Map units make up a flow-on-flow sequence of fine-grained lava flows that range in composition from tholeiitic (iron-rich) basaltic andesite (53.5–55.5 percent SiO2) in the four magnetostratigraphic units of the Grande Ronde Basalt to ferroandesite (56.5–60.5 percent SiO2) in the overlying units. Interflow zones within units commonly marked by horizontal vegetation lines. In the quadrangle, units include the following:

Tai **Ferroandesite of Indian Rock (middle Miocene)**—Dark-gray to gray, aphyric, iron-rich basaltic andesite flows that cap the ridgecrest at Indian Rock. Sequence of two or more thin lava flows marked by rubbly flow tops containing ropy, red to reddish-gray blocks of lava. Analyzed flows are microporphyritic with 1–5 percent plagioclase and clinopyoroxene phenocrysts < 1 mm in length set in an intergranular groundmass of feldspar, clinopyroxene, glass, and opaque minerals. Characterized by SiO_2 > 56 percent, TiO_2 > 2.29 percent, and P_2O_5 > 0.60 percent (Table 1, map nos. 9, 12, and 20). Measured flows display normal thermoremanent magnetism on a fluxgate magnetometer. Middle Miocene age is based on stratigraphic position between the approximately 15.5 Ma N2 magnetostratigraphic unit of the Grande Ronde Basalt (Baksi, 1989) and the overlying 13.38 Ma dacite of Mount Emily (unit Tpd)

Tav **Pyroclastic vent deposits (middle Miocene)**—Gray to brownish-gray volcaniclastic breccia. Massive bedded, matrix-supported breccia containing vesicular clasts as large as 30 cm in length. Clasts include dark-gray, aphyric, glassy vesicular scoria and sparsely plagioclase phyric scoria. Matrix comprises commingled altered gray glass, volcanic rock fragments, and rare plagioclase phenocrysts. Taubeneck (1980) considers these to be diatreme vent breccias

Tat **Lavas of Tucker Flat (middle Miocene)**—Iron-rich andesite and basaltic andesite. Dark-gray to gray and bluish-gray, generally glassy, aphyric to sparsely plagioclase-phyric lavas. Unit consists of at least three flows, and is capped by at least two glassy, sparsely plagioclase-phyric, iron-rich andesite flows. Generally poorly exposed. Grass-covered, rounded slopes mark the interiors of flows. Individual flows are relatively thin and consist largely of vesicular flow tops and basal flow breccias. Groundwater often seeps through the flow tops to support tree and brush lines. Lowermost flows are glassy to holocrystalline and are typified by intergranular textures in thin section. Glassy flows typically contain 2–5 percent phenocrysts of plagioclase and clinopyroxene set in a fine-grained groundmass of glass, feldspars, opaque minerals, and clinopyroxene. Uppermost flows (Table 1, map nos. 1, 6, 7, 8, and 21,) are ferroandesites with 59–60 percent SiO_2 and ~ 1.9 percent TiO_2. Lower flows (Table 1, map nos. 2, 22, and 46) contain less SiO_2 (56–58 percent) and more TiO_2 (2.1–2.3 percent). Separated from the Grande Ronde Basalt N2 magnetostratigraphic unit on the basis of distinctive chemistry (notably higher SiO_2, P_2O_5, and TiO_2). Near Indian Trail Canyon, an intervening, calc-alkaline, hornblende basaltic andesite (unit Tph) separates the unit from the underlying Grande Ronde Basalt R2 magnetostratigraphic unit (N2 is absent here). Although the majority of flows display normal porlarity thermoremanent magnetism, the uppermost flow consistently displays reversed polarity thermoremanent magnetism on a fluxgate magnetometer. Unit is equivalent to the High-TiO_2/P_2O_5/SiO_2 unit of the Columbia River Basalt Group of Reidel and others (1996) and is correlated with chemically similar lavas in the Tucker Flat quadrangle to the south that lie in the same stratigraphic position (Madin, 1997). Middle Miocene age is based on a 15.54 ± 0.01 Ma whole rock $^{40}Ar/^{39}Ar$ radiometric determination (R.A. Duncan, Oregon State University, College of Atmospheric and Oceanographic Sciences, written communication, 1998) from a sample in the Tucker Flat quadrangle (Madin, 1997). Age determination is consistent with stratigraphic position between the approximately 15.5 Ma N2 magnetostratigraphic unit of the Grande Ronde Basalt (Baksi, 1989) and the 13.38 Ma dacite of Mount Emily

Tgu **Grande Ronde Basalt, undifferentiated (middle and lower Miocene)**—Separated, where possible, into magnetostratigraphic units on the basis of magnetic polarity measured in field with a fluxgate magnetometer. The following units occur in this quadrangle:

Tgn2 **N2 magnetostratigraphic unit (middle Miocene)**—Bluish-black, aphyric to sparsely plagioclase-phyric, holocrystalline to glassy lava flows. Unit consists of a flow-on-flow sequence of fine-grained lava flows that form steep slopes and generally weather to orange-brown, angular blocks. Flows crop out forming small benches marked by alternating cliff- and slope-forming units. Analyses from flows near the top of the section (Table 1, map nos. 3 and 4) are similar to analyses of the Winter Water unit (Reidel and others, 1989) with characteristic P_2O_5 of 0.35–0.40 percent. Based on polarity measurements, unit thickens northward from Indian Trail Canyon from 0 m to more than 130 m in thickness. Unit generally forms steeper slopes than overlying lavas of Tucker Flat (unit Tat). Age of the N2 magnetostratigraphic unit lies between approximately 15.5 to 15.7 ± 0.3 Ma (Baksi, 1989)

Tgr2 **R2 magnetostratigraphic unit (middle Miocene)**—Flow-on-flow sequence of aphyric to sparsely plagioclase-phyric holocrystalline to glassy lava flows. Base of the unit is not exposed on the west flank of

Mount Emily. Unit is between 90 and 180 m thick on the east flank of Mount Emily. Age of the R2 magnetostratigraphic unit is considered to be between 15.7 ± 0.3 and 15.9 ± 0.2 Ma (Baksi, 1989)

Tgn1 **N1 magnetostratigraphic unit (middle Miocene)**—Flow-on-flow sequence of aphyric to sparsely plagioclase-phyric holocrystalline to glassy lava flows. Exposed only on east flank of Mount Emily, where unit, based on widely spaced magnetic polarity measurements, is approximately 180 m thick. Age of the N1 magnetostratigraphic unit is considered to lie between 15.9 ± 0.2 and approximately 16.1 Ma (Baksi, 1989)

Tgr1 **R1 magnetostratigraphic unit (middle and lower Miocene)**—Flow-on-flow sequence of aphyric to sparsely plagioclase-phyric holocrystalline to glassy lava flows. Distribution based on widely separated measurements of magnetic polarities. Exposed only on east flank of Mount Emily, where base of the unit is not exposed. Age of the R1 magnetostratigraphic unit is considered to lie between approximately 16.1 Ma to 17.0 ± 0.3 Ma (Baksi, 1989)

Ti **Dikes, undifferentiated (middle Miocene)**—Iron-rich basaltic andesite dikes exposed on Coon Ridge. Microporphyritic with 1–5 percent plagioclase and clinopyoroxene phenocrysts < 1 mm in length set in an intergranular groundmass of feldspar, clinopyroxene, glass, and opaque minerals. Chemistry (notably 55.5 percent SiO_2; 2.35 percent TiO_2, and 0.430 percent P_2O_5; Table 1, map no. 5) is similar to lower flows in the lavas of Tucker Flat (unit Tat)

