STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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GEOLOGY AND MINERAL RESOURCES MAP OF THE LITTLE VALLEY QUADRANGLE, MALHEUR COUNTY, OREGON

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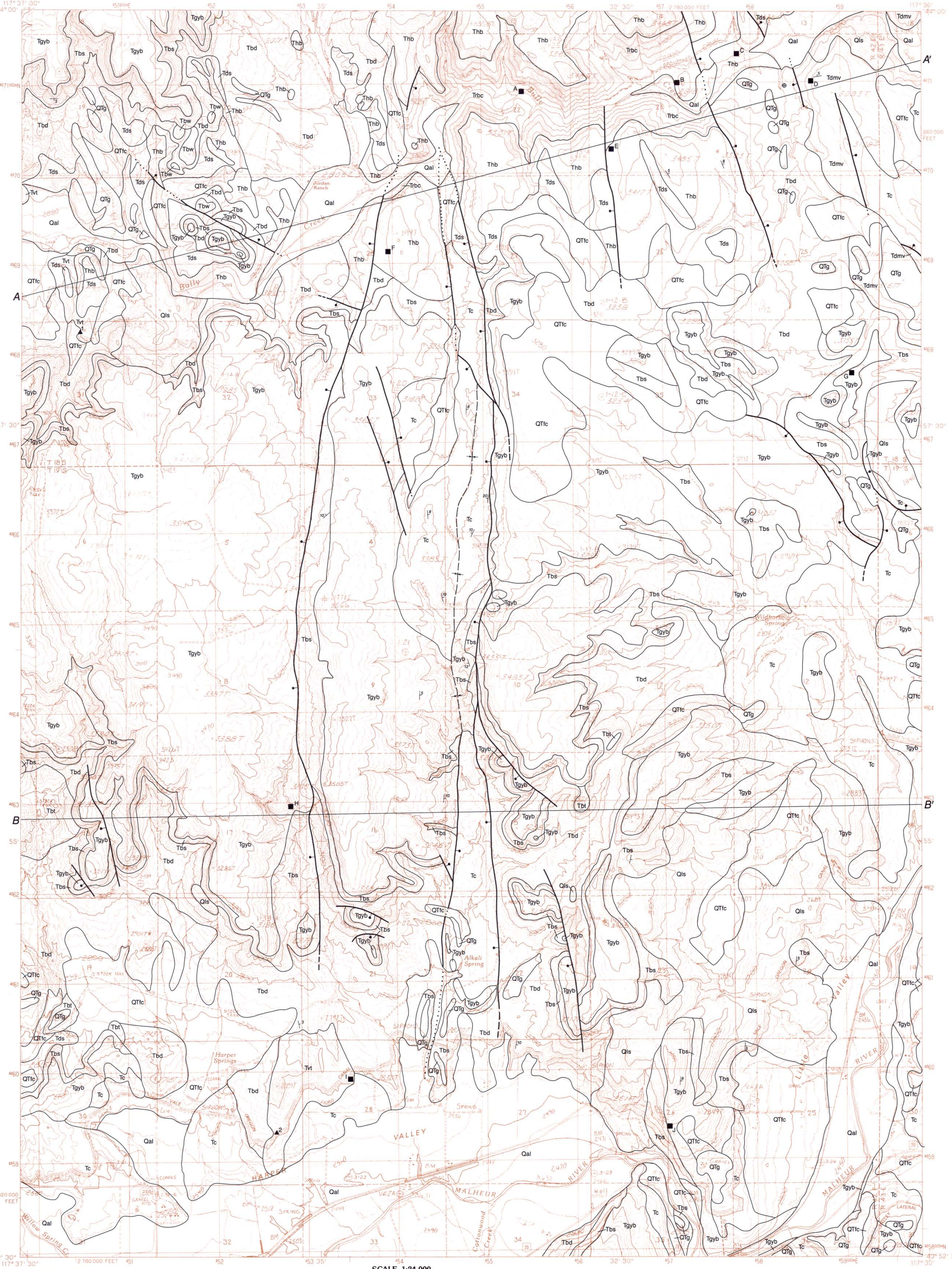
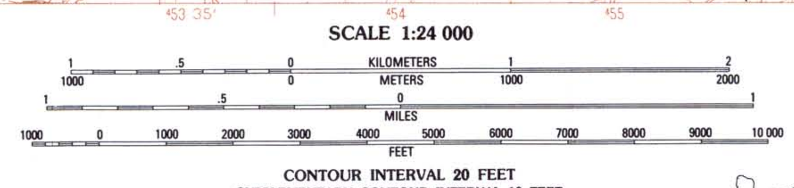
Geology and Mineral Resources Map of the Little Valley Quadrangle, Malheur County, Oregon
By H.C. Brooks and J.P. O'Brien

