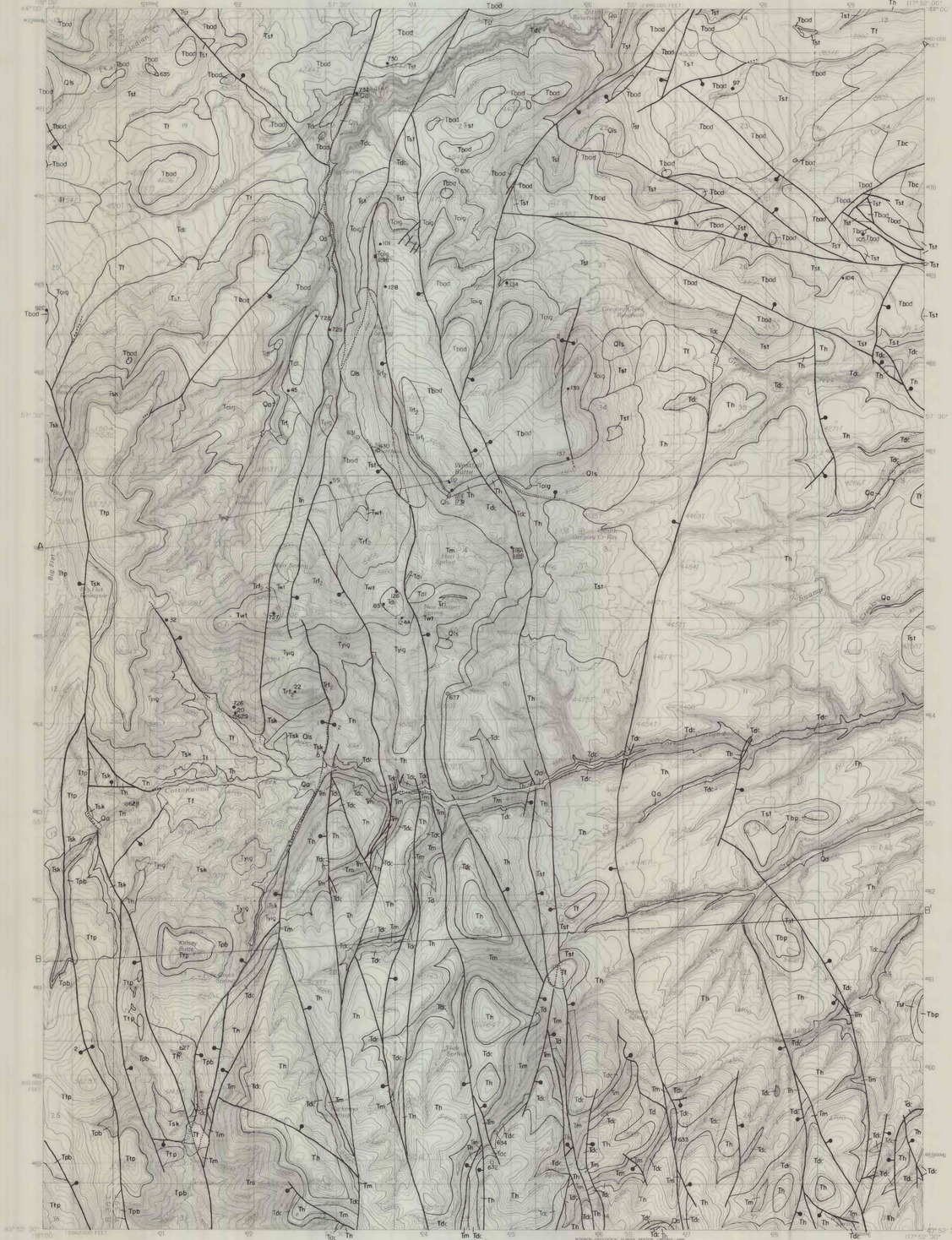
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 97-481
PLATE 1



Base from U.S. Geological Survey, 1990
Lambert conformal conic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 11

SCALE 1:24 000

KILOMETERS 0 1 2
METERS 0 1000 2000
MILES 0 .5 1
FEET 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL 20 FEET

