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

GEOLOGIC MAP OF THE CHALLIS 1°×2° QUADRANGLE, IDAHO

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Pamphlet to accompany
MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1819

CONTENTS

TABLES

EXPLANATION OF FORMAT

In this pamphlet, descriptions of rock units are arranged in the traditional manner (youngest to oldest) except for rocks of Tertiary age. Because of the large number of Tertiary units, the descriptions and correlation table (see map sheet) have been divided into seven sections on the basis of similarities in volcanotectonic history (see "Areal index to subdivisions of Tertiary rocks," on map sheet). Rock units that are present in more than one area are fully described for the area in which they are best known. Cross references between areas are provided. Within each area, the rocks are subdivided into intrusive and extrusive groups and described from youngest to oldest. An index to map units follows the list of references (p. 32).

Modal analyses are reported in abbreviated form: phenocryst abundance is reported as volume percent of rock sample ("phenocrysts (30)" means that 30 percent of the rock consists of phenocrysts); phenocryst mineral abundance is reported as percent of total phenocrysts. Names of minerals are abbreviated: q, quartz; af, alkali feldspar; pf, plagioclase feldspar; b, biotite; hb, hornblende; px, pyroxene; cpx, clinopyroxene; opx, orthopyroxene; ol, olivine; op, opaque oxides.

Wherever it was necessary to use place names in the description of map units, we have provided geographic coordinates to the nearest minute, shown with latitude first and longitude following. These should enable the reader to locate the feature, map unit, or structure in question. In many cases the named location does not appear on the base map due to lack of space. Such locations are, generally, named on topographic quadrangles of larger scale.

A number of dating methods have been used in the Challis quadrangle. Potassium-argon and ^{40}Ar–^{39}Ar ages are listed in tables 1, 2, and 3 and cited where appropriate in the description of map units. The correlation of Tertiary units shows our best estimates of the ages of Tertiary rocks; these estimates are based on stratigraphic relations, selected radiometric ages, and limited magnetic polarity data. Where the radiometric age falls outside the time span shown on the correlation, it is our opinion that other data are more compelling than the radiometric age.

DESCRIPTION OF MAP UNITS

QUATERNARY SURFICIAL DEPOSITS

Qd **Quaternary deposits, undivided (Holocene and Pleistocene)**—Includes modern stream alluvium, terrace gravel, talus and related slope material, landslide debris, and unconsolidated glacial moraines and outwash gravel

Qa **Alluvium, undivided (Holocene)**—Floodplain, terrace, and alluvial-fan deposits that include stream-deposited gravel, sand, and silt. Gravel and peat are in filled ponds and lakes

Qf **Alluvial-fan deposits (Holocene)**—Shown separately only in area near Challis and Antelope Flat (44°18′ N., 114°04′ W.), 30 km north of southeast corner of quadrangle

Ql **Landslide and related deposits (Holocene)**

Qm **Glacial deposits, undivided (Pleistocene)**—Unsorted boulders, cobbles, pebbles, sand, silt, and clay in moraines and in glaciofluvial outwash. Belt of coalescent moraines along eastern front of Sawtooth Range has been attributed to two major late Pleistocene glaciations, the Bull Lake and the Pinedale (Williams, 1961)

Qtr **Travertine (Pleistocene)**—Yellowish-white to cream-colored, irregularly thin- to medium-bedded, locally finely banded deposits of travertine showing varying degrees of irregular cellular and concentric texture with local cavities and encrustations. Layering in most of the deposit is nearly horizontal. Many exposures at eastern margin have steeply inclined layering; some of these clearly are of slumped blocks; others could be of undisturbed travertine deposited on steep slopes. Thought to once have covered about 2.5 km^2 on southwest side of Bradbury Flat (44°26′ N., 114°10′ W.). Probably related to presently extinct hot springs that issued from faults in underlying Paleozoic carbonate strata. Estimated thickness 100 m

MIOCENE VOLCANIC AND SEDIMENTARY ROCKS

Tcb **Columbia River Basalt Group (Miocene)**—Dark-gray to black, fine-grained ophitic basalt; consists chiefly of plagioclase laths embedded in augite, and scattered crystals of magnetite. Exposures include small cap on ridge immediately west of Grimes Pass (44°01′ N., 115°49.8′ W.) and small outcrops west of Paddy Flat (44°45′ N., 115°59′ W.), near northwest corner of quadrangle

Tpa **Payette Formation (Miocene)**—Stratified, tan to gray, loosely consolidated arkosic sandstone and siltstone and interstratified conglomerate and thin-bedded, dark-gray to black shale in which are abundant impressions of upper middle to lower upper Miocene leaves (W. C. Rember, written commun., 1983). Formation also contains seams of low-rank coal as much as 30 cm thick, bedded intervals several meters thick of light-gray to white diatomaceous earth, and beds of gray volcanic ash as much as 30 cm thick. Formation crops out along west side of Middle Fork of Payette River northwest of Crouch (44°07′ N., 115°58′ W.). It was deposited in an intermontane basin and is now part of a west-tilted, down-faulted block. Minimum thickness 1,680 m; base not exposed

EOCENE CHALLIS VOLCANIC GROUP; SEDIMENTARY AND IGNEOUS ROCKS

The Challis Volcanic Group is here raised in stratigraphic rank to replace the formation name "Challis Volcanics" (Ross, 1937) in this map area. The Challis Volcanic Group contains a large number of informal map units, many of which may be defined as formations in the future. The latite-andesite member and the Germer Tuffaceous Member of Ross (1937) are herein abandoned because these terms have fallen into disuse and they do not adequately describe the stratigraphic relations as currently understood. The term "Yankee Fork Rhyolite Member" was abandoned by Foster in 1982.

Thunder Mountain cauldron complex and environs

Intrusive rocks

Trd **Rhyolite dikes**—These small rhyolite intrusions have potassium-argon ages of 39.8±0.9, 41.1±0.9, 42.4±1.5, and 45.2±1.5 m.y. (see table 1). For description, see p. 19

Tqp **Quartz porphyry intrusions**—For description, see p. 4

Tr **Rhyolite intrusions**—Sanidine from a sample taken from Monumental Creek (44°56′ N., 115°12′ W.) was dated by potassium-argon methods at 44.6±1.5 (see table 1). For description, see p. 4

Tmi **Mafic intrusions**—For description, see p. 5

Granitic rocks of Casto pluton

Tg **Granite**—For description, see p. 5

Thg **Hornblende granite**—For description, see p. 5

Tgp **Gray porphyry**—Gray dacite porphyry and minor diorite porphyry. Consists of both extrusive and intrusive rock. These rocks mostly have a dense or cryptocrystalline groundmass but, locally, have a holocrystalline, fine-grained groundmass (diorite porphyry). Phenocrysts of plagioclase generally are conspicuous and, in Indian Creek area (44°48′ N., 115°13′ W.), commonly are 2–3 mm long. Quartz is sparse. Mafic minerals consist of varying proportions of biotite, hornblende, and pyroxene. Phenocryst content varies from about 20 to 50 percent. In places, dacitic rocks clearly intrude lapilli tuff (Tdq) and possibly younger tuff units as well. In other places, rocks appear to be stratiform, having flow layering that defines gentle dips and containing interlayered zones of flow breccia characteristic of contact zones between lava flows. As mapped, therefore, this unit in some places includes dacite lava that is correlative with the lower latite lava (Tll) and in other places includes dikes and irregularly shaped intrusives that probably are younger than lapilli tuff (Tdq). Also correlates in part with dacite and diorite porphyry (Tdc) mapped in western part of quadrangle (see p. 20). For additional description, see p. 5 and 10

Extrusive and sedimentary rocks

Tla **Latite of Lookout Mountain**—Black, nearly aphyric, vesicular lava interbedded with cinders and bombs. Rock locally contains sparse small (0.5 mm long) phenocrysts of plagioclase and small prisms (as long as 1.0 mm) of hypersthene set in groundmass of randomly oriented plagioclase microlites and glass. Leonard and Marvin (1982) report whole-rock potassium-argon ages of 41.0±1.4 m.y. and 43.4±1.4 m.y. for two samples collected just north of Challis quadrangle. Thickness 0–50 m

Tds **Beds of Dewey mine**—Cauldron-filling sedimentary rocks and bedded, reworked ash-fall tuff. Includes siltstone in varved lake beds and coarse volcaniclastic conglomerate containing intercalated landslide debris and talus; carbonaceous in part. Thickness 0–50 m

Tss **Sunnyside tuff of Shannon and Reynolds (1975)**—An informal term used by Shannon and Reynolds (1975) in the Thunder Mountain mining district and now used throughout the Thunder Mountain cauldron complex.

Potassium-argon ages of biotite from one sample and sanidine from two samples are 47.7±1.6, 46.3±1.1, and 46.3±1.0 m.y. (see table 1)

Tsu **Upper tuff**—Red- and red-brown-weathering, densely welded, devitrified rhyolite tuff; multiple-flow compound cooling unit that contains numerous small volcanic rock fragments and well-flattened pumice lapilli throughout. Base is marked by a black vitrophyre 3–10 m thick that is rich in lithic fragments. Extremely sparse biotite flakes are only visible mafic minerals in devitrified rock; pyroxene and hornblende are only visible mafic minerals in vitrophyre. Phenocrysts (12–31): q, 20–60; af, 40–80; b, 0–1; hb, trace (as many as four grains per thin section in basal vitrophyre only); cpx, trace (as many as eight grains pigeonite per thin section in basal vitrophyre only). Allanite is common accessory in basal vitrophyre only. Thickness 0–300 m

Tmx **Megabreccia**—Varicolored breccia consisting of fragments of lower tuff (Tsl, see below), a few centimeters to several meters in diameter, in a matrix of upper tuff (Tsu). The fragments probably slid into caldera from outer rims during initial eruptions of upper tuff. Possibly, rock is a coarse-fragment, lithic-rich, early cooling unit of upper tuff. Thickness 0–100 m

Tslu **Uppermost tuff that has mineralogy of lower tuff**—Reddish-gray, simple cooling unit of densely welded rhyolite tuff. Distinguished from upper tuff (Tsu) by more abundant plagioclase and biotite; separated from upper tuff by few meters of bedded tuff (not shown on map). These rocks are mineralogically similar to lower tuff (Tsl) but are separated from it by rhyolitic lava (Tsrl). Phenocrysts (26): q, 40; af, 44; pf, 12; b, 3; altered mafic, 1. Thickness 0–40 m

Tsrl **Rhyolite lava or tuff**—Red flow-layered lava or extremely hot ash-flow tuff; presence of several zones of black vitrophyre within rhyolite suggests presence of two or more cooling units; east of Marble Creek (44°50′ N., 114°59′ W.) a thin flow of black vesicular latite is intercalated within unit. Although rock in all places looks very similar, containing 5–10 percent phenocrysts (0.5–5 mm in length), rock east of Marble Creek contains more plagioclase than alkali feldspar, and rock exposed north of Dynamite Creek (44°53′ N., 114°05′ W.) contains more alkali feldspar than plagioclase. Thickness 0 to more than 100 m

Tsl **Lower tuff**—At least three cooling units, each of which grades upward from white to pink, nonwelded to slightly welded rhyolite at base to gray, densely welded quartz latite at top. Upper and middle cooling units commonly display vertical sheeting or jointing and contain very little recognizable pumice, whereas lower unit contains abundant pumice. Upper unit along Marble Creek (44°50′ N., 114°59′ W.) contains 28–49 percent phenocrysts: q, 9–45; af, 32–51; pf, 16–33; b, 2–11; hb, 0–3; zircon, trace. Middle unit along Little Cottonwood Creek (44°55′ N., 115°03′ W.) contains 15–34 percent phenocrysts: q, 26–51; af, 23–39; pf, 2–26; b, 4–13; hb, trace. Quartz latite upper part of this cooling unit contains sanidine phenocrysts as long as 8 mm. Lower cooling unit, same location, contains 18–28 percent phenocrysts: q, 6–51; af, 11–38; pf, 12–62; b, 9–21 (in books); zircon, trace. Phenocrysts in lower parts of all three cooling units rarely exceed 2 mm in length. Cauldron-wide hydrothermal alteration (mostly propylitization) has led to albitic replacement of sanidine. Thickness 0–500 m

