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Department of Geology and Mineral Industries
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PRELIMINARY GEOLOGIC MAP OF THE POWELL BUTTES 7.5′ QUADRANGLE, CROOK COUNTY, OREGON

By
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2006

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PRELIMINARY GEOLOGIC MAP OF THE POWELL BUTTES 7 ½' QUADRANGLE

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INTRODUCTION

The Powell Buttes 7 ½' quadrangle resides on the eastern margin of the Deschutes Basin near the juncture of the High Cascades, High Lava Plains, and Blue Mountains geomorphic provinces. Centrally located between the cities of Bend and Prineville, the quadrangle encompasses a historic ranching community that is rapidly transforming to a rural residential population. The quadrangle is juniper- and sage-covered high desert country that ranges in elevation from 5210 ft (1588 m) at Powell Buttes to a base of 2920 ft (890 m) in the Crooked River Canyon on the east. This map depicts a preliminary stratigraphic assessment for the Powell Buttes area and provides a framework for further geologic and geohydrologic analysis of the Lower Crooked River Basin.

Powell Buttes, an Oligocene rhyolite complex, forms the northwestern margin of the quadrangle and consists of a series of nested flows, domes, and associated dike-shaped intrusions. Arsenic and mercury associated with old uranium prospects occur within the rhyolite complex. Geothermal potential also exists around the periphery of Powell Buttes with water temperatures reaching 42^{o}C (108^{o}F) at depth. Powell Buttes is flanked by a plateau of late Miocene lava flows and sedimentary rocks of the Prineville basalt and Deschutes Formation. The Prineville basalt and Oligocene-Miocene sedimentary rocks form an eroded, irregular middle Miocene surface that is exposed in Swartz Canyon and the north-central portion of the map area. A younger succession of Deschutes Formation lava flows and sedimentary rocks both cap and fill channels incised into the Prineville basalt. The Pliocene basalt of Dry River is inset into Deschutes lavas and skirts the northwest corner of the map area.

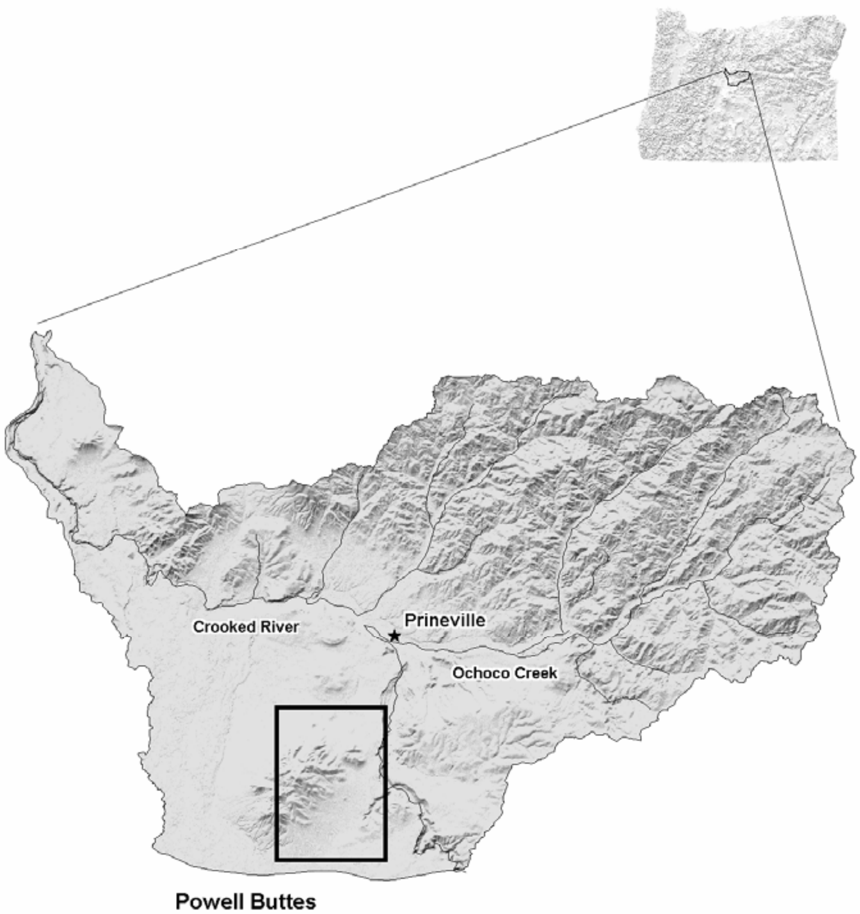

Figure 1. Digital Elevation Model (DEM) of the Lower Crooked River Basin, showing location of the Powell Buttes quadrangle.

Methodology and Previous Work

The 1:24,000 scale geologic map of the Powell Buttes 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.