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, revised from aerial photographs taken 1985, 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

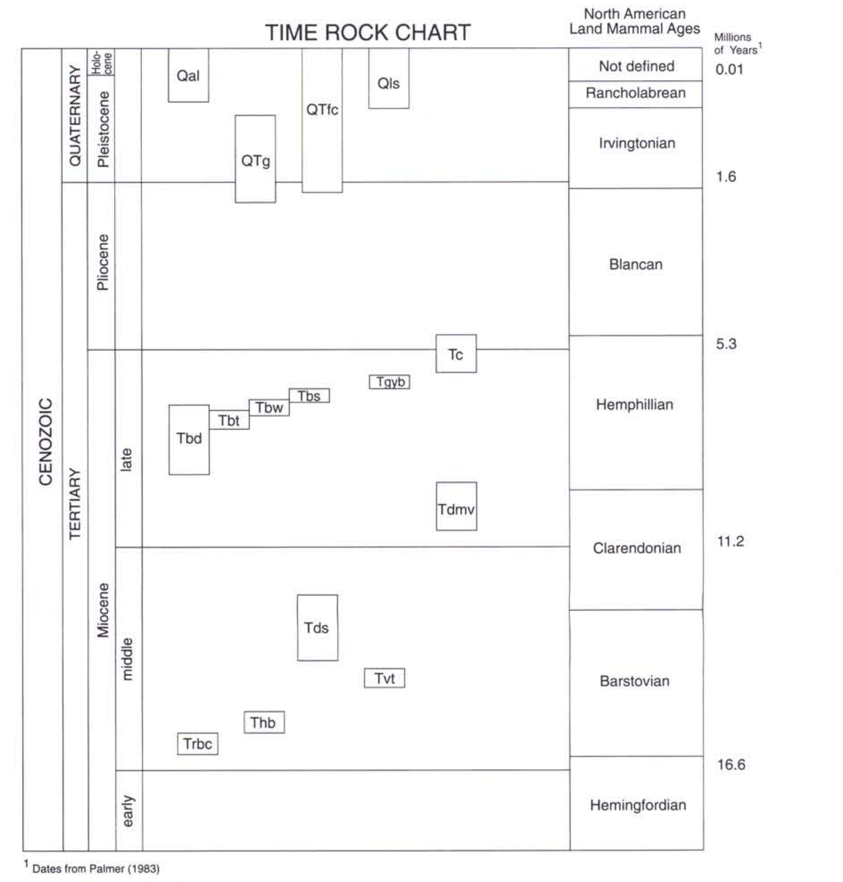
Geology by Howard C. Brooks and James P. O'Brien, Oregon Department of Geology and Mineral Industries

Field work conducted in 1990

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

Acknowledgments: The section on analytical methods was prepared by G.L. Baxter, Geochemist, Oregon Department of Geology and Mineral Industries.

Cartography by Allan Cartography



[1] Dates from Palmer (1983)

EXPLANATION

Qal — **Alluvium (Holocene and Pleistocene)**—Unconsolidated and unsorted to well-sorted deposits of gravel, sand, and silt. Mapped mainly in the flood plains of the Malheur River and Bully Creek

Qls — **Landslide deposits (Holocene and Pleistocene)**—Landslide and slump deposits formed as a result of bedrock failure. The large area of **Qls** in the southeastern part of the quadrangle is underlain by disoriented blocks of units **Tgyb**, **Tbs**, and **Tc**. Original eastward dips greater than 10° may have facilitated the sliding of basalt (unit **Tgyb**) over less competent sedimentary deposits (unit **Tbs**)