Tbr **Buff rhyolite**—Buff rhyolite, in contrast to lapilli tuff (Tdq, see below), is nearly aphyric, containing only about 1 percent phenocrysts consisting of plagioclase (0.5–1.5 mm in length), traces of biotite, and an altered prismatic mafic mineral. Rhyolite is flow laminated and layered; either it is an unusually widespread lava or it originated as an extremely hot ash-flow tuff that has not retained any identifiable fragmental or pyroclastic textures. Mapped in northwestern part of cauldron complex, where it presumably occupies same stratigraphic position as lapilli tuff. Thickness 0 to more than 300 m

Tpl **Perlitic rhyolite**—Three rhyolite cooling units separated by green epiclastic sediments. All units have black vitrophyre at base and grade upward to devitrified, lavender to salmon, flow-layered lava or high-temperature, densely welded tuff. Upper cooling unit is ash-flow tuff having nonwelded top. Upper unit vitrophyre in headwaters of Rush Creek (44°56.5′ N., 115°00′ W.) contains 14 percent phenocrysts: pf, 82; af, 11; hb, 7; cpx, trace. Lower unit, same location, contains

3–5 percent phenocrysts: pf, 31–76; af, 24–69; hb, 0–2; cpx, trace. Phenocrysts rarely exceed 2 mm in length. Thickness 0 to more than 300 m

Tdq **Dime- and quarter-size lapilli tuff**—A complex sequence of ash-flow tuff, commonly separated by beds of tuffaceous sandstone and siltstone, and locally by thin black latite lava. Eruption of these tuff units caused initial collapse of Thunder Mountain cauldron complex. They are Thunder Mountain analog of tuffs of Camas Creek-Black Mountain (Tc, see p. 6) in Van Horn Peak cauldron complex. Most are densely welded and contain collapsed pumice lapilli that in plan view are about the size of dimes and quarters; locally larger. Lapilli are mostly dark green or brownish green and contrast with lighter colored green-gray or buff matrix. Tuffs are pervasively propylitized and mafic minerals are altered to chlorite, calcite, and iron oxide. In contrast to overlying tuff (Tsl), lapilli tuff (Tdq) is chiefly pyroxene-bearing. In a specimen from Indian Creek (44°50′ N., 115°15′ W.), pyroxene is principally clinopyroxene. Phenocrysts generally less abundant and smaller than those in lower tuff of Sunnyside (Tsl), and most tuffs are quartz poor. Phenocrysts (9–16): q, trace–5; af, 2–8; pf, 70–83; b, trace–2; hb, 0–4; cpx (mostly altered), trace–16. Some crystal-poor, quartz-free, flow-layered tuffs near head of Prospect Creek (44°48′ N., 114°55′ W.), east of Marble Creek, contain more alkali feldspar than plagioclase. Similar tuffs occur west of Shellrock Peak (44°57′ N., 114°57′ W.) just below perlitic rhyolite (Tpl). Thickness 0 to more than 500 m

Tdql **Lower densely welded tuff**—Quartz-rich, gray tuff within lower latite lava (Tll, see below) that closely resembles lower tuff of Sunnyside (Tsl). Phenocrysts (23–30): q, 27–35; af, 20-26; pf, 34–38; b, 1–3; hb, trace–1; altered mafic mineral, 2–11. Thickness 0 to more than 30 m

Tll **Lower latite lava**—Mostly dark-gray and dark-purplish-gray, flow-layered lava consisting both of crystal-poor flows that probably are about same composition as much younger latite of Lookout Mountain (Tla) and conspicuously porphyritic flows that probably are dacite or rhyodacite in composition. Porphyritic flows contain 30–40 percent phenocrysts of plagioclase as long as 6 mm and abundant mafic minerals, consisting of varying proportions of biotite, hornblende, and pyroxene. Potassium-argon ages reported by Leonard and Marvin (1982) suggest an age range of 48–50 m.y. for this sequence—virtually the same as reported for older intermediate lava (Tdf) exposed farther east and southeast (McIntyre and others, 1982). Sanidine yielded an age of 50.8±1.7 m.y. (see table 1). Thickness 0 to more than 500 m

Tcv **Challis Volcanic Group, undivided**—Thickness 0 to more than 50 m

Northern part of Van Horn Peak cauldron complex and Panther Creek graben

Intrusive rocks

Tqp **Quartz porphyry intrusions**—Dikes and plugs of pink porphyry that varies greatly in size of phenocrysts and texture of groundmass; typically contains smoky quartz phenocrysts as much as 3–4 mm long, tabular alkali feldspar and sparse plagioclase phenocrysts as much as 6–8 mm long, and sparse flakes and books of biotite as much as 3 mm long, in dense micrographic groundmass of quartz and alkali feldspar; commonly, however, has microgranular or cryptocrystalline groundmass. Locally contains extremely large phenocrysts of resorbed quartz in bipyramids as much as 1 cm long and alkali feldspar and plagioclase phenocrysts as much as 3 cm long in graphic groundmass. Single large sanidine crystal 3 cm long from dike east of Yellowjacket Creek (44°59′ N., 114°24′ W.) yielded a potassium-argon age of 44.4±1.0 m.y. (see table 1). The quartz porphyry is described as pink granophyre by Ross (1934). Some dikes contain rhyolite without quartz phenocrysts; in places these quartz-poor dikes were included with lapilli tuff (Tdq), in other places with rhyolite intrusions (Tr, see below). Phenocrysts (19–35): q, 15–58; af, 37–83; pf, 0–12; b, trace–4

Tr **Rhyolite intrusions**—Dikes and plugs of mostly light-gray, dense, phenocryst-poor rhyolite; locally contains conspicuous phenocrysts of sanidine as long as 8 mm and sparse phenocrysts of quartz, as at Red Rock Peak, along northern border of Challis quadrangle at long 114°25°30′ W. Rock at Red Rock Peak grades into, and forms composite bodies with, quartz porphyry intrusions (Tqp). Sanidine from Red Rock Peak yielded potassium-argon age of 44.6±1.5 m.y. (see table 1)

Tmi **Mafic intrusions**—Dikes and plugs of basaltic composition similar to or same as basaltic lava (Tb, see below). Includes mafic to intermediate rocks, near Van Horn Peak and elsewhere, that are conspicuously porphyritic, containing phenocrysts of pyroxene (hypersthene, pigeonite, or both) and plagioclase as long as 5 mm; locally contains sparse biotite and hornblende

Tvp **Tuff of Van Horn Peak**—Vent-filling tuff exposed about 10 km south of Black Mountain consisting of a discontinuous outer rim as much as 50 m wide of light-gray tuff that is virtually identical to basal part of tuffs of Camas Creek-Black Mountain (Tc, see p. 7), and a core, 1 km or more in diameter, of tuff that appears identical to tuff of Table Mountain (Ttm, see p. 7)

Granitic rocks of Casto pluton

Tg **Granite**—Corresponds to "Casto pluton" of Ross (1934) and of Cater and others (1973). Mostly equigranular pink granite: q, 22–34 (0.2–5 mm long); af (perthitic cloudy orthoclase and microcline), 31–57 (0.5–10.0 mm long); pf, 18–33; b, 20–37; hb, 0–3.5; trace amounts of sphene and allanite. These rocks plot in granite field of both Johannsen (1948) and Streckeisen (1973). Also includes light-gray rocks that are distinctly richer in plagioclase and fall in quartz monzonite field of Johannsen (1948). Armstrong (1975) reports potassium-argon age on biotite of 43.9±1.3; Leonard and Marvin (1982) report potassium-argon age from the same locality, also on biotite, of 47.8±1.9 m.y. (see table 1). On Loon Creek (44°43′ N., 114°48′ W.), biotite from the granite has a potassium-argon age of 45.1±1.6 m.y. (see table 1). Biotite from fine-grained, light-gray rock exposed near Grouse Lake (44°50′ N., 114°41′ W.) has a potassium-argon age of 46.6±1.6 m.y. (see table 1)

Thg **Hornblende granite**—Corresponds to hornblende granite of Ross (1934). Mostly buff to pink, medium-grained hornblende granite (Johannsen, 1948); however, one sample from Marble Creek (44°48′ N., 114°58′ W.) and one from Loon Creek (44°44′ N., 114°49′ W.) are quartz syenite (Streckeisen, 1973). A sample from just south of Woodtick Summit (44°47′ N., 114°41′ W.) contained less quartz and alkali feldspar and is quartz monzonite according to both classifications. Rock in all three places tends to weather rusty. Composition of samples from Woodtick Summit area, Loon Creek, and Marble Creek, respectively: q, 8.3, 9.3, 13.4; af (mostly cloudy orthoclase), 39.7, 54.9, 57.4; pf, 36.7, 20.1, 12.1; b, 2.2, 0.6, 1.3; hb, 13.1, 12.5, 15.1. Loon Creek and Marble Creek samples each contained several grains of allanite

Tgp **Gray porphyry**—A mixed sequence of gray and green-gray extrusive and intrusive rocks of intermediate composition; most are dacite porphyry that locally displays flow layering, flow brecciation, and dense to glassy groundmass indicating they are lavas. In places, porphyry is massive, has crystalline groundmass, and locally exhibits intrusive contacts with country rock as young as basal part of tuffs of Camas Creek-Black Mountain (Tc, see p. 7). Therefore, this unit, as mapped, probably includes intermediate lava as old as 51 m.y. and younger dikes and irregularly shaped intrusive masses 48 m.y. old or younger. Phenocrysts (30–45): q, 0 (in most rocks) to 5; af, 0; pf, 60–75; b, 1–12; hb, trace–25; px (mostly altered but in places includes both fresh opx and cpx), trace–20. Contacts are gradational over short distances from hornblende- and biotite-rich varieties to pyroxene-rich varieties. Thickness 0 to more than 500 m. For additional description, see p. 2 and 10

Tdi **Dikes and plugs of intermediate composition**—Not shown separately in this area. For description, see p. 10

Extrusive and sedimentary rocks

Toc **Colluvium of Panther Creek**—Poorly consolidated sandstone, mudstone, boulder conglomerate, and tephra; locally carbonaceous; includes large landslide masses of diverse volcanic rocks. Deposited during subsidence of Panther Creek graben after extrusion of younger part of monolith-forming tuff (Tmt). Some subsidence of graben may have been due to magma withdrawal, but most was probably due to regional rifting concurrent with volcanism. This incompetent sequence of rocks is easily eroded, and landslides are common

Tuff of Castle Rock and related rocks—These rocks are intercalated in Panther Creek graben. The monolith-forming tuff (Tmt), tuff of Castle Rock (Tck), and quartz-biotite tuff (Tqb) were erupted from Castle Rock cauldron segment. Flow-layered rhyolite (Tfl) and basaltic lava (Tb) were derived from unknown sources outside Castle Rock cauldron segment. Strata preserved within Castle Rock half-moon, or trapdoor, cauldron are mostly densely welded. Outside cauldron the only densely welded cooling unit forms cliffs and is mapped as tuff of Castle Rock (Tck)

Tmt **Monolith-forming tuff**—Varicolored, nonwelded to partly welded ash-flow and ash-fall rhyolite tuff. Sequence overlies and underlies a single genetically related, densely welded cooling unit of tuff of Castle Rock (Tck) having identical phenocryst mineralogy. Lower part of monolith-forming tuff locally includes unrelated soft, bedded tuff containing abundant biotite; includes several zones rich in small, variegated volcanic lithic fragments. Rock above and below tuff of Castle Rock (Tck) weathers to tepee-shaped hoodoos and other variously shaped monoliths. Unit typically contains vitric, silky pumice lapilli and fresh black glass shards, but zeolitized and otherwise altered in many places. Phenocrysts (15–25): q, 33-50; af, 50–60; pf, 0–3; b, 0–1; hb, 0-trace; px (mostly pseudomorphs), 0–3; commonly contains smoky quartz and chatoyant alkali feldspar. Thickness 0–300 m

