DEPARTMENT OF THE INTERIOR
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TO ACCOMPANY MAP I-680

GEOLOGIC MAP OF THE BURNS QUADRANGLE, OREGON

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Description of map units

Qp *Playa deposits.*—Clay, silt, sand, and some evaporite deposits.

Qal *Alluvium.*—Sand, gravel, and silt.

Qf *Alluvial-fan deposits.*—Poorly sorted mixtures of gravel and sand, commonly found where small streams enter main valleys; locally include talus.

Qlb *Late basalt.*—Basalt, agglomerate, cinders, and ash of Diamond Craters (T. 28-29 S., R. 32 E.). Basalt mostly vesicular, medium gray, micrograined; contains less than 1 percent plagioclase and olivine phenocrysts; thin flows with ropy surfaces. Many small craters are rimmed with spatter, cinders, and bombs, and floored with basalt flows. Includes basalt flow(s) that show original flow surfaces in southeast corner of quadrangle.

Qa *Ash.*—Grayish red; mantles much of Diamond Craters; separately mapped where underlying flows concealed.

Qs *Sedimentary deposits.*—Mostly unconsolidated silt and clay, generally pale brown; sand and gravel locally present; coherent where diagenetically altered or cemented by caliche. Mostly lacustrine, in part fluviatile.

Qb *Basalt.*—Medium gray, micrograined, diktytaxitic. Seriate texture with large and small grains of plagioclase, olivine, and augite; also minor magnetite and glass. Several thin flows, tumuli at surface. Present in lowland south of Malheur Lake, canyon of South Fork Malheur River, near southeast corner of quadrangle, and in west part of quadrangle south of Squaw Butte (T. 24 S., R. 25 E.).

Qls *Landslide deposits.*—Unsorted mixtures of basalt blocks and tuffaceous sediments. Present near Warm Springs Reservoir and South Fork Malheur River, mostly where Drinkwater Basalt overlies poorly consolidated sedimentary rocks. Also occurs east of Calamity Butte.

Qmv *Mafic vent complexes.*—Basalt and andesite scoria, cinders, agglomerate, and thin flows, commonly reddish. Cinders dominant immediately south of Malheur Lake. Farther south and in southwest part of quadrangle forms small shields and domes.

QTtg *Terrace gravels.*—Unconsolidated deposits of gravel and sand. North of Burns consists of rounded welded-tuff pebbles and coarse sand. Near Juntura mostly gravel. Gravel of well-rounded quartzite cobbles as much as 12 inches in diameter near Gold Hill (T. 18 S., R. 31 E.) and south of Twelvemile Creek in T. 20 S., R. 23 E.

QTsb *Sedimentary rocks and basalt.*—Sandstone, siltstone, conglomerate, and interbedded thin flows of basalt; some flows, deposited in shallow lacustrine environment, highly fragmented and altered. Age, late Pliocene and early Pleistocene.

QTs *Sedimentary rocks.*—Tuffaceous sandstone and siltstone; locally contains abundant palagonitized basaltic debris and some pebble conglomerate. Exposed mostly in Sagehen Valley (T. 23-24 S., R. 28-29 E.) east and southeast of Riley (T. 23-24 S., R. 27 E.), and along south margin of Silver Creek Valley (T. 23 S., R. 25-26 E.). Includes some of the sedimentary part of the Harney Formation of Piper, Robinson, and Park (1939) in T. 24-25 S., R. 29-31 E.

QTb *Basalt.*—Mostly diktytaxitic olivine-bearing basalt, commonly vesicular but locally dense or platy; generally nonporphyritic. In places consists of several thin flows separated by thin layers of sedimentary rocks. Includes the basalt part of the Harney Formation of Piper, Robinson, and Park (1939) in T. 24-25 S., R. 29-31 E. Basalt flow capping Wrights Point (T. 24-25 S., R. 31 E.), which is at or near top of unit, is 2.4 million years old (potassium-argon date by J. C. Engels, 1968).

QTp *Pyroclastic rocks of cinder cones.*—Subaerial deposits of unconsolidated reddish fine to coarse scoriaceous basaltic ejecta. Some cones modified by erosion to low, rounded hills with slopes of cindery red soil that contains sparse bombs and bomb fragments. Locally includes some unfragmented basalt flows and dikes.

QTps *Subaqueous pyroclastic deposits.*—Partly consolidated yellowish-brown palagonitized basaltic ejecta; occurs as palagonitic tuff and breccia cones and rings surrounding maars and, in a few places, as tuff ridges. Locally contains intermixed fragments of older basalt, tuff, sedimentary rocks, and small basalt dikes.

QTmv *Mafic vent complexes.*—Basalt and andesite scoria, cinders, agglomerate, and thin flows, commonly reddish; forms lava cones and small shield volcanoes.

