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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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GEOLOGY AND MINERAL RESOURCES MAP OF THE WESTFALL QUADRANGLE, MALHEUR COUNTY, OREGON

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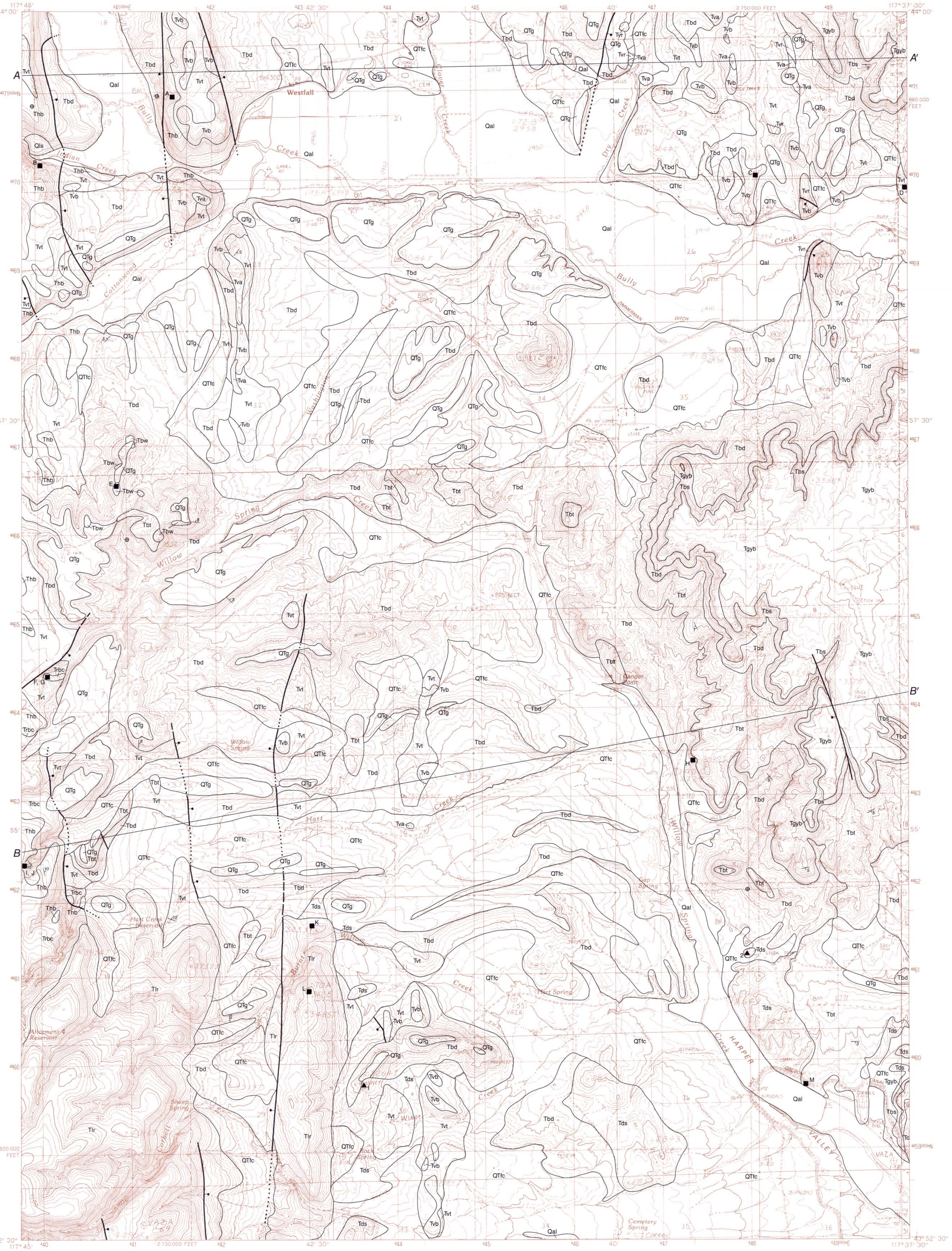
Geology and Mineral Resources Map of the Westfall Quadrangle, Malheur County, Oregon

By Howard C. Brooks and James P. O'Brien

Funded jointly by the Oregon Department of Geology and Mineral Industries, the Oregon State Lottery, and the U.S. Geological Survey COGEOMAP Program as part of a cooperative effort to map the west half of the 1° by 2° Boise sheet, eastern Oregon.