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. Unit **QTfc** on the slopes adjacent to Little Valley includes a soil horizon 10 or more feet thick consisting partly of eolian silt overlying units **Tgyb** or **Tc**. Unit **QTfc** deposits on the tablelands are mainly eolian silt and sand

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

Tc — **Tuffaceous sedimentary rocks and tuff (Pliocene? and upper Miocene)**—Chiefly interlayered, bedded to massive tuffaceous siltstone and sandstone, water-laid tuff, and minor amounts of gravel and limestone. Colors range through various light shades of brown, gray, green, and yellow. Beds range up to 10 ft in thickness. Beds composed largely of angular to subrounded glass shards and of variable amounts of fine ash and quartz and feldspar crystals are common. Includes pale-greenish-yellow to pale-brown fine sand and silt deposits composed mostly of rounded quartz, feldspar, and rock and glass fragments. Lenses of gravel and pebble-rich sand and silt deposits occur locally, e.g., in secs. 29, 30, 31, and 32, T. 19 S., R. 42 E. In places, the tuffaceous rocks have been altered largely to greenish-yellow bentonitic clay. Thin, tuffaceous, silty limestones interbedded with tuffaceous siltstone and sandstone are exposed for over a mile along the crest of the north-trending ridge in secs. 33 and 34, T. 18 S., R. 42 E., and secs. 3 and 4, T. 19 S., R. 42 E. The limestone beds vary from a few inches to about 6 ft in thickness and comprise a small part of the exposed sequence. Unit **Tc** is 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, weathering reddish-brown, medium-grained, aphyric to olivine and plagioclase phyric basalt flows with subophitic, ophitic, and hyalo-ophitic textures. Olivine phenocrysts are partly altered to serpentine minerals in some specimens. Groundmass minerals include olivine and clinopyroxene. Specimens from parts of at least one flow contain quartz xenocrysts, which may account for the relatively high silica content of sample J (Table 1). Sandstone and siltstone beds a few inches to a few tens of feet thick separate or overlie the flows locally. They comprise less than 10 percent of the total thickness of the unit. Parts of some flow outcrops are mantled by thin accumulations of disintegrated basalt, which 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, e.g., in sec. 7, T. 19 S., R. 42 E. The unit ranges to 200 ft in thickness and varies from a single flow less than 10 ft thick in the northeastern part of the quadrangle to six or more flows up to 30 ft thick in the western part. Cumulative thicknesses of 60 to 80 ft are common along the margins and in the cross-cutting draws of the tableland that dominates the west-central part of the map area. Large areas of the tableland-forming basalt are covered by large and small patches of eolian silt more than 20 ft thick locally. The unit extends a short distance eastward into the Vines Hill quadrangle, where it was mapped by Brooks as the upper part of his unit Tdmv (Brooks, 1991). The basalt flows are included in the upper part of the Grassy Mountain Formation of Kittleman and others (1967) and are continuous with the upper part of the Grassy Mountain Basalt of Bryan (1929) and with flows included in unit Tgyb of Ferns and O'Brien (1992a). They are chemically similar and may be stratigraphically equivalent to the unit Trsb flows of Ferns and Ramp (1989) and Urbanczyk and Ferns (unpublished mapping, 1989)

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

Tbs — **Tuffaceous sedimentary deposits (upper Miocene)**—Light-grayish-brown, locally pinkish-brown, light-gray or greenish-gray, poorly bedded to massive tuffaceous, locally calcareous sandstone and siltstone and small amounts of limestone, 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. Local, small concentrations of rounded pebble- and cobble-sized rock fragments 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 near the top of the unit range from a few inches to 6 ft in thickness. A 30-ft-thick sequence of interbedded ostracod-bearing limestone and clastic sedimentary rocks is exposed in sec. 30, T. 19 S., R. 42 E. The limestone is composed mainly of minute, interlocking calcite crystals and about 5 to 20 percent other minerals and rock fragments to 0.5 mm in size. Unit **Tbs** ranges from a few tens of feet to about 200 ft in thickness. Small exposures in the Vines Hill quadrangle were mapped by Brooks (1991) as part of his unit Tc, which is now known to be higher stratigraphically