PRE-GRANDE RONDE BASALT ROCKS

Basement rocks (lower Miocene and older)—Shown only in cross-sections. Age and lithology of units underlying the Grande Ronde Basalt in the Summerville quadrangle is currently unknown. Nearest pre-Grande Ronde Basalt units are Oligocene volcanic rocks exposed approximately 25 km to the southwest. Permo-Triassic greenstones are exposed in the Telocaset area, approximately 35 km to the southeast. Barrash and Bond (1980) report greenstone cuttings from a geothermal well north of Union, approximately 20 km from the Summerville quadrangle

STRUCTURE

The Grande Ronde Valley is a structural graben, bounded by prominent faulted escarpments on the east and west (Hampton and Brown, 1964). The west escarpment runs north from La Grande through the Summerville quadrangle and is bordered by the West Grande Ronde Valley fault system (Simpson and others, 1993), a complex series of parallel Quaternary fault segments. Although the faults along the West Grande Ronde Valley fault system are rarely exposed, stratigraphic evidence strongly suggests that they are mainly down-to-the-east, normal displacement faults. Elevation differences between exposures of the dacite of Mount Emily (unit Tpd) require vertical, down-to-the-east displacement in excess of 1,000 m. Large displacement fault segments typically extend for a few kilometers along strike and dip (based on outcrop patterns) of between 60 and 70 degrees. Areas with substantial amounts of vertical displacement, such as the east flank of Mount Emily, occur where movement has been concentrated along a single fault. In places such as Owsley Canyon, vertical displacement is less significant, as movement has been distributed along a series of parallel fault segments. Although Gehrels and others (1980) suggest substantial strike-slip offset along faults in the La Grande basin, we found no direct evidence for substantial lateral movement along any of the West Grande Ronde Valley faults.

Geomorphic evidence of late Quaternary and probable Holocene surface rupture is found along the West Grande Ronde Valley fault system in the Summerville quadrangle. Simpson and others (1993) identify a number of subtle topographic features, including linear range fronts, low linear escarpments in alluvial fans, and faceted spurs. Evidence for late Pleistocene or later movement includes springs aligned along a segment of faceted spurs along the Thimbleberry Mountain segment and a low, subdued scarp cutting alluvial fan gravels along the Mount Emily segment. The contact between alluvial fan and bedrock along the western Mount Emily fault segment is almost everywhere a well-defined fault. North of Owsley Canyon, the fan-bedrock contact is marked by a pronounced scarp where virtually no colluvial material has been deposited across the fault. Where the Mount Emily fault separates bedrock from alluvial fan, unbroken colluvial wedges are only rarely deposited across the Mount Emily fault, which argues for Holocene motion along most of the escarpment. As Simpson and others (1993) note, although the Mount Emily segment displays fewer features that can be dated as late Quaternary or Holocene than do other faults in the Grande Ronde Valley, the large (1,000 m) amount of vertical displacement along the Mount Emily segment indicates that it has been one of the more active faults in the valley.

GEOLOGIC RESOURCES

Metallic and nonmetallic minerals

Aggregate in the form of crushed rock for road building has been the only mineral resource mined from the quadrangle. Although an extremely thick section of Grande Ronde Basalt is exposed on the east flank of Mount Emily, future development is unlikely. The difficulty of developing a quarry and haul roads on the rugged, steep east flank alone precludes future development, given the very large volumes of similar Grande Ronde Basalt located in much more favorable, more easily mined locations elsewhere in the region. The siliceous dacite mined from a small quarry in Mount Emily dacite exposed on the valley floor is apparently not suitable as a high-quality aggregate.

Small amounts of sand and gravel have been produced from alluvial fan gravels in the northern part of the quadrangle, west of Willow Creek. Additional sand and gravel resources might be produced from Grande Ronde River fan (unit Qf) in the southern part of the quadrangle. According to Schlicker and Deacon (1971), most of the fan gravel on the bench is covered by as much as 10 ft of soil.

Energy resources

Significant low-temperature geothermal resources have been identified in the La Grande area south of the quadrangle (Brown and others, 1980). Elevated temperatures reported from deeper water wells along the eastern margin of the quadrangle indicate the potential for low-temperature geothermal resources that may underlie much of the valley portion of the Summerville quadrangle.

Water resources

Elevations of water table and first water-bearing zone shown on the geologic map are from water well logs submitted by drillers to the Oregon Department of Water Resources. As these wells have not been field located, the elevations are considered approximations. Within the Grande Ronde Valley, the water table generally lies no more than 5–10 m below the ground surface. Most domestic wells produce from multiple gravel zones within the fluvial and lacustrine sediments (unit QTal). Pump tests indicate that the yields from domestic wells are generally low (5–30 gpm) with significant drawdown (10–50 ft) (Hampton and Brown, 1964), suggesting that overall permeability in this rock unit is low.

Deeper irrigation wells typically produce about 1,000 gpm from artesian zones in underlying lavas. Most productive irrigation wells lie outside the Summerville quadrangle, where, as limited data indicate, they are tapping interflow zones near the top of the Grande Ronde Basalt.

GEOLOGIC HAZARDS

Landslides and debris flows along the face of Mount Emily are the major geologic hazards in the Summerville quadrangle. Although landslides are generally thought of as relatively slow moving features that are most active during periods of high precipitation, catastrophic debris avalanches off the steep east flank of Mount Emily may occur at any time. The contact between the dacite of Mount Emily (unit Tpd) and the underlying olivine basalt unit (unit Tpb) is unstable in many areas. Where that contact is exposed high on the Mount Emily escarpment, slides may have a tendency to cascade catastrophically down the face of the escarpment, flowing out onto the valley as rapidly-moving debris avalanches. Near Indian Trail Canyon, rock falls and debris avalanches have transported large (2–3 m) blocks of dacite as far as 2 km from the foot of the escarpment. Volumetrically larger slides—such as the one near Bull Canyon—have slipped from areas closer to the valley floor and do not appear to have been rapidly emplaced debris flows. Surfaces of both slides have been substantially modified by erosion.

Topographic features along segments of the West Grande Ronde Valley fault zone south of La Grande require the entire fault zone to be considered active (Simpson and others, 1993).

Holocene movement is indicated by a distinct, z-shaped topographic inflection along the western Mount Emily fault. The bedrock escarpment on the footwall side of the fault steepens markedly below aprons of skree and talus that lie on the escarpment at the angle of repose. The topographic surface at the head of the alluvial fans on the hanging-wall side of the fault forms a slightly sloping bench at the foot of the escarpment. As the talus cones should form a continuous apron onto the alluvial fan surface at the current angle of repose, the abrupt topographic inflection strongly suggests Holocene surface rupture.

Previous studies indicate that the West Grande Ronde Valley fault zone is capable of generating a maximum credible earthquake of magnitude 7 (Simpson and others, 1993). Geomatrix Consultants, Inc. (1995) define the 1,000-year probabilistic peak acceleration for the La Grande area as 0.07, based on slip rates of 0.03–

0.05 mm/year. As these calculations were based on earlier studies (Simpson and others, 1993) that did not recognize the western Mount Emily fault, the 1,000-year probabilistic peak acceleration for the La Grande area may be considerably greater than 0.07.

ANALYTICAL METHODS

Analyses for Table 1 were determined by X-ray fluorescence (XRF) at the Washington State University GeoAnalytical Laboratory, Pullman, Washington, and X-Ray Analytical Laboratories (XRAL), Toronto, Canada. Both laboratories use glass beads fused with lithium tetraborate. The Washington State University GeoAnalytical Laboratory uses an automatic Rigaku 3370 spectrometer. Each element analysis is fully corrected for line interference and matrix effects. See Hooper and others (1993) for a more complete description of Washington State University GeoAnalytical Laboratory analytical methods. XRAL uses a Siemens SRS 3000 sequential X-Ray fluorescence spectrometer which reportedly gives instrumental precision on most elements of about 0.5%. Results from both laboratories have been normalized on a volatile-free basis and recalculated with total iron expressed as FeO.

