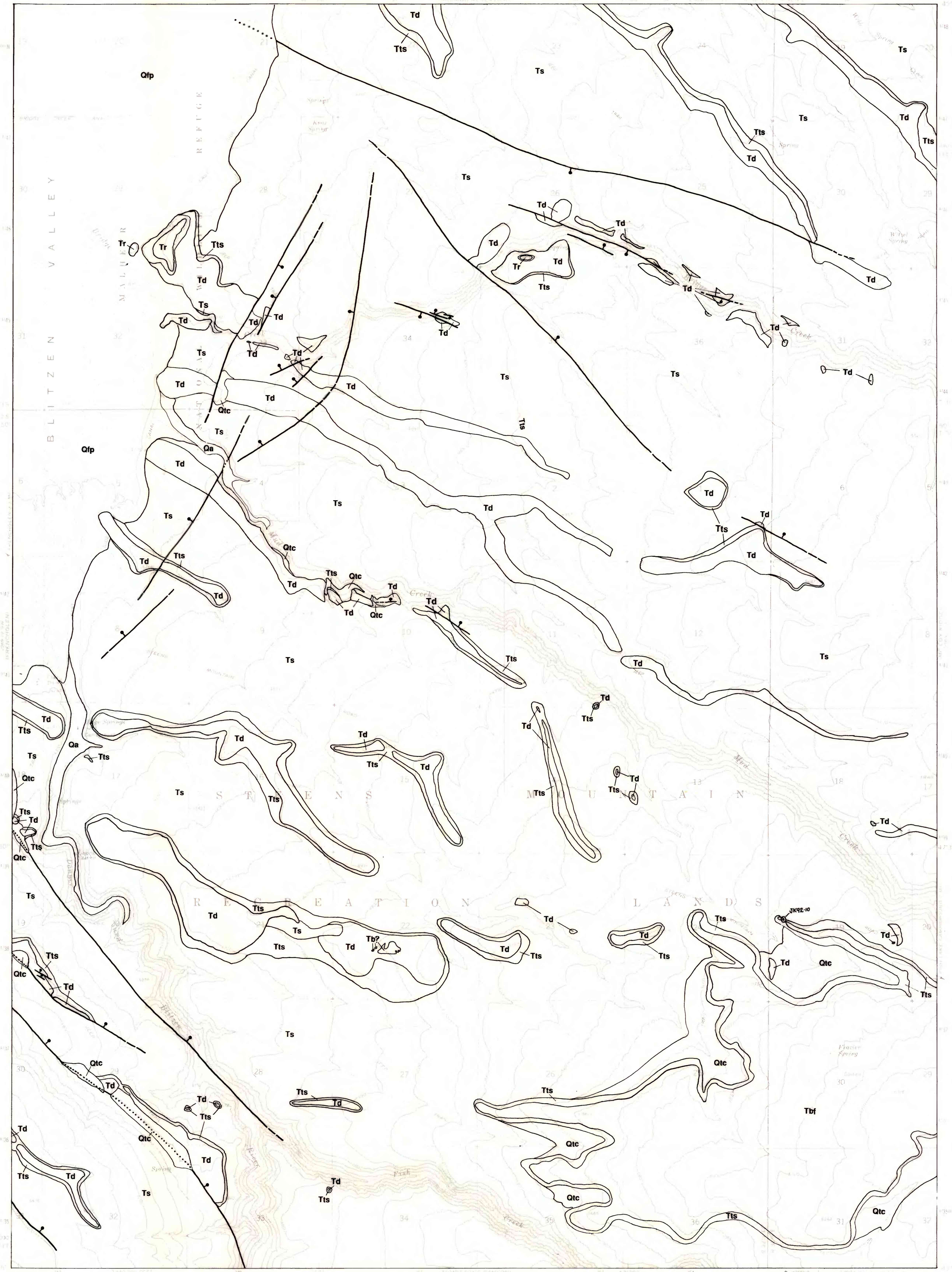


Base from U.S. Geological Survey, 1967
Photorevised 1980
Polyconic projection

UTM GRID AND 1980 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

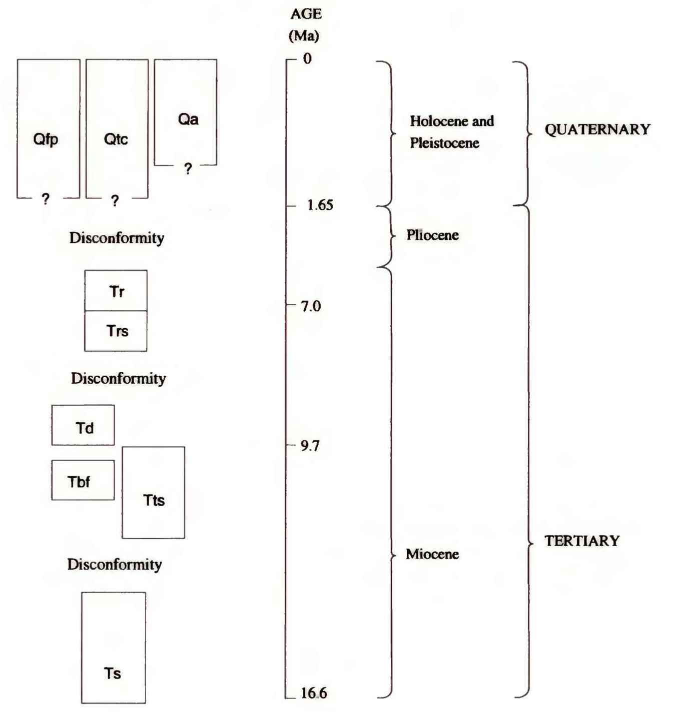
Geology mapped in 1992

GEOLOGIC MAP OF THE PAGE SPRINGS QUADRANGLE, HARNEY COUNTY, SOUTHEASTERN OREGON

By
Jenda A. Johnson

1996

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qfp **Flood-plain deposits (Holocene and Pleistocene)**—Bedded silt, sand, and gravel that fill floor of Blitzen Valley. Maximum estimated thickness 40 m in quadrangle

Qa **Alluvium (Holocene and Pleistocene)**—Unconsolidated fluviatile sand, and gravel in valley floors. Maximum estimated thickness 5 m

Qtc **Colluvium (Holocene and Pleistocene)**—Unconsolidated talus and slope detritus. Maximum estimated thickness 10 m

Tr **Rattlesnake Ash-flow Tuff (Miocene)**—Poorly to moderately welded, pumice-rich, crystal-poor, vitric tuff. Medium- or light-gray to light-olive-gray glassy groundmass. White and gray pumice lapilli as large as 15 cm (average 3-7 cm) form 10-20 percent of rock. Sparse phenocrysts (less than one percent) include subhedral alkali feldspar, embayed quartz, and rare anhedral green clinopyroxene. Weathers to grayish brown. Forms cliffs 1-7 m high in map area. The tuff forms a widespread sheet in south-central Oregon and is exposed over a region of 22,000 km^2 (Walker, 1979). Streck (1994) suggests that the tuff, which