State of Oregon
Department of Geology and Mineral Industries
Dr. Vicki S. McConnell, State Geologist

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PRELIMINARY GEOLOGIC MAP OF THE PRINEVILLE 7.5′ QUADRANGLE, CROOK COUNTY, OREGON

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

2006

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INTRODUCTION

The Prineville 7 ½' quadrangle is situated at the junction of the Crooked River and Ochoco Creek, near the intersection of the High Cascades, High Lava Plains, and Blue Mountains geomorphic provinces. Topographic relief in the juniper- and sage-covered high desert terrain ranges from 4080 ft (1244 m) in the low-lying hills in the northeast corner of the quadrangle to the floor of Prineville Valley at 2840 ft (866 m) downstream of the city of Prineville. The quadrangle encompasses a historic ranching and lumber-milling community that is rapidly transforming to a suburban residential population. This geologic map depicts a preliminary stratigraphic assessment for the Prineville urban area and provides a framework for further geologic and geohydrologic analysis of the Lower Crooked River Basin.

The Prineville quadrangle consists of a succession of Tertiary volcanic and sedimentary strata and includes from oldest to youngest: 1) Eocene lava flows of the Clarno Formation; 2) Oligocene rhyolite, tuff, and sedimentary rocks of the John Day Formation; 3) Oligocene(?) to Miocene sedimentary rocks; 4) middle Miocene basalt flows of the Prineville Basalt; 5) late Miocene to Pliocene sediments and lava flows of the Deschutes Formation; and 6) Quaternary surficial and valley fill deposits. The older Eocene lava flows form a volcanic uplands in the northeast corner of the quadrangle that are the local basement rocks. Highland-forming Clarno lava flows are abruptly truncated on the southwest, where more than 300 m of Oligocene pumice-lithic tuff fills the large structural depression in which Prineville is situated. The thick tuff section is invaded and displaced by late Oligocene rhyolite intrusions in the vicinity of Barnes Butte and is capped by rhyolite lava flows, oxidized pumice-tuff, and tuffaceous sedimentary rocks. South of Barnes Butte semi-consolidated Oligocene (?) to Miocene tuffaceous sedimentary rocks rest with minor angular unconformity on late Oligocene John Day Formation rocks. The Oligocene (?) to Miocene sedimentary section is capped by and interfingers with the Prineville basalt in the southern half of the quadrangle; south-dipping blocks of the Prineville basalt have been reworked and incised by middle to late Miocene fluvial systems. Plateau-forming basalt and sedimentary rocks of the Deschutes Formation fill and cap the channels incised into middle Miocene strata. The city of Prineville sits on Quaternary alluvium and terrace deposits of the Crooked River and tributary streams.

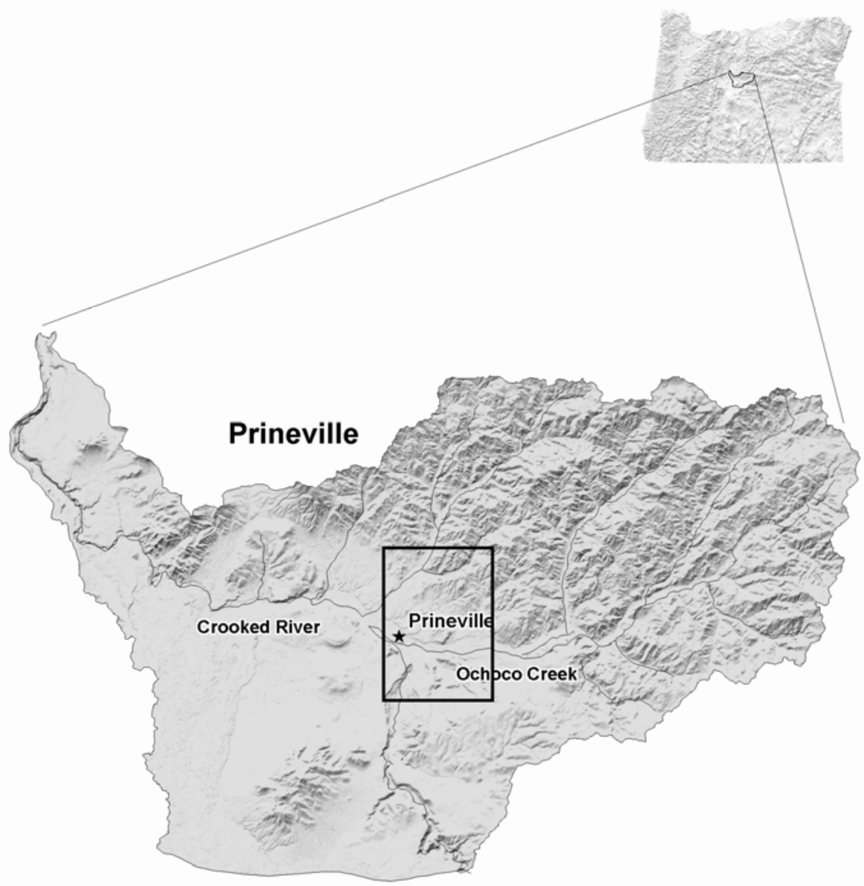

Figure 1. Digital Elevation Model (DEM) of the Lower Crooked River Basin, showing location of the Prineville quadrangle.

Methodology and Previous Work

The 1:24,000 scale geologic map of the Prineville quadrangle was funded by the USGS National Cooperative Geologic Mapping Program. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. The map is released as an interim open-file map product as part of a larger mapping project covering the Lower Crooked River Basin (Figure 1) and has not yet 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 combining 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. Mapping was supplemented with x-ray fluorescence (XRF) geochemical analyses from Franklin and Marshall College, Lancaster, PA. Age-date samples were prepared and analyzed by the College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon. Subsurface geology in cross sections is based on analyses of water-well drill records obtained from the Oregon Department of Water Resources.