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, about 5 percent subhedral quartz and feldspar crystals to 1.5 mm long, and a small amount of white pumice. Typical platy fracture roughly parallels the depositional surface. Overlies diatomite and tuff beds (unit **Tbd**) and underlies sedimentary deposits (unit **Tbs**) in secs. 19, 20, and 29, T. 18 S., R. 42 E. Exposures are small and about 15 ft in maximum thickness. Similar welded tuff as much as 150 ft thick is exposed in several places near Crowley (James J. 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 light gray and range to 5 in. across. Locally includes as much as 10 percent dark-gray vesicular rock fragments with diameters up to 2 in. 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 from exposures in the Westfall quadrangle a short distance to the west

Tbd — **Interbedded tuffaceous diatomite, diatomite, tuff, and tuffaceous siltstone (upper Miocene)**—Dominantly tuffaceous diatomite and diatomite with thin partings of vitric air-fall tuff and tuffaceous siltstone. Includes a few thin or poorly exposed ash-flow units. 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 bluish gray to dark gray. Individual beds range from less than 1 in. to more than 20 ft in thickness. Local grading and cross-bedding of tuff layers may reflect fluvial or turbidity current deposition of the ash. Moore (1937) described the diatomite-tuff deposits, including measured sections of deposits in the Westfall quadrangle, and identified the principal diatom species (mainly varieties of *Melosira*). Maximum local thickness of exposed beds is about 300 ft

Tdmv — **Mafic volcanic rocks (upper Miocene)**—Mainly aphyric to locally porphyritic basaltic andesite and andesite flows. Includes thin tuffaceous siltstone interlayers. Exposed only in the northeast corner of the quadrangle. The rocks typically are medium gray to dark gray on fresh surfaces and grayish to reddish brown in outcrop. Flows are commonly platy and dense to coarsely vesicular with fine-grained pilotaxitic to trachytic textures. Phenocrysts include plagioclase and hypersthene. Iddingsite and opaque minerals are common minor constituents. Analysis of one sample is given in Table 1 (sample D). The unit is over 200 ft thick in the quadrangle and is continuous with unit Tdmv flows of Brooks (1991) in the Vines Hill quadrangle to the east and correlative with unit Tdmv flows of Ramp and Ferns (1989) and Urbanczyk and Ferns (unpublished mapping, 1989)

Tds — **Drip Springs Formation (middle Miocene)**—Chiefly iron-stained tuffaceous sandstone and siltstone, silicic tuff and porcellanite, and rare arkosic sandstone. The 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, which, according to X-ray analysis by R.P. Geitgey (Oregon Department of Geology and Mineral Industries, personal communication, 1990), are composed largely of a form of opaline silica referred to as opal-CT (Jones and Segnit, 1971). Exposures typically are orangish yellow. Fresh surfaces are white to cream colored. Also includes low-density, light-colored, iron-stained silicic rock composed largely of fragmented, highly vesiculated glass. Analyses for samples 1 and 2 (Table 2) represent iron-stained, silica-rich rocks from this unit and unit **Tvt** (see below). Rocks of this unit are lithologically correlative with Drip Springs Formation (unit Tds) exposures in the Westfall quadrangle (Brooks and O'Brien, 1992) and Namorf quadrangle (Ferns and O'Brien 1992b) to the southwest that are continuous with the lower part of the Drip Springs Formation of Kittleman and others (1965, 1967)

Tvt — **Hydrovolcanic complex (middle Miocene)**—Mainly yellow to brown and gray hyaloclastic lithic tuffs and breccias. The deposits in the northwest corner of the map consist of abundant (5 to 25 percent) accidental rock fragments resembling rocks of the Hunter Creek Basalt and unit **Trbc** in yellowish to gray tuff matrix. The deposits range from massive to thin bedded and from unsorted to moderately sorted. Clast sizes range from less than 1 in. to more than 4 ft in unsorted deposits and to a few inches in the thin-bedded deposits. Some of the massive, poorly sorted deposits may be laharic. Similar tuffs and breccias are more widely exposed in the northern and western parts of the adjoining Westfall quadrangle to the west (Brooks and O'Brien, 1992). Unit **Tvt** exposures in the southwestern part of the map area consist of 4 or 5 percent mafic rock fragments up to about 6 in. in diameter and resembling Hunter Creek Basalt in mottled-brown to pale-yellow and near-white, clay-rich material that probably is a highly altered pumiceous tuff breccia. Chemical analysis is given in Table 1, sample I. One small patch of flow basalt about 20 ft across was observed. Most of the deposit is mantled by brownish-yellow, clayey soil containing angular fragments of the breccia and lesser mafic rock. The best exposures of the breccia are along the Vale-Oregon canal