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1998

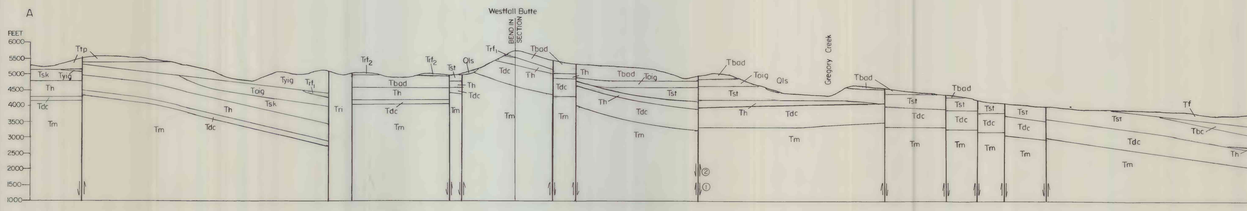
OREGON
QUADRANGLE LOCATION

Geology mapped in 1990
Manuscript approved for publication

GEOLOGIC MAP OF THE WESTFALL BUTTE 7 1/2' QUADRANGLE, MALHEUR COUNTY, OREGON

By
James G. Evans and G. Benjamin Binger

1996



CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

[See accompanying pamphlet for discussion, references cited, and tables]

Qa **Alluvium (Quaternary)**—Stream gravels and stream terraces. Unit composed of brown and gray unconsolidated, cross-bedded sand and conglomerate that contains pebbles and cobbles generally less than 10 cm long (maximum 40 cm). Unit includes a 15- to 30-cm-thick bed of white tephra in NW1/4 sec. 17, T. 19 S., R. 39 E.

Qls **Landslide deposits (Quaternary)**—Deposits occur along steep fault zones and at base of rhyolite, andesite, and basalt flows that overlie less consolidated rock units. Largest landslide deposits are on east and west flanks of Westfall Butte. Surface of unit is hummocky and unit contains large angular blocks of rhyolite, andesite, and basalt

Tf **Alluvial fan deposits (Pliocene and (or) Miocene)**—Poorly sorted unconsolidated sediments containing angular basalt, rhyolite, and welded tuff boulders as much as 1 m across in deposits generally covering less than 0.5 km² (maximum 2 km² in northeast corner of quadrangle). Locally, unit includes yellow lapilli tuff as much as 1 m thick. Alluvial fan morphology is preserved in places. The unit is as much as 30 m thick in northeast corner of quadrangle and unit appears to be younger than steep north-striking faults. Tentative age is based on degree of dissection of deposits, partial preservation of alluvial fan morphology, and stratigraphic relations of the unit in the adjacent Little Black Canyon 7.5' quadrangle to the east

Ttp **Tims Peak Basalt (middle Miocene)**—Named by Kittleman and others (1967). Dark-gray to black basalt flows. In places, basalt forms cliffs as much as 7 m high along western margin of quadrangle. Unit has coarse columnar jointing and tends to break into slabs as much as 1 m across that form perpendicular to column axes. Basalt flows are vesicular and diktytaxitic (5 to 15 percent cavities). Chemically, rock resembles high-alumina olivine tholeiites (Evans, 1990a, Table 1, Plate 2) although olivine is not modally abundant and is absent in some samples. Plagioclase laths are as much as 2 mm long, but the mineral grains are not clearly divided into phenocryst and groundmass phases. Most of the rock consists of plagioclase (45 to 60 percent), clinopyroxene (20 to 40 percent), and olivine (as much as 10 percent). Minor opaque minerals are present and are disseminated in interstitial glass in some rocks. Clinopyroxene is interstitial or forms oikocrysts as much as 4 mm long. Haddock (1967) determined an average modal composition for his samples: labradorite, 55 percent; subcalcic augite, 20 percent; olivine, 10 percent; opaque minerals, 5 percent; glass, 5 percent; voids, 5 percent; and traces of apatite and alteration products. Olivine is partly altered to bowlingite. Basalt unit is as much as 110 m thick in the quadrangle. The middle Miocene age of the unit is based on its stratigraphic position between two middle Miocene rock units (Dinner Creek Welded Tuff, age 15 Ma; and Shumway Ranch Basalt of Kittleman and others, 1965, age 12.4 Ma; ages in Fiebelkorn and others, 1983; stratigraphic relations from Shumway Reservoir 7.5' quadrangle, unpub. mapping by G. Evans, 1991). Lees (1994, $^{40}Ar/^{39}Ar$ method) dated a sample of Tims Peak Basalt at13.4±3.56Ma

Tpb **Pillow-basalt breccia (middle Miocene)**—Basaltic breccia and hyaloclastite deposits. Contains basalt pillows as much as 1 m long in a matrix of smaller basalt fragments, basaltic glass, and white to gray tuff and siltstone. Locally, unit contains beds of lapilli tuff that contain pale yellow angular lapilli as much as 3 cm across in a matrix of pale gray tuff containing fragments of basalt and basaltic glass. Unit also contains white tuffaceous siltstone and claystone. Locally, uppermost part of unit is yellow-gray pebbly conglomerate that contains 15 to 20 percent rounded basalt pebbles as much as 3 cm long. Basalt in unit is diktytaxitic and vesicular and contains as much as 30 percent phenocrysts mostly of plagioclase as much as 1.5 mm long, and olivine as much as 0.5 mm across. Phenocrysts tend to be glomeroporphyritic. Groundmass consists of glass that is opaque owing to disseminated opaque minerals and contains plagioclase laths, minor olivine, and an unidentified yellow-brown cryptocrystalline material. Unit is as much as 135 m thick in the southwest corner of the quadrangle and pinches out 4 km to the north. Age of unit is based on its stratigraphic position between two units (unit Ttp, older than 12.4 Ma and unit Tdc, 15 Ma) that have been assigned middle Miocene ages. Based on the close chemical similarity of basalts in the two units, Evans (1990a) suggested that both the pillow basalt breccia unit and Tims Peak Basalt are related to the same extrusive episode along a lake margin