Base map by U.S. Geological Survey

Control by USGS and NOS/NOAA

Topography compiled from aerial photographs taken 1964, field checked 1987, edited 1990

Lambert Conformal Conic Projection. 1927 North American datum 10,000-foot grids based on Oregon coordinate system, south zone

1000-meter Universal Transverse Mercator grid ticks, zone 11

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
SUPPLEMENTARY CONTOUR INTERVAL 10 FEET

QUADRANGLE LOCATION

Geology by Howard C. Brooks and James P. O'Brien, Oregon Department of Geology and Mineral Industries

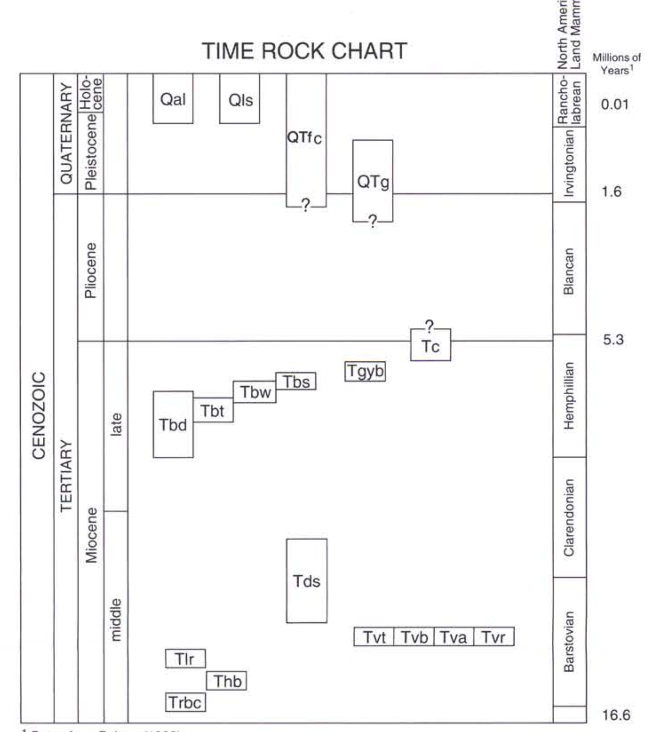
Field work conducted in 1990

Reviewed by G. W. Walker, retired, U.S. Geological Survey, J. G. Evans, U.S. Geological Survey, and M. L. Ferns, Oregon Department of Geology and Mineral Indusries

Cartography by Allan Cartography

Acknowledgments: The analytical discussion was prepared by Gary L. Baxter, Geochemist, Oregon Department of Geology and Mineral Industries

TIME ROCK CHART



[1] Dates from Palmer (1983)

EXPLANATION

Qal — **Alluvium (Holocene and Pleistocene)**–Unconsolidated and unsorted to well-sorted deposits of gravel, sand, and silt in the flood plains of Bully Creek, Cottonwood Creek, and Willow Spring Creek and their tributaries

Qls — **Landslide deposits (Holocene and Pleistocene)**–Unconsolidated mix of bedrock, soil, and colluvium in slump deposits formed as a result of bedrock failure

QTfc — **Colluvium and alluvial fan deposits (Holocene, Pleistocene, and Pliocene?)**–Alluvial fans and slope wash consisting of unconsolidated gravel, sand, and silt. Includes extensive accumulations of wind-blown silt and sand on tablelands, benches, and ridge tops and in broad valleys

QTg — **Terrace gravels (Pleistocene and Pliocene?)**–Mainly unconsolidated to poorly consolidated, poorly sorted deposits of gravel, sand, and silt exposed on benches, gentle slopes, and ridges above the level of modern flood plains. Unit **QTg** deposits have a more tabular, sheetlike pattern of exposure than those of unit **QTfc** and are an important source of detritus in unit **QTfc** deposits

Tc — **Sedimentary rocks and tuff (Pliocene? and upper Miocene)**–Interlayered, thick-bedded, greenish-gray to pale-brown tuffaceous siltstone and sandstone. Includes lenses of gravel and pebble-rich sand and silt deposits. In places, the tuffaceous rocks have been altered largely to greenish-yellow bentonitic clay. Exposed only along the west edge of sec. 30, T. 19 S., R. 42 E. More widely exposed in the adjacent Little Valley quadrangle to the east (Brooks and O'Brien, 1992). Equivalent in part to the Chalk Butte Formation of Corcoran and others (1962) and unit **Tc** of Brooks (1991)