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) and a MS thesis by Weidenheim (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 (Gannett and others, 2001; Lite and Gannett, 2002). The current mapping effort is designed in part to better define the geologic conditions along the east margin of the upper Deschutes Basin, building off of the stratigraphy established by Smith (1986a) and Sherrod and others (2004).

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

Surficial Deposits

Qa **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 plain of the Crooked River.

Qf **Alluvial fan deposits and colluvium. (Holocene and Pleistocene)** – Mainly alluvial fan deposits, colluvium, and stream alluvium deposited on the flanks of Powell Buttes. The deposits are typically unconsolidated to weakly consolidated, matrix supported gravel composed of angular to subround pebble- to boulder-sized clasts of rhyolite. The matrix fraction is dominated by sand-sized grains of angular to subangular feldspar, magnetite, and olivine derived from gravel-sized rhyolite clasts and reworked Deschutes sediments of unit Tdsg. Locally includes 1-m-thick accumulations of white-colored air-fall pumice.

Qls **Landslide deposits. (Holocene and Pleistocene)** – Unconsolidated, chaotically mixed, clast-supported deposits of interlocking, boulder-dominated breccia composed mostly of sanidine- and quartz-phyric rhyolite, deposited by gravity-driven mass-wasting processes. Upper surfaces form hummocks and ridges incised by drainages that locally contain Qls debris remobilized and deposited by sediment-gravity flows. A distinct amphitheater-shaped landslide scarp for the Qls deposit in the west-central portion of the buttes is present 400 m west-southwest of the Powell Buttes summit radio towers. Thickness is highly varied; maximum thickness is several tens of meters.

Qt **Terrace deposits (Pleistocene)** – Abandoned terraces of the Crooked River composed of well-sorted gravel, sand, and silt. Maximum thickness of the unit is approximately 20 m. Equivalent in part to unit Qs of Swanson (1969).

Tertiary Volcanic and Sedimentary Rocks

Tpb **Basalt of Dry River (Pliocene)** – Gray, fine-grained, open-textured olivine-phyric basalt flows that form the capping rimrock northwest of Powell Buttes. The top of the unit is marked by hummocky tumuli northwest of Powell Buttes; this surface retards groundwater infiltration creating a semi-saturated ground layer with abundant ponds. In thin-section, the basalt is aphyric with a groundmass marked by plagioclase lathes set in a matrix of intergranular olivine and clinopyroxene crystals as well as subophitic clinopyroxene crystals. Chemically the unit is a high alumina basalt with characteristically low amounts of potassium. A representative sample from the adjoining Huston Lake quadrangle has 50.37 weight percent SiO_2; 16.68 weight percent Al_2O_3;

1.46 weight percent TiO_2; and 0.41 weight percent K_2O (Ferns and McClaughry, 2006). The basalt displays reversed magnetic polarity and is not mantled by eroded sands of unit Tdsg. Sherrod and others (2004) consider the basalt of Dry River to be about the same age as the basalt of Redmond, which has an $^{40}Ar/^{39}Ar$ whole rock age of 3.56 $\pm$ 0.30 Ma (Smith, 1986a).

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 capping middle to 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), amphibole (15 percent), white pumice (10 percent), quartz (3 percent), and magnetite (2 percent). Some mineral grains maintain a euhedral crystal form. The gravel consists of surface-armoring lag-deposits and in-situ reworked upper surfaces of basalt lava flows. The highstand for Deschutes sediments is estimated to be approximately 3600 ft (1098 m) in elevation based on distinctive sand and gravel strand lines observed on the flanks of Powell Buttes. Unconformably overlain by the basalt of Dry River (Tpb).

Tdbs **Basalt of Swartz Canyon (late Miocene?)** – Dark gray, medium- to coarse-grained, holocrystalline olivine- and plagioclase- olivine-phyric basalt and basaltic andesite. The flow forms a low-lying, hummocky flow surface in the southeast part of the quadrangle; it crops out along the western rim of Swartz Canyon and forms the plateau along the Crooked River Canyon near Stearns Dam. In hand sample, the basalt is characterized by vesicles that are filled by either botryoidal-shaped masses of opaline quartz or white to pink, branch-shaped zeolite. In thin-section, the unit contains < 4 percent small (~0.5 mm) subhedral olivine and (~1.5 mm) euhedral plagiocalse phenocrysts set in a intergranular groundmass marked by crudely aligned plagioclase crystals separated by small clinopyroxene, olivine, and opaque mineral grains. Chemically the flow is basalt or basaltic andesite with ~52.00 weight percent SiO_2; 16.257 weight percent Al_2O_3; 1.55 weight percent TiO_2, and 1.00 weight percent K_2O (Samples 15, 27 and 30, Table 1.1). Flows display both reversed and normal magnetic polarity. The basalt of Swartz Canyon rests on the Rattlesnake Ash-Flow Tuff near Stearns Dam and is considered to be younger than the basalt of Meyers Butte based on stratigraphic position and magnetic polarity.