Tsk **Sedimentary and tuffaceous rocks of Kelsay Butte (middle Miocene)**—Interbedded sedimentary and pyroclastic rocks. Sedimentary rocks include generally poorly sorted, poorly bedded, and poorly lithified volcaniclastic conglomerate and sandstone and tuffaceous siltstone. The conglomerate contains 20 to 75 percent angular to subangular and locally subrounded clasts, generally less than 15 cm across (maximum 40 cm). Most of the clasts are black fine-grained glassy basalt that resembles Hunter Creek Basalt (see below). Other clast types include black obsidian, gray felsite, scoria, and light gray laminated welded tuff. The matrix is light gray sandstone. Bedding is 15 to 40 cm thick. The fine to coarse grained, and locally gritty, sandstone is gray, light brown, and light yellow with conglomeratic beds containing subangular pebbles. Bedding is 1 to 100 cm thick. In places, the sandstone contains apparent dropstones as much as 15 cm across of basalt that are larger than other clasts in the same bed and appear to have depressed the bedding under them. These stones may have been ballistic ejecta from eruptions at Westfall Butte. Most of the sandstone is friable, some of it is very hard owing to silica cement. The generally angular lithic sand-sized grains that comprise as much as 80 percent of the sandstone, consist of aphyric, very fine grained glassy basalt like Hunter Creek Basalt (see below), devitrified welded tuff resembling Dinner Creek Welded Tuff (see below), coarser grained basalt possibly from the basalt of Malheur Gorge (see below), granophyric and porphyritic rhyolite, glassy welded tuff, obsidian containing perlitic cracks, brown obsidian, obsidian containing microlites, and brown pumice. Mineral grains include plagioclase, quartz, potassium feldspar, clinopyroxene, and magnetite partly altered to hematite. Siltstone is dark to light gray and white; some of it contains fine-grained sand grains. Beds are laminated to 6 cm thick. Pyroclastic rocks include tuff and lapilli tuff. Tuff is white, pale yellow-brown, lithic-rich and crystal-poor. Most of the rock consists of clear and brown glass shards and contains as much as 5 percent phenocrysts of quartz, plagioclase and hornblende. The light gray, yellow and red lapilli tuff contains as much as 50 percent lapilli as much as 4 cm across of basalt, basaltic glass, felsite, and pumice. Some lapilli are subrounded, possibly owing to abrasion during emplacement. Some of the tuff and lapilli tuff are moderately lithified and may be partly welded. The generally angular to subangular lithic fragments in the tuff and lapilli tuff comprise as much as 80 percent of the rock and include aphyric rhyolite, basalt resembling Hunter Creek Basalt (see below), vesicular glassy basalt, brown pumice, devitrified welded tuff resembling Dinner Creek Welded Tuff (see below), laminated perlitic glass, and obsidian containing microlites. The unit is as much as 150 m thick at Kelsay Butte in the southwest corner of the quadrangle and pinches out to the west. Age is middle Miocene based on unit's stratigraphic position between middle Miocene units (Ttp, older than 12.4 Ma, and Tdc, 15 Ma)

Volcanics of Westfall Butte (middle Miocene)—A sequence of volcanic rocks that may represent at least three phases of eruption from local vents: 1) An older phase that includes an early silicic ignimbrite (Tsig) followed by rhyolite flows (Trf$_1$), and basaltic andesite, andesite, and dacite flows (Tbad); 2) A younger phase that includes an early silicic ignimbrite (Tyig) followed by a welded tuff (Twt) and late intrusion of rhyolite dikes (Tri) and equivalent of rhyolite flows (Trf$_2$) probably from one of the dikes; and 3) a youngest phase during which dacite (Tdi) intruded part of the volcanic pile and erupted compositionally similar glassy flows (Tdf). The older eruptive phase occurred after deposition of the sedimentary and tuffaceous rocks unit of Kelsay Butte (Tsk; see above). The younger eruptive episode occurred after unit Tsk was deposited and was completed before emplacement of Tims Peak Basalt (Ttp). Therefore, the age of most of, and probably all of these volcanics, is middle Miocene. Divided into:

Tdi **Dacite intrusion**—Black ortophyre that weathers dark brown, red-brown, and blue-gray. The rock locally contains as much as 15 percent feldspar phenocrysts as much as 1 cm across. Oval vent in SW 1/4 sec. 4 and SE 1/4 sec. 5, T. 19 S., R. 39 E. is 335 m in its longest dimension. A 30-m-wide black vitrophyre dike that contains 50 percent feldspar phenocrysts as much as 5 mm long and that strikes north-northeast in NW 1/4 sec. 4, T. 19 S., R. 39 E., is included in this map unit. The vitrophyre has the composition of a dacite (Table 2; samples 85 and 126)

Tdf **Dacite flows**—Black, platy aphyric dacite flows (Table 2, sample 728) in NW1/4 sec. 32, T. 18 S., R. 39 E., and SW1/4 sec. 29, same township, that overlies unit Tbad (described below) and in SW1/4 sec. 4, T. 19 S., R. 39 E. The flows may have erupted from the dacite vent (Tdi) described above. These flow remnants are as much as 15 m thick

Trf$_2$ **Younger rhyolite flows**—Light to dark gray, and black, maroon, lavender and pink rhyolite flows that weather brown, red-brown, and red, in places disintegrating into subangular boulders. Locally platy. Most of unit has flow layering from 1 to 15 cm thick that is paralleled by lenticular vesicles, lenses of maroon iron oxide-rich glass, and elongate white lithic xenoliths as much as 4 cm long. Contains as much as 50 percent angular lithic fragments of rhyolite, welded tuff, and black obsidian generally less than 15 cm long (maximum 1 m). The rhyolite contains 2 to 50 percent angular to subrounded phenocrysts that are mostly zoned and twinned plagioclase, potassium feldspar, and quartz and minor hornblende (less than 3 percent), clinopyroxene, and magnetite. Hornblende is altered to magnetite, clinopyroxene is altered to biotite, and magnetite is altered to hematite. The groundmass consists of feldspar laths as much as 0.2 mm long, microcrystalline material, probably quartz and feldspar, cryptocrystalline material, and disseminated minute grains of opaque minerals, including hematite. In places the feldspar laths of the groundmass show trachytic texture. Coalescing spherulites are locally developed. Some vesicles contain hematite, brown chalcedony and unidentified opaque material. The unit is at least 90 m thick on the butte in sec. 8, T. 19 S., R. 39 E. and probably erupted from the north-striking rhyolite dike (Tri) that extends 2 km to the north and (or) the east-striking dike (Tri) on summit 5492. Two samples of the flows that were analyzed (Table 2; samples 727 and 22) are rhyolite

Tri **Rhyolite dikes**—One 3.8-km-long rhyolite dike as much as 250 m wide strikes north in the northwestern part of the quadrangle. The dike consists largely of maroon vitrophyre that contains 35 to 40 percent feldspar phenocrysts as much as 4 mm long. The composition of the dike is rhyolite (Table 2; sample 729). A small rhyolite dike about 30 m wide in the SW1/4 sec. 4, T. 19 S., R. 39 E. is oriented east-west. This dike contains 35 percent anhedral to euhedral phenocrysts as much as 8 mm long of quartz, plagioclase, potassium feldspar, and hornblende in a groundmass of microcrystalline quartz and feldspar. Hornblende is altered to magnetite and hematite. Total mafic mineral content is about 3 percent

Twt **Welded Tuff and Lapilli Tuff**—Typically gray, strongly welded tuff, with anastomosing compaction laminations 2 to 10 mm thick that are isoclinally folded in places. Weathers lavender or pink and the laminae are more prominent on the weathered surfaces. Disintegrates to slabs and blocks 1 to 3 m across. Angular lapilli usually less than 6 cm long (maximum 30 cm at base of unit) consist of obsidian, gray felsite, and welded tuff. Along parts of the base, the unit contains intensely fractured obsidian and at least one zone of acicular perlite 15 m thick. The unit contains as much as 20 percent angular phenocrysts of quartz and feldspar, or is aphyric. Most of the unit is devitrified; the primary glass shards and angular lithic fragments of glassy welded tuff are largely recrystallized so that the original shard and lapilli boundaries are blurred in thin section. Very fine grained opaque mineral grains, including hematite, are disseminated in the rock. The unit is 107 m thick in the SW1/4 sec. 4, T. 19 S., R 39 E. A sample of the welded tuff that was analyzed for major oxides (Table 2; sample 124A) is rhyolitic