ACKNOWLEDGMENTS

Technical review of map, text, and geochemical data were provided by Dr. Peter Hooper, Washington State University, Pullman, Washington; Dr. Marvin Beeson, Portland State University, Portland, Oregon; and Dr. Stephen P. Reidel, Pacific NW Laboratories, Richland, Washington. We benefitted greatly from their geological knowledge and insights. Mike Doran, USDA Forest Service-Baker City, and Tracy Parker, USDA Forest Service-La Grande, aided the mapping project by providing stimulating observations, geochemical analyses, and air photographs. Boise Cascade Corporation is thanked for providing access to its lands along the foot of the Mount Emily escarpment. We would also like to thank the Oregon Water Resources Department for providing water-well logs. Dr Jay Van Tassel and students at Eastern Oregon University, La Grande, Oregon, who have done considerable work along the margins of the Grande Ronde Valley, provided stimulating insights into how the valley has developed over time.

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Table 1. Major- and trace-element geochemical XRF analyses, Summerville quadrangle, Union County, Oregon[1]
(layout extends to opposite page ➤)

Map no.	Field/ Lab no.	Latitude	Longitude	¼	¼	Sec.	T. (S.)	R. (E.)	Elev. (ft)	Map unit	Rock classification	SiO_2 %	Al_2O_3 %	TiO_2 %	FeO* %	MnO %
1*	LG 147B	45.4970	-118.1223	SW	NE	12	1	37	5,420	Tat	Ferroandesite	59.11	12.93	1.910	12.33	0.21
2	LG-144	45.4844	-118.1032	NW	NE	18	1	38	5,580	Tat	Ferroandesite	56.47	13.37	2.190	12.52	0.20
3	LG-145	45.4849	-118.1010	NE	NE	18	1	38	5,440	Tgn2	Ferro-basaltic andesite	54.36	14.03	2.040	12.14	0.18
4*	LG 146	45.4846	-118.0998	NE	NE	18	1	38	5,320	Tgn2	Ferro-basaltic andesite	53.61	13.35	2.260	14.27	0.20
5	LG-176	45.4820	-118.0954	NW	NW	17	1	38	4,840	Ti	Ferro-basaltic andesite	55.54	13.96	2.350	11.55	0.21
6	LG-179	45.4775	-118.1139	NW	SW	18	1	38	5,520	Tat	Ferroandesite	59.70	13.08	1.920	11.65	0.21
7	LG-180	45.4763	-118.1185	SE	SE	13	1	37	5,380	Tat	Ferroandesite	59.81	13.15	1.930	11.29	0.20
8	LG-138	45.4609	-118.1223	NW	SE	24	1	37	5,240	Tat	Ferroandesite	60.38	13.50	1.990	10.69	0.16
9	LG-162	45.4647	-118.0960	SE	NE	19	1	38	5,640	Tai	Ferroandesite	56.29	13.16	2.330	12.50	0.23
10	LG-152	45.4575	-118.0959	NW	SW	20	1	38	5,420	Tgn2	Ferro-basaltic andesite	54.10	13.59	2.140	13.46	0.24
11	LG153	45.4633	-118.0927	NW	SW	20	1	38	5,120	Tgn2	Ferro-basaltic andesite	55.25	13.93	2.304	12.85	0.22
12	LG-140	45.4575	-118.0959	SW	SW	20	1	38	5,600	Tai	Ferroandesite	56.04	13.16	2.290	13.22	0.21
13*	97LG5	45.4609	-118.0711	NW	SW	21	1	38	3,820	Tgru	Ferro-basaltic andesite	54.63	13.66	2.337	12.95	0.20
14*	97LG2	45.4671	-118.0696	NW	NW	21	1	38	3,720	Tgru	Ferro-basaltic andesite	54.09	14.03	1.647	12.82	0.20
15*	97LG3	45.4564	-118.0614	NW	NE	28	1	38	3,360	Tat	Ferro-basaltic andesite	58.45	13.13	2.065	12.43	0.19
16	SV-10	45.4331	-118.0925	SW	SW	32	1	38	5,860	Tpd	Dacite	65.06	16.70	0.750	4.24	0.07
17	SV-9	45.4376	-118.0906	SE	NW	32	1	38	6,110	Tpa	Andesite	58.28	17.69	1.030	5.65	0.10
18	SV49A	45.4396	-118.0855	NW	NE	32	1	38	5,745	Tpd	Dacite	64.76	16.48	0.711	4.26	0.09
19	SV49B	45.4396	-118.0841	NW	NE	32	1	38	5,540	Tpb	Olivine basalt	51.79	16.37	1.990	10.32	0.18
20	SV49C	45.4396	-118.0835	NW	NE	32	1	38	5,465	Tai	Ferroandesite	57.07	13.65	2.354	11.67	0.23
21	SV49D	45.4395	-118.0828	NW	NE	32	1	38	5,360	Tat	Ferroandesite	60.97	13.66	2.003	10.88	0.22
22	SV49E	45.4395	-118.0824	NW	NE	32	1	38	5,305	Tat	Ferroandesite	58.51	14.15	2.300	11.51	0.16
23	SV49F	45.4394	-118.0818	NW	NE	32	1	38	5,225	Tph	Hornblende andesite	56.61	17.58	1.311	7.44	0.07
24	SV49G	45.4394	-118.1121	NE	NW	32	1	38	5,180	Tgr2	Ferroandesite	57.13	13.72	2.275	12.49	0.19
25	SV49H	45.4394	-118.0808	NE	NE	32	1	38	5,120	Tgr2	Ferroandesite	56.31	13.52	2.177	12.04	0.194

[1] Samples marked by * analyzed through X-Ray Assay Laboratories (XRAL), Toronto, Canada; all other analyses by Washington State University Geoanalytical Laboratory, Pullman, Washington.

(Continued on page 12)

Table 1. Major- and trace-element geochemical XRF analyses, Summerville quadrangle, Union County, Oregon
(continued from opposite page)

CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	Ni ppm	Cr ppm	Sc ppm	V ppm	Ba ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Ga ppm	Cu ppm	Zn ppm	Pb ppm	La ppm	Ce ppm	Th ppm
5.08	1.70	2.41	3.55	0.770	NA	NA	NA	NA	900	71	309	52	268	18.0	NA	NA	NA	NA	NA	NA	NA
6.34	3.14	1.79	3.51	0.480	ND	12	27	261	718	48	306	42	194	15.0	26	ND	135	9	29	70	8
8.27	4.18	1.52	2.93	0.350	9	49	32	366	589	37	324	36	164	14.0	22	37	118	6	28	48	6
7.37	3.79	1.64	3.12	0.390	NA	NA	NA	NA	633	34	320	40	186	13.0	ND	NA	NA	NA	NA	NA	NA
7.14	3.44	2.30	3.07	0.430	10	23	29	350	808	54	303	42	203	15.0	22	16	129	7	28	38	11
4.95	1.50	2.34	3.87	0.780	ND	ND	24	72	993	70	306	57	241	19.0	23	ND	143	9	41	59	8
4.97	1.59	2.34	3.95	0.790	ND	ND	23	71	1008	67	313	56	244	20.0	22	ND	151	11	56	81	10
4.70	1.42	2.41	3.95	0.800	ND	1	21	77	1019	73	316	49	244	19.0	22	4	157	11	53	69	8
6.64	2.88	1.78	3.58	0.620	ND	10	29	243	789	42	316	46	202	16.0	22	5	145	5	32	60	7
7.86	4.00	1.31	2.90	0.400	ND	18	32	395	643	31	350	38	165	13.0	24	14	131	5	24	29	5
7.78	3.75	1.68	3.30	0.40	2	23	30	419	655	36	315	38	172	16	24.0	23	131	9	22	43	4
6.17	2.91	1.75	3.64	0.610	ND	11	27	230	745	46	308	44	202	16.0	21	3	136	8	47	61	8
7.48	3.53	1.96	2.86	0.405	NA	NA	NA	NA	768	51	319	49	216	13.0	NA	NA	NA	NA	NA	NA	NA
8.17	4.43	1.19	3.17	0.303	NA	NA	NA	NA	573	24	319	40	172	ND	NA	NA	NA	NA	NA	NA	NA
4.89	1.29	2.30	3.81	0.752	NA	NA	NA	NA	987	65	315	63	264	13.0	NA	NA	NA	NA	NA	NA	NA
5.25	1.72	1.68	4.21	0.300	19	39	12	100	623	25	612	17	162	11.0	19	20	78	5	22	48	4
6.90	3.82	1.45	4.58	0.500	71	81	18	154	691	9	1291	17	136	6.0	21	49	87	6	19	48	3
5.19	2.24	1.75	4.35	0.31	15	33	14	89	605	25	607	15	163	14	24.0	23	70	6	28	56	ND
9.28	6.69	0.95	3.35	0.62	85	192	29	258	534	11	502	26	134	18	19.0	45	93	4	18	39	3
6.80	3.08	2.11	3.44	0.64	ND	12	30	227	873	45	321	46	202	20	20.0	4	143	6	43	62	10
5.31	1.67	2.34	3.83	0.81	ND	ND	27	76	978	55	309	56	238	22	22.0	ND	149	8	33	67	10
6.25	2.71	1.94	3.70	0.53	ND	17	26	255	763	53	312	40	201	18	23.0	2	141	7	32	53	6
7.44	4.07	1.71	4.73	0.68	36	63	18	178	580	15	1426	14	154	15	24.0	40	100	6	42	49	2
6.88	3.22	1.93	3.32	0.40	ND	19	30	368	799	53	310	38	182	17	23.0	19	124	9	21	50	5
6.80	3.22	2.18	3.19	0.372	ND	18	24	357	798	50	311	36	178	12.6	18	13	121	8	19	44	6