Tds **Sedimentary rocks (late Miocene)** – Brown volcaniclastic sandstone, siltstone, and conglomerate in the Deschutes Formation. Sedimentary rocks are laterally discontinuous, interfinger with lava flows, are weakly consolidated and poorly exposed weathering to form soil-mantled hillslopes. Based on water well logs, the unit largely consists of sandstone and conglomerate. These rocks overly the Rattlesnake Ash-flow Tuff in Swartz Canyon and are considered to be correlative to the Deschutes Formation as defined by Farooqui and others (1981). The composite sedimentary section may be as much as 120-m-thick in the quadrangle.

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 marks the top of the Deschutes Formation along the western canyon wall of the Crooked River. Exposures in the canyon show massive columnar, tumuli capped, overlapping flow-lobes. Individual flow lobes have well-defined outer vesicular margins that grade inward to a massive crystalline core. Locally, the flow retains hollow lava tubes ($\leq$ 2-m-wide) and vesicle cylinders ($\leq$ 3-cm-wide). In thin section the basalt is holocrystalline with a diktytaxitic texture marked by plagioclase crystals that protrude into the vesicles. Microporphyritic with glomerocrysts of olivine and plagioclase crystals. Groundmass plagioclase crystals are set in a supophitic clinopyroxene matrix. Samples from adjacent quadrangles indicate that the flows are high alumina basalt with moderate titanium and potassium, with ~49.50 weight percent SiO_2; 16.40 weight percent Al_2O_3; 1.50 weight percent TiO_2, and 0.50 weight percent K_2O (Sample 12, Table 1.1). The flows display reversed magnetic polarity and are considered late Miocene in age based on stratigraphic position.

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, at the base, a palagonite breccia (>20-m-thick) that is made up of sub-angular, black glassy basalt blocks, bombs, and pillows. In thin section, the basalt is holocrystalline and diktytaxitic. The unit contains microphenocrysts of plagioclase and olivine set in a groundmass composed of plagioclase lathes and subophitic clinopyroxene crystals. Based on analyses from adjoining quadrangles, the unit is chemically indistinguishable from overlying unit Tdbm2, with moderate titanium and potassium contents, with about 49.50 weight percent SiO_2; 16.40 weight percent Al_2O_3; 1.50 weight percent TiO_2, and 0.50 weight percent K_2O (Ferns and McClaughry, 2006; McClaughry and Ferns, 2006). Locally interbedded with tuffaceous sandstone. The basalt displays reversed magnetic polarity.

Tdbw **Basalt of White Deer Ranch (late Miocene)** – Gray, medium-grained, vesicular, olivine-phyric basalt flows. In thin section, the basalt is holocrystalline, with a diktytaxitic texture. Contains microphenocrysts of plagioclase and olivine set in a groundmass marked by plagioclase surrounded by subophitic clinopyroxene crystals. Chemically a basalt with relatively high amounts of titanium; with 48.06 wt percent SiO_2; 15.44 wt percent Al_2O_3; 2.05 wt percent TiO_2, and 0.60 wt percent K_2O (Sample 10, Table 1.1). Late Miocene age based on stratigraphic position. The basalt displays reversed magnetic polarity and rests directly beneath the Rattlesnake Ash-flow Tuff (Tmr) in the canyon of the Crooked River.

Tdbd **Basalt of Dry Creek (late Miocene)** – Gray, medium-grained, vesicular, olivine-phyric basalt lava flow. In thin section, the basalt is holocrystalline, with iddingtized olivine microphenocrysts set in a groundmass marked by plagioclase crystals with intergranular olivine and clinopyroxene grains. Chemically a high alumina basalt with characteristically relatively low amounts of titanium; with 50.70 weight percent SiO_2; 16.47 weight percent Al_2O_3; 1.13 weight percent TiO_2, and 0.60 weight percent K_2O (Sample 11. Table 1). The late Miocene age is based on stratigraphic position. Displays normal magnetic polarity and directly underlies lava flows of unit Tdbw in the Crooked River Canyon.