Tck **Tuff of Castle Rock**—Within cauldron includes five cooling units of reddish ash-flow tuff and thin interbeds of ash-fall tuff. Upper cooling unit is densely welded and about 228 m thick. Beneath upper unit are, successively, two thin, partly welded, lithic-rich cooling units, each about 30 m thick; a cliff-forming, moderately welded cooling unit about 150 m thick; and a lowermost slope-forming, partly welded cooling unit rich in lithic fragments, about 190 m thick. Densely welded upper unit is inferred to correlate with densely welded part of outflow unit (Tmt). If this is the case, soft tuff preserved above densely welded unit in Panther Creek graben has been stripped away at Castle Rock (44°49′ N., 114°25′ W.). Phenocrysts, upper cliff-former (28): q, 47; af, 50; pf, 0.7; b, 0.3–0.7; altered cpx, 0.7 (base) to 2.9 (top). Phenocrysts in lower cliff-former show considerable variation from base to top: q, 15 (base) to 45 (top); af, 78 (base) to 49 (top); pf, 3.8 (base) to 4.1 (top); b, trace (base) to 1.0 (top); hb, trace; cpx, 3.1 (base) to 1.4 (top). Same minerals are present in thin cooling units between cliff-formers and in thick, moderately welded lower unit. Quartz is slightly smoky throughout sequence, and all units contain zones of chatoyant alkali feldspar. Total thickness 620 m

Tfl **Flow-layered rhyolite**—Probably at least two cooling units of reddish flow-laminated and layered rhyolite lava or remobilized tuff; had a source outside Castle Rock cauldron but is intercalated with tuff of Castle Rock (Tck) within Panther Creek graben. Phenocrysts (8–11): q, 0–3; af, 80–95; pf, 0–5; b, 0–trace; altered px, 2–12

Tb **Basaltic lava**—Black and brownish-gray lava that probably ranges in composition from potassium-rich basalt to trachyandesite or latite; vesicular to dense; contains scattered small (0.5–2 mm long) phenocrysts of pyroxene and plagioclase in pilotaxitic groundmass composed of plagioclase laths, pyroxene, and glass; locally contains small altered olivine phenocrysts and commonly contains xenocrysts of quartz that have reaction rims composed of tiny pyroxene prisms and glass. Unit is intercalated with rocks as young as basal tuff of Castle Rock (Tck) and with rocks as old as tuff of Ellis Creek (Te, see p. 8). Thickness 0–50 m

Tqb **Quartz-biotite tuff**—Light-green-gray and reddish-gray, locally flow-layered, densely welded ash-flow tuff erupted during collapse of Castle Rock cauldron segment (see table 4). Consists of at least two cooling units. Locally, unit in Panther Creek graben is flow laminated and layered from base to top; these characteristics indicate that hot ash flows there coalesced to liquids before coming to rest. Elsewhere, especially on slopes south of West Fork of Camas Creek (44°47′ N., 114°35′ W.), rock is only locally flow layered and displays zones containing abundant brown-green pumice lapilli that are darker than light-gray or light-greenish-gray enclosing matrix. Abundance and relative proportions of phenocrysts vary greatly. Phenocrysts (20–35): q, 19–50; af, 25–45; pf, 15–40; b, 2–20; hb, trace–5; px, trace. Some quartz phenocrysts in this unit show a peculiar tendency to be biaxial, even where they are not obviously strained. They tend to be smoky and nearly everywhere are incipiently to strongly resorbed. Allanite is a common accessory mineral. Thickness 0–300 m

Tap **Alkali feldspar-plagioclase tuff**—Light-greenish gray and reddish-gray tuff, commonly altered to yellow and various pastel shades; flow-layered and laminated, densely welded, locally containing recognizable well-flattened pumice lapilli. Ash flows in this unit coalesced to liquids before they stopped flowing. Named for sparse, but conspicuous, euhedral phenocrysts of water-clear, "plate glass" tabular alkali feldspar crystals as long as 5–6 mm and altered and inconspicuous euhedral plagioclase crystals as long as 5–6 mm. Spherulitic in several localities; unit has an altered perlitic basal vitrophyre. Phenocrysts (6–10): af, 30–40 (locally as much as 50); pf, 45–66; altered mafic mineral (probably pyroxene), 2–8. Unit is intruded by dense rhyolite at Singheiser (44°51′ N., 114°24′ W.) and Rabbit Foot (44°53′ N., 114°20′ W.) mines and is weakly mineralized. Thickness 0–300 m

Tdt **Dirty tuff**—Three thin, vitric cooling units of densely welded ash-flow tuff rich in lithic fragments. Recognized only in Panther Creek graben. Locally flow laminated and devitrified; typically having vitric gray matrices and well-flattened black, glassy pumice fragments as long as 15 cm; locally called "tiger rock." These units are crystal-poor, plagioclase-bearing tuff that most closely resembles some of the crystal-poor plagioclase tuff in dime- and quarter-size lapilli tuff (Tdq) exposed near Shellrock Peak (44°57.5′ N., 114°56′ W.). Thus, these three units presumably are distal ends of very hot ash flows erupted from Thunder Mountain cauldron complex to west, although their counterparts there have not been positively correlated. Phenocrysts (2–9): af, 0–6; pf, 75–98 (0.4–2 mm long, extensively resorbed); b, 0-trace; hb, 0-trace; opx, trace-19. Thickness 0–150 m

Tuffs of Camas Creek–Black Mountain and related rocks

Tc **Tuffs of Camas Creek–Black Mountain**—A cauldron-filling sequence of mostly very densely welded ash-flow tuff consisting of 10 or more separate cooling units that all are characterized by small phenocrysts (about 2 mm long) that in upper part of sequence consist of plagioclase and fairly abundant mafic minerals, in middle part consist of plagioclase and sparse to moderate amounts of alkali feldspar, and in lower part consist of plagioclase and sparse alkali feldspar and quartz. Entire sequence contains abundant mafic minerals consisting mostly of altered pyroxene, and includes variable amounts of biotite and sparse hornblende. Lower part of sequence has more biotite and hornblende than pyroxene. Assemblage is similar to tuff of Eightmile Creek (Tem, see below) although phenocrysts make up a greater proportion of tuff of Eightmile Creek. Phenocrysts in upper cooling unit (11–40): q, 0–trace; af, 0–trace; pf, 67–75; b, trace–13; altered hb, 0–trace; altered pyroxene, 10–20. Phenocrysts in middle cooling unit (5–25): q, 0–trace; af, trace–20; pf, 65–77; altered b, trace–9; altered hb, trace–3; altered px, 3–10. Phenocrysts in lower cooling unit (3–15): q, 2–12; af, 2–8; pf, 60–75; altered b, 2–10; altered hb, trace–3; altered px, trace–10. Sequence appears to have been almost entirely confined to cauldron complex formed principally as result of eruption of tuff of Ellis Creek (Te, see below). Only thin, partly welded ash-flow tuff and minor ash-fall tuff appear outside the complex. Outflow units are mapped with tuff of Pennal Gulch (Tp, see below). Thickness 0–3,000 m

Ttm **Tuff of Table Mountain**—Outflow equivalent of tuff of Van Horn Peak. For description, see p. 8

Tcs **Tuffs of Camas Creek–Black Mountain and bedded strata, undivided**—Thin ash-flow-tuff cooling unit of Camas Creek-Black Mountain lithology interbedded with thin-bedded ash-fall tuff of similar lithology and lacustrine tuffaceous siltstone, sandstone, and conglomerate. Thickness 0–100 m

Tp **Tuff of Pennal Gulch**—For description, see p. 13 and 16

Trb **Rhyolite of Red Butte**—For description, see p. 13

Tpq **Quartz-phenocryst perlite**—Pink and orange-gray, flow-laminated, hydrated rhyolite glass that has retained its perlitic texture despite deep weathering and alteration; mapped in all localities to include subjacent and superjacent horizontal beds of tuff and tuffaceous sandstone. Quartz is amethystine to smoky and as much as 4 mm long. Phenocrysts (21–33): q, 27–35; af, 9–31; pf, 19–47; b, 6–12; hb, 4–6.5; altered px, 2. Thickness 0–35 m

Tem **Tuff of Eightmile Creek**—Two or more cooling units of green-gray quartz latitic and rhyodacitic ash-flow tuff that together are more than 300 m thick near Sleeping Deer Mountain (44°46′ N., 114°41′ W.) within cauldron complex, but rarely exceed a few tens of meters each outside cauldron complex or Custer graben. Unit overlies tuff of Ellis Creek (Te), underlies the tuffs of Camas Creek-Black Mountain (Tc), and locally shares some characteristics of each unit. Included in tuff of Pennal Gulch (Tp) south of Table Mountain. Where densely welded and rich in phenocrysts, it is not easily distinguished from tuff of Ellis Creek; it differs only in containing significant amounts of alkali feldspar and fewer mafic minerals. Phenocrysts (14 (weakly welded) to 46 (densely welded within the cauldron complex)): q, 10–22; af, 6–16; pf, 44–63; b, 6–16; hb, 1–5; px, trace–2. Unit contains abundant apatite, modest amounts of zircon, and sparse allanite as accessories. Most quartz phenocrysts are slightly embayed. Large grains that are extensively embayed are common. Biotite from exposures of this unit near West Fork of Morgan Creek (44°43′ N., 114°15′ W.) has potassium-argon age of 48.4±1.7 m.y. (see table 1), which agrees with stratigraphic position of this tuff, below 47.8-m.y.-old tuff of Table Mountain (Ttm). Thickness 0 to more than 300 m. For additional description, see p. 9, 13, and 15

Tl **Potassium-rich andesite, latite, and basalt lava**—For description, see p. 17

Te **Tuff of Ellis Creek**—Rhyodacitic, crystal-rich ash-flow tuff characterized by phenocrysts of plagioclase, strongly resorbed quartz, and abundant biotite and hornblende, all of which are present in subequal amounts. Rocks exposed within cauldron complex commonly are partly altered to chlorite, epidote, and associated minerals. Locally, as along West Fork of Camas Creek (44°49′ N., 114°18′ W.), abundant very fine grained magnetite darkens rock. Sample from northeast of Duck Peak (44°55′ N., 114°29′ W.), in Panther Creek graben, has potassium-argon age on biotite of 48.4±1.6 m.y. (see table 1). Thickness 0 to more than 2,000 m. For additional description, see p. 9 and 13

Tdf **Dacitic and rhyodacitic lava**—Principally cliff-forming, dark-gray, conspicuously porphyritic lava of dacitic composition; blocky weathering; inconspicuous flow layering; unit locally includes phenocryst-poor, dark-purplish-gray latite or andesite. Phenocrysts, dacitic lava (25–40): q, 0–trace; pf, 60–70 (as long as 6 mm); b, 0–4; hb, 15–23; cpx, trace–15; opx, trace. In some areas mafic minerals are oxidized to black opaque iron oxides or replaced by chlorite and iron oxide. Latite or andesite lava contains 5–15 percent phenocrysts (0.5–2 mm long) of plagioclase and clinopyroxene, and traces of orthopyroxene and oxidized hornblende; locally, pyroxene and hornblende phenocrysts are as long as 1 cm. Biotite from sample collected near Red Rock Peak (45°00′ N., 114°25′ W.), in Panther Creek graben, gave potassium-argon age of 48.6±1.7 m.y. (see table 1). Sample from Little West Fork of Morgan Creek (44°42′ N., 114°19′ W.) has potassium-argon age on biotite of 51.1±1.8 m.y. (see table 1). Thickness 0 to more than 1,000 m. For additional description, see p. 14, 15, and 18

Tmz **Intermediate lava and breccia of mixed zone**—This lava crops out east of Morgan Creek Summit (44°47′ N., 114°15′ W.). For description, see p. 9

Tlt **Lithic tuff of Corral Creek**—For description, see p. 9

Tfr **Flow-laminated rhyolite or quartz latite lava**—For description, see p. 9

Corral Creek cauldron segment and area north and east of Challis

Intrusive rocks

Tmi **Mafic intrusions**—For description, see, p. 5

Tinm **Intermediate and mafic intrusions**—Similar to intermediate and mafic lavas (Tl), listed on p. 17. Additional description on p. 11