Thb — **Hunter Creek Basalt (middle Miocene)**—Dark-gray to bluish-black, weathering reddish brown basaltic andesite and andesite that commonly exhibit subconchoidal fracture and, where weathered, tend to form blocks less than 10 in. across. Flow tops generally are vesicular. 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. The unit overlies rhyolite and vitrophyre flows of unit **Trbc** in the north-central part of the quadrangle. Unit **Thb** is lithologically and compositionally equivalent to Hunter Creek Basalt of Brooks and O'Brien (1992), Evans (1990 and unpublished mapping, 1990), and Ferns and O'Brien (1992b). Chemically, rocks of the unit are tholeiitic andesite (icelandite) characterized by low alumina and high iron (see Table 1)

Trbc — **Rhyolite of Bully Creek canyon (middle Miocene)**—Chiefly reddish-gray, platy, porphyritic, locally spherulitic, lithoidal rhyolite flows and dark-gray to black vitrophyre. (See samples A and B, Table 1.) Phenocrysts are plagioclase and pigeonite. Groundmass of the lithoidal flows includes plagioclase, pyroxene, quartz, and opaque minerals. Vitrophyre flows locally exhibit columnar joints ranging from vertical to horizontal to fan-shaped. Vertical columns range up to 5 ft across and up to 60 ft high in Bully Creek canyon. Radially jointed flow lobes are exposed along Bully Creek in the SE ¼ sec. 23, T. 18 S., R. 42 E. Unit 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 individual vitrophyre flows. Locally, the flows or breccia are overlain by up to 20 ft of light-colored, bedded silicic tuff. Maximum thickness of exposures in Bully Creek canyon is about 650 ft. Some individual flows are over 100 ft thick. Rocks of this unit underlie flows of the Hunter Creek Basalt in Bully Creek canyon and are correlative with similar rocks in unit Trbc of Brooks and O'Brien (1992) and unit Tv of Evans (unpublished mapping, 1990) in secs. 18 and 19, T. 19 S., R. 41 E., in adjoining parts of the Westfall and Little Black Canyon quadrangles, respectively. Kittleman and others (1967) mapped these rocks 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

Axis of syncline

Strike and dip of beds or flows

Horizontal beds or flows

Location of sample analyzed in Table 1

Location of sample analyzed in Table 2

GEOLOGY

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

The lower part of the geologic section is comprised of the thick vitrophyre and lithoidal rhyolite flows of Bully Creek canyon (unit Trbc) and the overlying basaltic andesite flows of the Hunter Creek Basalt (unit Thb). The rhyolite unit was mapped as Littlefield Rhyolite by Kittleman and others (1967), a unit that overlies the Hunter Creek Basalt in areas to the west (Evans, 1990; Brooks and O'Brien, 1992; Ferns and O'Brien, 1992b). The rhyolite and vitrophyre flows of unit Trbc and those that overlie the Hunter Creek Basalt are megascopically similar, 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 pigeonite in unit Trbc and augite in the younger rocks. Zircon and barium abundances are significantly lower in samples from unit Trbc than in most samples of the post-Hunter Creek Basalt flows. One sample from the base of the latter sequence in Malheur River canyon contains zircon and barium abundances similar to those of unit Trbc (Ferns and O'Brien, 1992b).

Unit Tvt is part of a hydrovolcanic complex dominated by hyaloclastic lithic tuffs and breccias containing accidental fragments similar to rocks comprising units Thb and Trbc. The unit, which is better exposed in the adjacent Westfall quadrangle (Brooks and O'Brien, 1992), includes breccias with scoriaceous matrix and breccias with little or no matrix and small patches of basaltic andesite and rhyolitic vitrophyre. The presence of small patches of agglutinated scoria, widely associated with exposures of the unit in the Westfall quadrangle, indicates that much of 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 in a lake or a subsurface ground-water zone. These eruptions may record initial stages of development of the basin into which the Drip Springs and Bully Creek Formations were later deposited.