Detailed geologic maps of the Prineville area are of comparatively recent vintage. The first large scale reconnaissance geologic maps for the area were made by Hodge (1942) and Williams (1957). Later mapping efforts focused on groundwater studies and mercury mineralization (Robinson and Price, 1963; Waters and Vaughn, 1968), enabling Swanson (1969) to produce a more detailed 1:250,000 scale map of the east half the Bend AMS sheet. Subsequent studies included an investigation of the geothermal potential at Powell Buttes (Brown and others, 1980). In the 1990's, the U.S. Geological Survey and Oregon Department of Water Resources began a detailed study of the upper Deschutes Basin (e.g., Gannett and others, 2001, Lite and Gannett, 2002). The current mapping effort builds on the stratigraphy established by Smith (1986a) and Sherrod and others (2004) to refine the geologic relations along the east margin of the upper Deschutes Basin.

PRELIMINARY DESCRIPTION OF GEOLOGIC UNITS – PRINEVILLE 7 ½' QUADRANGLE, CROOK COUNTY, OREGON

Surficial Deposits

Qa **Stream alluvium (Holocene and late Pleistocene)** – Gravel, sand, and silt deposited in active stream channels and on adjoining flood plains. Includes gravel and channel sand deposited in active or recently active channels and overbank fines deposited on the modern flood plains of the Crooked River and Ochoco Creek.

Qf **Alluvial fan deposits and colluvium. (Holocene and Pleistocene)** – Mainly alluvial fan deposits, colluvium, and stream alluvium deposited on the flanks of Barnes Butte. The deposits are typically unconsolidated to weakly consolidated, matrix supported gravel composed of angular to subround pebble- to boulder-sized clasts of rhyolite and tuff. The matrix fraction is dominated by sand-sized grains of angular to subangular feldspar and magnetite.

Qls **Landslide deposits. (Holocene and Pleistocene)** – Unconsolidated clast-supported breccia deposited by gravity-driven mass-wasting processes. Landslide deposits in the Prineville quadrangle are subdivided into those derived from the rhyolite of Ochoco Reservoir and those derived from Deschutes Formation plateau basalts. Rhyolite-derived landslide deposits consist of unconsolidated, clast-supported, interlocking cobble and boulder-dominated, chaotically mixed breccia carrying clasts of flow-banded rhyolite (Tjro) and white tuffaceous sedimentary rocks (Tjs). Gravel-sized clasts have maximum diameters of several meters across. The matrix component makes up 15% of the unit volume and consists of purple to white silt- to sand-sized grains of rhyolite and tuffaceous sedimentary rocks; the crushed equivalent of the gravel-sized clasts. The landslide is sourced on the east in the Ochoco Reservoir quadrangle, but a toe of the unit laps onto sedimentary rocks of unit (QTsg) at the eastern edge of the Prineville quad, 1-mile-west of Ochoco Dam. Thickness is highly varied; maximum thickness is several tens of meters. Basalt-derived landslide deposits form irregular slopes to the south of Ochoco Creek and along the Crooked River, south of the city of Prineville. Landslide deposits consist of unconsolidated, clast-supported, interlocking boulders deposited from toppling, en masse rotation, and rock avalanches. Clast-size averages 1-3-m-across, with the maximum intact landslide blocks up to 300-m-across. Crackle- and jigsaw-breccia fabrics are common in clasts (sensu stricto Yarnold and Lombard, 1989). Landslides originate from oversteepened, tension-cracked cliff-faces that calve and topple or rotate listrically along fractured columnar joint margins. Older slides have vegetated and soil-mantled upper surfaces; more recent deposits lack vegetation and soil and in places may be confused for tumuli-capped intracanyon lava flows. Thickness is highly varied; maximum thickness is several tens of meters.

Qt **Terrace deposits (Pleistocene)** – Abandoned terraces of the Crooked River. Based on water well logs, the terrace deposits consist of brown clay, well-sorted gravel, and brown sand. Maximum thickness is approximately 20 m. Equivalent in part to fluviolacustrine sediments (Qpa) of Robinson and Price (1963) and unit Qs of Swanson (1969).

Tertiary Volcanic and Sedimentary Rocks

QTsg **Stratified sedimentary rocks (Pliocene to Pleistocene?)** – Moderately cemented to unconsolidated, brown, massive pebble-rich sandstone, gray to black plane-parallel to trough cross-stratified sandstone, and well-sorted pebble to cobble conglomerate. Age is unknown. The unit unconformably overlies unit Tjt of the John Day Formation and is overlain by Quaternary surficial deposits (Qls), 1 mile west of Ochoco Dam. Unit QTsg is differentiated from the fluviolacustrine deposits (Qpa) of Robinson and Price (1963) and unit Qs of Swanson (1969) based on lithologic character and stratigraphic position. Based on water well logs unit QTsg may be up to 55-m-thick.

Td – Deschutes Formation (Pliocene and late Miocene) – Interbedded lava flows and sedimentary rocks. Equivalent to the Deschutes Formation of Smith (1986a) and subdivided into:

Tdsg **Plateau mantling sand and gravel (Pliocene and late Miocene?) –** Degraded, unconsolidated sand and gravel that caps late Miocene plateau-forming basalts. The sand component is fine-to medium-grained, well-sorted, and consists of angular to subround grains of clear feldspar (70 percent by volume), amphibole (15 percent), white pumice (10 percent), quartz (3 percent), and magnetite (2 percent). Some mineral grains maintain a euhedral crystal form. The gravel is moderately sorted, locally imbricated, and consists of subround to well-rounded, cobble-sized clasts of basalt and rhyolite. The gravel is exposed as surface-armoring lag deposits, in-situ reworked upper surfaces of basalt lava flows, and incised channel deposits. The thickness of the unit is variable.

Tdbc **Basalt of Combs Flat (Pliocene) –** Gray, coarse-grained, vesicular plagioclase- and olivine-phyric basalt flows that form the distinct plateau south of Ochoco Creek. The basalt of Combs Flat displays multiple flow lobes capped by tumuli. The bases to individual lobes are marked by basal flow breccias and collapsed lava tubes. In thin section, the basalt displays a diktytaxitic texture with euhedral plagioclase phenocrysts (up to 1 mm in diameter) and olivine phenocrysts (up to 2 mm in diameter). Phenocrysts are set in a groundmass of plagioclase lathes separated by olivine and clinopyroxene grains and subophitic clinopyroxene crystals. The flow in the Prineville quadrangle displays low titanium content, with 49.65 weight percent SiO_2; 15.86 weight percent Al_2O_3; 1.23 weight percent TiO_2, and 0.75 weight percent K_2O (Sample 9, Table 1.1). Reversed magnetic polarity. The unit is traceable to a vent complex at the east end of Combs Flat (Ochoco Reservoir quadrangle). A Pliocene age is based on a K-Ar radiometric date of 3.36 ± 0.08 Ma (Smith, 1986a after Sutter, unpub.). Part of unit QTb of Swanson (1969).