Tyig **Younger ignimbrite**—Light to dark gray glassy welded tuff breccia that is perlitic in places. Generally poorly exposed; locally forms pinnacles 6 m high. Consists of as much as 50 percent angular fragments usually less than 30 cm across (maximum 3 m) of light gray laminated rhyolite, black vitrophyre, and light gray welded tuff in a crumbly matrix of light gray and black glass and partly welded tuff. In places, the laminae in the rock are irregularly folded. Some of the rock has pale red-brown cement containing cinnabar (Table 5, sample 629, 0.02 ppm mercury). The unit contains as much as 20 percent phenocrysts as much as 3 mm long of fractured and rounded grains of potassium feldspar, quartz, biotite, hornblende, and opaque minerals. Some hornblende is altered to biotite. The matrix consists of clear to light brown glass containing microlites, trichites, and minute grains of opaque minerals; it embays phenocrysts and shows poorly preserved shard texture. The unit is as much as 275 m thick, and may have been deposited over a surface of moderate relief so that what is preserved is largely canyon-fill. Two samples of the unit that were analyzed for major oxides (Table2; samples 726) are rhyolitic

Tbad **Basaltic andesite, andesite, and dacite flows**—Dark gray to black basaltic andesite, andesite, and dacite flows comprise the most mafic volcanics at Westfall Butte. Although the lower platy flows at the base of the sequence are mostly andesite and dacite and the upper flows are basaltic andesite, flows that have these compositions were not easily differentiated in the field. The flows are black, light to dark gray, brown, pink, maroon, dark blue-gray, rusty brown, and red where oxidized. Commonly platy with plates 1 to 4 cm thick that may be parallel to flow layering. Plate surfaces have ribbing with an amplitude of 1 mm. Laminae are usually planar, but are also contorted in places. Some fracture surfaces have a coating of yellowish green chalcedony. Unit contains 1 to 35 percent mostly anhedral to subhedral phenocrysts as much as 3 mm long of plagioclase, potassium feldspar, and quartz and minor hornblende, orthopyroxene, and clinopyroxene. Hornblende is altered to magnetite and hematite that retain the shapes of the primary hornblende grains. Locally contains 2-35 percent angular lithic fragments of rhyolite porphyry, granophyre, and minor basalt. Some of the rock has schlieren of opaque minerals and minor biotite. Phenocrysts are embayed by the groundmass that consists of microcrystalline plagioclase, potassium feldspar, quartz, and minute opaque mineral grains. In places the groundmass contains plagioclase grains as much as 0.15 mm long, interstitial brown glass that is partly devitrified, and cryptocrystalline material. The groundmass in places contains numerous vesicles as much as 0.5 mm long that are filled with tridymite. The groundmass surrounding the cavities is somewhat coarser grained than the other parts of the groundmass. The base of the andesite flows locally has black vitrophyre and flow breccia containing angular fragments of andesite as much as 30 cm across. The basaltic andesite flows are porphyritic, aphyric, vesicular, and diktytaxitic and commonly weather to slabs or blocks 2 m across; platy in places. Porphyritic parts of the unit contain as much as 10 percent olivine phenocrysts as much as 1 mm across and as much as 40 percent plagioclase phenocrysts as long as 3 mm. Modal composition is: plagioclase, 55 to 65 percent; clinopyroxene, which is interstitial and ophitic, 20 to 25 percent; olivine, as much as 15 percent; opaque minerals, as much as 5 percent; and 10 to 20 percent interstitial glass that contains abundant very fine grains of opaque minerals, in places so abundant that the glass is opaque. One sample contains microscopic fragments of quartz. In places, the basaltic andesite has been partially replaced by limonite nodules and brown chalcedony. Major oxide analyses of samples of the basaltic andesite, andesite and dacite are shown in Table 2 (basaltic andesite, samples 730, 92C, 97, 104, 112, and 139; andesite, samples 731, 45, 101, and 128; dacite, samples 728, 59, 105, and 111)

Trf$_1$ **Older rhyolite flows**—Gray porphyritic rhyolite flows in W1/2 sec. 32, T. 18 S., R. 39 E. and on west flank of Westfall Butte. The rhyolite weathers brown. Flows contain 35 percent feldspar phenocrysts as much as 4 mm across in a very fine-grained groundmass. As much as 43 m is exposed.