Tobt *Olivine basalt of Twelvemile Table.*—Basalt, medium-dark-gray, micrograined, commonly diktytaxitic; sparse olivine phenocrysts in ophitic groundmass of plagioclase, olivine, augite, magnetite, and glass. A few thin flows cap Twelvemile Table (T. 18-19 S., R. 23 E.). Overlies welded tuff of Twelvemile Table. Age 5.92±0.41 m.y. (potassium-argon date by J. C. Von Essen, 1967).

Tobg *Olivine basalt and andesite of Gum Boot Canyon.*—Basalt, medium-dark-gray, fine- to medium-grained, aphyric and diktytaxitic; contains olivine in the groundmass. Andesite, medium-gray with brownish mottling, aphanitic and nonporous; con-

tains less than 1 percent plagioclase and olivine phenocrysts. Several flows, each a few feet to a few tens of feet thick; maximum thickness of unit about 200 ft. Overlies welded tuff of Double O Ranch, present in two areas near Dry Mountain (T. 23 S., R. 24 E., to T. 22 S., R. 25 E.; and T. 23 S., R. 27 E.).

Tdo *Welded tuff of Double O Ranch.*—Pumiceous welded ash-flow tuff extensively exposed in western part of map area and adjacent areas to south and southwest. Informally named for Double O Ranch, which is about 5 miles north-northwest of the reference section. Reference section is on a southwest-facing fault scarp in SW1/4 sec. 23, T. 27 S., R. 28 E. The section is about 210 ft thick and consists of a basal vitric zone about 4 ft thick, a lower dense devitrified zone about 8 ft thick, a lithophysal zone about 190 ft thick and an upper dense zone about 8 ft thick. A similar sequence, 50-200 ft in total thickness, characterizes the unit in much of its area of occurrence. Tuff of the basal vitric zone is medium to dark gray, commonly porous, and contains abundant pumice. This zone grades upward into light-brownish-gray devitrified lithophysal tuff, which in turn grades upward into pale-brown dense devitrified tuff that also contains abundant pumice. Locally, as near Dry Mountain (T. 22 S., R. 26 E.) and east of Soldier Creek (T. 22 S., R. 32 E.), the tuff may be all dense devitrified or porous vitric. Many small erosional remnants not shown. Tuffs of all zones contain less than 1 percent phenocrysts. Phenocrysts are alkali feldspar, plagioclase, quartz, and augite; devitrified groundmass is alkali feldspar, cristobalite, tridymite, and quartz. A possible vent area for all or part of this tuff is located on Buzzard Creek (T. 28 S., R. 28 E.) (Walker, 1969). In central part of area, constitutes upper part (including tuff breccia member) of Danforth Formation of Piper, Robinson, and Park (1939); included in Rattlesnake Formation in Paulina Basin (T. 15-17 S., R. 23-25 E., north of map area) by Brown and Thayer (1966). Age, about 6 m.y., based on two potassium-argon dates, one of 6.82±0.33 m.y. from near Burns by J. C. Von Essen and J. C. Engels (1967), and one of 5.40±0.20 m.y. from Cricket Creek (T. 21 S., R. 28 E.) by J. C. Engels (1970).

Tsb *Tuffaceous sedimentary rocks and basalt.*—Sedimentary rocks and basalt, interlayered and not separately mappable.

Tst *Tuffaceous sedimentary rocks.*—Well- to semi-consolidated tuffaceous sedimentary rocks and tuffs, typically pale brown to yellowish gray and poorly stratified; commonly consists of poorly sorted mixture of pumice, scoria, other rock fragments, plagioclase grains, and glass shards in clay matrix; locally light gray to white, well stratified, and consisting of fresh pumice and glass shards. Mostly lacustrine, in part fluviatile, in part of air-fall origin. A few feet to a few hundred feet thick, generally present between major welded-tuff and basalt units, separately mapped where thick enough to show. Includes blanket of coarse pumice in matrix of finer pumice and rock fragments on east slope of Horsehead Mountain (T. 27-28 S., R. 25 E.), the site of a rhyodacite dome. Poorly fossiliferous. Age, mostly early and middle Pliocene, in many places bracketed by age of overlying and underlying welded tuffs or basalts. In central part of area includes sedimentary parts of Danforth Formation of Piper, Robinson, and Park (1939). Correlative, in part, with Idaho Group of Malde and Powers, (1962).

Tob *Basalt.*—Olivine-bearing basalt, dense dark-gray basalt, and some andesite not assigned to a specific unit. Locally includes thin interbeds of tuffaceous sediments.

Twt *Welded tuff.*—Welded ash-flow tuffs not assigned to a specific unit.