Tmr **Rattlesnake Ash-flow Tuff (late Miocene)** – Rust orange to gray, pumice-crystal-lithic tuff exposed along the western wall of Swartz Canyon and in the Crooked River Canyon. Considered equivalent to the Rattlesnake Ash-Flow Tuff of Walker (1979). The tuff is matrix-supported, and typically massively bedded; well-developed coarse-tail grading of both pumice and lithics occurs in Swartz Canyon. The tuff consists of a matrix (80 percent by volume) of angular to subround, fine- to medium-grained, sand-sized fragments of feldspar, quartz, amphibole, pumice, and lithics. The gravel fraction of the tuff consists of fresh appearing, pink to brown, flattened ovate spheroids of pumice (15 percent) up to 7-cm-long that are strongly aligned parallel to bedding planes. Angular lithic fragments of rhyolite and basalt up to 1-cm-across compose 5 percent of the unit. Based on bulk chemistry, the Rattlesnake is a rhyolitic ash-tuff with ~75 weight percent SiO_2, ~12.5 weight percent Al_2O_3, ~3.0 weight percent Na_2O, and ~5.0 weight percent K_2O (Samples 14 and 26, Table 1.1). The tuff rests directly on basalt cobble conglomerate in Swartz Canyon that is monolithic, containing only clasts of Prineville basalt (unit Tmcp). The tuff rests between reversed polarity Deschutes Formation basalt flows (Tbdw; Tbds) in the Crooked River Canyon. Reversed magnetic polarity (Smith 1986a). A late Miocene age is based on 7.05 ± 0.1 Ma $^{40}Ar/^{39}Ar$ age (Streck, 1994). Thickness up to 15 m.

Tcp **Prineville Basalt (middle Miocene)** – Black to dark gray, fine-grained, sparsely plagioclase-phyric and aphyric, iron-rich basalt and basaltic andesite lava flows. The basalt flows are equivalent to the Prineville Basalt as defined by Tolan and others (1989) and Hooper and others (1993). The Prineville basalt is exposed in northeast-southwest trending ridges south of Swartz Canyon and in quarry cuts north of Powell Buttes. Outcrop exposures are massive to columnar-jointed with lesser amounts of spheroidal weathering and pillow structures. Locally the basalt is vesicular with cavities filled with celadonite opal. In thin section the basalt is hypocrystalline, with 60 percent crystals, and 40 percent glass, with a hyalopilitic groundmass texture made up of glass, plagioclase lathes, clinopyroxene grains and abundant opaque mineral grains. The basalt contains < 2 percent olivine microphenocrysts. In the quadrangle, Prineville basalt flows are chemically similar to the Bowman Dam type flows of Hooper and others (1993) and are characterized by low amounts of alumina (~ 13.75 weight percent Al_2O_3) and high concentrations of iron (~ 13 weight percent FeO*) phosphorus (~ 1.4 weight percent P_2O_5) and barium (~1800 ppm Ba), (Samples 1, 2, 25, 28, and 29, Table 1.1). A thin flow in the southeast corner of the quadrangle interfingers with basalt-clast gravels atop tuffaceous sediments of unit Tmos. Southwest of Swartz Canyon, the lava flow surface has been reworked by fluvial processes marked by faceted boulders and lag gravels that indicate stream-transport directed ~N60°E. According to Hooper and others (1993) lower Bowman Dam type flows display reversed magnetic polarity while the capping Bowman Dam type flow displays normal magnetic polarity. A middle Miocene age is based on a radiomentric age 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).

Tmos **Tuffaceous sedimentary rocks (middle Miocene to late Oligocene?)** –Moderately indurated deposits of brown to tan tuffaceous siltstone, white to dark gray, stratified, plane-parallel to massively bedded volcaniclastic sandstone, black, well-sorted, clast supported cobble conglomerate composed of well-rounded clasts of Prineville basalt, and massively bedded white pumice-crystal-lithic tuff exposed in Swartz Canyon. The lowermost sedimentary rocks exposed in Swartz Canyon, locally contain silicified pods with associated opalized reed fragments and petrified wood. Diatomite and tuffaceous siltstone are intermixed with the base of a Prineville basalt flow in a gravel quarry southwest of Swartz Canyon along the G. Millican Highway. A middle Miocene age for the upper part of the unit is based on intertonguing relationships between Prineville Basalt, hyaloclastites, and Prineville Basalt clast conglomerates along the contact with overlying Prineville Basalt flows. Although previously considered to be the upper part of the John Day Formation (Swanson, 1969) herein tentatively considered to be correlative to the Simustus (Smith, 1986b) and Mascall (Merriam, 1901) Formations. The base of the unit is not exposed.

John Day Formation (early Miocene to early Oligocene) – Succession of interbedded subaerial tuffaceous sedimentary deposits and silicic lava flows and domes. Equivalent to the John Day Formation of Marsh (1875), Merriam (1901), and Robinson and others (1990) and subdivided into:

Tjs **Tuffaceous sandstone and siltstone (Oligocene?) –** Orange-white, yellow-brown, and white, tuffaceous siltstone and fine-grained tuffaceous sandstone. The unit weathers to angular chips and is exposed only in excavations. Sparse plant fossils include *Metasequoia occidentalis*. The outcrop area, marginal to the north slope of Powell Buttes, is overlain by an aphyric rhyolite lava flow (Tjrp). A late Oligocene age is inferred based on stratigraphic position.