Tdbm **Basalt of Meyers Butte (late Miocene)** – Olivine basalt flows in the Deschutes Formation. Subdivided, on basis of stratigraphic position and, locally, the presence of sedimentary interbeds into:

Tdbm2 upper flow package (late Miocene) – Dark-gray, medium-grained, vesicular olivine-phyric basalt flow that delineates the top of the Deschutes Formation along the western side of the Crooked River canyon. Cliff exposures in the canyon are marked by overlapping flow lobes of massive to columnar-jointed basalt, capped by rounded tumuli that pinch and swell along strike. Individual flow lobes have well-defined outer vesicular margins that grade inward to a massive crystalline core. Locally, the flow retains hollow lava tubes (≤ 2-m-wide) and vesicle cylinders (≤ 3-cm-wide). In thin section the basalt is holocrystalline with a diktytaxitic texture defined by plagioclase crystals that protrude into the vesicles. The unit also contains microphenocrysts of olivine and plagioclase, has glomerocrysts of olivine and plagioclase crystals, and groundmass plagioclase crystals set in a supophitic clinopyroxene matrix. Chemically unit Tdbm2 is a high alumina basalt with moderate titanium and potassium contents, with 50.04 weight percent SiO_2; 16.36 weight percent Al_2O_3; 1.51 weight percent TiO_2, and 0.60 weight percent K_2O (Sample 20, Table 1.1). Displays reversed magnetic polarity and directly overlies the Rattlesnake Ash-flow Tuff (unit Tmr). The upper flow has a radiometric age of 5.42 ± 0.11 Ma based on a sample in the Huston Lake quadrangle (Ferns and McClaughry, 2006b).

Tdbm1 lower flow package (late Miocene) – Gray, medium- to coarse-grained, vesicular plagioclase- olivine-phyric basalt resting directly beneath Tdbm2 in the west wall of the Crooked River Canyon. Includes a palagonite breccia at the flow base that is more than 20-m-thick, composed of sub-angular, black glassy basalt blocks, bombs, and pillows. In thin section, the basalt is holocrystalline and diktytaxitic. The basalt contains microphenocrysts of plagioclase and olivine set in a groundmass made up of plagioclase lathes and subophitic clinopyroxene crystals. Chemically the unit is indistinguishable from the overlying Tdbm2 flow, with moderate titanium and potassium contents, with 50.21 weight percent SiO_2; 16.23 weight percent Al_2O_3; 1.48 weight percent TiO_2, and 0.67 weight percent K_2O (Sample 19, Table 1.1). The flow is locally interbedded with tuffaceous sandstone. The basalt displays reversed magnetic polarity and directly overlies the Rattlesnake Ash-flow Tuff (unit Tmr) in the Powell Butte quadrangle (Ferns and McClaughry, 2006a).

Tdbw **Basalt of White Deer Ranch (late Miocene)** – Gray- to dark gray, medium-grained, vesicular, olivine-phyric basalt flows. The flows forms the plateau cap at Ochoco Wayside Viewpoint on the west side of the Crooked River and south of the city of Prineville along the east side of the Crooked River. In thin section, the basalt is holocrystalline, with a diktytaxitic texture. Microphenocrysts of plagioclase and olivine are set in a groundmass of plagioclase, clinopyroxene, olivine, opaque mineral grains, and subophitic clinopyroxene crystals. Chemically White Deer flows are basalt with relatively high amounts of titanium, with ~ 48.75 weight percent SiO_2; 15.50 weight percent Al_2O_3; 1.80 weight percent TiO_2, and 0.35 weight percent K_2O (Samples 7, 8, and 18, Table 1.1). The late Miocene age is based on stratigraphic position. Includes normal, indeterminate, and reversed magnetic polarity flows. The unit rests directly beneath the Rattlesnake Ash-flow Tuff (unit Tmr) in the canyon of the Crooked River (Ferns and McClaughry, 2006a); White Deer flows underly unit Tbdm1 on the west side of the Crooked River, at White Deer Ranch. Plateau-forming flows on the east side of the Crooked River are overlain by sand and gravel that contains agate and rhyolite clasts. Equivalent in part to unit QTb of Swanson (1969).

Tds **Sedimentary rocks (late Miocene)** – Interbedded, clast-supported cobble-conglomerate, matrix-supported conglomerate, and tuffaceous sandstone, locally exposed beneath the basalt of White Deer Ranch and basalt of Combs Flat. Clast-supported cobble-conglomerate beds are up to 4-m-thick, are heterolithic and moderately-sorted with inset, stratified pebbly sandstone channel-forms. Imbricated gravel clasts on the south side of Combs Flat indicate transport directed at ~S60^{o}E. The matrix-supported conglomerate consists of sub-angular to rounded cobbles floating in a matrix (75% of unit volume) of massive silt- to sand-dominated matrix, up to 10 cm across. Tuffaceous sandstone beds consist of 1- to 4-m-thick, massive to plane-parallel stratified and trough cross-stratified, crystal-lithic, fine-to medium-grained sand. The sandstone contains abundant well-rounded, pebble-sized pumice, cobble- to boulder-sized outsized clasts of vesicular basalt, and lenses of pebble-sized lithics, pumice, and palagonite. Lower contacts typically display cut and fill stratigraphic relations. Sedimentary rocks are generally poorly exposed, except in artificial exposures such as road cuts. The aggregate sedimentary section is as much as 120-m-thick near the Ochoco Wayside Viewpoint.