Extrusive rocks

Tcr **Tuff of Challis Creek, outflow unit**—For description, see p. 12 and 16

Ttm **Tuff of Table Mountain**—Pale-grayish-red to yellowish-brown, densely welded rhyolite or quartz latite ash-flow tuff; probably a simple cooling unit. Phenocrysts (10–13): pf, 82–90; b, 7–13; altered px, 2–5. Black basal vitrophyre a few meters thick contains abundant small volcanic lithic fragments a few millimeters to a few centimeters in diameter. Biotite from vitrophyre has a potassium-argon age of 47.8±1.7 m.y. (see table 1). Unit has reversed magnetic polarity. Source for this unit is a vent at Van Horn Peak (44°46.5′ N., 114°19.5′ W.) (Ekren, 1981). Thickness 0 to more than 100 m

Tp **Tuff of Pennal Gulch**—For description, see p. 13 and 16

Tem **Tuff of Eightmile Creek**—Light-gray and green-gray, massive-weathering, partly welded and densely welded quartz latite or rhyodacite ash-flow tuff; appears to be simple cooling unit in Corral Creek area (44°45′ N., 114°14′ W.), where it is poorly exposed and, in most areas, was not mapped separately at base of tuff of Pennal Gulch (Tp). Phenocrysts (25–35): q, 13-19; af, 12–18; pf, 47–57; b, 9–14; hb, trace–2; cpx, trace. Thickness 0–50 m. For additional description, see p. 8, 13, and 15

Tl **Potassium-rich andesite, latite, and basalt lava**—In Corral Creek area (44°45′ N., 114°14′ W.), thickness is 0–700 m. For description, see p. 17

Tdm **Tuff of Degan Mountain**—Pink and reddish-gray, densely welded rhyodacite ash-flow tuff; uncommonly rich in mafic minerals; appears to have erupted from west flank of Degan Mountain (44°57′ N., 114°06.5′ W.) where composite vent also contains mafic, nonfragmental intrusive rock (Tinm). Contains numerous small quartz phenocrysts about 1 mm long and a few slightly larger quartz xenocrysts that have reaction rims of tiny pyroxene microlites and glass. Phenocrysts (20–32): q (includes xenocrysts), 5–15; af, 4–18; pf, 29–58; b, 2–8; hb, 14–36; cpx, 6–26; opx, trace. Thickness 0–50 m

Te **Tuff of Ellis Creek**—Light-green-gray, massive-weathering, densely welded rhyodacite ash-flow tuff that is outflow from Van Horn Peak cauldron complex. A multiple-flow compound cooling unit or, possibly, two cooling units; everywhere contains conspicuous pumice; contains zones within which pumice lapilli are lighter than matrix and zones within which lapilli are darker than matrix. Phenocrysts (36–50): q, 4–15 (commonly "worm-eaten" and as long as 4 mm); pf, 60–75 (as long as 6 mm); b, 12–20; hb, 8–16; cpx, trace. Thickness 0–300 m. For additional description, see p. 8 and 13

Tdf **Dacitic and rhyodacitic lava**—For description, see p. 8, 14, 15, and 18. Thickness 0–900 m

Tmz **Intermediate lava and breccia of mixed zone**—A heterogeneous mixture of mafic and dacitic lava and flow breccia interbedded with tuff breccia, mud flows, and debris flows; locally includes well-stratified boulder and cobble conglomerate containing petrified tree stumps and logs; entire sequence principally forms slopes, but in and adjacent to canyons weathers to hoodoos and monoliths. Matrix of breccia and mud flows is rich in montmorillonite and weathers to spongy texture; slimy when wet. Individual tabular lava flows are mostly latite or andesite that appears to be same composition as lava in younger map unit Tl. Tabular lava flows are dark purplish gray and brownish gray; vesicular. Phenocrysts (5–30): pf, 55–70 (0.5–2 mm long); cpx, 10–20 (mostly less than 3 mm long); opx, 10–20 (mostly less than 2 mm long); hb, trace–5. In hand specimens of some of these mafic lavas, only clinopyroxene (as long as 1 cm) as phenocrysts is visible, whereas in others hornblende (as long as 3 cm) is only apparent phenocryst. Groundmasses are principally pilotaxitic. Dacitic lava and breccia are identical in composition to cliff-forming, conspicuously porphyritic lava (Tdf), but in this unit they consist mostly of slope-forming flow breccia. A porphyritic rhyodacite lava near base contains same phenocryst assemblage as tuff of Ellis Creek (Te). Thickness 0–900 m

Tlt **Lithic tuff of Corral Creek**—Reddish-gray, greenish-gray, and yellowish-gray, densely welded, cliff-forming dacite or rhyodacite ash-flow tuff rich in lithic fragments; possibly comprising two separate multiple-flow cooling units. Phenocrysts (13–38): q, 0–1; pf, 72–85; b, 0–4; hb, 3–5; opx, 7.5–22. Extrusion of this tuff apparently triggered subsidence of Corral Creek segment of Van Horn Peak cauldron complex (see table 4). In places, tuff grades upward into debris flow containing abundant latite and dacite clasts. Thickness 0–200 m

Tfr **Flow-laminated rhyolite or quartz latite lava**—Yellowish-brown, slope-forming, massive-weathering, aphyric rock; in most exposures this rock more closely resembles massive siltstone than volcanic rock. Thin sections contain a crystal or two of albite (2 mm long) and a single flake of biotite in groundmass of dense felt of alkali feldspar microlites

Twin Peaks caldera and southern part of Van Horn Peak cauldron complex

Intrusive rocks

Trf **Rhyolite dikes, plugs, and flows**—Light-gray, tan, and pinkish-red, generally crystal-poor or only moderately crystal-rich, porphyritic intrusive rocks and minor flows. Rock typically contains phenocrysts of quartz and sanidine in variable amounts; plagioclase locally present in minor amounts. Locally contains minor biotite and, rarely, trace amounts of pyroxene. These rocks display fabrics ranging from massive to flow-laminated to autobrecciated. In thin section, textures vary from glassy to devitrified to fine grained, allotriomorphic, and granular. In ridges between East Fork of Mayfield Creek and Yankee Fork (44°30′ N., 114°40′ W.) at least two generations of rhyolite are present. Older rhyolite is glassy to devitrified and is intruded by dikes and pluglike masses of more massive rhyolite. Narrow rhyolite dikes and irregularly shaped intrusive masses pervade west and north margins of Twin Peaks caldera and crosscut lower part of tuff of Challis Creek (Tcrl, see p. 12) and the caldera-wall slump debris (Tsd, see p. 11). Potassium-argon age of sanidine is 46.5±1.7 (see table 1)

Tfd **Felsic dike rocks**—Light-gray to brown-gray, light-brown-weathering dikes of porphyritic trachyte and(or) rhyolite that contain phenocrysts of sanidine, as long as 5 mm, and locally contain minor amounts of pyroxene and biotite. Plagioclase crystals, where present, generally are small, resorbed, and mantled by alkali feldspar. These dike rocks occur principally within Twin Peaks caldera, where they intrude tuff of Challis Creek (Tcrl, see p. 12) and caldera-wall slump debris (Tsd, see p. 11)

Tqp **Quartz porphyry intrusions**—For description, see p. 4

Tpe **Intrusive rocks of Pats Creek–Upper Eddy Creek**—Light-gray to pinkish-red or lavender, red- to lavender-weathering, fissile to flaggy, flow-laminated, and locally autobrecciated intrusive rock along north and east margins of Twin Peaks caldera. Phenocrysts (9–21): af, 0–25; pf (strong oscillatory zoning), 53–69; b, 17–34; hb, 0–5. Locally, near contacts, rock is black and vitrophyric or perlitic, devitrified, and gray-green weathering. Rock has steep to vertical flow foliation and locally has isoclinal flow folds with steep to vertical axial planes of variable strike. Locally, this rock contains cavities lined with chalcedonic quartz. In hand specimen, rock resembles rhyolite of Red Butte (Trb, see p. 13), except that, unlike rhyolite of Red Butte, it generally contains scattered sanidine phenocrysts. Unit is in intrusive contact with tuff of Challis Creek (Tcr) in upper Pats Creek area (44°36′ N., 114°21′ W.) and in upper Eddy Creek above Eddy Basin (44°40′ N., 114°27.5′ W.). A pluglike mass (not shown on map) containing plagioclase, biotite, sanidine, and hornblende phenocrysts is on Spider Creek (44°40.5′ N., 114°26.5′ W.). This rock is light greenish gray, medium brown weathering, and steeply flow foliated; it contains abundant gas cavities lined with rosettes of gypsum and minor calcite

Tdc **Diorite complex**—For description, see p. 20

Tgp **Gray porphyry**—Biotite from sample collected near Casto (44°34′ N., 114°50′ W.) gave potassium-argon age of 48.6±1.4 m.y. (see table 1). Sample collected from probable extrusive rock 8 km north of Casto yielded hornblende age of 46.9±2.8 m.y. and biotite age of 49.5±1.4 m.y. (see table 1). For description, see p. 2 and 5

Tii **Intermediate dikes or flows**—Dark-brown to purple-brown, dark-brown-weathering, porphyritic dikes or flows containing abundant phenocrysts as much as 3 mm in length of plagioclase and pyroxene, less abundant hornblende, and minor biotite. On lower Bear Creek (44°34.5′ N., 114°24′ W.) a probable dike of this unit, which appears to occupy ring-fracture fault of Twin Peaks caldera, contains phenocrysts of sanidine in addition to above minerals. Contacts of this unit near Mosquito Flat Reservoir (44°31′N., 114°26′ W.) are not exposed, and relations with tuff of Challis Creek (Tcr) are uncertain

Tdi **Dikes and plugs of intermediate composition**—Massive to faintly flow-laminated and locally vitrophyric at intrusive margins. Present in area of East Fork of Mayfield

Creek (44°29′ N., 114°37′ W.) and in Custer graben. In upper Tenmile Creek area (44°28′ N., 114°37′ W.), reddish-brown to lavender, porphyritic rhyodacite intrudes tuff of Eightmile Creek (Tem) and is intruded by porphyritic rhyolite (Trf). Phenocrysts (22–25): pf, 54–58; b, 10–15; hb, 23–26; op, 5–7. Potassium-argon age of intrusive mass on upper Tenmile Creek is 46.0±1.7 m.y. (biotite); 48.9±2.9 m.y. (hornblende) (see table 1)

Tip **Intermediate intrusive rocks of Spider Creek–Parker Creek**—Medium- to dark-gray, brownish-gray, gray- to brown-weathering, porphyritic intrusive rock containing abundant phenocrysts of plagioclase as long as 7 mm and less abundant hornblende, pyroxene, and minor biotite in pilotaxitic microcrystalline to devitrified, blotchy matrix. Where fine grained, rock has steep flow foliation of variable strike and in places flow folds have steep axial planes. This rock intrudes tuffs of Camas Creek–Black Mountain (Tc) at head of Parker Creek (44°37′ N., 114°32′ W.). Unit is intruded by rhyolite (Trf)

Tinm **Intermediate and mafic intrusions**—Includes dark-gray to bluish-black, dark-brown-weathering, aphanitic, porphyritic, intermediate intrusive rocks containing 3–5 percent euhedral plagioclase phenocrysts as much as 6 mm long and 1–2 percent altered euhedral pyroxene phenocrysts. Exposed on Challis Creek at mouth of Eddy Creek (44°35′ N. 114°19′ W.) and on Moose Creek (45° 48.5′ N., 114°10′ W.)