Tgyb — **Olivine basalt flows and interbedded sedimentary rocks (upper Miocene)**–Mostly dark-gray to black, reddish-brown-weathering, medium-grained, aphyric to olivine and plagioclase phyric basalt with subophitic, ophitic, and hyalo-ophitic textures. Olivine phenocrysts are partly altered to serpentine minerals in some specimens. Groundmass minerals include olivine and granular clinopyroxene. Specimens of one flow in the sequence exposed in the Little Valley quadrangle (Brooks and O'Brien, 1992) contain quartz-feldspar xenocrysts. Locally, the flows are separated or overlain by sandstone and siltstone beds a few inches to a few tens of feet thick. The mantling of parts of some flow outcrops by thin accumulations of disintegrated basalt may indicate that the affected basalt was deposited in water. Rip-up clasts of unit **Tbs** are included in the base of the unit locally. Unit ranges to 200 ft in thickness and varies from a single flow less than 20 ft thick in the southeastern part of the quadrangle to six or more flows up to 30 ft thick along the north margin of the tableland that dominates the east-central part of the map area. Cumulative thicknesses of 60 to 80 ft are common. The flows of the tableland are mantled in places by a mix of eolian silt and fragments of the underlying basalt. The unit is continuous with unit **Tgyb** of Brooks and O'Brien (1992) and correlative with unit **Tgyb** of Ferns and O'Brien (1992a); it is chemically similar and may be stratigraphically equivalent to the unit **Trsb** flows of Ferns and Ramp (1989) and Urbanczyk and Ferns (unpublished mapping, 1989). Correlative flows are included in the upper part of the Grassy Mountain Formation of Kittleman and others (1965, 1967) and the upper part of the Grassy Mountain Basalt of Bryan (1929)

Bully Creek Formation (upper Miocene)–Subdivided into the following units:

Tbs — **Tuffaceous sedimentary deposits (upper Miocene)**–Light grayish- to pinkish-brown, light-gray and greenish-gray, poorly bedded to massive tuffaceous, locally calcareous sandstone and siltstone. Includes thin limestone beds and scarce arkosic sandstone and conglomerate. The tuffaceous sandstone and siltstone largely consist of glass shards and angular to subrounded grains of feldspar and quartz and glassy volcanic rock fragments about 1 mm in size. Small, local concentrations of rounded pebbles and cobbles indicate that part of the unit is of fluvial origin. The upper few feet of the unit commonly are red or brown where baked by overlying basalt flows (unit **Tgyb**). Tuffaceous silty limestone interbeds a few inches up to 6 ft thick occur locally near the top of the unit. A 30-ft-thick sequence of interbedded ostrocod-bearing limestone and clastic sedimentary rocks is exposed in NW 1/4 sec. 30, T. 19 S., R. 42 E. The limestone is composed mainly of minute interlocking calcite crystals and 5 to 20 percent other minerals and rock fragments up to 0.5 mm in size. Unit **Tbs** ranges from a few tens of feet to about 200 ft thick

Tbw — **Welded tuff (upper Miocene)**–Light- to medium-gray vitric crystal tuff consisting mostly of moderately to firmly welded colorless glass shards and fine ash and about 5 percent subhedral quartz and feldspar crystals and white pumice grains to 1.5 mm in size. Typical platy fracture roughly parallels the depositional surface. Observed only in small exposures having maximum thickness of about 8 ft. Overlies diatomite and tuff sequences (unit **Tbd**) in sec. 31, T. 18 S., R. 41 E., and sec. 6, T. 19 S., R. 41 E. Underlies sedimentary deposits (unit **Tbs**) in secs. 19, 20, and 29, T. 18 S., R. 42 E., in the northeastern part of the Little Valley quadrangle (Brooks and O'Brien, 1992). A similar welded tuff as much as 150 ft thick is exposed in several places near Crowley (James Rytuba, personal communication, 1991)

Tbt — **Ash-flow tuff (upper Miocene)**–Gray to yellowish-gray, massive, nonwelded to slightly welded, pumiceous vitric ash-flow tuff. Pumice fragments are lighter gray and range to 5 in. across. Locally includes as much as 10 percent dark-gray vesicular rock fragments. Different lithologies may indicate that more than one cooling unit is included in unit **Tbt**, although only minor differences were noted in chemical analyses of two samples (samples H and M, Table 1). Rip-up fragments of the underlying diatomite and tuff beds (unit **Tbd**) are locally incorporated in the lower part of the flow, for example, near sample site H. Apparent maximum thickness of the unit is about 60 ft

Tbd — **Interbedded tuffaceous diatomite, diatomite, tuff, and tuffaceous siltstone (upper Miocene)**–Exposures are mainly tuffaceous diatomite and diatomite with relatively thin partings of vitric air-fall tuff, reworked tuff, and tuffaceous siltstone; also includes a few thin ash-flow tuffs. Diatomite and tuffaceous diatomite and siltstone generally are white to light gray. Air-fall tuff and some of the reworked tuff deposits are a contrasting light bluish gray. Individual beds range from less than 1 in. to more than 20 ft thick. Diatomite layers generally are not internally bedded. Local grading and crossbedding of tuff layers may reflect fluvial or turbidity-current deposition of some of the ash. Moore (1937) described the diatomite-tuff deposits, including measured sections, and identified the principal diatom species (mainly varieties of *Melosira*). Small-scale folding of interbedded diatomite and tuff sequences occurs in several places, for example, in a bulldozer cut in NE 1/4 sec. 28, T. 19 S., R. 41 E., which is probably the result of soft-sediment deformation. The folding typically involves bedded sequences 10 to 40 ft thick, overlain and underlain by nonfolded beds. Maximum local thickness of exposed beds in the quadrangle is about 400 ft