Tcp **Prineville basalt (middle Miocene)** – Dark gray to black, fine-grained, plagioclase-phyric and aphyric basalt, basaltic andesite, trachybasalt, and basaltic trachyandesite lava flows exposed in flat-lying to southerly tilted blocks south of Combs Flat. Outcrop exposures are massive to columnar-jointed. South of Combs Flat, upper flow surfaces have been reworked by fluvial processes into lag gravels composed of the basalt. Locally, the base of flows are composed of palagonite breccia with detached pillows encased in tuffaceous sedimentary rocks. In thin section the basalt is hypocrystalline (60 percent crystals, 40 percent glass), hyalopilitic with some intergranular olivine and clinopyroxene and abundant opaques. The basalt contains < 2 percent olivine microphenocrysts. Prineville flows in the quadrangle include Bowman Dam, Hi-Si, and possibly the Hi-PT chemical types as defined by Hooper and others (1993) and are chemically characterized by a range of silica values (SiO_2 from 51.21 to 55.40 weight percent) and elevated concentrations of phosphorus (P_2O_5 from 1.25 to 1.86 weight percent) and barium (Ba from 1865 to 2845 ppm) (Samples 11, 12,13, 14, 15, 16, and 17, Table 1.1). Contact relationships with underlying units are generally obscured by talus and landslide deposits. Flows of the Prineville basalt apparently thin to the northeast, where a single, HI-Si type flow no more than 10-m-thick interfingers with basalt-clast gravels. Columnar-jointed Bowman Dam-type flows reach a unit thickness of 30 m in Juniper Canyon. The unit includes both normal and reversed magnetic polarity flows (Hooper and others, 1993). A middle Miocene age is based on a radiometric date of 15.7 ± 0.1 Ma (Smith, 1986a) on the basal flow at Pelton Dam in the Deschutes Basin and intertonguing relationships between reversed magnetic polarity Bowman Dam type flows and R2 Grande Ronde Basalt flows north of the Deschutes Basin (Hooper and others, 1993). Equivalent to the Prineville Basalt of Tolan and others (1989) and Hooper and others (1993).

Tmos Volcaniclastic sedimentary rocks (middle to early Miocene? and Oligocene?) – Moderately indurated deposits of brown to tan tuffaceous siltstone, white to dark gray, stratified, plane-parallel stratified to massively bedded volcaniclastic sandstone, black, well-sorted, clast supported cobble conglomerate composed of well-rounded clasts of Prineville basalt with petrified wood, as well as massively bedded white pumice-crystal-lithic tuff. Diatomite and tuffaceous siltstone are intermixed with the Prineville basalt flows along the Post highway. A middle Miocene age for the upper part of the unit is based upon conformable or intertonguing relationships with overlying flows of the Prineville basalt. Although previously considered to be the upper part of the John Day Formation (Swanson, 1969) herein tentatively considered to be correlative to the Simtustus (Smith, 1986b) and Mascall (Merriam, 1901) Formations. Contact relationships with the upper part of the John Day Formation are not known. The base of the unit is not exposed in the quadrangle.

Tmot Pumice-lithic-crystal tuff (middle to early Miocene? and Oligocene?) – White to brown, matrix- to clast-supported, pumice-lithic-crystal tuff. The tuff is 1.5-m-thick and consists of two gradational flow-units. The basal flow unit is 36-cm-thick and consists of white, massive to faintly-stratified, ash tuff containing basalt lithics and pumice clusters. The upper unit consists of a base of 10 cm of plane-parallel stratified, distribution normally graded pumice tuff that grades upward into 1 m of, clast-supported and coarse-tail normally graded clast-supported pumice tuff. The upper unit is > 75% pumice fragments with a maximum observed pumice size of 2-cm-long. The interstitial matrix is composed of ash to fine- to medium-grained sand composed of 45 percent clear feldspar, 25 percent euhedral to subhedral amphibole and pyroxene, 20 percent subround pumice fragments, 10 percent gold-colored Fe-rich biotite, and accessory bi-pyramidal magnetite. Based on bulk chemistry, unit Tmot is an andesite tuff, with 57.01 weight percent SiO_2; 17.16 weight percent Al_2O_3; 9.03 weight percent FeO*, 2.61 weight percent Na_2O and 1.27 weight percent K_2O (Sample 10, Table 1.1). Stratigraphic position of the tuff is uncertain. The tuff unconformably overlies bedded claystones of unit Tjs (probable John Day Formation age) and underlies the Deschutes Formation basalt of Combs Flat (unit Tdbc).

Tj – John Day Formation (early Miocene to early Oligocene) Succession of Rhyolite domes and plugs, tuff, and tuffaceous sedimentary rocks. Equivalent to the John Day Formation of Marsh (1875), Merrriam (1901), and Robinson and others (1990) and subdivided into:

Tjs **Tuffaceous sandstone and siltstone (early Miocene? and Oligocene) –** Tan to yellow, massive to stratified, tuffaceous siltstone and sandstone. Includes massive, tuffaceous siltstone beds that range from 3- to 6-m-thick. Tuffaceous sandstone interbeds are as much as 15-cm-thick. The unit is best exposed in cliffs along the south rim of Combs Flat. The upper part of the unit is marked by a 15- to 20-cm-thick, gray to orange tuffaceous sandstone that is partially opalized. Partially opalized limb casts, petrified wood, and fragmental fossil imprints of *Metasequoia occidentalis* occur within the siltstone interbeds. The age is uncertain and the base of the unit is not exposed. The unit apparently overlies the welded ash tuff of Barnes Butte (unit Tjtb).

Barnes Butte rhyolite complex (late Oligocene); subdivided into:

Tjr **Sanidine-phyric rhyolite domes and plugs (late Oligocene) –** Gray to purple, massive to vertically flow-banded, sanidine-phyric to sparsely-phyric rhyolite domes. The unit includes the dome at Barnes Butte, which is locally marked by massive to distinctly flow-banded rhyolite with 0.5- to 1.5-m-thick vertically oriented, perlitic bands. The south margin of the Barnes Butte dome is marked by intensely silicified zones that contain cinnabar. The main alteration zone occurs along a N 75^{o} W trending fault zone, at the Barnes Butte mercury mine (Brooks, 1963). In thin section the rhyolite consists of a devitrifed groundmass of quartz and feldspar with sparse, albite-twinned K-feldspar (anorthoclase?) phenocrysts up to 1.5-mm-across. The groundmass contains abundant opaque minerals. The Barnes Butte dome has high amounts of silica (81.95 weight percent SiO_2) and low amounts of alumina (9.43 weight percent Al_2O_3) and sodium (2.55 weight percent Na_2O) (Sample 3, Table 1.1). The rhyolite contains comparatively low levels of zirconium (355 ppm) and yttrium (~ 20 ppm) (Sample 3, Table 1.1). The unit includes rhyolite knobs in the northwest corner of the map area; the rhyolite intrudes matrix-supported conglomerate and tuff of unit Tjt west of Barnes Butte. Although not in direct contact with unit Tjtb, the rhyolite appears to predate the ash-flow. Oligocene age based on $^{40}Ar/^{39}Ar$ age of 27.97 $\pm$ 0.32 Ma (Sample A1, plate 1; Table 1.2).