Powell Butte Rhyolite complex (late Oligocene) rhyolite lava flows, domes, and intrusions, subdivided into:

Tjqp **Quartz-phyric rhyolite flows and domes (late Oligocene) –** Gray to purple quartz-sanidine-phyric rhyolite. Includes a thin unit that forms a mass of low-lying, broken subcrop and outcrop at the southern margin and summit of Powell Buttes. Outcrops weather to a hard surface of subround boulders that are marked by clear quartz and potassium feldspar phenocrysts. In thin section phenocrysts of pseudohexagonal quartz up to 3-mm-across and subhedral microcline-twinned potassium feldspar (anorthoclase ?) are set in a devitrified, spherulitic matrix. Pleochroic blue amphibole (reibeckite ?) vapor phase microphenocrysts occur in vesicles. Blue amphibole also occurs along cracks in groundmass spherulites. Chemically, the rhyolite has low concentrations of aluminum and sodium (< 10 weight percent Al_2O_3 and < 3 weight percent Na_2O) and high concentrations of silica and iron (~ 77.0 weight percent SiO_2; > 6.0 weight percent FeO*) with moderate concentrations of potassium (~4.3 weight percent K_2O); Samples 20 and 31, Table 1. High levels of certain trace elements, including zirconium (> 800 ppm Zr), yttrium (> 80 ppm Y) and niobium ($\geq$ 70 ppm Nb) (Samples 20 and 31, Table 1.1) suggest peralkaline affinities. The unit is considered, on the basis of cross-cutting relationships and stratigraphic position, to be the youngest phase of the Powell Buttes rhyolite complex.

Tjsp **Sanidine-phyric rhyolite flows and domes (late Oligocene) –** Gray to purple sanidine-phyric rhyolite. Includes a mass at the top of the Powell Buttes and satellite masses east of Powell Buttes. Upper surfaces are locally pumiceous and marked by strong, vertically oriented, flow-banding. In hand sample, the rhyolite is distinctly porphyritic with clear sanidine phenocrysts. In thin section the rhyolite contains blocky sanidine phenocrysts up to 2-mm-across and corroded blue amphibole (reibeckite ?) phenocrysts up to 1.2-mm-across set in a spherulitic matrix. Spherulites are composed of radiating acicular needles of blue amphibole and sanidine. Opaque and iron-oxide minerals are abundant. In comparison to the quartz-phyric rhyolites, the sanidine-phyric unit contains intermediate concentrations of aluminum, potassium, and sodium (~ 11.5 weight percent Al_2O_3, ~ 4.8 weight percent K_2O, and ~ 3.80 weight percent Na_2O) and appreciably lower amounts of iron (~ 3.0 weight percent FeO*) (Samples 10, 21, and 22, Table 1). The rhyolite contains appreciably high levels of certain trace elements, including zirconium (> 700 ppm Zr), yttrium (> 80 ppm Y), and niobium (> 50 ppm Nb) (Samples 10, 21, and 22, Table 1.1), indicating peralkaline affinities. Considered, on the basis of cross-cutting relationships and stratigraphic position, to be of intermediate age in the Powell Buttes rhyolite complex. Robinson and others, 1990 report a radiometric age of 25.8 ± 0.2 Ma for the sanidine rhyolite exposed at the summit of Powell Buttes (Sample A1, plate 1, Table 1.2).

Tjrp **Rhyolite flows and domes (late Oligocene)** – Purple to gray, ledge-forming, stony, aphyric-rhyolite flows and domes that make up the main part of the Powell Buttes rhyolite complex. Includes a distinct, tightly flow-banded, aphyric-rhyolite on the north flank of Powell Buttes rhyolite complex. Unit Tjrp also includes sparsely plagioclase-phyric, glassy rhyolite lava flows on the south flank of Powell Buttes. In both areas, the bases of individual lava flows are defined by vesiculated zones and basal flow breccias. Tops of flows commonly have pumiceous flow top breccia and perlitic vitrophyre. Unit Tjrp includes some flows referred to as dacite by Weidenheim (1980). In thin section, the rhyolite is aphyric, with a devitrified, spherulitic groundmass. The groundmass contains small (~ 0.1 mm-diameter) high birefregence, high relief minerals tentatively identified as zircons. The northern mass includes rhyolite that, in comparison to the porphyritic rhyolites, contains markedly lower amounts of iron (~ 1.0 weight percent FeO*), zirconium (~ 500 ppm Zr), yttrium (~ 60 ppm Y) and niobium (~ 45 ppm Nb), with high concentrations of silica (~ 79 weight percent SiO_2) (Sample 8, Table 1.1). A late Oligocene age is based on a 28.3 $\pm$ 1.0 K-Ar whole rock age (Evans and Brown, 1981) (Sample A2, plate 1, Table 1.2).