Tds — **Drip Springs Formation (middle Miocene)**–Chiefly tuffaceous sandstone and siltstone, silicic tuff and porcellanite, and rare arkosic sandstone. Unit typically is mantled by pale-orange to yellow soil containing abundant fragments of dense, iron-stained, white to light-gray silicic tuff and porcellanite. The porcellanite probably is altered silicic tuff that, according to X-ray analysis by R.P. Geitgey, is composed largely of a form of opaline silica referred to as opal-CT (Jones and Segnit, 1971). Weathered rocks typically are pale yellow or orange. Fresh surfaces are white to cream colored. Includes low-density silicic rock composed largely of fragmented, highly vesiculated glass. Samples 1 and 2 (Table 2) are iron-stained silica-rich rocks. Rocks of this unit are continuous with exposures in the Namorf quadrangle to the south that Ferns and O'Brien (1992b) correlated with the upper part of the Drip Springs Formation of Kittleman and others (1965, 1967)

Hydrovolcanic complex (middle Miocene)–Subdivided into the following units:

Tvt — **Hyaloclastic lithic tuffs and breccias (middle Miocene)**–Chiefly yellow to brown and gray, massive to thin-bedded, unsorted to moderately sorted hyaloclastic lithic tuffs, breccias, and lapilli tuffs containing abundant (5 to 25 percent) mafic and silicic volcanic rock fragments that closely resemble rocks of the Hunter Creek Basalt (unit **Thb**) and units **Trbc** and **Tlr**. Rock fragments resembling Dinner Creek Welded Tuff were found in NW 1/4 sec. 18, T. 19 S., R. 41 E. Includes water-laid tuff, patches of units **Tvb**, **Tva**, and **Tvr** too small to map separately, and thin lenses of sandstone and gravel. Clasts in the tuffs range in size from less than 1 in. to more than 4 ft in unsorted deposits and to a few inches in the thin-bedded deposits. A typical mafic clast was analyzed (sample D, Table 1) and found to be chemically like samples from outcrops of Hunter Creek Basalt. The original glass of the tuff commonly is hydrated and replaced by clay, zeolite minerals, and iron oxides that readily decompose to form brownish-yellow soil. Some gray to pale-yellow tuffs and pumiceous lapilli tuffs exposed along the western edge of the quadrangle contain relatively few accidental clasts. Sample G (Table 1) is representative of much of the altered tuff

Tvb — **Scoria-flow breccias and block breccias (middle Miocene)**–Chiefly red to reddish-brown agglutinated scoria containing accidental basaltic andesite and rhyolitic rock fragments similar in composition and quantity to those in unit **Tvt**. Exposures are commonly visible from a distance as red ridges and mounds. The scoria appears to have been brecciated during transport and to have agglutinated on emplacement. It is feldspar phyric. In several exposures, for example, locality for sample C, Table 1, vesicles and small fractures are lined with amorphous silica. Unit also includes breccias having little or no matrix, whose chief components are angular to subrounded blocks of andesite and lesser rhyolite. A good exposure of the latter breccia occurs near the Bully Creek road in SE 1/4 NW 1/4 sec. 25, T. 18 S., R. 41 E.

Tva — **Basaltic andesite (middle Miocene)**–Small patches of flow rocks that megascopically resemble rocks of the Hunter Creek Basalt (unit **Thb**). A sample from an exposure in SW 1/4 sec. 29, T. 18 S., R. 41 E., contains atypically large zoned plagioclase and clinopyroxene phenocrysts and large clots of altered glass

Tvr — **Rhyolite vitrophyre (middle Miocene)**–Small patches of flow or dike material resembling vitrophyre of units **Tlr** and **Trbc**