Tjtb **Welded ash-tuff (late Oligocene) –** Oxidized, pink to red, indurated to friable, ledge-forming, columnar jointed pumice-lithic-tuff. Pumice fragments are rounded, flattened, or occur as blocks and lenses as large as 7-cm-across. Lithics are angular to subrounded and include rhyolite clasts as much as 1-cm-across. The matrix is composed mostly of ash and welded glass shards. In thin section, the tuff displays a distinct groundmass structure, composed mostly of flattened and contorted glass shards; the groundmass is cut by bands of spherulitic quartz. Sparse phenocrysts include potassium feldspar and quartz. The tuff is strikingly similar in chemical composition to the dome at Barnes Butte, with high amounts of silica (~ 81.5 weight percent SiO_2) and low amounts alumina (9.4 weight percent Al_2O_3) and sodium (2.00 weight percent Na_2O) (Samples 4 and 5, Table 1.1). It contains comparatively low levels of zirconium (~ 325 ppm) and higher levels of yttrium (~ 60 ppm). Based on chemical similarities, the tuff is considered to be genetically related to the rhyolite dome at Barnes Butte. The tuff has a maximum thickness of 30 m. The age of the rhyolite dome at Barnes Butte is 27.97 $\pm$ 0.32 Ma.

Tjro **Rhyolite of Ochoco Reservoir (late Oligocene) –** Purple to gray, massive, platy to columnar jointed, porphyritic rhyolite lava flow that forms a 25-m-high cliff along the south side of Ochoco Creek in section 1, Township 15 South, Range 16 East. The main mass of the rhyolite crops out in the adjoining Ochoco Reservoir quadrangle. Although interpreted by Waters and Vaughn (1968) as a rheomorphic ash-flow tuff, herein considered, on basis of basal flow breccias and internal flow folding, to be a planar-topped rhyolite lava flow. In thin section, the rhyolite is marked by a cryptocrystalline groundmass of alkali feldspar and quartz with scattered opaque minerals. Cross-hatch textured potassium feldspar phenocrysts as much as 5-mm-across are sparse. Chemically the unit is a rhyolite, with ~ 74.00 weight percent SiO_2; ~ 12.50 weight percent Al_2O_3; ~ 4.30 weight percent Na_2O, and ~ 4.12 weight percent K_2O. The flow is marked by elevated levels of zirconium (~ 770 ppm Zr) and yttrium (110 ppm Y). An Oligocene age is based on a $^{40}Ar/^{39}Ar$ age of 27.54 $\pm$ 0.36 Ma from a sample collected in the Ochoco Reservoir quadrangle.

Tjt **Pumice-lithic tuff (late Oligocene) –** Gray to green, matrix-supported, indurated to friable, pumice-lithic tuff, weathering to form angular chips and rounded, low-elevation hills around Barnes Butte. Constituents include tan to green, well-rounded pumice fragments up to 6-cm-across and brown to black, angular to subround mafic and silicic rock fragments as much as 10-cm-across. The matrix contains a mixture of ash and feldspar crystals. The unit includes an upper, massive, brown, matrix-supported, boulder conglomerate west of Barnes Butte. Petrified wood is locally found in the tuff near the contact with unit Tca. Based on geochemical analysis, the unit is a rhyolite tuff, with 75.47 weight percent SiO_2, 12.65 weight percent Al_2O_3, and 1.64 weight percent Na_2O

(Sample 2, Table 1.1). The tuff contains relatively high levels of zirconium (512 ppm Zr) and yttrium (96 ppm Y) (Sample 2, Table 1.1). The tuff is intruded by distinct knobs of rhyolite of unit Tjr (rhyolite of Barnes Butte) and is overlain by unit Tjtb (tuff of Barnes Butte) north of the city of Prineville. Based on water-well drill records, unit Tjt is more than 335-m-thick in the vicinity of Barnes Butte. The section of tuff thins to the north where it is in abrupt high angle contact with and onlaps dacite and andesite lava flows of unit Tca. The unit is interpreted as caldera-fill facies to the Crooked River caldera and is correlative with the tuff of Smith Rock of Robinson and Stensland (1979).

Tjb **Rhyolite breccia and dacite tuff (late Oligocene) –**Silicified rhyolite breccia and welded tuff exposed as a domal mass south of Old Dry Creek in sections 14 and 15, Township 14 South, Range 16 East. The breccia is purple to brown, welded, clast-supported and consists of angular to subround clasts of rhyolite, expanded pumice, and coarse-grained, K-feldspar-dominated , granitic lithics up to 11-cm-across. Many clasts display bleached halos. The matrix component (~15% of the unit volume) is purple-colored, crystalline, porphyritic, and apparently welded. Bulbous masses of aphyric rhyolite are exposed beneath the breccia; angular coarse-grained granitic rock fragments are commonly mixed with the eroding breccia float. A distinct massive to perlitic, porphyritic vitrophyre outcrops with the breccia in the southwest corner of section 14. The breccia unit includes an overlying brown to gray, welded, banded pumice tuff. The tuff is massive, with horizontally aligned, flattened pumice clasts up to 30-cm-long and smaller, distinct s-shaped fiamme shards, and pebble-sized angular rhyolite lithic clasts. Many pumice clasts have feathery, irregular margins that merge with the fine- to medium-grained matrix. The deposit is internally marked by 10- to 20-cm thick shear zones that may indicate remobilization at the time of deposition. Chemically, the tuff is a dacite with relatively low levels of silica (66.01 weight percent SiO_2) and high levels of alumina (13.3 weight percent Al_2O_3) and sodium (3.63 wt % Na_2O). The tuff contains relatively high levels of zirconium (610 ppm) and yttrium (85.9 ppm Y) (Sample 1, Table 1). The unit is onlapped by pumice-lithic tuff of unit Tjt.