(Continued on page 13)

Table 1. Major- and trace-element geochemical XRF analyses, Summerville quadrangle, Union County, Oregon, cont.
(layout extends to opposite page ➤)

Map no.	Field/ Lab no.	Latitude	Longitude	¼	¼	Sec.	T. (S.)	R. (E.)	Elev. (ft)	Map unit	Rock classification	SiO_2 %	Al_2O_3 %	TiO_2 %	FeO* %	MnO %
26	SV49I	45.4394	-118.0804	NE	NE	32	1	38	5,080	Tgr2	Ferro-basaltic andesite	54.39	14.19	2.085	12.29	0.191
27	SV49J	45.4393	-118.0793	NE	NE	32	1	38	5,020	Tgr2	Ferro-basaltic andesite	54.37	14.11	1.968	12.03	0.201
28	SV49K	45.4392	-118.0794	NE	NE	32	1	38	4,980	Tgr2	Ferro-basaltic andesite	54.14	14.14	1.915	11.92	0.200
29	SV49L	45.3910	-118.0788	NE	NE	32	1	38	4,920	Tgr2	Ferro-basaltic andesite	55.09	13.67	2.364	12.71	0.189
30	SV49M	45.4390	-118.0781	NE	NE	32	1	38	4,840	Tgr2	Ferro-basaltic andesite	54.37	13.82	2.199	12.83	0.198
31	SV49N	45.4389	-118.0771	NE	NE	32	1	38	4,760	Tgn1	Ferro-basaltic andesite	55.55	13.61	2.265	12.65	0.185
32	SV49O	45.4387	-118.0768	NE	NE	32	1	38	4,700	Tgn1	Ferro-basaltic andesite	54.84	13.69	2.150	12.20	0.229
33	SV49P	45.4385	-118.0764	NE	NE	32	1	38	4,620	Tgn1	Ferro-basaltic andesite	55.31	13.64	2.165	12.40	0.235
34	SV49Q	45.4382	-118.0759	NE	NE	32	1	38	4,540	Tgn1	Ferro-basaltic andesite	54.08	13.74	2.221	13.44	0.201
35	SV49R	45.4380	-118.0755	NE	NE	32	1	38	4,460	Tgn1	Ferro-basaltic andesite	54.69	13.50	2.201	12.85	0.202
36	SV49S	45.4375	-118.0744	SW	NW	33	1	38	4,280	Tgn1	Ferroandesite	56.14	13.25	2.308	12.70	0.218
37	SV49T	45.4371	-118.0737	SW	NW	33	1	38	4,180	Tgn1	Ferroandesite	56.71	13.57	2.277	12.21	0.169
38	SV49U	45.4367	-118.0729	SW	NW	33	1	38	4,040	Tgr1	Ferro-basaltic andesite	55.27	14.19	1.846	10.98	0.182
39	SV49V	45.4368	-118.0727	SW	NW	33	1	38	4,000	Tgr1	Ferro-basaltic andesite	55.12	13.81	2.065	12.25	0.207
40	SV49W	45.4366	-118.0722	SW	NW	33	1	38	3,920	Tgr1	Ferro-basaltic andesite	55.73	14.12	1.907	10.93	0.199
41	SV49X	45.4365	-118.0713	SW	NW	33	1	38	3,820	Tgn1	Ferro-basaltic andesite	54.77	13.39	2.300	13.41	0.208
42	SV49Y	45.4362	-118.0705	SW	NW	33	1	38	3,720	Tgn1	Ferro-basaltic andesite	54.62	13.51	2.297	12.64	0.196
43	SV47	45.4341	-118.0418	NW	SW	34	1	38	2,840	Tpd	Dacite	64.29	16.95	0.745	4.93	0.07
44	SV55	45.4420	-118.0199	NW	NE	35	1	38	2,720	Tpa	Andesite	57.99	17.75	1.079	7.35	0.11
45	LG-205	45.4143	-118.0934	SW	SW	5	2	38	4,680	Tpb	Olivine basalt	51.55	16.32	1.190	8.42	0.14
46	LG-206	45.4061	-118.1000	SE	NE	7	2	38	4,800	Tat	Ferroandesite	57.80	13.54	2.330	10.86	0.25
47	SV-12	45.3957	-118.1052	NW	NE	18	2	38	4,400	Tpd	Dacite	65.18	16.49	0.660	3.83	0.06
48	SV-8	45.3926	-118.1155	NW	NW	18	2	38	4,980	Tpd	Dacite	65.49	16.35	0.700	4.17	0.08

Table 1. Major- and trace-element geochemical XRF analyses, Summerville quadrangle, Union County, Oregon, cont.
(continued from opposite page)

CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	Ni ppm	Cr ppm	Sc ppm	V ppm	Ba ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Ga ppm	Cu ppm	Zn ppm	Pb ppm	La ppm	Ce ppm	Th ppm
7.89	4.07	1.51	3.03	0.355	7	33	31	376	664	42	322	39	179	13.2	21	29	115	5	26	53	8
8.01	4.30	1.56	3.08	0.356	8	36	31	343	652	37	312	36	171	13.1	20	34	115	3	18	45	7
8.15	4.42	1.62	3.14	0.357	10	43	32	332	604	37	311	36	170	12.7	19	35	116	6	14	44	6
6.93	3.33	2.23	3.03	0.437	5	18	25	356	854	55	300	43	206	13.9	23	21	125	10	32	56	6
7.48	3.83	1.52	3.36	0.412	3	36	25	365	647	43	324	40	166	13.2	21	24	122	5	28	48	5
6.90	3.35	2.02	3.07	0.395	ND	23	31	347	747	54	349	37	179	14.0	23	7	121	9	29	56	9
7.60	3.97	1.58	3.32	0.411	4	23	27	347	743	42	331	38	167	11.8	23	17	119	10	20	41	4
7.17	3.63	1.84	3.26	0.352	ND	22	30	388	655	45	320	37	175	10.7	24	4	121	5	15	45	6
7.51	3.99	1.69	2.74	0.376	ND	28	31	413	591	38	319	34	167	10.6	19	5	123	10	28	45	5
7.34	3.78	1.59	3.48	0.376	2	28	35	401	644	45	306	34	164	12.9	23	17	120	7	26	40	5
6.57	3.20	1.72	3.49	0.396	ND	17	32	340	703	48	305	40	183	14.1	22	2	125	9	23	38	8
6.44	2.92	1.79	3.55	0.373	ND	20	26	352	743	48	307	41	192	14.8	23	16	128	9	12	47	4
8.10	4.42	1.61	3.14	0.265	ND	32	29	323	518	37	323	32	158	10.9	20	18	102	4	4	23	5
7.47	3.85	1.50	3.40	0.335	1	21	29	382	612	35	311	38	179	13.0	21	20	118	6	20	48	7
7.87	4.28	1.61	3.06	0.291	ND	23	35	311	589	38	338	34	170	11.8	20	16	112	4	33	39	6
7.00	3.41	1.58	3.53	0.399	ND	15	35	388	655	38	327	41	198	14.8	22	20	126	7	22	63	6
7.40	3.96	1.49	3.55	0.339	5	26	28	376	560	39	316	39	189	13.0	22	58	119	7	21	42	2
5.55	1.92	1.51	4.37	0.32	29	50	15	101	530	20	647	15	157	14	21.0	32	79	5	31	58	3
6.20	2.75	1.81	4.40	0.474	NA	NA	NA	NA	786	27	738	27.0	198	16	NA	NA	NA	NA	NA	NA	NA
10.16	8.31	0.66	2.89	0.350	463	29	233	333	8	412	101	9.0	23	15	54	78	1	23	21	3	ND
6.38	2.50	2.27	3.37	0.700	ND	5	29	197	1220	55	345	55	216	17.0	28	2	153	7	25	55	7
5.14	2.49	1.66	4.18	0.300	30	44	9	89	533	23	607	16	158	9.0	21	16	74	8	22	76	6
5.01	1.89	1.73	4.26	0.320	28	46	11	99	656	23	670	17	163	10.0	21	13	84	5	ND	46	5

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources
(layout extends to opposite page ➤)

				Location	Elevation		Depth (ft) from surface to						
Owner	Date drilled	Latitude	Longitude	precision (± m)	(ft)	Precision (± ft)	First gravel	First sand	Second gravel	Second sand	First lava	Third sand	Second lava
McClure	8/13/65	45.3645	-118.1024	200	3,020	140	0	28	0	0	274	0	0
Boothman	4/18/67	45.3643	-118.0927	200	2,900	80	52	89	241	150	0	0	0
Loudermilk	10/7/92	45.3579	-118.0815	200	2,920	60	6	0	12	0	66	310	0
Hampton	3/9/66	45.3560	-118.0769	200	2,820	60	0	30	89	82	0	0	0
Schaad	4/30/65	45.3561	-118.0728	200	2,795	15	0	0	150	0	0	0	0
Carnes	8/20/65	45.3683	-118.0735	100	2,900	20	0	97	2	76	35	2	0
Clark	4/22/65	45.3681	-118.0366	200	2,720	10	0	0	125	0	0	0	0
Van Blakland	8/25/95	45.3569	-118.0201	200	2,710	10	0	0	309	356	0	0	0
Cuthbert	9/11/69	45.3715	-118.0013	200	2,710	25	0	0	330	495	0	0	0
Kohr	7/23/95	45.3822	-118.0469	200	2,730	10	0	325	0	0	0	0	0
Price	3/12/69	45.3709	-118.0730	200	2,900	100	0	300	0	0	0	0	0
Long	8/15/71	45.3703	-118.0745	25	2,920	20	0	0	0	0	205	0	0
Wick	1/24/69	45.3821	-118.0671	200	2,800	40	0	47	53	0	0	0	0
Kliphardt	6/1/67	45.3912	-117.9879	25	2,760	10	0	621	303	81	0	0	0
Samples	1/13/95	45.3901	-118.0770	200	2,920	80	20	0	0	0	170	0	0
Shaw	10/3/76	45.3935	-118.0774	200	2,960	80	55	239	0	0	0	0	0
Price	6/7/83	45.3896	-118.0926	200	3,560	200	0	0	0	0	465	0	0
Waite	10/2/96	45.3890	-118.0677	200	2,800	40	0	0	120	216	0	0	0
Marshall	9/10/72	45.3972	-118.0732	200	2,920	120	36	0	24	265	0	0	0
Hammerstaedt	7/12/66	45.3984	-118.0653	25	2,860	40	24	0	62	429	0	0	0
Hire	8/28/67	45.3859	-118.0665	200	2,800	10	26	0	61	223	0	0	0
Jackman	9/8/64	45.3909	-118.0653	25	2,800	10	0	18	47	273	0	0	0
Waldrop	9/17/76	45.3972	-118.0570	200	2,800	10	54	0	216	290	0	0	0
Anchondd	11/2/76	45.3965	-118.0724	100	2,880	40	6	0	77	102	0	0	0
Wells	11/28/70	45.3931	-118.0675	200	2,840	80	40	199	0	0	0	0	0
Westenskow	10/8/79	45.3986	-118.0429	25	2,730	10	0	24	14	64	0	0	0
Koza	5/10/79	45.3969	-118.0157	200	2,750	40	0	150	0	0	0	0	0
Van Blokland	9/5/80	45.3874	-118.0316	25	2,710	10	0	45	16	25	0	0	0
Strand	6/25/68	45.4113	-118.0522	200	2,800	40	11	31	36	386	0	0	0
Livingston	5/12/68	45.4007	-118.0620	200	2,840	80	70	0	75	20	0	0	0
Kreger	9/11/80	45.4115	-118.0577	200	2,840	60	26	0	114	90	0	0	0
Lester	4/19/76	45.4082	-118.0729	100	3,120	120	0	71	59	60	0	0	0
Lusk	8/29/78	45.4039	-118.0673	200	2,920	80	98	0	162	0	0	0	0
Simonis	5/21/93	45.4072	-118.0634	200	2,920	80	0	350	0	0	8	0	0
Savage	8/9/91	45.4113	-118.0621	200	2,880	80	75	105	105	0	0	0	0
Bavemore	9/18/93	45.4000	-118.0581	200	2,800	40	0	263	0	0	0	0	0

(Continued on page 16)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources
(continued from opposite page)

Owner	Static water level (ft) (depth below ground surface)	Depth (ft) to First water zone	Depth (ft) to Second water zone	Depth (ft) to Third water zone	Total depth of well (ft)	Depth to artesian zone (ft)	Elevation of first lava (ft)
McClure	27	0	0	0	302	0	2,992
Boothman	20	125	386	0	532	0	2,368
Loudermilk	85	180	320	380	394	0	2,902
Hampton	32	161	0	0	201	0	2,619
Schaad	50	50	90	130	150	0	2,645
Carnes	40	30	0	0	212	0	2,725
Clark	4	68	0	0	125	0	2,595
Van Blakland	14	10	0	0	665	0	2,045
Cuthbert	6	48	175	290	825	0	1,885
Kohr	0	40	100	0	325	2	2,405
Price	70	240	0	0	300	0	2,600
Long	58	21	0	0	205	0	2,920
Wick	37	80	0	0	100	0	2,700
Kliphardt	27	190	420	0	1,005	0	1,755
Samples	110	160	0	0	190	0	2,900
Shaw	55	56	197	294	294	0	2,666
Price	250	340	465	0	465	0	3,560
Waite	45	40	220	290	336	0	2,464
Marshall	24	30	120	0	325	0	2,595
Hammerstaedt	39	40	120	0	515	0	2,345
Hire	13	210	0	0	310	0	2,490
Jackman	16	320	0	0	338	0	2,462
Waldrop	57	155	320	0	560	0	2,240
Anchondd	30	76	111	185	185	0	2,695
Wells	12	14	138	239	239	0	2,601
Westenskow	21	46	101	0	102	0	2,628
Koza	15	90	110	150	150	0	2,600
Van Blokland	13	53	78	0	86	0	2,624
Strand	50	0	0	0	464	0	2,336
Livingston	18	131	0	0	165	0	2,675
Kreger	100	21	195	0	230	0	2,610
Lester	80	173	0	0	190	0	2,930
Lusk	19	36	100	0	260	0	2,660
Simonis	85	180	250	350	358	0	2,570
Savage	85	10	275	0	285	0	2,595
Bavemore	60	56	120	180	263	0	2,537