Toa *Olivine andesite.*—Andesite, medium-gray, mottled in shades of dark gray and grayish red, in part aphyric, in part porphyritic. Consists of phenocrysts of plagioclase, olivine, clinopyroxene, and magnetite; groundmass of oriented plagioclase microlites, cryptofelsite, and magnetite grains. Some flows contain clots of plagioclase phenocrysts. Locally flow banded, commonly strongly flow jointed, local hackly jointing, locally scoriaceous. Age, early or middle Pliocene. Includes separate flows and flow sequences west-southwest of Riley (T. 23-24 S., R. 26 E.), on flanks of Squaw Butte (T. 24 S., R. 25 E.), northeast flank of Egli Ridge (T. 25 S., R. 25 E.), and southwest of Wagontire Mountain (T. 26-27 S., R. 23 E.).

Ta *Andesite.*—Andesite, dark-gray with brownish mottling, aphanitic; less than 1 percent phenocrysts of plagioclase and augite. Several thin flows, total thickness a few tens to 100 ft. Present between Little Emigrant Creek (T. 20 S., R. 27 E.) and Burns. Underlies welded tuff of Double O Ranch and locally overlies welded tuff of Devine Canyon.

Twtp *Welded tuff of Prater Creek.*—Welded ash-flow tuff, pale-reddish-brown, no phenocrysts, little pumice, nearly all devitrified. West of Devine Canyon (T. 21 S., R. 31 E.) consists of a dense lower zone, a highly inflated lithophysal central zone, and a dense upper zone; east of Devine Canyon, central zone is absent, and tuff is light gray and finely porous. Present at scattered localities as far west as Sawtooth Creek (T. 20 S., R. 28 E.), where the unit is too thin to map. Thickness commonly 20-40 ft. Main area of occurrence is in north-central part of quadrangle; small occurrence on Jackass Mountain (T. 29 S., R. 30-31 E.). Overlain by welded tuff of Double O Ranch and underlain by welded tuff of Devine Canyon, commonly with nonwelded tuff and tuffaceous sedimentary rocks intervening. Part of Danforth Formation of Piper, Robinson, and Park (1939).

Tdw *Drinkwater Basalt.*—Named by Bowen, Gray, and Gregory (in Shotwell, 1963, p. 31-32). Type section is at Drinkwater Pass (sec. 34, T. 20 S., R. 34 E.). Thicker and better exposed on the south part of Drinkwater Mountain (sec. 1, T. 22 S., R. 36 E.; sec. 6, T. 22 S., R. 37 E.), designated a reference section. Basalt, medium-dark-gray, micrograined, diktytaxitic, in part porphyritic. Phenocrysts and glomerocrysts of plagioclase and olivine locally abundant; ophitic groundmass of plagioclase, olivine, augite, magnetite, and glass. Commonly one, locally several flows, total thickness 20 to 200 ft. Caps mesas in eastern third of quadrangle. Age, 6.91±1.09 m.y., potassium-argon date by J. C. Engels (1970) on a sample from Crane (T. 25 S., R. 34 E.).

Tr *Rhyodacite.*—Medium to light gray, pale red or pale brown; commonly streaked, mottled, or flow banded; aphanitic or vitrophyric, locally vesicular. Some flows aphyric, others porphyritic containing as much as 20 percent plagioclase phenocrysts

and sparse phenocrysts of augite, hypersthene, and magnetite. Groundmass is alkali feldspar, plagioclase, silica minerals, and glass. Forms a prominent hill (Burns Butte, T. 23 S., R. 30 E.) and adjacent highlands. Much angular debris, including obsidian, at surface. Age, 7.82±0.26 m.y., potassium-argon date by J. C. Engels (1970).

Tvs *Volcanic sedimentary rocks.*—Pumice and pumiceous sedimentary rocks, light-brown to white, slightly to moderately well consolidated; ash-flow tuff with abundant lump pumice, in part densely welded. Present on south side of Burns Butte (T. 23 S., R. 30 E.).

Twtt *Welded tuff of Twelvemile Table.*—Welded tuff, generally two zones: lower zone vitric, medium gray, abundant pumice, commonly porous and friable; upper zone devitrified, medium light gray, dense. Both zones contain less than 1 percent alkali feldspar phenocrysts. Thickness, 25 to 50 ft. Present near Twelvemile Creek, T. 19 S., R. 34 E., extends west to Hampton Butte, in Crescent quadrangle (Walker and others, 1967). Overlain by olivine basalt of Twelvemile Table, underlain by Miocene basalt and andesite (Tba) and pre-Tertiary rocks. Age, 9.29±0.23 m.y., potassium-argon date by J. C. Engels and M. A. Lanphere (1966), from east side of Hampton Butte.