Extrusive rocks

Tuff of Challis Creek—Principal ash-flow tuff sequence erupted with collapse of Twin Peaks caldera (see table 4) (Hardyman, 1981). Caldera-wall slump debris (Tsd) and three ash-flow-tuff units (Tcru, Tcrm, Tcrl) are mapped within caldera. A single ash-flow tuff (Tcr) is mapped outside caldera

Tsd **Caldera-wall slump debris (megabreccia**—Heterogeneous deposit of coarse talus and megabreccia (following usage of Lipman, 1976) interfingering and admixed with ash-flow tuff. Deposits of this material are localized along ring-fracture system on southeast margin of Twin Peaks caldera (44°34′ N., 114°23′ W.) and in northern part of caldera, where they extend into caldera from its north and west margins. In lower part of unit are bedded, indurated, coarse conglomeratic sandstone and angular talus deposits, resembling concrete on fresh fracture; these deposits also form thin, lenslike layers and pods throughout the map unit. Megabreccia consists of tuffaceous matrix-supported to block-supported deposits of angular, unsorted pebble- to boulder-size clasts and house-size blocks of ash-flow tuff, intermediate and siliceous lava, epiclastic rock, and abundant fragments of tuff of Challis Creek. Ash-flow tuff matrix of megabreccia is nonwelded and crystal poor; it resembles tuff of Challis Creek except for higher plagioclase content. Phenocrysts (4–20): af, 40–47; q, 37–57; pf, 3–17; b, trace. Thickness more than 400 m

Tcru **Tuff of Challis Creek, upper unit**—Multiple-flow, compound cooling unit of crystal-rich rhyolite ash-flow tuff. Phenocrysts (22–26 in basal nonwelded tuff, 36–44 in remainder of unit): af, 54–69; q, 25–45; pf, 0–3; b, trace; hb, rare; px, 0–4.5. Accessory minerals are zircon, allanite, and trace amounts of apatite. Sanidine phenocrysts, as long as 5 mm, are chatoyant. Quartz phenocrysts commonly are slightly resorbed, bipyramidal, and smoky. Phenocrysts are somewhat smaller and less abundant in basal part of unit than in densely welded tuff. This unit, like middle and lower cooling units (Tcrm and Tcrl), has little or no plagioclase or ferromagnesian minerals. Plagioclase does not generally exceed 0.5 percent of total phenocrysts, biotite is uncommon, and minor pyroxene grains are preserved only in most densely welded tuff. Except locally near base, this unit is medium-gray to brownish-gray, brown-weathering, densely welded, devitrified ash-flow tuff containing pumice lapilli as much as 12 cm long and 3 cm thick (uncommonly as much as 26 cm long and 2 cm thick) and scattered pebble- to cobble-size fragments of gray to lavender, aphyric intermediate to rhyolitic lava. Pumice lapilli are in places medium to rusty brown and darker than matrix or light gray and lighter than matrix. Sanidine has been dated by ^{40}Ar–^{39}Ar methods at 45.5±0.3 m.y. (see table 3). At base, this tuff is light gray to light brown, nonwelded to moderately welded, and glassy and contains more abundant lithic fragments than do rocks exposed above; lithic fragments less than about 8 cm in diameter constitute 4–6 percent of rock and include porphyritic intermediate lava, light-gray, flow-banded rhyolite (in places as much as 1 m long at base of unit), and fragments of ash-flow tuff that has mineralogy of tuff of Challis Creek. The most pumiceous non-welded to moderately welded basal part of tuff is as much as 60 m thick and is overlain by densely welded tuff at the base of which is a laterally discontinuous vitrophyre as much as 6 m thick. Original top of unit is not exposed. Thickness is more than 700 m

Tcrm **Tuff of Challis Creek, middle unit**—Two, or possibly three, cooling units of light-gray to greenish-gray or brownish-gray, partly to densely welded, pumiceous rhyolite ash-flow tuff that weathers gray, light brown, or lavender. Phenocrysts (as much as 2 mm long) (15–26): af, 43–59; q, 38–57; pf, 0–trace; b, 0–1.5; px, 0–2. Pumice lapilli in upper cooling unit are greenish brown, darker than matrix, and as much as 6 cm, but generally less than 1 cm, long. In lower cooling unit, pumice lapilli are pale greenish gray and lighter than matrix. Sanidine from zeolitized middle unit gives an ^{40}Ar–^{39}Ar age of 45.9±0.2 m.y. (see table 3). Middle unit (Tcrm) typically is in sharp contact with overlying upper unit (Tcru). There are concentrations of lithic fragments near contact. Middle unit locally overlies thin tuffaceous sediments at contact with underlying lower unit (Tcrl). Thickness 22–48 m

Tcrl **Tuff of Challis Creek, lower unit**—Light- to dark-brownish-gray, brownish-gray-weathering, moderately to densely welded, crystal-rich, pumiceous rhyolite ash-flow tuff. Phenocrysts (2–4 mm long) (15–48): af, 50–71; q, 26–47; pf, 0–3 (generally less than 0.5); b, rare; px (preserved only in vitrophyre), 0–2. Variable amounts of pumice and vertical variation in compaction (welding zonation) within this unit, especially in upper part, suggest compound cooling. Unit shows similar alternating variations in crystal and lithic fragment content. Lithic fragments generally are small and scattered but locally are as much as 0.3 m in diameter and constitute as much as 10 percent of rock. They consist principally of flow-banded, aphyric, felsic lava and moderately crystal-rich, quartz- and sanidine-bearing ash-flow tuff that resembles tuff of Challis Creek. Pumice is lighter or darker than matrix depending on degree of welding, and lapilli commonly range from 1 to 6 cm in diameter but can be as much as 15 cm. Vitrophyric zones of this unit locally are as much as 22 m thick. Tuff forms distinct buff to pale-green, treeless or sparsely tree-covered outcrops where altered to zeolites north and west of Twin Peaks (44°36′ N., 114°28′ W.). Sanidine crystals from this unit were dated at 45.8±0.2 m.y. and 46.5±0.1 m.y. (see table 3). Thickness more than 610 m (base not exposed)

Tcr **Tuff of Challis Creek, outflow unit**—Reddish- to gray-brown, partly to densely welded rhyolite ash-flow tuff containing 13–45 percent phenocrysts (as much as 4 mm long): af, 38–70; q, 27–60; pf, 0–3; b, trace; px, 0–3. Comprises rocks outside Twin Peaks caldera that cannot be correlated with certainty with units within caldera. Outflow tuff of Challis Creek, where it caps high mountain peaks north and west of Twin Peaks caldera, consists of single cooling unit at least 200 m thick. Locally, as exposed on uppermost Tenmile Creek (44°29′ N., 114°39′ W.), outflow tuff of Challis Creek grades upward from crystal-rich, moderately welded tuff to very fine grained, crystal-poor ash-fall tuff. Tuff there and in nearby exposures on upper East Fork of Mayfield Creek (44°30′ N., 114°39′ W.) is interpreted to be associated with an early collapse segment of Twin Peaks caldera that is west of west margin of Twin Peaks caldera proper. This early collapse segment is obscured by a mass of intrusive rhyolite (Trf). Sanidine from this unit was dated by ^{40}Ar–^{39}Ar methods at 46.3±0.2 m.y. (see table 3)

Tqb **Quartz-biotite tuff**—For description, see p. 6

Tc **Tuffs of Camas Creek–Black Mountain**—For description, see p. 7

Tmb **Megabreccia of Ibex Creek**—Heterogeneous deposit of cobble- to house-size blocks of volcanic rock. Blocks include highly fractured pyroclastic rocks that resemble tuffs of Camas Creek–Black Mountain (Tc), rocks that may be tuff of Ellis Creek (Te) and tuff of Eightmile Creek (Tem), intermediate porphyritic lava, and blocks of coarse-grained volcaniclastic rock. Indurated matrix consists of smaller fragments of same materials that make up the blocks. Exposed in slope west of lower Ibex Creek (44°34.5′ N., 114°43.5′ W.). Megabreccia is intruded on all sides by rhyolite (Trf) and gray porphyry

(Tgp). Megabreccia is interpreted to represent caldera-wall slump debris shed from west margin of Van Horn Peak cauldron complex after eruption of tuffs of Camas Creek–Black Mountain (Tc). Thickness more than 150 m

Tp **Tuff of Pennal Gulch**—In Darling Creek area (44°38′ N., 114°17′ W.), unit consists of gray-brown to buff to pale-green or red bedded tuff, tuffaceous sediment, nonwelded ash-flow tuff, and pumice flows. Typical pumice-rich ash-flow tuff or pumice flows contain phenocrysts (2 mm in length) (9–14): af, 0–15; q, 0–7; pf, 62–83; b, 12–26; hb, trace. Ash-flow tuff ranges in thickness from 1 to 52 m and is rich in pumice. Noncollapsed pumice fragments in these tuff beds generally are 1–2 cm in maximum diameter and constitute 30–70 percent of rock, so many of these units are pumice flows. Lithic fragments in these tuff beds typically are pebble-size clasts of aphyric felsic lava and intermediate porphyritic lava containing feldspar and biotite phenocrysts. Interbedded with pumice-flow tuff beds are buff to green and lavender, thin-bedded, fine- to medium-grained fluvial tuffaceous sandstone, siltstone, reworked pumice beds, and coarse conglomerate beds that contain debris-flow lenses and siltstone and range from 1 to 35 m thick. Map unit is at least 355 m thick and is unconformably overlain by tuff of Challis Creek (Tcr). Also see description on p. 16

Trb **Rhyolite of Red Butte**—Red, reddish-gray, lavender, pale-brown, or buff, pinkish-tan to reddish-brown-weathering, flow-laminated and layered rhyolite that forms a cap rock on Red Butte (44°39′ N., 114°20.5′ W.), east of Twin Peaks caldera. On ridge between mouth of Pats Creek and Eddy Creek, just north of Challis Creek (44°35′ N., 114°20′ W.), this unit contains basal flow-banded vitrophyre 10 m thick that grades upward into flow-banded rock that displays crude columnar jointing and contains abundant flattened gas cavities (as much as 8 cm long). Vitrophyre locally flow brecciated with blocks up to 0.3 m. To north, in Morgan Creek area (44°40′ N., 114°17′ W.), rhyolite locally displays pyroclastic characteristics and may represent a pyroclastic deposit that flowed after coalescing to liquid. Phenocrysts (2–5 mm in length) (5–16): pf, 76–81; b, 15–17; hb, 0–11; af (with reaction rims of pf), rare. Abundant accessory apatite and zircon. Allanite uncommon. Biotite from a sample collected on east side of Red Butte (44°37′ N., 114°18′ W.) has a potassium-argon age of 46.9±1.6 m.y. (see table 1). Thickness 0–250 m

Tem **Tuff of Eightmile Creek**—Erosional remnant of this tuff on lower Mill Creek (44°32′ N., 114°17′ W.) overlies thin-bedded tuffaceous sandstone, siltstone, and reworked pumice beds that in turn overlie aphanitic intermediate lava (Tl, see p. 12). Tuff is light greenish gray to brownish gray, nonwelded, and only slightly devitrified; it contains pale-green to white pumice lapilli. Phenocrysts (approximately 26): af, 15; q, 22; pf (strong oscillatory zoning), 33; b, 23; hb (green), 7. On southwest side of Corkscrew Mountain (44°32′ N., 114°23′ W.), erosional remnants of tuff of Eightmile Creek are light gray to greenish gray, nonwelded, and pumiceous, containing medium-brownish-gray pumice lapilli that are darker than matrix. Crystals, as much as 2 mm long, commonly are broken. Phenocrysts (42): af, 15; q, 8; pf (strong oscillatory zoning), 64; b, 12; hb, 1. At Red Butte (44°39′ N., 114°20.5′ W.) about 60 m of this tuff underlies rhyolite of Red Butte (Trb). Tuff is nonwelded to partly welded, very pale gray, and rich in pumice. Phenocrysts (as much as 2.5 mm long) (27–33): af, 11–12; q, 17–22; pf (strong oscillatory zoning), 52–55; b, 13–15; hb, 0–2. From upper Spider Creek to upper Parker Creek (44°38′ N., 114°33′ W.), unit is greenish-gray, densely welded, and pumiceous; contains whitish-green pumice lapilli that generally are lighter than matrix. The tuff is altered to calcite and chlorite; sericite, clay minerals, and epidote locally are present. Biotite from sample from West Fork of Morgan Creek (44°42′ N., 114°18′ W.) has potassium-argon age of 48.4±1.7 (see table 1). Phenocrysts (25–35): af, 12–17; q, 9–27; pf, 43–66; b, 7–18; hb, 2–4. For additional description, see p. 8, 9, and 15.