(Continued on page 17)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(layout extends to opposite page ➤)

Owner	Date drilled	Latitude	Longitude	Location precision (± m)	Elevation (ft)	Elevation Precision (± ft)	Depth (ft) from surface to First gravel	First sand	Second gravel	Second sand	First lava	Third sand	Second lava
Cox	8/27/91	45.4078	-118.0618	200	2,900	50	190	115	0	0	135	0	0
Barbour	6/27/84	45.4093	-118.0645	25	2,920	40	23	115	54	8	0	0	0
Savage/Nichols	8/23/95	45.4125	-118.0660	200	3,000	120	28	177	0	0	275	0	0
Sorenson	5/23/68	45.4054	-118.0778	25	3,160	40	262	37	66	0	0	0	0
Haverfield	8/27/77	45.4016	-118.0779	25	3,040	40	144	27	0	0	0	0	0
Larson	7/6/67	45.4033	-118.0754	25	3,040	40	101	99	0	0	93	0	0
Tewinkel	10/19/81	45.4048	-118.0763	200	3,120	120	176	104	0	0	0	0	0
Tewinkel	3/30/92	45.4052	-118.0806	200	3,200	160	162	0	0	0	258	40	0
Sorenson	8/28/87	45.3992	-118.0790	200	3,000	160	230	0	0	0	195	0	0
Hoxie	3/3/67	45.3993	-118.0945	200	3,800	360	48	151	0	0	121	0	0
Voetberg	3/16/72	45.4151	-118.0621	200	2,860	40	18	432	0	0	0	0	0
Jambura	8/31/70	45.4176	-118.0619	200	3,000	120	97	111	142	18	0	0	0
Rost	6/18/88	45.4224	-118.0622	200	3,000	120	14	406	0	0	0	0	0
Davidson	10/26/84	45.4150	-118.0671	200	3,080	120	0	14	0	0	366	0	0
Kelly	5/22/88	45.4243	-118.0702	200	3,400	320	124	0	6	0	0	0	0
Kuensting	3/19/92	45.4267	-118.0450	200	2,840	80	131	0	0	0	84	50	112
Rasmussen	12/20/64	45.4200	-118.0430	200	2,760	40	0	34	66	670	150	90	51
Graham	12/29/65	45.4197	-118.0446	25	2,760	10	0	40	58	67	0	0	0
McClennan	9/2/77	45.4231	-118.0515	200	2,880	40	55	187	0	0	0	0	0
Weems	10/19/96	45.4226	-118.0481	100	2,840	40	27	273	0	0	0	0	0
Berry	10/7/70	45.4262	-118.0396	200	2,780	60	18	142	0	0	0	0	0
Lester	3/2/70	45.4237	-118.0512	25	2,880	40	92	238	0	0	0	0	0
Cuthbert	5/9/95	45.4156	-117.9948	200	2,780	20	0	1,000	0	0	0	0	0
Davis	12/11/78	45.4383	-118.0070	200	2,750	20	0	335	0	0	1,059	0	0
Woodell	11/25/65	45.4387	-117.9956	25	2,780	10	0	760	0	0	360	25	405
DeLashmutt	9/30/71	45.4289	-118.0391	200	2,750	60	14	131	0	0	0	0	0
Teeters	7/30/63	45.4399	-118.0475	200	2,800	40	18	27	0	0	5	28	0
Hulse	6/10/70	45.4380	-118.0535	25	2,960	40	214	128	0	0	0	0	0
Gruis	10/19/85	45.4329	-118.0421	200	2,800	40	0	0	0	0	120	0	0
Waibel	4/20/89	45.4331	-118.0414	200	2,800	40	0	0	0	0	135	0	0
B-W Angus	1/28/83	45.4298	-118.0380	200	2,720	20	0	0	240	0	0	0	0
Bingaman	7/12/77	45.4448	-117.9747	200	2,760	10	0	632	0	0	63	187	418
Bingaman	11/20/82	45.4448	-117.9753	200	2,760	10	0	1,110	0	0	81	0	0
Bingaman	2/8/90	45.4335	-117.9646	200	2,740	20	0	1,070	0	0	732	0	0
Wilson	11/20/78	45.4513	-118.0624	200	3,280	160	83	33	147	117	0	0	0
Pryse	5/10/72	45.4604	-118.0504	25	2,840	40	197	606	0	0	0	0	0

(Continued on page 18)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(continued from opposite page)

Owner	Static water level (ft) (depth below ground surface)	Depth (ft) to First water zone	Depth (ft) to Second water zone	Depth (ft) to Third water zone	Total depth of well (ft)	Depth to artesian zone (ft)	Elevation of first lava (ft)
Cox	125	260	380	0	440	0	2,595
Barbour	72	138	0	0	200	0	2,720
Savage/Nichols	180	442	0	0	480	0	2,795
Sorenson	32	305	0	0	365	0	2,795
Haverfield	44	112	0	0	171	0	2,869
Larson	10	173	0	0	293	0	2,840
Tewinkel	80	198	0	0	280	0	2,840
Tewinkel	85	12	280	0	460	0	3,038
Sorenson	92	90	396	0	425	0	2,770
Hoxie	15	160	260	0	320	0	3,601
Voetberg	137	329	0	0	450	0	2,410
Jambura	195	368	0	0	405	0	2,632
Rost	62	382	0	0	420	0	2,580
Davidson	98	340	0	0	380	0	3,066
Kelly	17	3	0	0	130	0	3,270
Kuensting	67	230	310	0	377	0	2,709
Rasmussen	0	40	366	710	1,061	40	1,990
Graham	22	138	0	0	165	0	2,595
McClennan	17	234	0	0	242	0	2,638
Weems	140	230	0	0	300	0	2,540
Berry	55	145	0	0	160	0	2,620
Lester	27	240	310	0	330	0	2,550
Cuthbert	87	76	0	0	1,000	0	1,780
Davis	0	1,294	0	0	1,394	1,294	2,415
Woodell	0	1,000	1,310	0	1,550	800	2,020
DeLashmutt	81	130	0	0	145	0	2,605
Teeters	80	0	0	0	78	0	2,755
Hulse	120	208	322	0	342	0	2,618
Gruis	48	115	0	0	120	0	2,800
Waibel	66	112	126	0	135	0	2,800
B-W Angus	80	230	0	0	240	0	2,480
Bingaman	0	371	0	0	1,300	7	2,128
Bingaman	0	0	0	0	1,191	38	1,650
Bingaman	0	1,418	0	0	1,802	1,418	1,670
Wilson	120	360	0	0	380	0	2,900
Pryse	103	361	660	770	803	0	2,037

(Continued on page 19)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(layout extends to opposite page ➤)