Tjip **Aphyric rhyolite dikes (late Oligocene)** – Purple-gray to white, massive, aphyric rhyolite dikes trending N55^{o}E at Hat Rock and the Rooster Combs, just south of the summit of Powell Buttes. The dike at Hat Rock is vertically flow banded and has well-developed vesicular zones concurrent with vertical-oriented fracture zones. Locally, the dike is pumiceous near its upper surface and shows perlitic textures along its margin with the hosting sedimentary strata. In comparison to rhyolite flows sampled to the north, the dike contains higher amounts of alumina (12.95 wt percent Al_2O_3) and lesser amounts of silica (~ 75.6 wt percent SiO_2), zirconium (~ 430 ppm zr), yttrium (~ 38 ppm Y) and niobium (~ 26 ppm Nb) (Sample 19, Table 1.1). Based on cross-cutting relationships, the dike is interpreted to have been the feeder system for the basal flows in the Powell Buttes rhyolite complex.

Tjt **Pumice-lithic tuff (late Oligocene)** – Bedded green pumice tuff, light-green volcaniclastic sandstone, and clast-supported, monolithic rhyolite pebble breccia, and pale-green lapilli tuff that contains blocks of basaltic andesite. Includes vitric ash-flows and ignimbrites of Weidenheim (1980). The tuff and sedimentary rock succession is invaded and displaced at Hat Rock by intrusive rhyolite of unit Tjip. Although spatially associated with the Powell Buttes rhyolite complex, the tuffaceous rocks apparently predate the earliest known dome eruptions at Powell Buttes.

STRUCTURE

The Oligocene age Powell Buttes rhyolite complex forms a northeast-trending, north-tilted horst in the west section of the quadrangle that is segmented by north-northeast and west-northwest, relatively small displacement, normal faults. The topographically and structurally high Powell Buttes is flanked on the east by a relatively stable Miocene volcanic plateau; Oligocene to Miocene (?) normal faults crosscutting the rhyolite at Powell Buttes apparently do not offset the younger onlapping strata. Deformation in the middle to late Miocene volcanic succession is limited to a northwest trending normal fault (sense is top to the northeast) that cuts sedimentary rocks of unit Tmos and the Rattlesnake Ash-flow Tuff. The fault does not penetrate the immediately overlying, normal-polarity basalt of Swartz Canyon. The spatial relations and onlapping stratigraphic relations of Miocene to Pliocene volcanic and sedimentary strata on and around the eastern margin of the Oligocene rhyolite complex indicates that Powell Buttes was a topographic high in the Miocene. Powell Buttes was apparently a barrier that controlled the distribution of younger lava flows and fluvial systems, forcing them to depocenters located east and north.

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Table 1.1. Analyses of major oxide and selected trace elements from samples collected in the Powell Buttes 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	4897660	4897570	4898390	4898810	4897123	4896720	4895830
UTM_E	0661110	0661180	0662880	0663380	0663910	0662650	0662280
Group							
Formation	John Day	John Day	John Day	John Day	John Day	John Day	John Day
Map unit	Tjrp	Tjrp	Tjrp	Tjrp	Tjrp	Tjrp	Tjrp
Lithology	Rhyolite	Rhyolite	Rhyolite	Rhyolite	Rhyolite	Rhyolite	Rhyolite
SiO2	77.12	81.12	77.87	81.3	79.26	78.97	78.05
Al2O3	9.79	10.72	11.24	11.36	11.55	11.04	11.72
TiO2	0.3	0.2	0.149	0.103	0.141	0.149	0.257
FeO_	4.5	1.1	2.39	2.38	1.06	1.79	3.5
MnO	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	n.d.
CaO	0.1	0.1	0.1	0.1	0.09	0.1	0.21
MgO	0	0	0	0	0.05	0	0
K2O	5	4.06	4.77	1.03	4.32	4.48	2.57
Na2O	3.2	2.7	3.48	3.72	3.49	3.48	3.7
P2O5	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.
Ni	n.d.	n.d.	n.d.	n.d.	2	n.d.	n.d.
Cr	n.d.	n.d.	n.d.	n.d.	b.d.	n.d.	n.d.
Sc	n.d.	n.d.	n.d.	n.d.	1	n.d.	n.d.
V	n.d.	n.d.	n.d.	n.d.	8	n.d.	n.d.
Ba	n.d.	n.d.	n.d.	n.d.	963	n.d.	n.d.
Rb	n.d.	n.d.	n.d.	n.d.	115	n.d.	n.d.
Sr	n.d.	n.d.	n.d.	n.d.	10	n.d.	n.d.
Zr	n.d.	n.d.	n.d.	n.d.	462	n.d.	n.d.
Y	n.d.	n.d.	n.d.	n.d.	63.1	n.d.	n.d.
Nb	n.d.	n.d.	n.d.	n.d.	45	n.d.	n.d.
Ga	n.d.	n.d.	n.d.	n.d.	23	n.d.	n.d.