erupted from a caldera located 80 km northwest of the map area, had an original areal extent of 35,000 km^2 with a volume of approximately 332 km^3. Formally named by Walker (1979). Originally included in the Rattlesnake Formation of Merriam and others (1925), a sedimentary sequence exposed in the John Day River valley. Other workers recognized the ash-flow tuff as the more widespread, stratigraphically important part of the formation and renamed it the (informal) Rattlesnake ignimbrite of the Danforth Formation (Davenport, 1971) or the Rattlesnake Ignimbrite Tongue of the Rattlesnake Formation (Enlows, 1976). In the Harney Basin, the ash-flow tuff was first named the tuff-breccia member of the Danforth Formation by Piper and others (1939). Greene and others (1972) mapped it separately as the informally named welded tuff of Double O Ranch. Walker (1979) redefined the original Rattlesnake Formation to exclude its sedimentary strata and, for clarity, renamed the ignimbrite sheet the Rattlesnake Ash-flow Tuff. The new reference locality is at Poison Creek about 10 km north of Burns, Oregon (Walker, 1979). Age is late Miocene; $^{40}Ar/^{39}Ar$ weighted mean age of 7.05±0.01 Ma was obtained from 15 crystals separated from a single pumice in the tuff (Streck, 1994). A weighted mean age of 6.7 Ma was derived from 10 K-Ar ages recalculated by Fiebelkorn and others (1983). Unit has reversed-polarity magnetization (Parker, 1974; Stimac and Weldon, 1992)