Clarno Formation (Eocene) Dacite to rhyolite lava flows, intrusions, and volcaniclastic rocks. Equivalent to the Clarno Formation of Merriam (1901) and Walker and Robinson (1990), and subdivided into:

Tca **Dacite and andesite lava flows (Eocene to early Oligocene?) –** Stacked succession of gray to black, purple-weathering, fine- to medium-grained, aphyric, plagioclase phyric, and plagioclase-hornblende phyric dacite and andesite lava flows and domes. The flows are platy to locally columnar-jointed; outcrops weather to steep-sided, rounded hills littered with angular rock chips. Individual flow packages locally contain purple to brown, basal and marginal autobreccia deposits. Topographic breaks between flow units are locally marked by brick red, red-orange, and maroon clay soils. In thin section these rocks are aphyric to porphyritic, with pilotaxitic texture defined by aligned feldspar lathes. Phenocrysts include blocky, zoned plagioclase crystals as much as 4-mm-across and orthophyroxene crystals. Embayed quartz crystals rimmed by clinopyroxene grains and broken, twinned plagioclase crystals may be present as xenocrysts. Some rocks also contain crystalline xenoliths made up of intergrown clinopyroxene and plagioclase crystals. Based on geochemical analyses, including those from the Ochoco Reservoir quadrangle (Sample 1, Table 1.1), the unit includes dacite and andesite, with 63.92 weight percent SiO_2; 16.54 weight percent Al_2O_3; 0.82 weight percent TiO_2; and 1.31 weight percent K_2O. Equivalent to the Clarno Formation of Merriam (1901).

CROOKED RIVER CALDERA

The distribution and thickness of late Oligocene silicic tuff (Tjt), rhyolite intrusions and breccia (Tjr), flanking rhyolite domes and lava flows, and an accompanying gravity low indicate that the Prineville Basin rests in a tuff-filled volcanic depression. The volcanic depression is herein named the Crooked River caldera. The Crooked River caldera is a northeast trending depression, measuring ~30 km in length by ~20-km-across. The eroded core of the caldera interior consists of a 300 m+ section of late Oligocene zeolitized pumice-lithic tuff that can be traced from Ochoco Reservoir on the southeast margin to a lithic-rich facies equivalent at Smith Rock on the northwest margin. South of Old Dry Creek, the altered, white to pale yellow pumice-lithic tuff is in high angle depositional contact with sheared dacite of the older Clarno Formation. Small shear zones and faults, based in the Clarno rocks, parallel the contact; blocks of dacite are incorporated within the tuff along the contact. In the hills above this contact zone, at least 150 m of the pumice-lithic tuff is exposed. Water well drill logs located in the interior of the caldera indicate that the section of vent-filling, pumice-lithic tuff may exceed 320 m; the base of the tuff is not exposed. The facies equivalent tuff of Smith Rock on the northwestern rim of the caldera is approximately 1.1-km-thick (Smith and others, 1998).

The thickest accumulation of caldera-filling tuff corresponds to a prominent, closed, gravity low, centered west of Barnes Butte (Figure 2) that Couch and others (1982) previously interpreted as a basin, filled with ~0.5 km of sedimentary deposits. The gravity low is flanked on the northwest, northeast, and southwest margins by large (50 – 80 km^2) fields of late Oligocene rhyolite lava flows and domes. Smaller domes and masses of brecciated rhyolite and welded ash-flow tuff mark the caldera margin southeast of Old Dry Creek. The rhyolite of Ochoco Reservoir flanks the southeast margin of the caldera. Smaller, sometimes perlitic rhyolite intrusions and domes, including the Barnes Butte dome, intrude the caldera-fill tuff near Prineville and at Smith Rock. Radiometric age dates from caldera-rimming rhyolite domes and flows at Barnes Butte, Powell Buttes, and Ochoco Reservoir range from 25.8 Ma to 28.3 Ma (Evans and Brown, 1981; this report; McClaughry and Ferns, 2006)(Table 1.2). Smith and others (1998) indicate an age of 28.82 $\pm$ 0.23 for the rhyolite of Gray Butte on the northwest rim of the caldera; those workers correlated the Gray Butte rhyolite and tuff of Smith rocks to member G of the John Day Formation. Smith and others (1998) report radiometric ages that range from 29.53 to 29.61 Ma for a welded-ash-flow tuff at the base of member G that is exposed a short distance north of Smith Rock. An age of 27.62 $\pm$ 0.63 Ma is reported for a welded ash-flow tuff at the base of the member H (Smith and others, 1998). Additional field reconnaissance is needed to clarify the relations of intra-caldera tuff facies (Tjt) of the Crooked River caldera to the apparently age-eqivalent ash-flow tuffs of member G and H.

STRUCTURE

In addition to the large caldera structure, the Prineville quadrangle is segemented by northwest-trending faults and east-west trending faults and folds. Faults are generally poorly exposed and their locations are inferred on basis of apparent stratigraphic offset of marker beds and structurally disrupted zones of mineralization.

A cross-cutting series of perpendicular normal faults segment the succession of Clarno lava flows and John Day tuffs in the northeast corner of the quadrangle. These structures are inferred from slickenside coated fault planes, maroon-colored soil horizons, and topographic lineations. Total offset on these structures is indeterminate. A distinct fault trending N70^{o}W cuts John Day Formation tuff (Tjw) and conglomerate (Tjc) in sections 14 and 15, Township 14 South, Range 16 East. This structure is distinguished by a 6-m-wide zone of purple, red, and yellow jasper marked with a dense slickenside striated surface. The indicated last relative motion is top to the south. Total offset is indeterminate.

A series of generally east-west trending faults are exposed on Barnes Butte at the site of a circa. 1940's mercury mine. The main fault in the mine workings on the west side of the butte occurs in white, heavily silicified rhyolite and strikes N60^{o}W and dips 66^{o}S. This structure curves and merges with a N70^{o}E striking fault at the saddle above the main mine workings. A second west-northwest-trending fault displaces the tuff on the south. North-northwest faults perpendicular to this structure warp the base of the Barnes Butte tuff, exposing a west-northwest-trending anticlinal flexure. An additional striated fault surface, exposed in a construction cut in the north part of Prineville shows vertical displacement along a plane which strikes N 78^{o}E and dips 69^{o} south. The fault cuts the contact between perlitic, intrusive rhyolite (Tjr) and tuff (Tjt).