Toig **Older ignimbrite**—Light to dark gray and brown pyroclastic breccia, strongly welded lithic lapilli tuff, and vitrophyre. Top of unit commonly forms a ledge 3 m thick of very strongly welded, light gray lapilli tuff with eutaxitic structure; the fiamme, as long as 20 cm, are 5 percent of the rock. Contact with the overlying andesite of unit Tbad is a thin (5 cm) mixed zone of vitrophyre containing fragments of welded tuff as long as 2 cm. Below the uppermost welded lapilli tuff the unit contains 10 to 90 percent angular to subangular fragments of obsidian, gray laminated rhyolite, brown pumice, vitrophyre that contains clinopyroxene phenocrysts, argillically altered rhyolite porphyry, white glassy rhyolite that contains orthopyroxene phenocrysts, brown welded tuff, and chert that contains recrystallized radiolaria tests. Lithic fragments are usually less than 15 cm long, but in places may approach 1 m long. The matrix of the welded lapilli tuff is glassy, poorly laminated welded tuff that contains as much as 10 percent anhedral to subhedral phenocrysts as much as 2 mm long of quartz, plagioclase, potassium feldspar, hornblende, magnetite, and hematite. The matrix consists of fine grained quartz, feldspar, and magnetite. In places, the phenocrysts are embayed by microcrystalline material that contains disseminated hematite, shows relict shard texture, and contains numerous gas cavities filled with clear chalcedony. Outcrops in S1/2 sec. 25, T. 18 S., R. 38 E. are brown chaotic to coarsely layered (30 to 100 cm thick) welded pyroclastic breccia and brown and gray lapilli tuff. The chaotic part contains as much as 10 percent angular fragments of basalt and Dinner Creek Welded Tuff as long as 1 m. The layered part contains lithic lapilli as long as 2 cm of basalt, devitrified welded tuff that resembles Dinner Creek Welded Tuff, laminated rhyolite, and white glassy rhyolite. Unit is 60 to 120 m thick, no base exposed; the thickest part underlies the thick section of the younger ignimbrite, Tyig, and may be part of a valley-fill sequence. Three samples of the unit that were analyzed for major oxides (Table 2; samples 129B, 134, and 137) are rhyolite

Tbp **Basalt sill (middle Miocene)**—Dark gray, vesicular, diktytaxitic, and porphyritic basalt exposed in southeast part of quadrangle in the Cottonwood Creek area. Contains as much as 30 percent spherical vesicles as much as 1 cm across. The plagioclase is glomeroporphyritic, and forms conspicuous white aggregates of grains as much as 1 cm across. The rock is ophitic, and contains oikocrysts of clinopyroxene as much as 3 mm long. Modal composition is plagioclase, 55 to 60 percent; clinopyroxene, 30 to 35 percent; voids, 5 to 20 percent, and minor interstitial opaque minerals and glass. Major oxide analysis of a sample from the unit collected several meters east of the quadrangle boundary shows that it is a high-alumina basalt (50.2 percent SiO_2; 22.9 percent Al_2O_3). Evidence that suggests that this basalt is a sill or invasive flow was found in the adjacent Little Black Canyon 7.5' quadrangle (Evans, unpub. mapping, 1990), where similar basalt intrudes middle Miocene sedimentary rock

Tbc **Bully Creek Formation (middle Miocene)**—Named by Kittleman and others (1967). Consists of white tuffaceous siltstone. Occurs in sec. 24, T. 12 S., R. 39 E. where as much as 98 m of the formation are exposed.

Tst **Sedimentary and tuffaceous rocks (middle Miocene)**—Generally poorly exposed, poorly lithified, white, gray, and yellow volcaniclastic conglomerate, sandstone, siltstone, tuff, lapilli tuff, and welded tuff. In places, the rock is brown where cemented by iron oxide; in SE 1/4 sec. 32, T. 19 S., R. 39 E. unit contains beds of magnetite nodules as much as 6 cm long. The finely to coarsely bedded (1 to 200 cm) and massive, poorly sorted conglomerate contains 15 to 50 percent angular to subrounded clasts 1 to 30 cm across of felsic material, black glass, white to dark gray pumice, sandstone, basalt resembling Hunter Creek Basalt (see below), and siltstone. Some of the poorly bedded to massive sandstone has horizontal columnar jointing, suggesting that the sediment may have been deposited as a hot mud flow and that cooling occurred adjacent to vertical joints that formed in the deposit. Lapilli tuff is white to light gray and partly welded. It contains as much as 50 percent angular pumice and obsidian lapilli. Light gray, friable, glassy welded tuff contains irregular white pumice fragment to 1 cm and weathers to slabs as much as 1 m across. Unit varies in thickness from 30-150 m and may thicken to the northeast. The unit is assigned a middle Miocene age based on its stratigraphic position between middle Miocene units (Ttp, older than 12.4 Ma, and Tdc, 15 Ma)