Trs **Tuffaceous sedimentary deposit (Miocene)**—Massive, fine-grained, poorly consolidated, tuffaceous sedimentary rock forms gentle silty slopes. The volcaniclastic strata lie concordantly on the Devine Canyon Ash-flow Tuff

Td **Devine Canyon Ash-flow Tuff (Miocene)**—Moderately to densely welded, crystal-rich ash-flow tuff. Lower densely welded zone is medium light gray to greenish gray with pale-olive streaks; weathers to moderate-reddish-brown coarse hackly gravel. Groundmass consists of clear glass shards with incipient spherulitic devitrification. Phenocrysts (15-20 percent), 0.5 to 3 mm in length, include subhedral to anhedral alkali feldspar, embayed quartz, and green clinopyroxene. Sparse black fiamme 1-4 mm are also present. Subrounded volcanic lithic fragments (3 to 5 percent) as large as 2 mm are composed of fine-grained sodic plagioclase (An_{40}) and iron-titanium oxide needles in an altered groundmass. Forms cliffs as high as 17 m. An unconsolidated 2-m-thick basal fallout deposit of pumiceous ash and lapilli is exposed only in streams and road cuts. Moderately welded, medium- to light-gray platy basal zone is rarely exposed in the map area. The upper moderately welded zone, preserved locally, is pale red to moderate reddish brown. The upper zone contains 8-20 percent phenocrysts of embayed quartz and alkali feldspar and green augite with a thin reaction rim. Small dark-gray fiamme (3 percent) are flattened 4:1. Fine-grained dusty groundmass contains both clear and tan glass shards and shows incipient devitrification. The Devine Canyon Ash-flow tuff originally covered more than 18,600 km^2 of southeastern Oregon and had a volume of approximately 195 km^3 (Greene, 1973). Outcrops in the map area represent the southeastern distal margin of the tuff where it is exposed as elongate east- to southeast-trending lobes (see Discussion, Paleogeography). Maximum thickness in study area is about 8 m but averages 3-6 m. Measured thicknesses represent minimum values, however, because the nonwelded to poorly welded uppermost part of the unit has been removed by erosion. The Devine Canyon Ash-flow Tuff was formally named by Walker (1979) for its type locality about 13 km north of Burns, Oregon. Unit is late Miocene; $^{40}Ar/^{39}Ar$ single-crystal age of 9.68±0.03 Ma was obtained from sanidine in the tuff (A.L. Deino and A.L. Grunder, unpub. data, 1993). Potassium-argon ages on sanidine range from 8.7 to 10.3 Ma (Fiebelkorn and others, 1983). Unit has normal-polarity magnetization (Stimac and Weldon, 1992)

Tbf **Basalt of Frazier Spring (Miocene)**—The informally named basalt of Frazier Spring is comprised of homogeneous fine-grained, intergranular olivine basalt flows. Phenocrysts include 10-12 percent euhedral to subhedral plagioclase (1 to 5 mm long), 5-10 percent anhedral olivine (0.2-2.5 mm in diameter, 50 percent have Fe-Ti oxide inclusions), 2 percent Fe-Ti oxides (0.2 mm in diameter). Groundmass comprises 75-80 percent euhedral laths of unaltered plagioclase, 7-10 percent Fe-Ti oxides (0.1 mm), 5-7 percent clinopyroxene, 2-3 percent clay-altered glass. Compositionally it is a high-potash, high-titania tholeiite (by the criteria of Hart and others, 1984) that is similar in major and some trace elements to upper flows of Steens Basalt at Steens Mountain (Table 1). It differs from the Steens Basalt in having higher MgO, Sr, and Cr and lower P_2O_5/Zr relative to MgO. Maximum estimated thickness is 30 m. Unit is younger than Steens Basalt and older than Devine Canyon Ash-flow Tuff