Owner	Date drilled	Latitude	Longitude	Location precision (± m)	Elevation (ft)	Elevation Precision (± ft)	Depth (ft) from surface to First gravel	First sand	Second gravel	Second sand	First lava	Third sand	Second lava
4-H Center	10/29/93	45.4620	-118.0514	200	2,880	20	226	42	34	198	0	0	0
Michel	3/7/66	45.4671	-118.0479	25	2,840	10	160	115	80	3	0	0	0
Davis	9/30/76	45.4622	-118.0363	200	2,730	10	120	180	0	0	0	0	0
Gaither	8/27/84	45.4605	-118.0596	400	3,000	120	210	0	0	0	0	0	0
Mecham	10/28/77	45.4743	-118.0537	25	2,920	20	48	104	0	0	0	0	0
Polar Fur	8/23/62	45.4802	-118.0620	200	3,010	20	302	0	0	0	0	0	0
Rogers	10/17/87	45.4734	-118.0621	200	3,010	30	268	82	0	0	0	0	0
Starr	5/15/67	45.4897	-118.0215	25	2,730	20	146	642	192	180	114	168	158
Roberts	1/7/94	45.4979	-118.0582	200	2,820	20	143	127	56	0	0	0	0
Uhl	10/15/93	45.4906	-118.0578	200	2,920	40	78	32	228	0	0	0	0
Vann	6/22/80	45.4877	-118.0577	200	2,920	40	270	0	0	0	0	0	0
Fry	7/22/96	45.4879	-118.0729	200	3,120	80	320	0	0	0	20	0	0
Hudson	6/12/86	45.4944	-118.0782	200	3,380	100	38	24	78	0	0	0	0
Taggart	8/25/71	45.3625	-117.9782	25	2,705	10	0	390	0	0	0	0	0
Royes	3/31/78	45.4810	-117.9647	200	2,740	10	0	755	0	0	257	40	315
Wagner	1/10/67	45.3933	-118.0420	200	2,730	10	0	470	261	270	0	0	0
Davis	9/30/76	45.4621	-118.0265	200	2,700	10	94	212	0	0	0	0	0
Wagner	1/1/49	45.4571	-118.0000	800	2,710	30	0	665	0	0	295	142	48
Hall	10/8/57	45.3983	-118.0666	250	2,860	10	60	139	110	0	0	0	0
Hoxie	2/13/67	45.4017	-118.0745	50	3,000	20	165	0	34	0	121	0	0
Shaw	7/29/58	45.4427	-118.0051	25	2,750	10	0	0	0	0	100	0	0
Lewandoski	7/19/94	45.5201	-118.0575	200	2,980	20	68	58	39	0	0	0	0
Needles	4/10/72	45.5238	-118.0564	25	3,000	10	188	113	0	0	0	0	0
Giesbrecht	3/21/80	45.5177	-118.0726	25	3,140	10	190	250	0	0	0	0	0
Kilby	2/13/84	45.5185	-118.0193	100	2,820	5	62	13	88	17	0	0	0
Barker	7/18/90	45.5241	-118.0217	200	2,840	40	160	40	0	0	0	0	0
Starr	10/23/67	45.5128	-118.0014	200	2,840	40	79	0	0	0	106	0	0
Corriel	8/10/82	45.5135	-118.0247	200	2,800	10	15	90	0	0	0	0	0
Fisher	1/1/53	45.5124	-118.0248	25	2,800	10	25	107	0	0	0	0	0
Forkan	8/29/88	45.5123	-118.0410	200	2,880	40	36	134	0	0	0	0	0
Blanchard	8/6/92	45.5056	-118.0671	200	3,080	40	200	219	0	0	0	0	0
Hamilton	5/25/57	45.5469	-118.0534	25	3,040	20	0	200	0	0	0	0	0
Royes	1/1/48	45.5216	-118.0475	50	2,920	20	0	88	102	160	0	0	0
Hopkins	1/1/53	45.5015	-118.0608	25	2,920	20	47	153	0	0	0	0	0
Hopkins	9/24/83	45.5015	-118.0614	200	2,920	20	102	0	123	0	0	0	0
Hopkins	3/15/95	45.5009	-118.0613	400	2,920	20	80	0	260	0	133	0	0

(Continued on page 20)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(continued from opposite page)

Owner	Static water level (ft) (depth below ground surface)	Depth (ft) to First water zone	Depth (ft) to Second water zone	Depth (ft) to Third water zone	Total depth of well (ft)	Depth to artesian zone (ft)	Elevation of first lava (ft)
4-H Center	18	135	0	0	500	0	2,380
Michel	360	0	0	0	358	0	2,482
Davis	11	65	120	205	300	0	2,430
Gaither	30	180	0	0	210	0	2,790
Mecham	50	130	0	0	152	0	2,768
Polar Fur	90	34	64	193	302	0	2,708
Rogers	180	268	0	0	350	0	2,660
Starr	-1	575	1,460	0	1,600	1,460	1,570
Roberts	1	140	310	0	326	0	2,494
Uhl	-1	60	260	312	338	0	2,582
Vann	5	145	216	0	270	0	2,650
Fry	65	200	320	0	340	0	2,800
Hudson	23	125	0	0	140	0	3,240
Taggart	6	80	0	0	390	0	2,315
Royes	-1	1,267	0	0	1,367	1,267	1,985
Wagner	-1	130	425	725	1,001	725	1,729
Davis	4	128	212	254	300	0	2,394
Wagner	999	512	0	0	1,150	0	2,045
Hall	20	0	0	0	309	0	2,551
Hoxie	15	160	260	0	320	0	2,801
Shaw	1	0	0	0	100	0	2,750
Lewandoski	50	150	0	0	165	0	2,815
Needles	11	190	240	286	301	0	2,699
Giesbrecht	170	37	185	0	215	0	2,700
Kilby	21	160	0	0	180	0	2,640
Barker	27	40	60	160	200	0	2,640
Starr	53	85	145	0	185	0	2,761
Corriel	30	85	0	0	105	0	2,695
Fisher	8	130	0	0	132	0	2,668
Forkan	100	150	0	0	170	0	2,710
Blanchard	65	60	300	400	419	0	2,661
Hamilton	12	0	0	0	200	0	2,840
Royes	0	0	0	0	350	0	2,570
Hopkins	0	0	0	0	200	0	2,720
Hopkins	22	22	102	0	225	0	2,695
Hopkins	0	80	350	450	478	0	2,580

(Continued on page 21)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(layout extends to opposite page ➤)