Tdv *Welded tuff of Devine Canyon.*—Crystal-rich welded ash-flow tuff extensively exposed in map area and adjacent areas to north and south. Informally named for Devine Canyon (T. 21 S., R. 31 E.). Reference section (NW¼ sec. 32, T. 21 S., R. 31 E.) is located along Poison Creek about 1 mile from its junction with Devine Canyon, and is 104 ft thick. Vitric tuff, light-gray to light-greenish-gray, moderately dense and coherent; flattened pumice common; forms basal part of thick sections and all of thinner sections. Devitrified tuff, medium-light-to greenish-gray, generally streaked and mottled; commonly dense but may have large lenticular voids; weathers to small bits. Phenocrysts of alkali feldspar commonly 2-25 percent, of quartz ½-6 percent, augite, trace amounts. A multiple-flow simple cooling unit. North of Burns 80-104 ft thick, thins to 20 ft near Juntura (T. 21 S., R. 28 E.), 35 ft near Follyfarm (T. 29 S., R. 37 E.), and 25 ft near Swamp Creek (T. 22 S., R. 24 E.). In central part of area apparently forms the basal part of Danforth Formation of Piper, Robinson, and Park (1939). In northeast part of area, mapped as welded tuff member of Drewsey Formation by Bowen, Gray, and Gregory (in Shotwell, 1963) and by Haddock (1967). North of map area not separated from marginal facies of Columbia River Group, undivided volcanic and fluviatile deposits of Tertiary and Quaternary age, and Strawberry Volcanics (Brown and Thayer, 1966). Part of unit Tst on Adel quadrangle (Walker and Repenning, 1965) and of unit Ttu of Owyhee Region (Kittleman and others, 1967). Age, about 9.2 m.y., average of following potassium-argon dates: 8.5±0.3 m.y. from near Diamond (T. 29 S., R. 33 E.) by R. W. Kistler, H. C. Whitehead, and Lois Schlocker; 8.9 m.y. from Drinkwater Pass (T. 20 S., R. 36 E.) (Evernden and others, 1964, sample KA122S); 9.21±0.50 m.y. from Devine Canyon (T. 21 S., R. 31 E.) by J. C. Von Essen (1967); 9.45±0.21 m.y. from near Swamp Creek (T. 22 S., R. 23 E.) by J. C. Engels and M. A. Lanphere (1966); and 9.7±0.3 m.y. from the west edge of Catlow Valley (T. 34 S., R. 29 E.) by R. W. Kistler and F. G. Walthall.

Ttb *Ash-flow tuff near Buchanan.*—Tuff, medium-gray where vitric and yellowish-gray where devitrified, slightly welded. Contains abundant pumice. About 20 ft thick. Present near Buchanan (T. 22 S., R. 33 ½ E.).

Tb *Basalt.*—Medium to dark gray, locally grayish red, fine grained, subophitic and diktytaxitic, locally porphyritic. Near Donnelly Butte (T. 20 S., R. 26 E.) contains abundant plagioclase phenocrysts and groundmass olivine. Many flows, maximum total thickness about 400 ft; underlies welded tuff of Devine Canyon. Age, 11.8±5.1 m.y., potassium-argon date by J. C. Engels (1970). In T. 27-28 S., R. 26 E., southwest of Harney Lake, the basalt contains 1-5 percent slightly altered olivine phenocrysts. May intertongue locally with sedimentary rocks of units Tst and Tts. Consists of several flows, each 10-20 ft thick and totaling about 150 ft. Age, late Miocene(?) and early Pliocene.

Tha *Hypersthene andesite.*—Andesite, dark-gray with greenish or brownish spots, aphanitic to fine-grained; contains less than 1 percent olivine phenocrysts; groundmass of plagioclase, hypersthene, augite, magnetite and pyrite, and glass. Many flows; forms a large shield volcano (Dry Mountain, T. 22 S., R. 26 E.).

Tsts *Tuffaceous sedimentary rocks.*—Well-consolidated to semi-consolidated tuffaceous sediments and tuffs; contains abundant white diatomite in the area between Drewsey and Juntura (T. 20 S., R. 35-36 E., and T. 21 S., R. 35-37 E.). Yellowish-brown palagonitic sediment locally abundant between Drewsey (T. 20 S., R. 35 E.) and Van (T. 18 S., R. 33½ E.). A combination of units Tst and Tts, used where welded tuff of Devine Canyon is thin or absent. In Drewsey-Juntura area, has yielded Barstovian (late Miocene) plant fossils and Hemphillian (early Pliocene) vertebrates (Shotwell, 1963). Includes Drewsey and Juntura Formations of Shotwell (1963).

Tmv *Mafic vent complexes.*—Basaltic and andesitic agglomerate, breccia, scoria, cinders, flows, and intrusive masses forming lava cones and small shield volcanoes.

Tir *Intrusive rhyodacite.*—Pale red; aphanitic groundmass with 10-20 percent phenocrysts of alkali feldspar and quartz. Present on Stinkingwater Mountain (T. 23 S., R. 34 E., and T. 22 S., R. 33 E.). Smaller bodies not shown.