Tts **Tuff and tuffaceous sedimentary rocks (Miocene)**—Poorly indurated volcaniclastic strata that form gentle slopes beneath the Devine Canyon Ash-flow Tuff (Td) and the basalt of Frazier Spring (Tbf) are exposed in roadcuts and stream canyons. Sedimentary strata beneath Tbf range from silty beds that contain reworked ash with 1-2 percent fine-grained clear crystals, to sand-sized poorly sorted volcaniclastic material with 10-15 percent feldspar to 5 mm in length. Here the unit varies from white in the lower part of the unit, to pale orange near the contact with the overlying basalt flow. Beneath Td the unit consists of fine- to medium-grained, well-sorted, sand- and silt-sized pumiceous ash, crystals, and lithic fragments, as well as reworked sandstone. Yellowish gray where fresh, but generally weathers grayish orange to dark yellowish orange. Beds range from laminated (centimeter scale) to massive (4 m thick), with maximum total thickness of 10 m. The rocks are lithologically similar to and perhaps temporally correlative with the Miocene Mascall Formation (Davenport, 1971). Mammalian fossils of Barstovian age were reported from the Mascall Formation 25 km west of map area in Keg Springs Valley (G.W. Walker, written commun., 1992; for location see Walker and Repenning, 1965)

Ts **Steens Basalt (Miocene)**—Aphanitic to coarsely porphyritic, diktytaxitic olivine basalt lava flows. Dark gray to medium dark gray. Flow tops are commonly vesicular. In the map area the rock comprises 60-70 percent tabular euhedral plagioclase as long as one centimeter; 10-15 percent anhedral olivine (altered to iddingsite); 8-10 percent subhedral clinopyroxene; and 3-5 percent iron-titanium oxides. Textures include intergranular, intersertal, ophitic, and subophitic. The Steens Basalt, oldest unit exposed in the quadrangle, is a thick, laterally continuous sequence of lava flows widespread in southeastern Oregon (Fuller, 1931; Watkins and Baksi, 1974; Hart and Carlson, 1985). Lava flows average 5 m thick; maximum thickness in map area is more than 150 m, but base not exposed. The Steens Basalt originally covered at least 15,000 km^2 of southeastern Oregon (Carlson and Hart, 1983) and is over 900 m thick at the inferred source at Steens Mountain (Minor and others, 1987). Named by Fuller (1931) for exposures at Steens Mountain. $^{40}Ar/^{39}Ar$ laser fusion of coarse plagioclase crystals yielded ages of 16.58±0.05 Ma and 16.59±0.022 Ma, determined using from flows 1 and 31, respectively, at the type section (Swisher and others, 1990)

Contact—Approximately located

Fault—Long-dashed where approximately located, short-dashed where inferred, dotted where buried. Ball and bar on downthrown side

JK92-10 **Chemically analyzed rock sample**—Showing location and sample number (table 1).

DISCUSSION

INTRODUCTION

The Page Springs 7.5-minute quadrangle encompasses parts of the Blitzen Valley and northwestern flank of Steens Mountain in the Basin and Range physiographic province of southeastern Oregon (fig. 1). The entire map area is underlain by a bimodal assemblage of middle and upper Miocene olivine basalt flows and rhyolite ash-flow tuffs (fig. 2). This assemblage is characteristic of volcanic rocks in the northern Basin and Range province and is thought to result from a combination of tectonic influences including east-west-directed basin-range extension (Stewart, 1978), Cascade Range back-arc volcanic activity (Hart and Carlson, 1987), and a propagating transform margin related to Basin and Range extension (Christiansen and McKee, 1978; Johnson, 1995). Locally derived Quaternary alluvium, colluvium, and flood-plain deposits cover part of the area.

STRUCTURE

Faults in the area can be grouped into two broad sets on the basis of their orientation. High-angle normal faults that strike N. 45° W. to N. 75° W. are parallel to the northwest-striking faults of the Brothers fault zone (fig. 1), a northwest-trending zone of closely spaced, discontinuous fractures which extends across southeastern Oregon (Walker, 1969; Lawrence, 1976). A second set of faults trends N. 5° E. to N. 45° E. and is subparallel to the major graben-forming faults of the northwestern Basin and Range province including those which form Steens Mountain. Faulting associated with Basin and Range extension has created Blitzen Valley, which occupies the lower part of a half-graben associated with the Steens Mountain uplift to the east (Sherrod and Johnson, 1994). The central part of Steens Mountain is a homoclinal block that dips westward into the Blitzen Valley (Fuller, 1931; Johnson, 1992). Most volcanic strata in the map area dip between 2.5° at lower elevations to 3.5° upslope. Although the basal contact of the basalt of Frazier Spring has a slightly greater dip than that of the Devine Canyon Ash-flow Tuff (3.5° vs. 3.2°), figure 3 shows that this may be a result of upslope projection. Change in dip upslope may result from either the originally steeper slopes of the shield volcano toward its source or time-progressive tilting of the Steens Mountain fault block. Any angular unconformity between the two units is indeterminate because the tuff appears to have ramped onto erosional surfaces in the older units (see Paleogeography) and the differing dip between units is trifling.