Tlr — **Littlefield Rhyolite (middle Miocene)**–Chiefly reddish-gray, platy, locally spherulitic lithoidal rhyolite flows and dark-gray to black vitrophyre. Upper and lower parts of flows are vitrophyric; interiors are lithoidal. Vitrophyre locally exhibits columnar jointing; most joint sets are vertical, some are horizontal, some are fan shaped. Radially jointed flow lobes with brecciated carapaces are exposed in places. The top of some vitrophyre flows is marked by autoclastic breccia composed of blocks of highly vesicular vitrophyre in a white to light-gray ash matrix. Locally, the flows are separated by bedded, light-gray tuff deposits up to about 40 ft thick. Phenocrysts are plagioclase and augite. Chemical analyses of two samples (K and L), one of vitrophyre and one of lithoidal rhyolite, are given in Table 1. See Ferns and O'Brien (1992b) for additional analyses. Flow compositions range from metaluminous rhyodacite to rhyolite. Maximum thickness of exposures in the southwest corner of the quadrangle is about 800 ft. Individual flows are over 100 ft thick. The unit is part of the Littlefield Rhyolite of Kittleman and others (1965, 1967) and is continuous with the Littlefield Rhyolite of J.G. Evans (unpublished mapping, Little Black Canyon quadrangle, 1991) and unit **Tlr** of Ferns and O'Brien (1992b). Source areas have not yet been identified, although Evans (personal communication, 1990) suggests a possible vent to the southwest

Thb — **Hunter Creek Basalt (middle Miocene)**–Dark-gray to bluish-black, reddish-brown-weathering, aphyric basaltic andesite and andesite that is characterized in many places by subconchoidal fracture. Flow tops commonly are coarsely vesicular, and the rocks generally weather to blocks of irregular to semi-equal dimensions up to about 10 in. Typical rocks are microcrystalline with intergranular or subophitic texture. Most thin sections contain a few microphenocrysts of plagioclase and clinopyroxene and small amounts of altered glass and iron oxide. Some sections contain two different clinopyroxenes. Exposures of this unit along the west edge of the quadrangle are continuous with rocks in the adjoining Little Black Canyon quadrangle that are mapped by Evans (unpublished mapping, 1990) as part of the Hunter Creek Basalt of Kittleman and others (1965, 1967). Compositionally, the rocks are tholeiitic andesite (icelandite) characterized by low alumina and high iron. Five analyses are given in Table 1. Additional analyses are given by Brooks and O'Brien (1992) and Ferns and O'Brien (1992b)

Trbc — **Rhyolite of Bully Creek canyon (middle Miocene)**–Informally named by Brooks and O'Brien (1992) for better exposures of the unit in Bully Creek canyon in the northern part of the Little Valley quadrangle to the east. Chiefly dark-gray to black vitrophyre. Includes reddish-gray, platy, lithoidal, locally spherulitic rhyolite. Phenocrysts are plagioclase and pigeonite. The vitrophyre commonly weathers to roundish blocks 1 to 3 ft in diameter and locally displays columnar jointing. Includes breccia composed of blocks of highly vesicular vitrophyre in a white to light-gray ash matrix that may represent autobrecciation of the tops of vitrophyre flows. Locally, the flows or breccia are overlain by up to 20 ft of bedded, light-colored silicic tuff. Underlies flows of the Hunter Creek Basalt and lithoidal rhyolite and vitrophyre of unit **Tlr**. The contact between unit **Trbc** and the overlying units is marked by a poorly exposed layer of light-gray sedimentary rocks 20 to 40 ft thick that include lithic tuff, bedded tuffaceous sedimentary rocks, and a small amount of arkosic sandstone. Unit **Trbc** is continuous with unit **Tv** of Evans (unpublished mapping, 1990) in the adjacent Little Black Canyon quadrangle. The rocks were mapped by Kittleman and others (1967) as part of their Littlefield Rhyolite, although they described the Littlefield as stratigraphically above the Hunter Creek Basalt

MAP SYMBOLS

Contact–Approximately located.

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

12 **Strike and dip of beds or flows**

Horizontal beds or flows

G **Location of sample analyzed in Table 1**

2 **Location of sample analyzed in Table 2**

GEOLOGY

The Westfall quadrangle is underlain by middle and upper Miocene and lower Pliocene volcanic and sedimentary rocks mantled by upper Pliocene and younger alluvial deposits.

The lower part of the geologic section is comprised of two rhyolitic units (units Trbc and Tlr) and basaltic andesite flows of the Hunter Creek Basalt (unit Thb) which stratigraphically separate the two rhyolite units. Both rhyolite units were mapped by Kittleman and others (1967; see also Weeden, 1961 and 1963) as part of the Littlefield Rhyolite which overlies the Hunter Creek in areas to the west and south (Evans, 1990, and unpublished mapping of the Little Black Canyon quadrangle, 1990; and Ferns and O'Brien, 1992b). Components of the two units are indistinguishable megascopically, and only minor petrographic and compositional differences have been noted (see analyses in Table 1 and in Brooks and O'Brien, 1992, and Ferns and O'Brien, 1992b). Pyroxene phenocrysts are mainly augite in unit Tlr and pigeonite in unit Trbc. Zircon and barium abundances are significantly lower in most samples from unit Trbc than in those from unit Trl. One sample from the basal unit Tlr flow in Malheur River canyon contains zircon and barium abundances similar to those of unit Trbc (Ferns and O'Brien, 1992b). The name "Littlefield Rhyolite" is restricted here to the rhyolite unit Tlr that stratigraphically overlies Hunter Creek Basalt.