Th **Hunter Creek Basalt (middle Miocene)**—Named by Kittleman and others (1967). Mostly aphyric, black, massive basaltic andesite flows that typically weather into irregular, angular, equant fragments as much as 20 cm across. In places, the rocks break into slabs as much as 50 cm across. Locally, basalt flows have as much as 15 percent phenocrysts of plagioclase as much as 3 mm long and minor clinopyroxene. The upper part of unit is very vesicular; in places the vesicles are filled with brown jasper. Some of the flows show flow layering, have flow breccia, and are separated by rare, thin, interbeds of pale brown, poorly lithified, unsorted arkosic sandstone. Plagioclase phenocrysts are euhedral and glomeroporphyritic in a groundmass mostly of plagioclase laths as long as 0.25 mm. Some of the rock contains as much as 50 percent glass that contains trichites or is opaque owing to disseminated opaque minerals. Olivine, a minor constituent, is locally altered to hematite. Haddock (1967) determined modal compositions of three samples that were coarser than average: labradorite, 46 to 55 percent; clinopyroxene, 27 to 33 percent; opaque minerals, 5 to 8 percent; and glass, 13 to 15 percent. Rare basaltic tuff between basalt flows consists of angular fragments as much as 1.5 mm across mostly of brown scoria, dark basaltic glass, very fine-grained vesicular basalt, and brown basaltic welded tuff, and minor devitrified silicic welded tuff, fine grained rhyolite, microcrystalline material, obsidian some of which is filled with trichites, and chert. Less than 1 percent of the tuff consists of mineral grains (plagioclase, clinopyroxene, and opaque minerals). The lower contact of the unit with the underlying Dinner Creek Welded Tuff (Tdc) in sec. 35, T.18 S., R.39 E. is gradational over a few meters as the silicic unwelded upper part of the Dinner Creek grades to dark gray porous basaltic tuff that grades into basalt flow breccia. Two samples of Hunter Creek Basalt were collected from the Jonesboro and South Mountain quadrangles to the south and were analyzed for major oxides (Evans, 1990a, b). Both samples are basaltic andesite that is high in iron (14 percent Fe_2O_3), low in magnesium (3 percent MgO), and relatively low in alumina (13 percent Al_2O_3). The unit ranges in thickness from 100 to 120 m in the southern and southeastern parts of the quadrangle and pinches out along the south and east flanks of Westfall Butte. $^{40}Ar/^{39}Ar$ age determinations by Lees (1994) range from 15.78±0.59 to 16.39±1.2 Ma. Based on its stratigraphic position, the age of the Hunter Creek is middle Miocene (older than Ttp, which is older than 12.4 Ma, and younger than Tdc, 15 Ma).

Tdc **Dinner Creek Welded Tuff (middle Miocene)**—Named by Greene and others, 1972). Mostly rhyolitic welded ash-flow tuff. The densely welded part is typically well exposed in brown and gray cliffs 6 to 100 m high. This part of the unit is orange-brown, brown, maroon, and light gray and appears to form one cooling unit. It contains as much as 3 percent anhedral to subhedral phenocrysts as much as 5 mm long of plagioclase, quartz, altered pyroxene, and magnetite that are usually corroded by the matrix. The rock also contains as much as 50 percent angular lithic fragments of very fine grained rhyolite, tuff, welded tuff, devitrified welded tuff, fragments of spherulitic rock, chert, and argillite, one fragment of which appears to contain recrystallized radiolaria. Tridymite in gas cavities of the lithic fragments are partly recrystallized to quartz. The matrix consists of microcrystalline quartz and feldspar, sericite, and opaque dust and is partly replaced by spherulites. In places the rock contains 15 to 20 percent gas cavities that are partly filled with magnetite, tridymite, and quartz. The strongly welded part has undergone enough crystallization to obliterate much of the primary pyroclastic structures and textures. The welded tuff commonly contains lithophysae as much as 3 cm across, and, in places, is cut by numerous white, yellow, and black chalcedony veins. Haddock (1967) identified phenocrysts of anorthoclase, minor plagioclase (An_{30}), and clinopyroxene in his samples. Poorly welded and unwelded lapilli tuff is 7 to 10 m thick above the cliffs and as much as 30 m thick below the cliffs. The tuff is light to dark gray, black, yellow, and yellow-brown, locally welded to varying degrees, or partly cemented with brown chalcedony. Bedding is thin (1 to 8 cm) to thick (15 to 50 cm). Lapilli, comprising as much as 85 percent of the rock, include mostly pumice, but also black glass, laminated basaltic and rhyolitic welded tuff, devitrified welded tuff, spherulitic rock, basalt, vitrophyre, and possibly fragments of chert and argillite. Locally, black glass comprises as much as 50 percent of the rock. Some lithic fragments contain gas cavities filled with tridymite partly recrystallized to quartz. Pumice fragments as much as 14 cm across are discoidal and flattened along a compaction foliation. Sparse euhedral to subhedral phenocrysts as much as 3 mm long consist of plagioclase, quartz, potassium feldspar, and rare olivine. The matrix consists of microcrystalline quartz and feldspar and opaque dust. The poorly welded parts of the unit above and below the cliffs are usually covered by talus. The unit thickens from 20 m along the south margin of the quadrangle to over 120 m in Indian Creek Canyon near the northern margin, no base exposed. Age of the unit is middle Miocene based on K-Ar radiometric dates of two samples, averaging 15 Ma (Fiebelkorn and others, 1983). Three samples of the welded tuff that were analyzed for major oxides (Table 2, samples 728, 118A, and 118B) are rhyolite and high-silica rhyolite