Tl **Potassium-rich andesite, latite, and basalt lava**—For description, see p. 15

Te **Tuff of Ellis Creek**—Along lower Eddy Creek this unit consists of two outflow cooling units, each about 60 m thick, separated by 1–2 m of thin-bedded tuff and reworked, cross-bedded, fluvial tuffaceous sandstone containing abundant biotite. Ash-flow tuff in both cooling units is gray green and moderately welded; contains pale-green pumice lapilli as much as 3 cm long. Phenocrysts (28–34): q, 3–6; pf, 66–67; b, 22–24; hb, 5–6. For description, see p. 8 and 9

Trm **Rhyolite of Mill Creek Summit**—For description, see p. 17

Tsb **Sedimentary breccia**—A heterogeneous unit consisting primarily of poorly sorted, poorly bedded, coarse sedimentary breccia that contains angular to rounded, pebble- to boulder-size clasts of aphyric and porphyritic intermediate lava and fragments of siltstone and claystone in a matrix of coarse sand to clay. Also contains discontinuous beds of tan-gray to light-brown, light-brown-weathering, coarse conglomerate and thin interbeds of coarse-grained tuffaceous sandstone containing abundant grains of feldspar, altered ferromagnesian minerals, and minor quartz. Locally present are mudflow breccia deposits containing intermediate lava clasts in biotite-bearing epiclastic matrix and log-size and smaller fragments of petrified wood. Unit underlies potassium-rich andesite, latite, and basalt lava (Tl) exposed along lower Challis Creek (44°34.5′ N., 114°18′ W.). May be correlative with intermediate lava and breccia of mixed zone (Tmz) exposed in Corral Creek cauldron segment. Thickness 0–130 m

Tdf **Dacitic and rhyodacitic lava**—Rhyodacite lava and agglomerate exposed southeast of Challis Creek near Corkscrew Mountain (44°32′ N., 114°23′ W.) and north of Challis Creek (44°36′ N., 114°20′ W.) between Pats Creek and Eddy Creek. Dark-brown-weathering, brown to gray, porphyritic, locally vitrophyric, massive rhyodacite lava and coarse agglomeratic breccias containing 0.2–3 m blocks of monolithologic rhyodacite porphyry in matrix of glassy to devitrified rhyodacite. Phenocrysts (28–44): pf (as much as 5 mm long), 60–75; b, 1–14; px (both opx and cpx), 7–35; hb, 0–13. Contacts between massive and agglomeratic phases of unit are irregular and commonly steep. Cavities filled with chalcedonic silica locally abundant. Biotite from sample collected from southwest side of Corkscrew Mountain (44°32′ N., 114°23′ W.) has potassium-argon age of 50.4±1.8 m.y. (see table 1). For additional description, see p. 8, 15, and 18

Tvs **Volcaniclastic and sedimentary rocks**—For description, see p. 15 and 18

Custer graben area

Intrusive rocks

Tdi **Dikes and plugs of intermediate composition**—Brown- and reddish-brown-weathering, crystal-poor rocks that contain phenocrysts less than 2 mm in length of plagioclase, amphibole or pyroxene, and minor biotite

Trd **Rhylolite dikes**—These rocks occur outside Custer graben to south and west. For description, see p. 19

Td **Dikes**—Gray, brownish-gray and greenish-gray, holocrystalline, medium- to fine-grained dike rocks, primarily gabbro and diabase, made up chiefly of plagioclase and clinopyroxene; pyroxene commonly partly or wholly altered to chlorite. Have reversed magnetic polarity

Tr **Rhyolite intrusions**—Gray, white, and pink dikes, plugs, and domes that contain phenocrysts of alkali feldspar and quartz, and minor amounts of biotite and plagioclase

Tgi **Intrusive rocks east of Bonanza**—Porphyritic to equigranular rocks that range in composition from granodiorite to quartz monzonite. Major element analysis of quartz monzonite resembles analysis of tuff of Eightmile Creek (Tem). Rocks exposed are in roof zone of pluton intruding intermediate lava (Tdf, see below); blocks of lava are common as inclusions, and in some exposures intrusion more closely resembles swarm of closely spaced dikes cutting lava, as first described by Anderson (1949). Aeromagnetic data and distribution of thin dikes indicate buried extension of intrusion for at least 3 km west of principal outcrop area. Intrusion and country rock both are propylitized; minor hydrothermal biotite locally developed in intrusion

Extrusive and sedimentary rocks

Trl **Rhyolite lava**—Gray and grayish-red, chiefly crystal-poor rhyolite containing phenocrysts of alkali feldspar and quartz. On ridgecrest east of upper Basin Creek (44°22′ N., 114°53′ W.) it is unaffected by faults that offset underlying volcaniclastic rocks (Tps) and intermediate lava (Tdf)

Tpc **Tuffs of Pennal Gulch and Camas Creek–Black Mountain, undivided**—Nonwelded tuff sequence that overlies tuff of Eightmile Creek (Tem, see below) in Custer graben, chiefly east of Jordan Creek. Locally includes tuff of Ninemile Creek (McIntyre and others, 1982), a densely welded unit not shown separately on this map, and debris possibly derived from rhyolite domes in upper Jordan Creek area (44°26′ N., 114° 44′ W.) (Foster, 1982). Thickness more than 600 m

Tvc **Volcaniclastic rocks**—Ash-flow and ash-fall tuff that overlies tuff of Eightmile Creek west of Bonanza (44°23′ N., 114°43.5′ W.). Coarser grained rocks in this unit are characterized by crystals of plagioclase, sanidine, and quartz (quartz more abundant than sanidine in most places); biotite is only mafic mineral present. On ridge west of Lightning Creek (44°25.5′ N., 114°49′ W.), thin flow of intermediate lava occurs within the unit. For additional description, see p. 17

Tem **Tuff of Eightmile Creek**—Gray, greenish-gray, pale-brown, and grayish-pink, bluff-forming, pumice-rich, crystal-rich, densely welded, quartz latitic ash-flow tuff characterized by phenocrysts, as much as 4 mm long, of plagioclase, quartz, sanidine, biotite, amphibole, clinopyroxene, orthopyroxene, zircon, apatite, and allanite. Biotite from vitrophyre exposed west of mouth of Tenmile Creek (44°28′ N., 114°35′ W.) has potassium-argon age of 47.5±1.3 m.y. (see table 1); this age supersedes previously published age of 46.9±1.6 m.y. (McIntyre and others, 1982). Unit has reversed magnetic polarity. On west side of Eightmile Creek about 4 km above its mouth (44°27′ N., 114°39′ W.), four cooling units having total thickness of more than 215 m are exposed. For additional description, see p. 8, 9, and 13

Trm **Rhyolite of Mill Creek Summit**—For description, see p. 17

Tdf **Dacitic and rhyodacitic lava**—In Custer graben consists chiefly of crystal-poor, potassium-rich andesite that contains phenocrysts, generally smaller than 2 mm long, of plagioclase and clinopyroxene. Characterized by propylitic alteration in Sunbeam mine-Estes Mountain area (44°27′ N., 114°44′ W.) and in area surrounding Custer (44°23.5′ N., 114°41′ W.). For description, see p. 8 and 14

Tvs **Volcaniclastic and sedimentary rocks**—Volcanic sandstone, conglomerate, siltstone, and mudstone exposed northeast of Basin Creek. The coarsest grained rocks in lower part of unit, which include volcanic sandstone, conglomerate, and massive, pumice-rich pyroclastic flow more than 15 m thick, contain crystals of plagioclase, sanidine, quartz, and biotite. Rocks higher in unit lack sanidine and contain plagioclase, quartz, biotite, and hornblende. Beds of nonvolcaniclastic arkosic sandstone locally present in upper part of unit

Tar **Arkosic sandstone and conglomerate** —Gray arkosic sandstone and local beds of conglomerate that contains pebbles and cobbles of gray quartzite. Occurs as discontinuous lenses at base of sequence east of Basin Creek (44°18′ N., 114°51′ W.). Many occurrences too small to be shown at this map scale

Southeastern part of quadrangle

Intrusive rocks

Rhyodacite domes and plugs at Bradbury Flat —Black, columnar-jointed, glassy rhyodacite and gray, grayish-brown, or red-purple devitrified rhyodacite containing as much as 30 percent phenocrysts as much as 4 mm long of plagioclase, orthopyroxene, clinopyroxene, biotite, apatite, and opaque oxides

Tdbi **Rhyodacite plugs**—Cross-cutting plugs of rhyodacite in bluff exposures along Salmon River west of Bradbury Flat (44°26′ N., 114° 10′ W.) and in hills north and east of Bradbury Flat. Have normal magnetic polarity. Northeast-dipping slab of similar rock at southwest margin of Bradbury Flat has reversed magnetic polarity

Tdb **Rhyodacite domes**—Irregularly shaped dome-like masses of rhyodacite in hills northwest of Bradbury Flat. Potassium-argon age for columnar-jointed rhyodacite exposed at northwest margin of Bradbury Flat is 39.7±1.2 m.y. (see table 1)

Tib **Mafic intrusive rocks**—Olivine-bearing intrusive rocks that have been mapped separately only along Road Creek (44°10′ N., 114° 10.5′ W.), and Horse Basin Creek

Tdl **Diabase and lamprophyre dikes**—Similar to dikes described on page 19, except that in this area, trends are primarily northeast rather than northwest

Til **Potassium-rich andesite, latite, and basalt intrusions**—Dikes, sills, and plugs that commonly consist of brown- or reddish-brown-weathering, dark-gray, greenish-gray, or black, crystal-poor rocks containing variable proportions of phenocryst minerals clinopyroxene, orthopyroxene, olivine, and plagioclase. Exposed as dikes, sills, and plugs along Salmon River near Centennial Flat (44°22′ N., 114°16.5′ W.), in region between Summit Rock and Bald Mountain, and as altered, irregularly shaped intrusive masses north of Little Antelope Flat. Near Centennial Flat, intrusive rocks were altered by reaction with wet, semiconsolidated sediments they intruded to produce chlorite-, clay-, and carbonate-rich, light-greenish-gray rocks. Whole-rock potassium-argon age for the unaltered part of one intrusive mass is 48.2±1.4 m.y. (see table 1). Magnetic polarities are normal and reversed

Tsy **Syenite intrusion**—Irregularly shaped, sill-like mass of medium- to coarse-grained syenite that crops out east of Tub Spring, in upper Spar Canyon (44°15.5′ N., 114°11′ W.). Rock contains potassium feldspar, clinopyroxene, biotite, apatite, and magnetite. Clinopyroxene commonly altered to carbonate; both clinopyroxene and biotite commonly altered to chlorite. Carbonate also occurs as veins. Some, if not most, carbonate may be primary. Marginal facies of intrusion are dark, basalt-like rocks containing altered olivine phenocrysts; thin sections show that these rocks have holocrystalline matrices made up chiefly of alkali feldspar and biotite. Emplacement of intrusion probably penecontemporaneous with eruption of nearby latite lava (Tl, see p. 17)

Tdi **Dikes and plugs of intermediate composition**—Intrusive equivalent of intermediate lava (Tdf, see p. 18). Most prominent occurrence is near Sheep Mountain (44°04′ N., 114°22′ W.), where swarm of dikes probably marks site of concealed felsic pluton and source vent for surrounding pyroclastic rocks and intermediate lava (Tdf). Biotite from unaltered vitrophyric dike about 3 km south of mouth of Pine Creek (44°05′ N., 114°22′ W.), north of principal dike swarm, has potassium-argon age of 50.0±1.8 m.y. (see table 1). Large body northwest of Thompson Creek (44°21′ N., 114°36′ W.) has well-exposed intrusive contacts near its western end, but toward east resembles dome or thick flow mass

Extrusive and sedimentary rocks

Tbau **Mafic lava**—Olivine-bearing basaltic lava and associated volcaniclastic rocks that crop out south of Road Creek (44°10′ N., 114°10.5′ W.)