Miocene age faulting is indicated along the Post Highway east of Juniper Canyon, where southward dipping Prineville Basalt flows are topographically overlain by younger, gently dipping Prineville flows. Swanson (1969) considered this structural block to be a paleolandslide deposit composed of an intact block measuring 1600 m by 3200 m, but the observed contact relations indicate that interbedded Prineville Basalt and sedimentary rocks of unit Tmos have been rotated along an east-west trending fault. The apparent sense of displacement is top-to-the-south. Deformation in the Prineville quadrangle does not affect younger rocks of the relatively stable Deschutes Formation volcanic plateau.

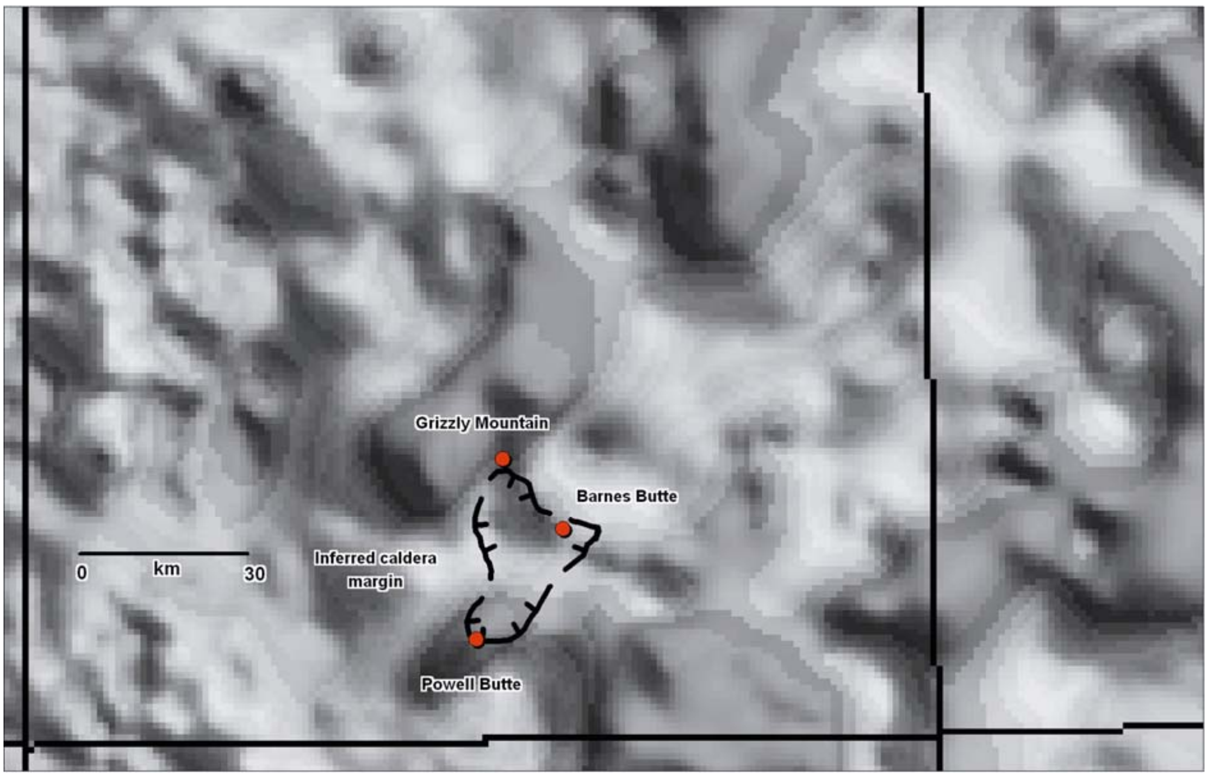

Figure 2. Regional isostatic gravity map of the Prineville area. Relative gravity highs are shown as positive relief features. Gravity lows are shown as depressions. The thickest accumulation of pumice tuff (Tjt) occurs just west of Barnes Butte. The inferred caldera margin is based on the distribution of pumice-lithic tuff (presumed caldera fill) and marginal rhyolite flows and domes.

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Table 1.1. Analyses of major oxide and selected trace elements from samples collected in the Prineville quadrangle, Crook County, Oregon. Major oxides in percent and selected trace elements in parts per million (ppm). XRF analyses normalized to 100 percent on a volatile-free basis with total iron expressed as FeO_. Samples analyzed by the Franklin and Marshall College, GeoAnalytical Laboratory, Lancaster, PA. Sample location numbers are keyed to the accompanying preliminary geologic map.

Map #	**1**	**2**	**3**	**4**	**5**	**6**	**7**
UTM_N	4913066	4911015	4909935	4908729	4908099	4912221	4907229
UTM_E	0676496	0671452	0674019	0674747	0674918	0679009	0670446
Group							
Formation	John Day	John Day	John Day	John Day	John Day	Clarno	Deschutes
Map unit	Tjb	Tjt	Tjr	Tjtb	Tjr	Tca	Tdbw
Lithology	Dacite	Rhyolite tuff	Rhyolite	Rhyolite tuff	Rhyolite	Dacite	Basalt
SiO2	66.14	75.47	81.95	81.29	81.53	63.92	48.81
Al2O3	13.33	12.65	9.43	9.15	9.44	16.54	15.68
TiO2	1	0.31	0.16	0.13	0.13	0.82	1.91
FeO_	9.53	2.67	1.42	1.7	1.5	5.39	12.21
MnO	0.13	0.05	0.03	0.03	0.02	0.09	0.22
CaO	2.19	1.83	0.25	0.37	0.2	5.65	9.62
MgO	0	0.6	0.06	0.11	0.09	2.47	8.15
K2O	3.64	4.71	4.12	5.47	4.88	1.31	0.33
Na2O	3.63	1.64	2.55	1.55	2.16	3.56	2.69
P2O5	0.42	0.08	0.03	0.19	0.06	0.25	0.39
Ni	9	0	1	3	1	35	144