Tm **Basalt of Malheur Gorge (middle Miocene or older)**—Named by Evans (1990a, b). These rocks previously called "unnamed igneous complex" by Kittleman and others (1965). Recent studies of mafic rocks under the Dinner Creek Welded Tuff suggest that the basalt of Malheur Gorge contains within it stratigraphic and geochemical equivalents of the Imnaha and Grande Ronde Basalts of the Columbia River Basalt Group (G.B. Binger, unpub. data, 1996). The unit consists mostly of poorly exposed dark gray to black tholeiitic basalt flows, locally weathering red in the south and central parts of the quadrangle. Rocks of the unit to the south are described in detail by Evans (1990a, b). In the southwest corner of the quadrangle as much as 300 m of the unit are present. In the Jonesboro quadrangle to the south, as much as 600 m of the unit is present, base not exposed. Samples of the unit dated by Lees (1994, $^{40}Ar/^{39}Ar$ method) range in age from 16.8±1.2 to 18.5±1.37 Ma.

MAP SYMBOLS

Contact

Fault. Dotted where concealed; bar and ball on down-thrown side. Where more than one direction of movement is indicated, the oldest direction is labeled "1"

Location of unaltered rock sample shown in Table 1

Location of altered rock sample shown in Table 4

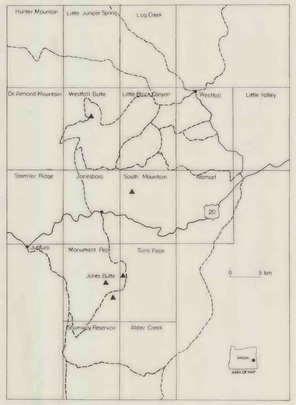


Figure 1. Index map showing locations of the Westfall Butte quadrangles and other quadrangles mentioned in this report. The broader uninterrupted lines are paved roads. The broader dashed lines are dirt roads. Triangles are peaks and buttes.

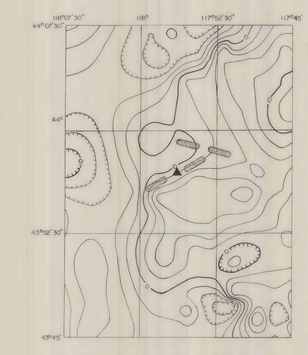


Figure 2. Isostatic residual gravity anomaly map of the Westfall Butte and adjacent quadrangles. Modified from Griscom and Halvorson (1994). Contour interval 2 milligals. Hachures indicate closed lows. Solid triangle is summit of Westfall Butte. Stippled hatchings mark the west-northwest-trending Adrian fault zone of Ferns and others (1993) and the northeast-trending fault that passes through Westfall Butte. See Figure 1 for names of quadrangles adjacent to the Westfall Butte quadrangle.

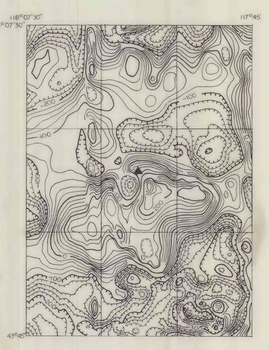
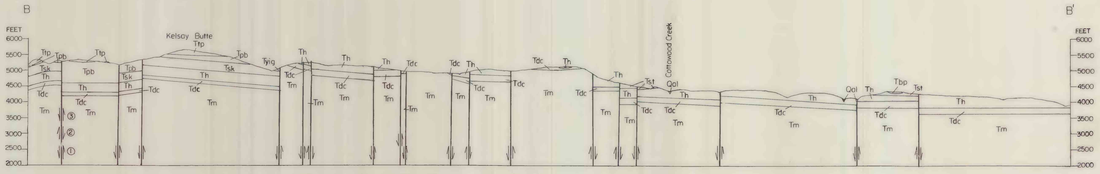



Figure 3. Aeromagnetic map of the Westfall Butte and adjacent quadrangles. Modified from Griscom and Halvorson (1994). Contour interval 20 and 100 nanoteslas. Hachures indicate closed lows. Solid triangle is summit of Westfall Butte. See figure 1 for names of quadrangles adjacent to the Westfall Butte quadrangle.