Trr *Rhyolite and rhyodacite.*—Light-gray, light-brownish-gray, pale-red, and grayish-orange, commonly flow banded, vitrophyric, hyalopilitic, or pilotaxitic rhyolite and rhyodacite; mostly porphyritic with phenocrysts of plagioclase, alkali feldspar, and quartz. Varietal minerals include biotite, basaltic hornblende, hypersthene, and, rarely, olivine. Glass of groundmass commonly devitrified and spherulitic. Locally flow jointed or brecciated. Contains masses of obsidian or perlitic glass and, locally, masses of opalite. Occurs as exogenous domes and related flows and plugs. Age, late Miocene(?) and Pliocene.

Tts *Tuffaceous sedimentary rocks.*—Tuffaceous sedimentary rocks and pumiceous tuffs, white or

light shades of yellow, brown, or gray, mostly fine grained and poorly to moderately well bedded. Contains local beds of pebble conglomerate. Glass fragments, commonly fresh, in some beds, devitrified. Flood-plain or shallow-lake deposits. Includes welded tuff in canyon of Silvies River (T. 19-20 S., R. 30-31 E). Underlies welded tuffs of Devine Canyon and Twelvemile Table and basalt (Tb). Correlative, in part, with Mascall Formation (Merriam, 1901) and Juntura Formation of Shotwell (1963). Includes rocks of late Miocene and early Pliocene age.

Ttp *Tims Peak Basalt.*—Tims Peak Basalt was named and described from exposures in the SE¼ sec. 34, T. 21 S., R. 40 E., the type locality (Kittleman and others, 1965, p. 20). The type locality is 3½ miles east of Tims Peak (sec. 31, T. 21 S., R. 40 E.) and 14 miles east of Juntura (T. 21 S., R. 38 E.). Medium- to dark-gray, fine-grained and diktytaxitic basalt. Some flows contain plagioclase phenocrysts; olivine in groundmass; locally interbedded with volcanic sandstone and diatomite. Several flows, each several tens of feet thick; maximum total thickness about 400 ft (Haddock, 1967, p. 25). Present near northeast corner of quadrangle (T. 18-20 S., R. 38 E.). Overlies Hunter Creek Basalt.

Tba *Basalt and andesite.*—Medium to dark gray, commonly streaked or mottled with lighter grays or browns. Aphanitic to fine grained, generally nonporous. Mostly aphyric, locally contains a few percent plagioclase phenocrysts or less than 1 percent olivine phenocrysts. Fresh or slightly altered. Color indices range from 30 to 40 (andesite) and from 40 to 50 (basalt). Tuffaceous sedimentary rocks locally interbedded, as on Stinkingwater Mountain (T. 21-22 S., R. 34 E.) and west of North Fork Malheur River (T. 19-20 S., R. 37 E.). Mostly porphyritic andesite (equant plagioclase phenocrysts) on King Mountain and west side of Calamity Butte (T. 19-20 S., R. 32 E.). On Steens Mountain (T. 28-29 S., R. 34-37 E.) some flows contain abundant elongate plagioclase phenocrysts. Many flows, each a few feet to several tens of feet thick; maximum total thickness about 2,000 ft on Steens Mountain near Follyfarm (T. 29 S., R. 36 E.). In northwest part of quadrangle, partly equivalent to flows of Columbia River Group as mapped in adjacent areas (Walker and others, 1967; Swanson, 1969; and Brown and Thayer, 1966). In north-central part of quadrangle, partly equivalent to Strawberry Volcanics of Brown and Thayer (1966). In northeast part of quadrangle, includes unnamed igneous complex of Haddock (1967) and of Kittleman, in part, and others (1965, 1967), equivalent to their Owyhee Basalt. In southeast part of quadrangle continuous with Steens Basalt of Fuller (1931). Mapped as units Tfb, Tbf, and Taf on Adel quadrangle (Walker and Repenning, 1965) and on Jordan Valley quadrangle (Walker and Repenning, 1966). Ages shown by following potassium-argon dates: 19.4±0.8 m.y., west of Calamity Butte (T. 20 S., R. 32 E.) (J. C. Engels, 1970), 12.1 m.y. at Stinkingwater Pass (T. 22 S., R. 34 E.) (Evernden and others, 1964), and 15.3±1.0 m.y. on Riddle Mountain (T. 29 S., R. 35 E.) (J. C. Von Essen, 1968). Steens Basalt dated at 14.5 m.y. (Evernden and others, 1964) and about 15 m.y. (Baksi, York, and Watkins, 1967) for flows on Steens Mountain south of the map area.

Thc *Hunter Creek Basalt.*—Hunter Creek Basalt was named and described from exposures along Hunter Creek, the type locality, in SW¼ NW¼ sec. 26, T. 21 S., R. 39 E., 8 miles east of Juntura (Kittleman and others, 1965, p. 19). Basalt, dark-gray, aphanitic and aphyric; shows characteristic closely spaced columnar jointing and flow jointing. Maximum total thickness 140 ft; may be one or several flows (Haddock, 1967, p. 15-16). Present near northeast corner of quadrangle (T. 19-22 S., R. 38 E.). Overlies Dinner Creek Welded Tuff and is equivalent in age to part of unit Tba.