Cu	n.d.	n.d.	n.d.	n.d.	b.d.	n.d.	n.d.
Zn	n.d.	n.d.	n.d.	n.d.	43	n.d.	n.d.
Pb	n.d.	n.d.	n.d.	n.d.	3	n.d.	n.d.
La	n.d.	n.d.	n.d.	n.d.	30	n.d.	n.d.
Ce	n.d.	n.d.	n.d.	n.d.	68	n.d.	n.d.
Th	n.d.	n.d.	n.d.	n.d.	12	n.d.	n.d.
U	n.d.	n.d.	n.d.	n.d.	4.8	n.d.	n.d.
Co	n.d.	n.d.	n.d.	n.d.	b.d.	n.d.	n.d.

Map #	**8**	**9**	**10**	**11**	**12**	**13***	**14***
UTM_N	4896930	4897728	4897728	4897728	4897728	4893560	4894170
UTM_E	0666299	0669568	0669568	0669568	0669568	0660070	0660740
Group							
Formation	John Day	Deschutes	Deschutes	Rattlesnake	Deschutes	John Day	John Day
Map unit	Tjsp	Tdbd	Tdbw	Tmr	Tdbs	Tjrp	Tjrp
Lithology	Rhyolite	Basalt	Basalt	Rhyolite tuff	Basalt	Rhyolite	Rhyolite
SiO2	76.49	50.17	48.06	75.14	51.27	79.03	72.76
Al2O3	11.5	16.3	15.44	12.23	16.32	9.93	14.15
TiO2	0.172	1.119	2.047	0.218	1.531	0.304	0.354
FeO_	2.79	10.48	14	2.01	11.43	4.05	3.03
MnO	0.051	0.173	0.213	0.104	0.201	n.d.	n.d.
CaO	0.16	9.73	9.19	1.14	8.56	0.1	1.52
MgO	0.22	8.47	7.07	0.63	6.09	0	0
K2O	4.88	0.59	0.6	5.19	0.9	3.04	3.54
Na2O	3.71	2.65	2.86	3.24	3.3	3.55	4.65
P2O5	0.03	0.326	0.527	0.093	0.393	n.d.	n.d.
Ni	3	211	141	b.d.	74	n.d.	n.d.
Cr	b.d.	425	199	4	89	n.d.	n.d.
Sc	2	28	34	6	29	n.d.	n.d.
V	5	215	329	19	246	n.d.	n.d.
Ba	408	293	367	665	388	n.d.	n.d.
Rb	120	8	6	89	12	n.d.	n.d.
Sr	16	402	340	60	334	n.d.	n.d.
Zr	721	90	96	270	153	n.d.	n.d.
Y	84.3	24.8	34.3	85.4	41.3	n.d.	n.d.
Nb	53.7	6.5	6.8	29.9	8.4	n.d.	n.d.
Ga	26	16	18	17	20	n.d.	n.d.
Cu	4	69	82	6	54	n.d.	n.d.
Zn	137	78	108	105	89	n.d.	n.d.
Pb	12	1	2	16	3	n.d.	n.d.
La	56	12	12	39	20	n.d.	n.d.
Ce	124	22	22	95	30	n.d.	n.d.
Th	13.7	0.9	0	7.7	1.6	n.d.	n.d.
U	2.7	b.d.	b.d.	3.1	0.5	n.d.	n.d.
Co	2	44	52	1	41	n.d.	n.d.

Map #	**15**	**16***	**17**	**18**	**19**	**20***	**21***
UTM_N	4894007	4893270	4894249	4894840	4894142	4894210	4893350
UTM_E	0660989	0660710	0662320	0661383	0663213	0664170	0666060
Group							
Formation	John Day	John Day	John Day	John Day	John Day	John Day	John Day
Map unit	Tjrp	Tjs	Tjsp	Tjqp	Tjsp	Tjrp	Tjsp
Lithology	Rhyolite	Basaltic Andesite	Rhyolite	Rhyolite	Rhyolite	Dacite	Rhyolite
SiO2	75.41	54.94	74.93	76.92	75.35	70.07	75.39
Al2O3	12.92	15.63	11.62	8.17	11.61	16.12	9.75
TiO2	0.284	2.016	0.284	0.296	0.282	0.83	0.298