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 largely by volcanic rocks including Hunter Creek Basalt (unit Thb) and rhyolite flows of unit Trbc and Littlefield Rhyolite. Exposures of Drip Springs Formation in the quadrangle are mostly water-laid tuffs and tuffaceous sedimentary rocks. The formation is thicker and lithologically more complex to the southwest (Ferns and O'Brien, 1992b). The Bully Creek Formation is mainly composed 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 of 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 (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. The Bully Creek Formation apparently pinches out between units Tdmv and Tgyb along the east margin of the quadrangle.

Tuffaceous sedimentary rocks (unit Tc) stratigraphically above the basalt flows may represent distal facies of sedimentary deposits in the Western Snake River Basin, whose depocenter is east of the quadrangle.

STRUCTURE

The volcanic and sedimentary rocks of the quadrangle are offset by faults having displacements of a few hundred feet or less. Trends of the more extensive faults are within a few degrees of north. Offsets along the faults cutting unit Tgyb and older rocks in the central part of the quadrangle tend to have west side down with some eastward tilting of the western block. Synclinal warping related to drag occurs along a north-trending fault (or faults) cutting the tableland in the central part of the quadrangle. Small-scale folding of interbedded diatomite and tuff sequences (unit Tbd) has been noted in several places, e.g., along the Vale-Oregon canal in sec. 27, T. 19 S., R. 42 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. Bedding in the Bully Creek Formation typically dips east or southeast ranging up to 5° in the northern and western parts of the quadrangle and averages about 10° in the southeastern part. The large landslide area west of Little Valley is composed of disoriented blocks of units Tgyb, Tc, and Tbs.

MINERAL RESOURCES

Large quantities of diatomite occur within the quadrangle and in the adjoining Westfall quadrangle to the west. 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 Westfall quadrangle. There is no record of subsequent production. Results of more recent investigations by a number of companies and individuals indicate that beds of usable-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.

A hot spring in Little Valley (NE¼ SW¼ sec. 30, T. 19 S., R. 43 E.) produces 90 gallons of 158°F water per minute (James A. Blackburn, owner, personal communication, 1990). In the early 1980's, an alcohol production plant was built near the spring and operated for a short time by Blackburn and son operating as Little Valley Ethanol, Inc. The hot water was used in the distillation process. Two wells, 530 and 400 ft deep, respectively, were completed near the spring in the search for hotter water. Both are said to be capable of producing 80 gallons per minute of water averaging about 125°F.

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

WATER RESOURCES

Much of Harper Valley and Little Valley are 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 ¼-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 ¼-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: ¼ 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.

REFERENCES

Brooks, H.C., 1991, Geology and mineral resources map of the Vines Hill quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-63, 1:24,000.

Brooks, H.C., and O'Brien, J.P., 1992, Geology and mineral resources map of the Westfall quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-71, 1:24,000.

Bryan, K., 1929, Geology of reservoir and dam sites, with a report on the Owyhee irrigation project, Oregon: U.S. Geological Survey Water-Supply Paper 597-A, 72 p.

Corcoran, R.E., Doak, R.A., Porter, P.W., Pritchett, F.I., and Privrasky, N.C., 1962, Geology of the Mitchell Butte quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-2, 1:125,000.

Evans, J.G., 1990, Geology and mineral resources map of the South Mountain quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-67, 1:24,000.

Ferns, M.L., and O'Brien, J.P., 1992a, Geology and mineral resources map of the Harper quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-69, 1:24,000.

———1992b, Geology and mineral resources map of the Namorf quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-70, 1:24,000.

Ferns, M.L., and Ramp, L., 1989, Geology and mineral resources map of the Grassy Mountain quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-57, 1:24,000.

Jones, J.B., and Segnit, E.R., 1971, The nature of opal: I. Nomenclature and constituent phases: Journal of the Geological Society of Australia, v. 18, pt. 1, p. 57-67.

Kittleman, L.R., Green, A.R., Haddock, G.H., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 8, 1:125,000.

Kittleman, L.R., Green, A.R., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1965, Cenozoic stratigraphy of the Owyhee region, southeastern Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 1, 45 p.