Tps *Pumiceous sedimentary rocks.*—Sandstone and conglomerate composed of angular pumice, scoria, basalt, and andesite fragments in clay matrix; light olive gray to yellowish gray, well consolidated. Present east of Cottonwood Creek (T. 19 S., R. 36 E.) and on Stinkingwater Mountain (T. 22 S., R. 34 E.).

Tdc *Dinner Creek Welded Tuff.*—Dinner Creek Welded Tuff was named and described from exposures on Dinner Creek and at the type locality in the NW¼ SE¼ sec. 30, T. 21 S., R. 39 E., on Conroy Creek 1½ miles west of Dinner Creek and 5 miles east of Juntura (Kittleman and others, 1965, p. 18). A threefold unit, lower part pumice lapilli tuff, middle part welded ash-flow tuff, upper part pumice lapilli tuff and pumiceous sandstone (Haddock, 1965, p. 12-13). Welded tuff of middle part complexly zoned into vitric, dense devitrified, cavernous, and lithophysal zones. Devitrified tuff commonly brownish to grayish red. Tuff contains 1 to 3 percent alkali feldspar phenocrysts. Maximum thickness 248 ft, north of Beulah Reservoir (T. 18 S., R. 37 E.), thins south and eastward. Equivalent in age to part of unit Tba.

Trd *Rhyodacite.*—Light to dark gray, pale red, and reddish brown, commonly streaked, mottled, or banded. Mostly aphanitic; commonly contains less than 1 percent phenocrysts of one or more of the following: plagioclase, alkali feldspar, quartz, augite, hypersthene, hornblende, biotite. Groundmass commonly alkali feldspar, plagioclase, cristobalite, and glass. Vitrophyres commonly associated, including perlite near Buchanan (T. 23 S., R. 33½-34 E.). Underlies basalt and andesite of unit Tba. Most occurrences are exogenous domes. Maximum thickness about 2,000 ft on Duck Butte. Equivalent to rocks mapped as Littlefield Rhyolite near Crowley by Kittleman and others (1967).

Tsv *Sedimentary and silicic volcanic rocks.*—Rhyodacite or dacite and andesite flows and intrusive rocks, tuffaceous sedimentary rocks, and ash-flow tuffs. Present north of Calamity Butte (T. 18 S., R. 32 E.). Mapped as Strawberry Volcanics in adjacent area to north (Brown and Thayer, 1966), equivalent in age to part of unit Tba.

Jlt *Lonesome and Trowbridge Formations of Lupher (1941).*—Upper part (Lonesome) is interbedded volcanic sandstone and mudstone. Sandstone is medium gray, fine to coarse grained and pebbly, commonly in graded beds; composed mostly of plagioclase grains and volcanic rock fragments. Mudstone is dark gray and massive. Lower part (Trowbridge) is dark-gray, massive to faintly laminated mudstone. Poorly fossiliferous but yields diagnostic ammonites. Age, Callovian (Late Jurassic) (Dickinson and Vigrass, 1965, p. 67; Bateman, 1961, p. 28). May include unrec-

ognized Snowshoe Formation of Dickinson and Vigrass (1965).

Jsv *Sedimentary and volcanic rocks.*—Sandstone, siltstone, shale, and porphyritic andesite. Present south of Allison Guard Station (T. 19 S., R. 26 E.). Age uncertain.

Jsn *Middle member of Snowshoe Formation of Dickinson and Vigrass (1965).*—Approximate equivalent of Basey Member of Snowshoe Formation of Dickinson and Vigrass (1965). In T. 18 S., R. 27 E., and to the west and southwest, dominantly massive dark-gray volcanic sandstone, poorly sorted, composed mostly of plagioclase grains and rock fragments; interbedded, especially in upper part, are thin-bedded greenish-gray siltstone and mudstone and minor amounts of tuff and chert. Porphyritic basalt at base in parts of T. 18-19 S., R. 25 E. In T. 18-19 S., R. 30-31 E., the unit is fine- to medium-grained greenish-gray volcanic sandstone. In south part of T. 20 S., R. 28 E., it consists of gray volcanic sandstone, thin bedded, in part fine grained, in part coarse grained and poorly sorted. Sparsely fossiliferous but yields diagnostic ammonites. Age, Bajocian (Middle Jurassic) (Dickinson and Vigrass, 1965, p. 49, 57).