Units Tvt, Tvb, Tva, and Tvr are parts of a poorly exposed hydrovolcanic complex dominated by hyaloclastic lithic tuffs and breccias (unit Tvt) containing accidental fragments of units Thb and Trbc and possibly unit Tlr. Breccias with scoriaceous matrix and breccias with little or no matrix (unit Tvb) and small patches of basaltic andesite (unit Tva) and rhyolite vitrophyre (unit Tvr) that appear to be suspended in tuffs and breccias of unit Tvt are included. Rocks of the unit are depositional on rocks of the Littlefield Rhyolite in the southwestern part of the quadrangle and the Hunter Creek Basalt in the northwestern part. Parts of the unit, particularly some of the massive, poorly sorted deposits, may be lahars. The presence of agglutinated scoria, small patches of which are widely distributed, indicates that the material was hot when emplaced. The deposits probably are largely the result of explosive volcanic eruptions caused by the entry of magma into a water-saturated environment, either a lake or a subsurface groundwater zone.

The Drip Springs Formation (unit Tds), Bully Creek Formation (units Tbd, Tbt, Tbw, and Tbs), and unit Tgyb are part of a sedimentary and volcanic sequence deposited in a structural basin underlain and bounded on the west largely by volcanic rocks of the Hunter Creek Basalt and Littlefield Rhyolite. Exposures of Drip Springs Formation in the quadrangle are made up mostly of water-laid tuffs and tuffaceous sedimentary rocks. The formation is thicker and lithologically more complex to the south (Ferns and O'Brien, 1992a,b). The Bully Creek Formation consists mainly of interbedded diatomite, tuff, and tuffaceous sedimentary rocks (unit Tbd) that represent quiet-water deposition of diatomite with periodic influxes of air-fall ash from volcanoes in the region and tuffaceous sediment carried into the basin by streams. Units Tbt and Tbw represent ash-flow tuff and welded tuff, respectively, deposited in the upper part of the diatomite-tuff sequence. The upper sedimentary unit (unit Tbs) is of mixed fluvial and lacustrine origin and represents the waning stages of sedimentation in the basin. Basalt flows (unit Tgyb) cap the basin-fill sequence and in places interfinger with the youngest deposits of unit Tbs.

STRUCTURE

The volcanic and sedimentary rocks of the quadrangle are offset by normal faults having displacements of up to several hundred feet. Trends of the more extensive faults are within a few degrees of north. The northerly elongation of several exposures of the hydrovolcanic complex suggests that north-trending faults began to develop prior to deposition of the Bully Creek Formation. The youngest observed fault offsets gravel of unit QTg in sec. 15, T. 18 S., R. 41 E.

Dips of bedding in the Bully Creek Formation and younger Miocene units typically range from near-horizontal to 5°, locally 10°, east or south. Small-scale folding of interbedded diatomite and tuff sequences (unit Tbd) has been noted in several places, for example, a bulldozer cut in the NE 1/4 sec. 28, T. 19 S., R. 41 E., and probably is the result of soft-sediment deformation. The folding typically involves bedded sequences 10 to 40 ft thick, overlain and underlain by nonfolded beds.

MINERAL RESOURCES

Large quantities of low-grade diatomite occur within the quadrangle and in the adjoining Little Valley quadrangle to the east. Moore (1937) reported that investigations of the deposits began as early as 1910, and there was small intermittent production during 1917-1934 from occurrences in the northern part of the quadrangle. There is no record of subsequent production. Results of more recent investigations by a number of companies and individuals indicate that beds of useable-quality diatomite are no more than a few inches thick and discontinuous. Most of the diatomite beds that look good in outcrop contain excessive amounts of fine tuffaceous material, clay, and silt.

No metallic-mineral mines or prospects are known to exist in the quadrangle.

WATER RESOURCES

Much of Harper Valley and Little Valley is farmed by irrigation. Most of the water for irrigation is diverted from the Malheur River by small dams west of Harper Valley and carried by canals along the valley margins to ditches that supply individual farms. A few small areas are irrigated by drilled wells. Also, most of the flood plain of Bully Creek is farmed. Irrigation water is supplied in part by small diversions from the creek and in part by drilled wells.