Owner	Date drilled	Latitude	Longitude	Location precision (± m)	Elevation (ft)	Elevation Precision (± ft)	Depth (ft) from surface to First gravel	First sand	Second gravel	Second sand	First lava	Third sand	Second lava
Hug	5/26/70	45.4871	-117.9913	800	2,695	20	33	117	0	0	0	0	0
Wagoner	1/5/70	45.4861	-118.0510	25	2,860	20	68	51	0	0	0	0	0
Rodriguez	9/4/91	45.4949	-118.0160	200	2,730	20	0	18	112	30	0	0	0
Wagner	1/1/52	45.4897	-118.0278	25	2,720	20	26	72	0	0	0	0	0
McBride	5/27/80	45.4891	-118.0056	25	2,710	10	0	0	66	0	0	0	0
Brickel	4/12/78	45.4916	-118.0087	25	2,710	10	17	45	0	0	0	0	0
McDonald	3/20/70	45.4989	-118.0120	25	2,730	10	33	68	0	0	0	0	0
Hurst	10/4/81	45.4881	-118.0005	200	2,700	10	0	80	0	0	0	0	0
Calhoun	10/25/90	45.4888	-118.0022	200	2,700	10	0	0	93	0	0	0	0
Taylor	6/17/77	45.4739	-118.0375	200	2,760	20	56	0	107	0	0	0	0
Myers	10/26/95	45.4738	-118.0470	200	2,840	20	110	210	0	0	0	0	0
Geraci	9/26/80	45.4806	-118.0469	200	2,840	20	80	0	50	0	0	0	0
Beardsley	8/2/71	45.4839	-118.0382	25	2,760	20	120	120	0	0	0	0	0
ArnolduS	11/17/89	45.4738	-118.0416	200	2,800	20	96	54	0	0	0	0	0
Vandenburg	10/26/95	45.4630	-118.0469	200	2,820	20	280	100	0	0	0	0	0
Burke	6/30/80	45.4435	-118.0485	25	2,800	20	28	145	0	0	0	0	0
Nelson	6/16/72	45.4544	-118.0514	200	2,850	40	8	152	0	0	0	0	0
Bump	9/14/93	45.4440	-118.0463	200	2,800	40	10	250	0	0	0	0	0
Park	8/27/74	45.4953	-117.9851	200	2,710	20	0	265	0	0	0	0	0
House	8/1/90	45.4874	-118.0734	200	3,340	60	0	0	0	0	320	0	0
Jopnson	9/7/88	45.4897	-117.9382	300	2,680	20	0	46	0	0	454	0	0
Eisiminger	11/1/77	45.4885	-117.9431	200	2,690	10	0	711	0	0	234	31	682
Royes	9/2/90	45.4769	-117.9639	200	2,740	10	0	575	0	0	240	0	0
Fox	6/29/64	45.4698	-117.9641	200	2,140	10	0	305	7	0	19	311	826
Imbler	12/12/87	45.4579	-117.9624	25	2,720	10	0	408	0	0	668	15	429
Summerville Cemty.	1/1/57	45.4744	-117.9882	25	2,760	10	0	600	0	0	360	0	0
Bingaman	2/20/74	45.4481	-117.9545	200	2,690	10	0	250	0	0	0	0	0
Shaw	11/9/77	45.4315	-117.9776	25	2,760	10	0	858	0	0	62	0	0
Zurbrick	10/28/76	45.3736	-118.0278	400	2,710	10	0	32	24	0	0	0	0
Klein	3/15/72	45.3752	-118.0247	200	2,710	10	0	0	125	0	0	0	0
Lorenzen	2/9/68	45.3754	-118.0157	200	2,700	10	0	70	30	0	0	0	0
Burleigh	1/1/52	45.3552	-118.0447	50	2,735	10	0	0	95	0	0	0	0
Mt. Emily Seed	5/17/79	45.4149	-117.9710	25	2,740	0	0	100	0	0	0	0	0
Shaw	1/30/78	45.3956	-117.9320	25	2,690	10	0	495	0	0	0	0	0
Case	10/16/63	45.3900	-117.9651	200	2,740	10	0	425	0	0	0	0	0
Hamann	11/13/69	45.3623	-117.9365	25	2,700	10	0	385	0	0	0	0	0

(Continued on page 22)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(continued from opposite page)

Owner	Static water level (ft) (depth below ground surface)	Depth (ft) to First water zone	Depth (ft) to Second water zone	Depth (ft) to Third water zone	Total depth of well (ft)	Depth to artesian zone (ft)	Elevation of first lava (ft)
Hug	-1	52	140	0	150	140	2,545
Wagoner	19	55	80	0	119	0	2,741
Rodriguez	15	140	0	0	160	0	2,570
Wagner	10	96	0	0	96	0	2,622
McBride	4	44	58	0	66	0	2,644
Brickel	4	41	54	0	62	0	2,648
McDonald	6	75	91	0	101	0	2,629
Hurst	4	60	0	0	80	0	2,620
Calhoun	12	9	63	0	93	0	2,607
Taylor	16	81	0	0	163	0	2,597
Myers	130	280	0	0	320	0	2,520
Geraci	42	107	0	0	130	0	2,710
Beardsley	25	176	0	0	240	0	2,520
ArnolduS	160	160	0	0	160	0	2,650
Vandenburg	186	338	0	0	380	0	2,440
Burke	29	47	160	0	173	0	2,627
Nelson	18	140	0	0	160	0	2,690
Bump	52	240	0	0	260	0	2,540
Park	5	30	104	253	265	0	2,445
House	-1	286	0	0	320	286	3,340
Jopnson	237	236	482	0	500	0	2,634
Eisiminger	-10	285	1,435	0	1,458	1,453	1,979
Royes	-1	636	0	0	815	636	2,165
Fox	-1	740	1,340	0	1,468	1,340	1,828
Imbler	-10	729	1,343	1,495	1,520	729	2,312
Summerville Cemty.	-1	600	0	0	960	600	2,160
Bingaman	8	40	70	234	242	0	2,440
Shaw	-1	900	0	0	920	900	1,902
Zurbrick	8	32	0	0	56	0	2,654
Klein	9	12	91	0	125	0	2,585
Lorenzen	11	36	0	0	100	0	2,600
Burleigh	0	0	0	0	95	0	2,640
Mt. Emily Seed	6	65	90	0	100	0	2,640
Shaw	500	500	0	0	475	0	2,195
Case	0	0	0	0	425	0	2,315
Hamann	12	0	0	0	385	0	2,315

(Continued on page 23)

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(layout extends to opposite page ➤)

Owner	Date drilled	Latitude	Longitude	Location precision (± m)	Elevation (ft)	Elevation Precision (± ft)	Depth (ft) from surface to First gravel	First sand	Second gravel	Second sand	First lava	Third sand	Second lava
Hamann	11/22/69	45.3592	-117.9363	25	2,700	10	0	510	0	0	0	0	0
Trico	7/20/94	45.3605	-117.9590	200	2,710	10	0	265	0	0	0	0	0
Key	5/4/78	45.3630	-117.9596	25	2,710	10	0	133	0	0	0	0	0
Boise Cascade	8/16/65	45.3505	-118.0260	25	2,715	10	0	0	132	767	0	0	0
Borden	5/27/66	45.3494	-118.0299	25	2,720	10	0	0	146	757	750	0	0
Taggart	8/25/71	45.3590	-117.9831	25	2,700	10	0	18	46	326	0	0	0
Trico	4/23/92	45.3515	-117.9674	400	2,695	10	0	18	8	334	0	0	0
Hamann	8/12/63	45.3429	-117.9432	200	2,695	10	0	430	0	0	0	0	0
Barton	9/18/96	45.3428	-117.9488	100	2,695	10	0	0	158	0	42	0	0
Gulzow	2/27/64	45.3406	-118.0543	25	2,750	10	0	300	0	0	0	0	0
Niemitalo	12/31/68	45.3478	-117.9055	25	2,700	10	0	76	100	334	0	0	0
Davis	8/28/89	45.3526	-117.9071	200	2,695	0	0	950	0	0	0	0	0
Trico	7/6/93	45.3575	-117.9603	200	2,700	10	0	514	0	0	0	0	0
Puckett	3/29/95	45.3531	-117.8667	200	2,700	10	0	629	0	0	0	0	0
Bingaman (IM-1)	1/1/95	45.4335	-117.9338	100	2,690	10	0	0	0	0	0	0	0
Sv-51	1/1/97	45.4094	-117.9669	10	2,737	5	0	1,000	0	0	920	0	0

Table 2. Water-well logs. Data from drill logs on file with the Oregon Department of Water Resources, cont.
(continued from opposite page)

Owner	Static water level (ft) (depth below ground surface)	Depth (ft) to First water zone	Second water zone	Third water zone	Total depth of well (ft)	Depth to artesian zone (ft)	Elevation of first lava (ft)
Hamann	11	0	0	0	510	0	2,190
Trico	6	130	0	0	265	0	2,445
Key	0	0	0	0	0	0	2,577
Boise Cascade	4	847	0	0	899	0	1,816
Borden	-10	750	0	0	903	700	1,817
Taggart	6	80	0	0	390	0	2,310
Trico	26	21	280	345	360	0	2,335
Hamann	10	126	0	0	430	0	2,265
Barton	57	110	160	0	200	0	2,537
Gulzow	60	88	140	0	300	0	2,450
Niemitalo	16	0	0	0	510	0	2,190
Davis	3	490	0	0	950	0	1,745
Trico	12	170	210	260	514	0	2,186
Puckett	7	12	0	0	629	0	2,071
Bingaman (IM-1)	0	0	0	0	2,900	0	2,690
Sv-51	0	0	0	0	3,065	0	1,737