Jwsw *Warm Springs and Weberg Formations of Lupher (1941).*—Upper part (Warm Springs), dark-gray calcareous shale and mudstone with minor interbedded siltstone and limestone; lower part (Weberg), sandy limestone, calcareous sandstone, and pebble conglomerate. Mapped by Dickinson and Vigrass (1965) in part as Warm Springs and Weberg Members of the Snowshoe Formation, in part as lower member of the Snowshoe Formation. Abundant ammonites and pelecypods give a Bajocian (Middle Jurassic) age. (Dickinson and Vigrass, 1965, p. 52-54, table 9.)

Jwb *Basalt.*—At base of Weberg Formation.

Js *Sedimentary rocks.*—In T. 18 S., R. 26-27 E., Mowich Group of Dickinson and Vigrass (1965), including Robertson, Suplee, Nicely, and Hyde Formations: sandstones composed of plagioclase grains and volcanic-rock fragments; calcareous sandstone, black shale and mudstone, lenses of limestone, and basal pebble conglomerate. Abundant fossils, mostly ammonites and pelecypods. Age, Pliensbachian and Toarcian (Early Jurassic) (Dickinson and Vigrass, 1965, p. 36-43; Imlay, 1968, p. C8-C16). In T. 19 S., R. 25 E., thin-bedded argillaceous limestone, sandy siltstone, and tuffaceous sandstone. Contains ammonites establishing a Hettangian (Early Jurassic) age (Buddenhagen, 1967, p. 137). In northwest part of T. 20 S., R. 38 E., mostly siltstone and shale, some sandstone and conglomerate with basalt boulders, and minor amount of limestone. Ammonites give a Sinemurian (Early Jurassic) age (H. J. Buddenhagen, written commun., 1968). Mapped as the Donovan Formation by Lupher (1941, p. 235).

Trsv *Sedimentary and volcanic rocks.*—In T. 18 S., R. 26 E., and adjacent part of Rs. 25 and 27 E., Begg and Brisbois Formations of Dickinson and Vigrass (1965). Upper part (Brisbois), dark-gray thin-bedded shale and siltstone, with minor interbedded sandy limestone, calcareous sandstone, and limestone boulder conglomerate; lower part (Begg), mostly greenish-black to black shale and siltstone, with interbedded calcareous and coarse volcanic sandstones, conglomerates, and minor keratophyre flows. Diagnostic ammonite collections in secs. 29 and 32, T. 17 S., R. 26 E., north of the map area. Age, Karnian (Late Triassic) (Dickinson and Vigrass, 1965, p. 26-27). In north part of T. 19 S., R. 25 E., and adjacent part of T. 18 S., R. 25 E., upper part is black shale and mudstone, lower part is mostly massive coarse argillaceous sandstone, in part containing angular chert and siltstone fragments and limestone pebbles. In T. 18 S., R. 24 E., and adjacent R. 25 E., mostly coarse argillaceous sandstone with angular chert fragments, some fine- to medium-grained sandstone and siltstone, minor amount of conglomerate without limestone clasts (H. J. Buddenhagen, written commun., 1968).

TrPs *Sedimentary rocks.*—Thinly interbedded fine-grained sandstone, siltstone, siliceous shale, bedded chert, sandstone with chert fragments, and sandstone composed of volcanic detritus. Overlies Permian beds; contains blocks of limestone with Permian fossils which may have been transported (H. J. Buddenhagen, written commun., 1968).

TrPv *Volcanic rocks.*—Dacite and andesite, massive, aphanitic.

PDs *Sedimentary rocks.*—Includes fossiliferous beds of Permian, Pennsylvanian, Mississippian, and Devonian age. Permian rocks are gray limestones, thin bedded and lenticular, interbedded with chert, siliceous shale, and sandstone. Limestones contain brachiopods, crinoids, bryozoans, and diagnostic fusulinids. Pennsylvanian rocks are predominantly fine- to medium-grained feldspathic sandstone, conglomeratic sandstone, and conglomerate with boulders of plutonic and volcanic rocks; greenish mudstone in upper part. Contains fossil plants. Mississippian rocks are limestone and calcareous shale with fossils, also unfossiliferous sandstone, siltstone, and black limestone. Devonian rocks in one occurrence only, NW¼NW¼ sec. 30, T. 19 S., R. 25 E.—limestone, light-brown, massive, contains corals, stromatoporoids, and brachiopods (H. J. Buddenhagen, written commun., 1968; Kleweno and Jeffords, 1961).

REFERENCES

Baksi, A. K., York, D., Watkins, N. D., 1967, Age of Steens Mountain geomagnetic polarity transition: Jour. Geophys. Research, v. 72, p. 6299-6308.

Bateman, Richard L., 1961, The geology of the south-central part of the Sawtooth Creek quadrangle, Oregon: Oregon Univ., Eugene, M.S. thesis, 97 p.

Beeson, M. H., 1962, The geology of the north-central part of the Sawtooth Creek quadrangle, Oregon: Oregon Univ., Eugene, M.S. thesis, 89 p.