Trr **Tuff of Red Ridge**—Red- and reddish-brown-weathering, grayish-purple or reddish-purple, blocky to platy, crystal-poor ash-flow tuff containing phenocrysts less than 1 mm long of alkali feldspar (chiefly anorthoclase). Vitrophyre at east end of Red Ridge (44° 06′ N., 114°29.5′ W.) contains a few crystals of green pyroxene and amphibole. This unit found only along east flank of White Cloud Peaks (44°11′ N., 114°27′ W.) and in Spar Canyon-Sand Hollow (44°13′ N., 114° 12.5′ W.) area. Thickness 0 to more than 140 m

Tcr **Tuff of Challis Creek, outflow unit**—Red, reddish-purple, yellowish-brown, or gray, densely welded, devitrified ash-flow tuff containing 5–20 percent crystals as long as 3 mm of chatoyant alkali feldspar and smoky quartz in matrix of fine shards. Locally contains abundant pumice. Also contains sparse zircon, allanite, biotite, and a few crystals of plagioclase. Near Challis, single cooling unit overlies an irregular erosion surface carved on underlying tuff of Pennal Gulch (Tp). Two, or possibly three, densely welded cooling units present in Spar Canyon-Sand Hollow area. One of these units may be younger than tuff of Red Ridge (Trr). Unit has normal magnetic polarity. Potassium-argon age of sanidine is 45.0±1.3 m.y. (see table 1)

Tp **Tuff of Pennal Gulch**—Gray, pale-pink, or pale-green, silicic, crystal-poor pyroclastic flows and airfall, both subaqueous and subaerial. Chiefly massive to crudely bedded, pumice-rich, coarse tuff and pumice-lapilli tuff, but also includes beds of sorted, thin-bedded volcanic sandstone and mudstone. Commonly contains crystals as much as 2 mm long of plagioclase, sanidine, and biotite, and subordinate or very minor quartz, amphibole, allanite, zircon, and apatite. Sparse carbonized or silicified plant fragments are present in some pyroclastic flows. Locally in exposures east and north of Round Valley (44° 30′ N., 114°11′ W.) and northwest of Ellis (44°41.5′ N., 114°03′ W.), a ledge-forming vitrophyre as much as 15 m thick consists of black, crystal-poor, perlitic, rhyodacitic glass containing crystals of plagioclase, sanidine, clinopyroxene, and zircon. Some samples contain abundant lithic inclusions. Unit has reversed magnetic polarity. Tuff of Eightmile Creek (Tem) included within basal part of map unit south of Table Mountain (44° 44′ N., 114°12′ W.). Thickness 0 to more than 370 m. For additional description, see p. 13

Tvc **Volcaniclastic rocks**—Ash-flow tuff, thin-bedded volcanic sandstone, siltstone, and mudstone, containing local zones of impure lignite; unit exposed from Little Antelope Flat (44°23′ N., 114°04′ W.) southwestward to Spar Canyon area (44°14′ N., 114° 13′ W.). Coarsest grained rocks in this unit are characterized by crystals of plagioclase, sanidine, and quartz (quartz commonly more abundant than sanidine); biotite is only mafic mineral present. West of mouth of Spar Canyon nonwelded and densely welded ash-flow tuff related to the tuff of Challis Creek are locally present but have not been mapped separately. Subaqueous pyroclastic flow that is probable equivalent of tuff of Eightmile Creek (Tem) crops out in Spar Canyon and in Sand Hollow. Conglomerate containing clasts of quartzite, slate, and granitic rock, in addition to volcanic clasts, caps sequence south of Spar Canyon and is exposed in hills east of Tub Spring (44°15.5′ N., 114° 11′ W.). For additional description, see p. 15

Th **Tuff of Herd Lake**—Red-purple or red-brown, devitrified, flow-laminated, locally lithophysal, crystal-poor rhyolitic rock that contains phenocrysts of plagioclase, biotite, and clinopyroxene 1 mm long. Two cooling units, separated by breccia zone, present north of Herd Lake (44°05′ N., 114°10′ W.). In most places these rocks resemble rhyolite lavas; however, exposure on ridge about 3 km south of Jerry Peak reveals marginal vitrophyre rich in shards. This exposure and sheetlike aspect of deposit indicate that unit was emplaced as very hot ash flow that coalesced and moved like lava prior to final chilling. Biotite from vitrophyre has potassium-argon age of 48.1±1.7 m.y. (see table 1). Map unit has reversed magnetic polarity. Overlies unit Tl. Thickness 0–150 m

Tl **Potassium-rich andesite, latite, and basalt lava**—Predominantly aphyric, reddish-brown-weathering, gray, purple, and greenish-gray, blocky to platy lava, locally containing interbedded oxidized breccia. Olivine and pyroxene occur as phenocrysts in some samples. Plagioclase not commonly found as phenocrysts. Microphenocrysts include olivine, clinopyroxene, orthopyroxene, and sieve-textured plagioclase. Quartz xenocrysts commonly present. Plagioclase-rich groundmass commonly is trachytic or pilotaxitic and may contain apatite and reddish-brown, strongly pleochroic mica. In region surrounding Challis, rock compositions range from potassium-rich andesite to potassium-rich basalt, andesite probably predominating. Farther south, in area between East Fork of Salmon River and Jerry Peak (44°03.5′ N., 114°06.5′ W.), compositions range from potassium-rich andesite to latite. Latite is more common toward top of section. Magnetic polarity indeterminate in area near Challis; lava toward south has reversed magnetic polarity. Near Challis, the lava overlies tuff of Ellis Creek (Te, 48.4±1.6 m.y.) and is overlain by tuff of Eightmile Creek (Tem, 48.4±1.6 m.y. and 47.5±1.3 m.y.) and tuff of Table Mountain (Ttm, 47.8±1.7 m.y.). Toward south, lava overlies tuff dated at 49.0±2.9 m.y. (Tvs) and is overlain by tuff of Herd Lake (Th, 48.1±1.7 m.y.)

Trm **Rhyolite of Mill Creek Summit**—Black, gray, and greenish-gray vitrophyric rhyolite lava and gray to pink, banded, devitrified rhyolite lava containing 1–5 percent phenocrysts, as much as 2 mm in length, of plagioclase and biotite. Also contains hornblende, allanite, zircon, apatite, and opaque oxides. Some flows also contain alkali feldspar and quartz. Four flows that have aggregate thickness of about 235 m are present in butte east of Mill Creek Summit (44°28′ N., 114°29′ W.). Potassium-argon age on biotite is 48.5±1.2 m.y. (see table 1). All flows have reversed magnetic polarity

Tbam **Mafic lava**—Dark, sparsely porphyritic basaltic and andesitic lava, exposed along Salmon River near Centennial Flat (44°22′ N., 114°17′ W.) that contains variable proportions of olivine, pyroxene, or plagioclase phenocrysts. Probably related to mafic intrusive rocks (Til) that crop out nearby

Tvs **Volcaniclastic and sedimentary rocks**—Includes subaqueously deposited pyroclastic flows, mudflow breccia and conglomerate, volcanic sandstone, and mudstone exposed along the Salmon River west and south of Challis, near Centennial Flat, along East Fork Salmon River, along Road Creek, and along Herd Creek. Also includes subaerial ash-fall and ash-flow deposits intercalated with and overlying intermediate lava in and north of Squaw Creek drainage basin (44°22′ N., 114°28′ W.). Volcanic components of all these rocks contain plagioclase, biotite, and amphibole. Quartz is minor and variable in amount. Some samples contain a few grains of pyroxene. Coeval with parts of intermediate lava sequence (Tdf); ranges in age from about 50 m.y. to about 48 m.y. Potassium-argon dating on sample from southeast of Jerry Peak yielded ages of 49.0±1.8 m.y. on biotite and 49.0±2.9 m.y. on hornblende (see table 1). A subaqueous pyroclastic flow, about 12 m thick, that is probable equivalent of tuff of Ellis Creek (Te, 48.4±1.6 m.y.) occurs within this unit in area south of Centennial Flat. Arbitrarily included in this unit are outcrops of pyroclastic flow exposed south of mouth of Squaw Creek that contains significant alkali feldspar, in addition to plagioclase and quartz, and biotite as sole mafic mineral

Tdf **Dacitic and rhyodacitic lava**—Contains heterogeneous group of rocks erupted from numerous vents scattered over area from Challis to south edge of quadrangle. Individual, local units generally can be consistently distinguished during mapping at large scales (see, for example, Hobbs and others, 1975). Compositions mainly dacite and rhyodacite; contain as phenocrysts various combinations of the minerals plagioclase, biotite, amphibole, clinopyroxene, orthopyroxene, and, uncommonly, olivine or quartz. Includes minor amounts of potassium-rich andesite characterized by phenocrysts of pyroxene and(or) olivine. Has normal and reversed magnetic polarity. Ranges in age from about 49 m.y. to about 51 m.y. Potassium-argon ages on biotite are 49.2±1.2 m.y. and 51.1±1.7 m.y.; plagioclase is dated at 49.3±1.4 m.y. (see table 1). For additional description, see p. 8, 14, and 15

Tbal **Mafic lava**—Dark, sparsely porphyritic basaltic and andesitic lava that crops out below, and is interbedded with, flows of intermediate-composition lava (Tdf) in hills southwest of Challis. Mafic lava contains variable proportions of olivine, pyroxene, and plagioclase phenocrysts. Sample from Garden Creek (44°29.5′ N., 114°19′ W.), west of Challis, has whole-rock potassium-argon age of 50.3±1.5 m.y. (see table 1)

Tgc **Tuff of Germania Creek**—Densely welded, vitrophyric ash-flow tuff and associated volcanic sediments exposed in ridges northwest and southeast of Germania Creek (44°01′ N., 114°32′ W.). Includes "ignimbrite of Germania Creek" of Motzer (1978). Ash-flow tuff contains as much as 40 percent phenocrysts, as long as 1 mm, of plagioclase, amphibole, clinopyroxene, orthopyroxene, and biotite. Mafic phenocrysts make up more than 40 percent of total phenocrysts. Ash-flow tuff resembles tuff of Burnt Creek (Tbc, below) except for preponderance of amphibole. More thorough sampling may show that this characteristic is not consistent. Has reversed magnetic polarity

Tbc **Lava and ash-flow tuff of Burnt Creek**—Dacitic lava and ash-flow tuff, locally vitrophyric, but commonly rusty brown and devitrified, containing phenocrysts of plagioclase, orthopyroxene, clinopyroxene, amphibole, and biotite. More than 40 percent of total phenocrysts in ash-flow tuff commonly are mafic minerals. Presence of one thin ash-flow tuff cooling unit that has these mineralogic features within tuff of Sage Creek (Tsc) in Sage Creek drainage basin (44°05′ N., 114°05′ W.) shows that the two units are contemporaneous, despite large contrast in composition. Probably has normal magnetic polarity

Tsc **Tuff of Sage Creek**—Ash-flow and ash-fall tuff and associated sedimentary rocks characterized by phenocrysts of plagioclase and sanidine, together with minor biotite, amphibole, and rare pyroxene. Quartz not present. Exposed chiefly near southeast corner of quadrangle in the drainage basin of Sage Creek, and on ridge south of Sheep Mountain. There are isolated outcrops of this rock type, too small to show on map, opposite mouth of Spar Canyon, east of lower Herd Creek, and along East Fork of Salmon River northwest of mouth of McDonald Creek (44°08.5′ N., 114°19′ W.). At all these localities, these rocks crop out beneath volcaniclastic rocks mapped as Tvs. Near Sheep Mountain, tuff of Sage Creek is mixed with breccia and intermediate lava (Tdf); contact between the two units is arbitrary. In some samples of breccia containing blocks with phenocrysts of plagioclase, quartz, biotite, and amphibole, dominance of matrix by crystals of plagioclase and sanidine demonstrates intermingling of material from two sources. Has normal magnetic polarity

Tcg **Conglomerate and fanglomerate**—Chiefly cobble and boulder (as large as 2 m in diameter) conglomerate; black, pink, gray, or white quartzite clasts predominate near base, and volcanic clasts predominate near top. Matrix of conglomerate contains volcanic component throughout. Locally includes pyroclastic flow that contains lava blocks containing plagioclase, biotite, amphibole, and quartz phenocrysts. Present only near southeast corner of quadrangle. Also included in this unit is prevolcanic fanglomerate exposed southeast of Lone Pine Peak (44°21′ N., 114°10′ W.). Clasts in fanglomerate were derived from nearby exposures of Paleozoic rocks, which formed topographically high ridges prior to volcanism

Western and south-central parts of quadrangle

Intrusive rocks

Tdl **Diabase and lamprophyre dikes**—Diabase dikes are the more common. Rock is dark and fine to medium grained; consists chiefly of lathlike crystals of plagioclase enclosed in matrix of pyroxene crystals. Diabase dikes are youngest dikes and crosscut all others. They are the most continuous and commonly trend northwest. Lamprophyric dikes are dark gray to black, fine grained, and somewhat porphyritic; commonly range from a few centimeters to a meter or so in width and are only a few meters in strike length. Augite, brown hornblende, biotite, and plagioclase are principal minerals of this rock, which is a young rock but its relation to the diabase is unknown