Age of the faults in the quadrangle can be constrained only as younger than the Devine Canyon Ash-flow Tuff. In the Krumbo Reservoir quadrangle to the north, however, faults are younger than the 7.05-Ma Rattlesnake Ash-flow Tuff (Johnson, 1994). Movement on the Blitzen Valley fault system, which formed the 400-m-high Jackass Mountain escarpment, appears to have postdated deposition of all exposed units (Sherrod and Johnson, 1994).

An episode of roughly east-west-directed extensional tectonism began about 16 Ma (Stewart, 1978) and may continue to present (Minor, 1986; Hemphill-Haley and Carver, 1988). This stress regime is reflected in N-S-striking dikes of Steens Basalt along the axis of Steens Mountain and is responsible for the north-trending elongate fault blocks that form the high mountains and valleys of southeastern Oregon. Evidence for faulting prior to 10.5 Ma is found at the north end of the Steens Mountain escarpment (Johnson, 1995). Although there is no stratigraphic evidence for faulting in the map area before deposition of the Rattlesnake Ash-flow Tuff, paleogeographic patterns suggest that northwest-trending lineaments may have existed prior to Devine Canyon Ash-flow time (see below). No evidence was found for recent faults cutting the Quaternary units.

PALEOGEOGRAPHY

Pyroclastic flows of the Devine Canyon Ash-flow Tuff probably covered the entire region but in the map area are preserved as erosional remnants. West-northwest elongate exposures of the densely welded Devine Canyon Ash-flow Tuff form a topographic grain both parallel to the Brothers fault zone and to the dip of Steens Basalt in this area. These outcrops, which range from less than 0.05 to 0.5 km wide and are as long as about 10 km, are interpreted as the result of thicker deposition of the ash flow in shallow paleovalleys cut into the Steens Basalt and the tuff and tuffaceous sedimentary rocks (units Ts and Tts). Topographic ridges now lie along the trace of ancient paleovalleys owing to preservation of erosionally resistant, thicker valley-filling parts of the Devine Canyon Ash-flow Tuff. Several lobes in the southern part of the map area bifurcate upslope away from the inferred source area of the Devine Canyon Ash-flow Tuff. In plan view these features resemble inverted stream confluences that have since been truncated by erosion. No cobbles or other evidence of stream deposits were found beneath the Devine Canyon Ash-flow Tuff where its base is exposed along lobe axes.

Field evidence indicates a gentle paleoslope on the western flanks of the Steens Mountain fault block (see Structure). The absence of cobbles at the base of the Devine Canyon Ash-flow Tuff suggests that the streams had a low gradient and carried only fine sediment. Meandering streams might be expected given the gentle slope of units and the fine-grained nature of the poorly indurated strata above the Steens Basalt. Yet the paleovalleys are parallel and relatively straight, and their trend parallels the west-northwest strike of faults in the northern part of the map area. These relations indicate that the pyroclastic flows filled paleovalleys that may have in part been structurally controlled by west-northwest-striking fractures developed prior to the emplacement of the Devine Canyon Ash-flow Tuff.

The lack of sedimentary strata beneath much of the Devine Canyon Ash-flow Tuff across the center of the map indicates that either sedimentary material was stripped off before the pyroclastic flow was emplaced, or that the sediment was never deposited, which is unlikely in that much of the unit appears to be air fall. Remnants of the tuff slapped in the canyon walls of Bridge Creek (NW 1/4 of map) and near the mouth of Mud Creek may reflect paleodrainages. The long remnants of tuff between these creeks is topographically higher than the other remnants, as determined from a structure-contour diagram of the base of the tuff throughout the map area. This may reflect elevated fault-bound structures that were stripped of the sedimentary unit. Elsewhere in the region, evidence for northwest-trending faults prior to Devine Canyon Ash-flow Tuff time is seen in fault-bound valleys near the north end of Steens Mountain (Johnson, 1995)

REFERENCES CITED

Carlson, R.W., and Hart, W.K., 1983, Areal extent and isotope geochemistry of the Steens Mountain flood basalt, southeastern Oregon [abs.]: Eos (American Geophysical Union Transactions), v. 64, no. 18, p. 338.