Moore, B.N., 1937, Nonmetallic mineral resources of eastern Oregon: U.S. Geological Survey Bulletin 875, 180 p.

Palmer, A.R., 1983, The Decade of North American Geology 1983 geologic time scale: Geology, v. 11, no. 9, p. 503-504.

Ramp, L., and Ferns, M.L., 1989, Geology and mineral resources map of the Double Mountain quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-58, 1:24,000.

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

Map letter	Laboratory no.	1/4	1/4	Sec.	T. (S.)	R. (E.)	U.T.M. 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-402	SW	NE	22	18	42	4870920N 455470E	2,740	Vitrophyre	Trbc	68.8	12.2	0.68	4.27	0.10	1.79	0.56	4.95	2.74	0.16	3.31	99.8	<10	139	183	42	297	25	1,430
B	AYB-410	SW	NE	23	18	42	4871000N 457160E	2,720	Rhyolite	Trbc	70.3	12.4	0.70	3.73	0.06	1.30	0.34	4.23	3.83	0.15	1.85	99.1	14	213	199	<10	296	26	1,420
C	AYB-409	NW	NW	24	18	42	4871320N 457860E	2,700	Andesite	Thb	58.3	12.2	1.39	12.2	0.32	4.84	1.25	3.13	3.00	0.47	1.62	99.0	<10	122	281	51	320	35	1,170
D	AYB-413	SW	NE	24	18	42	4871000N 458700E	3,000	Andesite	Tdmv	59.8	17.1	0.85	6.16	0.10	5.71	2.05	2.12	4.38	0.39	1.31	100.0	37	27	677	36	206	28	1,010
E	AYB-406	SW	SW	23	18	42	4870270N 456440E	3,340	Basaltic andesite	Thb	55.5	13.0	2.22	12.3	0.22	6.35	2.78	2.17	2.98	0.47	0.70	98.9	15	62	325	47	236	16	871
F	AYB-407	SW	NE	28	18	42	4869150N 453940E	3,100	Basaltic andesite	Thb	55.0	12.8	2.21	12.6	0.27	6.53	2.81	2.19	2.99	0.46	1.39	99.4	<10	40	304	36	217	31	923
G	AYB-415	SE	NE	36	18	42	4867730N 459110E	3,120	Basalt	Tgyb	48.1	16.9	1.7	13.2	0.22	10.1	3.97	0.66	2.58	0.42	2.31	100.0	94	18	293	69	108	41	466
H	AYB-405	SE	NE	17	19	42	4862940N 452820E	3,180	Basalt	Tgyb	45.7	15.7	1.06	10.1	0.17	10.3	9.02	0.31	2.00	0.20	3.93	98.6	283	86	176	<10	53	16	182
I	AYB-419	SE	NW	28	19	42	4859920N 453480E	2,610	Tuff	Tvt	50.8	10.7	1.99	11.6	0.13	4.66	2.67	1.01	0.66	0.80	14.8	100.0	11	57	252	58	235	18	1,360
J	AYB-408	NE	SW	26	19	42	4859350N 457000E	2,780	Basalt	Tgyb	52.7	16.0	1.12	8.65	0.15	8.19	5.44	1.43	2.95	0.32	1.93	99.0	148	<10	523	18	117	<10	588

[1] XRF analyses by XRAL.

Table 2. Trace-element analyses, altered rocks, Little Valley quadrangle, Oregon[1]

Map no.	Laboratory no.	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-304	B-O-276	NE	NW	31	18	42	4868260N 450510E	2,990	Silicified tuff	Tds	0.02	12.3	<1.0	2.88	<0.10	1.42	0.74	0.324	<0.5	1.35	<0.25	<0.10	<0.50	<1.0	<0.5	29	<0.5	68	0.26	0.6	36	<4	<5
2	AYB-300	B-O-138	NE	SE	29	19	42	4859320N 452650E	2,620	Argillized tuff	Tvt	0.03	25.7	<1.0	16.0	<0.10	0.403	7.30	<0.25	<0.5	114.0	<0.25	0.244	18.2	<1.0	<0.5	530	15.5	13	7.75	13.6	1280	20	<5

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

GEOLOGIC CROSS SECTIONS