FeO_	2.26	10.69	4.24	7.39	3.58	5.19	5.67
MnO	0.01	n.d.	0.041	0.112	0.04	n.d.	n.d.
CaO	0.69	7.66	0.29	0.5	0.14	2.39	0.04
MgO	0.14	4.23	0.14	0.11	0.08	0.31	0
K2O	4.52	1.31	4.68	4.29	4.77	0.83	5.27
Na2O	3.71	3.53	3.72	2.14	4.08	4.26	3.58
P2O5	0.051	n.d.	0.051	0.061	0.06	n.d.	n.d.
Ni	6	n.d.	6	7	6	n.d.	n.d.
Cr	b.d.	n.d.	b.d.	b.d.	b.d.	n.d.	n.d.
Sc	3	n.d.	1	2	b.d.	n.d.	n.d.
V	13	n.d.	10	21	12	n.d.	n.d.
Ba	908	n.d.	516	233	496	n.d.	n.d.
Rb	117	n.d.	112	109	114	n.d.	n.d.
Sr	63	n.d.	17	22	10	n.d.	n.d.
Zr	429	n.d.	826	872	849	n.d.	n.d.
Y	37.6	n.d.	105.7	86.7	104.4	n.d.	n.d.
Nb	26.3	n.d.	70.2	69.9	70.8	n.d.	n.d.
Ga	18	n.d.	29	25	30	n.d.	n.d.
Cu	2	n.d.	5	7	4	n.d.	n.d.
Zn	58	n.d.	155	217	107	n.d.	n.d.
Pb	8	n.d.	11	16	5	n.d.	n.d.
La	41	n.d.	68	82	71	n.d.	n.d.
Ce	94	n.d.	155	173	157	n.d.	n.d.
Th	11.4	n.d.	13.3	14.6	17.7	n.d.	n.d.
U	4	n.d.	1.5	2.9	5.3	n.d.	n.d.
Co	b.d.	n.d.	4	11	3	n.d.	n.d.

Map #	**22**	**23**	**24**	**25**	**26**	**27**	**28**
UTM_N	4891875	4892500	4891281	4890978	4889678	4889502	4890217
UTM_E	0668521	0669152	0667640	0667825	0667514	0669570	0660600
Group		CRBG		CRBG	CRBG		
Formation	Rattlesnake	Prineville	Deschutes	Prineville	Prineville	Deschutes	John Day
Map unit	Tmr	Tcp	Tdbs	Tcp	Tcp	Tdbs	Tjqp
Lithology	Rhyolite tuff	Trachy-basalt	Basalt	Basalt	Basalt	Basaltic Andesite	Rhyolite
SiO2	75.48	51.17	51.4	51.21	51.4	52.65	76.23
Al2O3	12.53	13.85	16.21	13.55	13.6	15.97	8.69
TiO2	0.22	2.688	1.507	2.662	2.652	1.572	0.333
FeO_	2.17	13.35	11.52	13.71	13.5	11.24	7.14
MnO	0.105	0.245	0.191	0.244	0.243	0.201	0.212
CaO	0.86	8.01	8.77	8.03	7.96	8.1	0.13
MgO	0.71	4.2	5.92	4.26	4.31	5.44	0.11
K2O	4.97	1.97	1	1.86	1.84	1.06	4.46
Na2O	2.88	3.1	3.1	3.08	3.09	3.32	2.64
P2O5	0.073	1.411	0.382	1.402	1.407	0.443	0.05
Ni	b.d.	13	77	14	15	64	3
Cr	10	18	81	20	19	66	b.d.
Sc	5	33	29	34	33	28	b.d.
V	15	322	235	300	311	217	32
Ba	624	1900	391	1763	1695	480	250
Rb	84	45	14	42	43	16	136
Sr	51	399	326	399	397	319	15
Zr	278	162	155	161	167	182	1185
Y	82.7	51.8	40.3	51.2	51.8	45.2	145
Nb	28.7	8.9	8	8.5	8.5	8.8	93.1
Ga	18	20	20	20	20	21	31
Cu	6	36	85	43	45	76	7

Zn	103	117	91	118	121	93	159
Pb	18	5	3	5	6	6	22
La	51	30	15	27	27	18	93
Ce	108	64	34	60	59	41	197
Th	9.2	5.3	1.7	5.8	5.1	2	17
U	3.5	2.4	0.9	3.5	1.4	1.3	1.2
Co	b.d.	36	41	36	36	38	10

*denotes samples from Weidenheim (1980)

Table 1.2. Whole-rock K/Ar age determinations in the Powell Buttes quadrangle, Crook County, Oregon. The sample location number is keyed to the accompanying preliminary geologic map.

Map #	Map label	Lithology	Age (Ma)	Method	Material dated	Formation	Utm_n	Utm_e
A1[a]	Tjrp	Rhyolite	28.3 ± 1.0	K/Ar	Anorthoclase	John Day	4895610	662480
A2[b]	Tjsp	Rhyolite	25.8 ± 0.2	K/Ar	Sanidine	John Day	nd	nd

[a] Evans and Brown (1981), sample # PB5; [b] Robinson and others (1990), sample # 648-623B