Christiansen, R.L., and McKee, E.H., 1978, Late Cenozoic volcanic and tectonic evolution of the Great Basin and Columbia Intermontane regions: Geological Society of America Memoir 152, p. 283-311.

Davenport, R.E., 1971, Geology of the Rattlesnake and older ignimbrites in the Paulina Basin and adjacent area, central Oregon: Corvallis, Oregon State University, Ph.D. dissertation, 132 p.

Enlows, H.E., 1976, Petrography of the Rattlesnake Formation at the type area, central Oregon: Oregon Department of Geology and Mineral Industries Short Paper 25, 34 p.

Fiebelkorn, R.B., Walker, G.W., MacLeod, N.S., McKee, E.H., and Smith, J.G., 1983, Index to K-Ar age determinations for the state of Oregon: Isochron/West, no. 37, p. 3-60.

Fuller, R.E., 1931, The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: University of Washington Publications in Geology, v. 3, no. 1, 130 p.

Greene, R.C., 1973, Petrology of the welded tuff of Devine Canyon Ash-flow, southeastern Oregon: U.S. Geological Survey Professional Paper 797, 26 p.

Greene, R.C., Walker, G.W., and Corcoran, R.E., 1972, Geologic map of the Burns quadrangle, Oregon: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-680, scale 1:250,000.

Hart, W.K., and Carlson, R.W., 1985, Distribution and geochronology of Steens Mountain-type basalts from the northwestern Great Basin: Isochron/West, no. 43, p. 5-10.

———1987, Crustal genesis on the Oregon Plateau: Journal of Geophysical Research, v. 92, no. B7, p. 6,191-6,206.

Hemphill-Haley, M.A., and Carver, G.A., 1988, Late Holocene displacement along the Alvord fault, Steens Mountain, southeastern Oregon [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 3, p. 168.

Johnson, J.A., 1994, Geologic map of the Krumbo Reservoir quadrangle, Harney County, southeastern Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-2267, scale 1:24,000

——1995, Geologic evolution of the Duck Creek Butte eruptive center, High Lava Plains, southeastern Oregon: Corvallis, Oregon State University, M.S. thesis, 151 p.

Lawrence, R.D., 1976, Strike-slip faulting terminates the Basin and Range province in Oregon: Geological Society of America Bulletin, v. 87, no. 6, p. 846-850.

Merriam, J.C., Stock, Chester, and Moody, C.L., 1925, The Pliocene Rattlesnake Formation and fauna of eastern Oregon, with notes on the geology of the Rattlesnake and Mascall deposits: Carnegie Institute of Washington Publication 347, p. 43-92.

Minor, S.A., 1986, Stratigraphy and structure of the western Trout Creek and northern Bilk Creek Mountains, Harney County, Oregon, and Humboldt County, Nevada: Boulder, University of Colorado, M.S. thesis, 177 p.

Minor, S.A., Rytuba, J.J., Goeldner, C.A., and Tegtmeyer, K.J., 1987, Geologic map of the Alvord Hot Springs quadrangle, Harney County, Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1916, scale 1:24,000

Parker, D.J., 1974, Petrology of selected volcanic rocks of the Harney Basin, Oregon: Corvallis, Oregon State University, Ph.D. dissertation, 119 p.

Piper, A.M., Robinson, T.W., Jr., and Park, C.F., Jr., 1939, Geology and ground-water resources of the Harney Basin, Oregon: U.S. Geological Survey Water-Supply Paper 841, 189 p.

Sherrod, D.R., and Johnson, J.A., 1994, Geologic map of the Irish Lake quadrangle, Harney County, south-central Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-2256, scale 1:24,000.

Stewart, J.H., 1978, Basin and range structure in western North America, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 1-31.

Stimac, J.P., and Weldon, R.J., II, 1992, Paleomagnetism and tectonic rotations of the Rattlesnake and Devine Canyon Ash-flow Tuffs, northern Basin and Range, southern Oregon [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 5, p. 83.