GEOCHEMISTRY

Sample preparation

Samples for whole-rock analysis (Table 1) were crushed to minus 1/4-in. in a steel-jawed Braun chipmunk crusher and split in a Jones-type splitter in the Oregon Department of Geology and Mineral Industries (DOGAMI) laboratory. A split of about 60 g was ground to minus 200 mesh in agate grinding media by X-ray Assay Laboratories (XRAL) of Don Mills, Ontario, Canada.

Samples for trace-element analysis of altered rocks (Table 2), were crushed to minus 1/4-in. and split as indicated above to obtain a nominal 250-g subsample. Each subsample was milled to about minus 200 mesh in chrome-steel media in an Angstrom disc mill in the DOGAMI laboratory. Each milled subsample was split again to produce two analytical samples: one to determine gold and one to determine the other trace elements.

Chemical analysis

Whole-rock analysis: X-ray fluorescence (XRF) analyses (Table 1) were performed by XRAL. XRAL used a fused button for its analyses (1.3 g of sample roasted at 950 °C for one hour, fused with 5 g of lithium tetraborate, and the melt cast into a button). Loss on ignition (LOI) was determined from weight loss during roasting.

Trace-element analysis:

1. Gold–Bondar-Clegg, Ltd., of North Vancouver, British Columbia, performed the analyses for gold. The method employed was fire-assay preconcentration of the gold in a 20-g sample (gold was collected in added silver), acid dissolution of the resulting bead, and a direct current plasma (DCP) emission spectrometer finish. The detection limit was 1 part per billion (ppb).

2. Fourteen trace elements–Geochemical Services, Inc., (GSI) of Sparks, Nevada, performed the analyses for 14 trace elements. The method employed a proprietary acid dissolution/organic extraction of a 5-g sample. The finish was by induction coupled plasma (ICP) emission spectrometry. GSI considers the digestion to provide total metal contents except for gallium and thallium.

3. Eight trace elements–The DOGAMI laboratory performed the analyses for eight elements: barium, cobalt, chromium, iron, lithium, manganese, nickel, and tungsten. For the first seven elements, a 1-g sample was digested with nitric and hydrofluoric acids, the solution taken to near-dryness with percholoric acid, and the residue redissolved and taken to 100-ml volume with 10-percent nitric acid. The finish was by flame atomic absorption and (for lithium) flame emission spectrometry. The digestion provides total metal content except for barium and possibly chromium. Tungsten was determined by a method that gives semi-quantitative results: 1/4 g of sample fused with potassium pyrosulfate and dissolved with hydrochloric acid, an aliquot treated with stannous chloride and zinc dithiol, the tungsten extracted into 0.5 ml amyl acetate, and the colored complex visually compared with standards. The detection limit for tungsten was 5 ppm.

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Table 1. Whole-rock analyses, Westfall quadrangle, Malheur County, Oregon[1]