Bowen, R. G., 1956, Geology of the Beulah area, Malheur County, Oregon: Oregon Univ., Eugene, M.S. thesis, 152 p.

Brown, C. E., and Thayer, T. P., 1966, Geologic map of the Canyon City quadrangle, northeastern Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I-447, scale 1:250,000.

Buddenhagen, H. J., 1967, Structure and orogenic history of the southwestern part of the John Day Uplift, Oregon: Ore Bin, v. 29, no. 7, p. 129-138.

Corcoran, R. E., Doak, R. A., Porter, P. W., Pritchett, F. I., Jr., and Privrasky, N. C., 1962, Geology of the Mitchell Butte quadrangle, Oregon: Oregon Dept. Geology and Mineral Industries Geol. Map Ser. GMS 2, scale 1 in. to 2 miles.

Dickinson, W. R., 1958, Geology of the Izee area, Grant County Oregon: Stanford Univ., Stanford, Calif., Ph. D. thesis, 360 p.

Dickinson, W. R., and Vigrass, L. W., 1965, Geology of the Suplee-Izee area, Crook, Grant, and Harney Counties, Oregon: Oregon Dept. Geology and Mineral Industries Bull. 58, 109 p.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Amer. Jour. Sci., v. 262, no. 2, p. 145–198.

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

Gray, W. L., 1956, The geology of the Drinking Water Pass area, Harney and Malheur Counties, Oregon: Oregon Univ., Eugene, M.S. thesis, 86 p.

Gregory, C. D., 1962, The geology of the Stinkingwater Creek area, Harney County, Oregon: Oregon Univ., Eugene, M.S. thesis, 59 p.

Haddock, G. H., 1967, The Dinner Creek welded ash-flow tuff of the Malheur Gorge area, Malheur County, Oregon: Oregon Univ., Eugene, Ph. D. thesis, 111 p.

Imlay, R. W., 1968, Lower Jurassic (Pliensbachian and Toarcian) ammonites from eastern Oregon and California: U.S. Geol. Survey Prof. Paper 593-C, p. C1-C48.

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: Oregon Univ. Mus. Nat. History Bull. 8, scale 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 Owhyee region, southeastern Oregon: Oregon Univ. Mus. Nat. History Bull. 1, 45 p.

Kleweno, W. P., and Jeffords, R. M., 1961, Devonian rocks in the Suplee area of central Oregon [abs.]: Geol. Soc. America Spec. Paper 68, p. 34.

Lupher, R. L., 1941, Jurassic stratigraphy of central Oregon: Geol. Soc. America Bull., v. 52, no. 2, p. 219–269.

Malde, H. E., and Powers, H. A., 1962, Upper Cenozoic stratigraphy of western Snake River Plain, Idaho: Geol. Soc. America Bull., v. 73, no. 10, p. 1197–1219.

Merriam, C. W., and Berthiaume, S. A., 1943, Late Paleozoic formations of central Oregon: Geol. Soc. America Bull., v. 54, no. 2, p. 145–171.

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

Peterson, N. V., and Groh, E. A., 1964, Diamond Craters, Oregon: Ore Bin, v. 26, no. 2, p. 17–34.

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

Shotwell, J. A., 1963, The Juntura Basin—Studies in earth history and Paleoecology: Am. Philos. Soc. Trans., v. 53, pt. 1, 77 p.

Swanson, D. A., 1970, Reconnaissance geologic map of the east half of the Bend quadrangle, Crook, Wheeler, Jefferson, Wasco, and Deschutes Counties, Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I-568, scale 1:250,000.

Vigrass, L. W., 1961, Geology of the Suplee area, Crook, Grant, and Harney Counties, Oregon: Stanford Univ., Stanford, Calif., Ph. D. thesis.

Walker, G. W., 1963, Reconnaissance geologic map of the eastern half of the Klamath Falls (AMS) quadrangle, Lake and Klamath Counties, Oregon: U.S. Geol. Survey Mineral Inv. Field Studies Map MF-260, scale 1:250,000.

———1969, Possible fissure vent for a Pliocene ash-flow tuff, Buzzard Creek area, Harney County, Oregon, *in* Geological Survey research, 1969: U.S. Geol. Survey Prof. Paper 650-C, p. C8-C17.

Walker, G. W., Peterson, N. V., and Greene, R. C., 1967, Reconnaissance geologic map of the east half of the Crescent quadrangle, Lake, Deschutes, and Crook Counties, Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I-493, scale 1:250,000.

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

———1966, Reconnaissance geologic map of the west half of the Jordan Valley quadrangle, Malheur County, Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I-457, scale 1:250,000.

Walker, G. W., and Swanson, D. A., 1968, Summary report on the geology and mineral resources of the Harney Lake and Malheur Lake areas of the Malheur National Wildlife Refuge, north-central Harney County, Oregon: U.S. Geol. Survey Bull. 1260-L, p. L1-L17.