Streck, M.J., 1994, Volcanology and petrology of the Rattlesnake Ash-flow Tuff, eastern Oregon: Corvallis, Oregon State University, PhD. thesis, 184 p.

Swisher, C.C., Ach, J.A., and Hart, W.K., 1990, Laser fusion $^{40}Ar/^{39}Ar$ dating of the type Steens Mountain Basalt, southeastern Oregon, and the age of the Steens geomagnetic polarity transition [abs.]: Eos (American Geophysical Union Transactions), v. 71, no. 43, p. 1,296.

Walker, G.W., 1969, Geology of the High Lava Plains Province, *in* Weissenborn, A.W., ed., Mineral and water resources of Oregon: Oregon Department of Geology and Mineral Industries Bulletin 64, p. 77-79.

———1979, Revisions to the Cenozoic stratigraphy of Harney Basin, southeastern Oregon: U.S. Geological Survey Bulletin 1475, 35 p.

Walker, G.W., and Repenning, C.A., 1965, Reconnaissance geologic map of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Map I-446, scale 1:250,000.

Watkins, N.D., and Baksi, A.K., 1974, Magnetostratigraphy and oroclinal folding of the Columbia River, Steens, and Owyhee basalts in Oregon, Washington, and Idaho: American Journal of Science, v. 274, no. 2, p. 148-189.

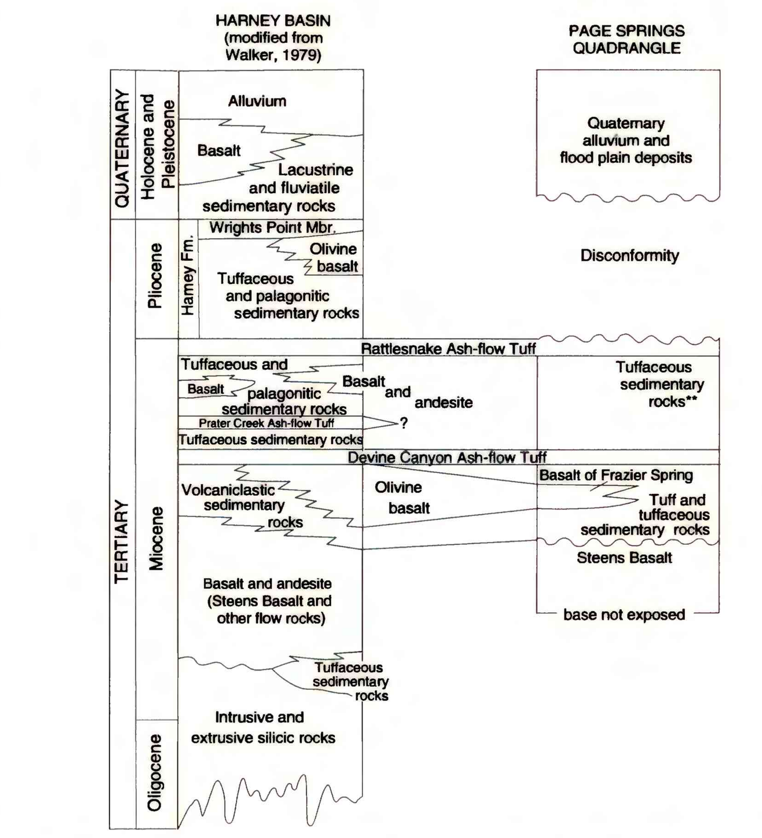


Figure 2. Comparison between stratigraphic units in Harney Basin region and units exposed in the Page Springs quadrangle.