Cr	5	0	<2	5	2	53	252
Sc	25	5	1	1	1	14	32
V	43	24	3	31	10	112	302
Ba	836	957	764	569	518	477	255
Rb	87	96	125	125	120	31	7
Sr	167	76	26	15	14	411	343
Zr	610	512	355	355	290	183	121
Y	85.9	95.8	19.7	61	58.5	22.2	34.3
Nb	45.2	57.5	47.1	36.8	36.8	13.8	7.5
Ga	22	20	18	16	17	19	20
Cu	9	12	<2	2	16	40	53
Zn	131	118	49	69	78	71	105
Pb	8	12	<1	1	2	6	1
La	66	60	16	51	48	25	12
Ce	140	157	35	1	104	53	26
Th	10.5	14.4	5.4	13.1	12.3	2.7	2.9
U	3.6	5.9	2	3	3.4	1.3	1.2
Co	15	<1	<1	0	<1	17	53

Map #	**8**	**9**	**10**	**11**	**12**	**13**	**14**
UTM_N	4906167	4906025	4905577	4905555	4904850	4904465	4904094
UTM_E	0673485	0676122	0676746	0677300	0677454	0676211	0676723
Group				CRBG	CRBG	CRBG	CRBG
Formation	Deschutes	Deschutes		Prineville	Prineville	Prineville	Prineville
Map unit	Tdbw	Tdbc	Tmot	Tcp	Tcp	Tcp	Tcp
Lithology	Basalt	Basalt	Andesite tuff	Basaltic trachyand.	Basaltic trachyand.	Basalt	Basaltic trachyand.
SiO2	48.59	49.65	57.01	55.4	52.22	51.21	54.69
Al2O3	15.33	15.86	17.16	14	13.34	13.33	13.9
TiO2	1.79	1.23	1.12	2.48	2.79	3.13	2.61
FeO_	13.29	9.33	9.03	9.85	12.6	12.43	10.36
MnO	0.21	0.17	0.14	0.23	0.24	0.26	0.24
CaO	9.29	11.47	7.67	6.47	7.54	8.4	6.82
MgO	8.23	8.98	3.79	3.49	4.11	4.55	3.7
K2O	0.37	0.75	1.27	3.08	2.4	1.68	2.84
Na2O	2.55	2.25	2.61	3.54	3.07	3.15	3.35
P2O5	0.34	0.31	0.2	1.46	1.69	1.86	1.5
Ni	166	168	43	9	11	17	8
Cr	270	399	87	17	23	22	16

Sc	33	32	25	25	35	35	30
V	278	238	181	219	280	286	231
Ba	218	527	391	2185	2395	2845	2112
Rb	6	11	26	44	39	31	41
Sr	339	768	489	319	365	414	320
Zr	120	101	135	147	141	138	144
Y	34	23.4	23	50.4	52	53.6	50.6
Nb	6.6	7.7	8.9	8	8.2	7.5	8.6
Ga	19	16	18	20	19	20	19
Cu	58	65	37	40	39	51	48
Zn	106	67	77	103	124	119	117
Pb	2	3	4	5	3	3	6
La	11	18	19	28	25	28	29
Ce	2	41	4	60	5	60	63
Th	2.1	1.6	3.2	5.3	4	4.8	4.2
U	<	<0.5	2	2	1	2.6	0.9
Co	54	47	29	27	33	37	30

Map #	**15**	**16**	**17**[a]	**18**	**19**	**20**	**21**
UTM_N	4904701	4903750	4903600	4903332	4904560	4904567	4902297
UTM_E	0674011	0674120	0674100	0672023	0670780	0670795	0669784
Group	CRBG	CRBG	CRBG				
Formation	Prineville	Prineville	Prineville	Deschutes	Deschutes	Deschutes	Deschutes
Map unit	Tcp	Tcp	Tcp	Tdbw	Tdbm2	Tdbm1	Tdbw
Lithology	Basaltic Andesite	Basaltic trachyand.	Basalt	Basalt	Basalt	Basalt	Basalt
SiO2	52.2	52.33	51.94	48.6	50.21	50.04	48.42
Al2O3	13.52	13.81	14.58	15.65	16.23	16.36	15.07
TiO2	2.65	2.68	2.77	1.83	1.48	1.51	2.17
FeO_	13.08	12.08	12.38	12.14	11.91	11.96	13.98
MnO	0.23	0.24	0.24	0.21	0.19	0.2	0.22
CaO	7.96	7.97	7.9	9.96	9.32	9.34	9.24
MgO	4	4.36	4.3	8.18	6.92	6.76	7.11
K2O	1.95	1.99	1.85	0.36	0.67	0.6	0.56
Na2O	2.99	3.09	2.79	2.7	2.74	2.88	2.73
P2O5	1.42	1.44	1.25	0.38	0.32	0.35	0.51
Ni	14	13	n.d.	137	103	90	117
Cr	21	19	n.d.	196	120	102	198
Sc	34	32	n.d.	28	30	30	34

V	330	313	n.d.	257	252	253	345
Ba	1882	1865	n.d.	363	251	306	374
Rb	43	45	n.d.	7	8	9	9
Sr	400	402	n.d.	356	338	349	330
Zr	162	170	n.d.	121	114	121	115
Y	51	51.5	n.d.	33.3	32	34	38
Nb	8.7	8.3	n.d.	7.4	6.4	5.8	6.9
Ga	20	21	n.d.	20	20	21	21
Cu	39	42	n.d.	60	90	93	99
Zn	124	118	n.d.	94	93	90	106
Pb	4	6	n.d.	2	2	3	3
La	28	29	n.d.	11	13	12	14
Ce	6	61	n.d.	25	3	2	3
Th	5.5	5	n.d.	0.7	2.2	1.2	1.6
U	2	1.3	n.d.	0.6	1	<	<
Co	37	35	n.d.	49	47	45	52

[a] Smith (1986a)

Table 1.2. Whole-rock $^{40}Ar/^{39}Ar$ age determination for the Barnes Butte rhyolite (Tjr) in the Prineville quadrangle, Crook County, Oregon. Sample A1 prepared and analyzed by the College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon. The sample location number is keyed to the accompanying preliminary geologic map.

Map #	Map unit	Lithology	Age (Ma)	Method	Material dated	Formation	UTM_N	UTM_E
A1	Tjr	Rhyolite	27.97 ± 0.32	$^{40}Ar/^{39}Ar$	Whole rock	John Day	4909935	0674019