Map letter	Laboratory no.	1/4	1/4	Sec.	T. (S.)	R. (E.)	UTM coordinates	Elev. (ft)	Lithology	Map unit	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	LOI	Total	Cr	Rb	Sr	Y	Zr	Nb	Ba
											Oxides (wt. percent)												Trace elements (ppm)						
A	AYB-403	SE	NE	19	18	41	4870920N 441560E	3,200	Basaltic andesite	Thb	54.8	13.0	2.25	12.9	0.21	6.54	2.98	1.97	3.07	0.44	1.23	99.6	11	119	304	20	240	30	902
B	AYB-404	SW	SW	19	18	41	4870210N 440050E	3,100	Basaltic andesite	Thb	53.6	12.9	2.18	13.3	0.23	6.94	3.31	2.10	2.87	0.41	0.39	98.9	26	120	290	12	222	19	708
C	AYB-418	SE	SE	23	18	41	4870030N 448160E	3,010	Scoria	Tvb	65.3	10.0	1.92	10.1	0.13	3.30	0.39	1.33	2.45	0.50	4.39	100.0	<10	41	276	20	178	28	778
D	AYB-414	NW	NW	30	18	42	4869860N 449860E	2,960	Basaltic andesite clast	Tvt	55.3	12.7	2.21	12.9	0.49	6.31	2.39	2.28	3.04	0.70	1.70	100.0	<10	67	340	37	263	36	1,070
E	AYB-420	NW	NE	6	19	41	4866550N 440910E	3,500	Welded tuff	Tbw	72.8	10.8	0.22	3.32	0.06	0.22	0.16	6.17	2.83	0.05	3.23	100.0	20	137	<10	189	1,230	101	145
F	AYB-416	SW	NW	7	19	41	4864380N 440090E	3,420	Vitrophyre	Trbc	69.2	12.6	0.68	3.98	0.08	1.70	0.52	5.57	2.52	0.12	2.93	100.0	<10	146	202	49	303	24	1,520
G	AYB-421	SW	NW	7	19	41	4864380N 440090E	3,420	Tuff	Tvt	55.4	12.7	1.12	9.10	0.10	3.53	1.90	1.67	1.31	0.22	13.2	100.0	21	67	226	65	212	24	834
H	AYB-424	NW	NE	14	19	41	4863410N 447390E	2,880	Ash-flow tuff	Tbt	65.3	12.4	0.53	4.49	0.19	1.23	0.85	4.10	2.31	0.12	8.70	100.0	14	86	65	74	392	20	969
I	AYB-422	SW	NW	18	19	41	4862290N 439800E	3,740	Vitrophyre	Trbc	69.5	12.6	0.68	3.88	0.08	1.60	0.45	5.32	2.69	0.13	3.00	100.0	<10	136	203	65	290	28	1,470
J	AYB-423	SW	NW	18	19	41	4862290N 439800E	3,760	Basaltic andesite	Thb	54.7	13.4	2.18	13.2	0.21	6.73	3.17	1.92	2.99	0.40	0.85	100.0	15	61	321	29	206	19	818
K	AYB-400	NE	NE	20	19	41	4861560N 443060E	3,190	Vitrophyre	Tlr	67.9	12.0	0.4	5.02	0.14	1.72	0.23	5.03	3.24	0.08	3.23	99.3	11	131	151	89	544	44	1,840
L	AYB-401	NE	SE	20	19	41	4860800N 443010E	3,428	Rhyolite	Tlr	74.8	12.0	0.41	1.77	0.03	0.62	0.17	4.00	4.34	0.05	1.39	99.9	20	131	169	28	537	44	1,830
M	AYB-425	SE	NW	25	19	41	4859690N 448620E	2,620	Ash-flow tuff	Tbt	60.2	11.6	0.48	3.96	0.14	2.83	0.86	4.15	2.48	0.15	13.4	100.0	<10	86	135	67	353	24	816
*	AYB-411	NW	NW	2	19	40	4861420N 438420E	4,120	Basaltic andesite	Thb	55.0	13.5	2.22	12.4	0.20	7.01	3.21	1.82	3.24	0.38	1.08	100.0	<10	63	314	35	231	29	952
*	AYB-412	NW	NW	2	19	40	4861450N 438330E	4,080	Basaltic andesite	Thb	54.6	13.2	2.24	13.4	0.21	6.93	3.14	1.96	2.90	0.39	1.16	100.0	11	52	306	41	235	26	818
*	AYB-417	NW	NE	14	18	41	4872850N 447430E	3,120	Basaltic andesite	Thb	54.5	13.4	2.29	12.8	0.26	6.93	3.24	1.94	2.97	0.39	1.16	100.0	14	54	315	37	227	33	837

[1] XRF analyses by XRAL

* Sample sites are short distances outside the quadrangle. Sites AYB-411 and 412 are to the west in the Little Black Canyon quadrangle. Site AYB-417 is to the north in the Buckbrush Creek quadrangle.

Table 2. Trace-element analyses, altered rocks, Westfall quadrangle, Malheur County, Oregon[1]

Map no.	Laboratory/ field no.	1/4	1/4	Sec.	T.(S.)	R.(E.)	UTM coordinates	Elev. (ft.)	Lithology	Map unit	Ag (ppm)	As (ppm)	Au (ppb)	Cu (ppm)	Hg (ppm)	Mo (ppm)	Pb (ppm)	Sb (ppm)	Tl (ppm)	Zn (ppm)	Bi (ppm)	Cd (ppm)	Ga (ppm)	Se (ppm)	Te (ppm)	Ba (ppm)	Co (ppm)	Cr (ppm)	Fe (wt.%)	Li (ppm)	Mn (ppm)	Ni (ppm)	W (ppm)
1	AYB-302 B-O-167	SW	NW	28	19	41	4859750N 443630E	3,230	Silicified tuff	Tds	0.041	18.3	<1.0	5.67	<0.10	0.649	8.33	0.39	<0.5	41.5	<0.25	0.298	3.96	<1.0	<0.5	805	4.3	22	0.63	2.7	357	7	<5
2	AYB-303 B-O-140	SE	NE	23	19	41	4861200N 447990E	2,730	Argillized and silicified tuff	Tds	0.048	26.3	<1.0	43.3	<0.10	2.23	4.45	1.00	<0.5	56.0	<0.25	0.139	8.73	<1.0	<0.5	1,748	12.3	50	3.24	14.5	1,201	35	<5

[1] Gold analyses by Bondar-Clegg; 14 elements by GSI; 8 elements by DOGAMI

GEOLOGIC CROSS SECTIONS