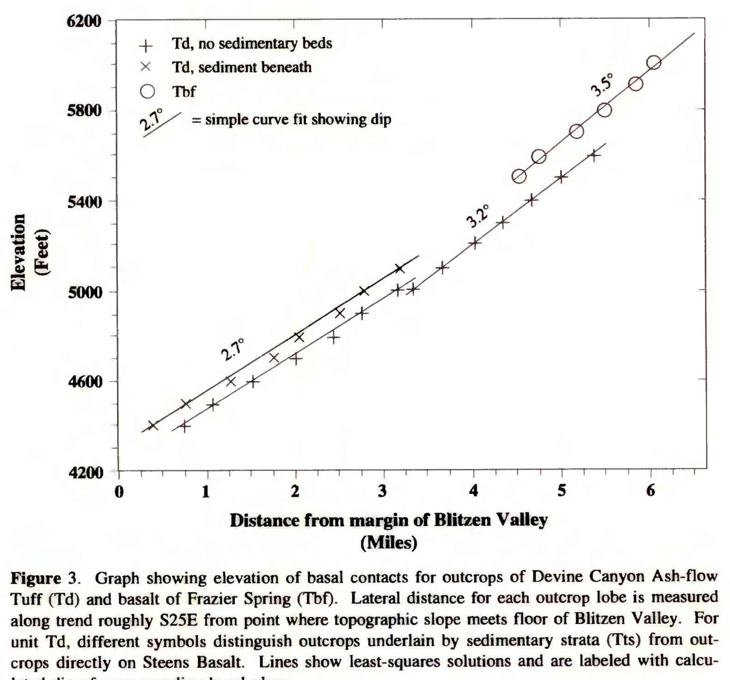


Figure 3. Graph showing elevation of basal contacts for outcrops of Devine Canyon Ash-flow Tuff (Td) and basalt of Frazier Spring (Tbf). Lateral distance for each outcrop lobe is measured along trend roughly S25E from point where topographic slope meets floor of Blitzen Valley. For unit Td, different symbols distinguish outcrops underlain by sedimentary strata (Tts) from outcrops directly on Steens Basalt. Lines show least-squares solutions and are labeled with calculated dip of corresponding basal plane.

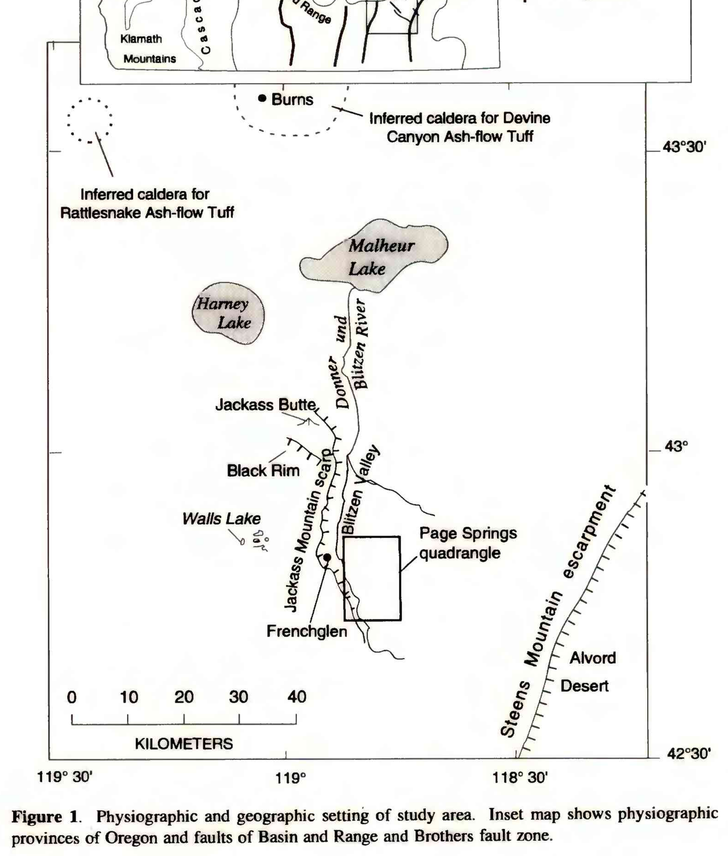


Figure 1. Physiographic and geographic setting of study area. Inset map shows physiographic provinces of Oregon and faults of Basin and Range and Brothers fault zone.

Table 1. Major- and trace-element concentrations in basalt of Frazier Spring (JK92-10) normalized to 100 percent. Prenormalization value 101.00 percent. Analyses by GeoAnalytical Lab, Washington State University, Pullman WA.

Major elements	
SiO_2	49.10
Al_2O_3	16.37
TiO_2	2.19
FeO	10.81
MnO	0.19
CaO	9.07
MgO	7.06
K2O	1.40
Na_2O	3.25
P_2O_5	0.579
Trace elements (ppm)	
Ni	85
Cr	159
Sc	31
V	335
Ba	550
Rb	13
Sr	896
Zr	127
Y	28
Nb	9.9
Cu	97
Zn	98
La	23
Ce	13

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