Trd **Rhyolite dikes**—Rocks are light colored and generally porphyritic, containing rounded and embayed quartz phenocrysts. Potassium feldspar phenocrysts are more plentiful than plagioclase. Matrices are pinkish gray and aphanitic. Modal compositions include rhyolite, quartz-latite, and rhyodacite. The rocks are altered: sericite is developed from feldspars and iron oxides from pyrite. Dikes range from a few meters to more than 30 m wide and are as much as several hundred meters long. Rhyolite dikes are more numerous near bodies of granite (Tg), to which they probably are related, and, like that rock, are more radioactive than other plutonic rocks or dikes. Granophyric matrices common in dikes cutting Idaho batholith rocks north of Stanley. Some dikes in that area also are composite, having marginal zones more mafic than rhyolite

Tri **Rhyolite stock**—Red-weathering, yellowish-gray, aphanitic rhyolite that contains sparse phenocrysts of quartz as long as 1 mm and pyrite or pyrite casts. Forms massive outcrops. Rhyolite is well exposed on ridge southeast of Cape Horn Creek (44°21.5′ N., 115°11.5′ W.), where stock contains roof pendants of granodiorite (Kgd, see p. 21) and metasedimentary rocks (rp, see p. 26)

Td **Dikes**—Rocks are dark green to gray and commonly porphyritic, containing phenocrysts of zoned plagioclase as long as 2 cm; compositions are primarily andesite, dacite, and latite. Phenocrysts of hornblende, somewhat altered to chlorite, and euhedral biotite also commonly present. Quartz phenocrysts are sparse. Phenocrysts are set in groundmass of andesine-oligoclase, minor potassium feldspar, hornblende, and magnetite. Sphene and allanite are common accessories. Dikes range from a few meters to more than 30 m wide and are as much as several hundred meters long. They are more numerous near exposures of Tertiary diorite complex (Tdc), to which they probably are related

Tdu **Tertiary dikes, undivided**—Rhyolite to diabase dikes

Tg **Granite**—Pink to gray, medium- to coarse-grained granite characterized by pink perthitic feldspar. Relative proportion of salic minerals (calculated from the CIPW norm): q, 39; af, 34; pf, 27. Rock contains miarolitic cavities, locally lined with smoky quartz crystals, and is more radioactive than granodiorite of Idaho batholith. Hornblende from one sample was dated by potassium-argon methods at 44.3±1.3 m.y. (see table 1). Granite includes part of Sawtooth batholith (Reid, 1963)

Tdc **Dioite complex**—Complex suite of rocks ranging from nonporphyritic diorite to porphyritic granodiorite, which is prevalent. Rock is characterized by abundance of hornblende, euhedral biotite, and magnetite, which together make up as much as 35 percent of it. Phenocrysts in porphyritic rocks are chiefly zoned plagioclase and pale-red perthitic microcline, which may be as long as 1 cm; phenocrysts are set in fine-grained, pale-red matrix. Quartz phenocrysts are rare. Relative proportion of salic minerals (calculated from CIPW norm): q, 19; af (microcline), 21; pf, 60. Rocks weather to chocolate-brown soil, darker than soil formed from granitic rocks of area. Diorite and dark-greenish-gray aphanitic andesitic phases are generally peripheral to porphyritic rock. Biotite, hornblende, and whole-rock potassium-argon ages for three samples collected in Jackson Peak (44°05′ N., 115°25′ W.) and Monumental Peak areas are 46.2±0.9 m.y., 46.6±0.5 m.y., 47.7±1.1 m.y., 48.2±3.0 m.y., and 46.0±1.7 m.y. (see table 1). In some areas this unit is mapped to include large numbers of andesite, dacite, and latite dikes (Td)

Tgp **Gray porphyry**—For description, see p. 2, 5, and 10

Extrusive rocks

Twt **Welded tuff of Obsidian**—Light-gray welded lithic tuff exposed north of Obsidian, near south edge of quadrangle. Weathers reddish purple, brownish gray, and brown. Rock is light-gray ash-flow tuff that contains phenocrysts of sanidine and quartz in a fine, light-gray matrix

Tva **Andesite**—Dark-gray to black, thinly layered, flow-banded, aphanitic lava that has pilotaxitic texture. Contains olivine phenocrysts, rimmed by iddingsite, set in groundmass of andesine microlites and interstitial pyroxene and magnetite. Overlies rhyolitic flows where exposed on ridge top between Knapp and Beaver Creeks (44°25′ N., 115°05′ W.)

Tvr **Rhyolite flows**—Yellowish-gray to pale-red to purple, aphanitic lava that commonly shows flow-banding and flattened quartz-lined vugs along flow laminae. Contains phenocrysts of platy sanidine and rounded, embayed quartz. Rock erodes to conspicuous massive knobs on ridge line and to reddish, slabby scree. Includes minor amounts of rhyolitic tuff. Sanidine has a potassium-argon age of 37.6±2.1 m.y. (see table 1). Geologic relations suggest that this age is too young. Preserved in a graben between Knapp and Beaver Creeks (44°23′ N., 115°08′ W.)

Tcv **Challis Volcanic Group, undivided**—Includes three small ridge caps of rhyolite and discordant rhyolitic tuff near headwaters of North Fork of Boise River (44°05′ N., 115°11′ W.) and, in northern part of area, exposures on headwaters of Rapid River (44°40′ N., 115°02′ W.) and on headwaters of Riordan Creek (44°49′ N., 115°24′ W.)

CRETACEOUS INTRUSIVE ROCKS

Ki **Granitic rocks of Idaho batholith, undivided**

Klg **Leucocratic granite**—Light-gray to white, fine- to medium-grained granite having distinctive anhedral texture. Principal minerals are quartz (33 percent), potassium feldspar (29 percent), and plagioclase (An_{26-30}, 33 percent). Biotite may constitute as much as 2 percent of rock, garnet is common, and feldspars are altered to sericite and small irregular flakes of muscovite. This rock, described as leucocratic quartz monzonite by Reid (1963) and by Kiilsgaard and others (1970), as aplite by Cater and others (1973), and as aplitic quartz monzonite by Anderson (1947), occurs as dikes and irregularly shaped stocks that are resistant to erosion and tend to form high points on ridges. Rubbly, weathered scree from these high points may be extensive on lower hillsides and may give the impression of being eroded from larger masses than actually exist. Intrudes biotite granodiorite (Kgd, see below) and is itself intruded by Tertiary granite (Tg) and stocks of Tertiary diorite complex (Tdc). It also occurs as small dikes and plugs intrusive into biotite granodiorite and granite (Kgd, see below) in exposures along east side of Stanley Basin. Potassium-argon ages of biotite from five samples range from 63.6±1.4 to 72.6±2.5 m.y. (see table 2)

Kg **Muscovite-biotite granodiorite and granite**—Gray to light-gray, medium- to coarse-grained, equigranular to porphyritic granodiorite; contains books of muscovite that are visible in hand specimen and make up as much as 5 percent of rock. Except for visible muscovite, rock is similar to biotite granodiorite (Kgd), with which it is transitional through zone about 2 km or more wide. It is exposed in western part of quadrangle and comprises what is considered to be core of Atlanta lobe of Idaho batholith. Includes quartz monzonite of Warm Lake of Schmidt (1964). Potassium-argon ages of nine samples range from 65.3 to 73.9±2.7 m.y. for biotite and from 68.8±0.2 to 74.7±2.7 for muscovite (see table 2)

Kgd **Biotite granodiorite**—Gray to light-gray, medium- to coarse-grained, and equigranular to porphyritic rock. Plagioclase (An_{22-30}) is chief component of rock, which has lesser quantities of quartz and potassium feldspar. Biotite is principal mafic mineral, constituting as much as 5 percent of rock in most places; however, east of Stanley Basin it makes up 25 percent of rock. Hornblende is rare. Biotite granodiorite is most common granitic rock of Idaho batholith and is exposed over vast areas. In western part of quadrangle rock was identified by Schmidt (1964) as granodiorite of Gold Fork. Biotite granodiorite is intruded into older tonalite (Kt, see below) and in the 60- to 90-m-wide contact zone it exhibits intensive primary foliation as well as xenoliths of tonalite. Includes foliated diorite in Loon Creek (44°35′ N., 114°51′ W.) and at mouth of Camas Creek (44°53′ N., 114°44′ W.). Potassium-argon ages of biotite range from 61.5 to 98.1±3.3 m.y. (see table 2)

Kgds **Sphene-enriched biotite granodiorite**—Mapped by Schmidt (1964) as leucocratic quartz diorite of Little Valley

Kgdp **Porphyritic biotite granodiorite and granite**—Coarsely porphyritic granitoid rock containing metacrysts of pink potassium feldspar (microcline) from 3 to 10 cm long in medium- to coarse-grained matrix that contains roughly equal amounts of microcline, plagioclase, and quartz; generally 5–15 percent biotite and variable amounts of hornblende. Foliation commonly present and locally strongly developed in area west and north of Stanley Basin. Also included in this unit are rocks that form cores of stock at White Cloud Peaks and large pluton east of Stanley Basin. In those areas rocks are unfoliated porphyritic biotite granite and biotite granodiorite that contain metacrysts of microcline 1–3 cm long in medium-grained granitoid matrix containing predominantly 5–10 percent, and rarely as much as 20–25 percent, biotite and approximately equal amounts of quartz, potassium feldspar, and plagioclase. Equigranular margins of two bodies are separated from porphyritic granite cores by potassic metasomatized transition zone as much as 1.5 km wide that contains abundant veins and pods of potassium feldspar and locally abundant secondary muscovite that coats joints. Potassium-argon ages of biotite from four samples range from 62.6 to 84±2 m.y. (see table 2)

Kgdh **Hornblende-biotite granodiorite**—Gray, medium- to coarse-grained, equigranular to porphyritic, commonly foliated granodiorite; biotite and hornblende are aligned in plane of foliation. Rock commonly is associated with xenoliths and pendants on high ridges in western part of quadrangle. It is intermixed with tonalite (Kt); the two rock types form border zone of Atlanta lobe of Idaho batholith

Kt **Tonalite and granodiorite**—Gray to dark-gray, medium- to coarse-grained, equigranular to porphyritic rock. Plagioclase (andesine) is dominant mineral of rock, some of which contains biotite or hornblende and which ranges from massive to highly foliated. It is exposed in western part of quadrangle, where it includes quartz dioritic gneiss of Donnelly (Schmidt, 1964), and in west-central part of quadrangle in Loon Creek drainage basin (44°32′ N., 114°51′ W.). East of Stanley and southwest of mouth of Warm Spring Creek (44°08′ N., 115°58′ W.) this unit is equigranular, medium-grained, granitoid rock containing 30–35 percent amphibole laths, 40–50 percent plagioclase, and about 20 percent quartz. Amphibole is partly altered to brown, highly pleochroic biotite and to epidote. Sphene is principal accessory mineral. Potassium-argon ages of biotite from three samples range from 71.9±2.5 to 81.6±2.9 m.y. (see table 2)

Kim **Mixed rock units**—Mainly alaskite that encloses Precambrian metamorphic xenoliths

JURASSIC INTRUSIVE ROCKS

Jg **Gabbro**—Dark-grayish-green, medium- to coarse-grained rock containing primary mineral assemblage of calcic plagioclase, clinopyroxene, and magnetite, whose texture is overprinted by alteration assemblage of chlorite, pale-green acicular amphibole, albite, sphene, and small amounts of apatite, prehnite(?), pumpellyite(?), carbonate and(or) secondary quartz. Occurs as numerous small, irregular dikes, small plugs, and sill-like tabular masses scattered over area east and northeast of Clayton. Most commonly found intruded along or near thrust fault at base of Clayton Mine Quartzite (O€q). Fission-track age of 140.1±17.4 m.y. was obtained from zircon in quartzite immediately adjacent to contact with gabbro at mouth of Bayhorse Creek (44°22.5′ N., 114°15′ W.) (R. A. Zimmermann, written commun., 1983). This age for the zircon indicates time of track annealing caused by heat from gabbro intrusion. It also serves as limiting age for thrust fault beneath Clayton Mine Quartzite,

already in existence prior to intrusion of gabbro

PALEOZOIC SEDIMENTARY ROCKS

Pg **Grand Prize Formation (Lower Permian)**—Well-exposed sequence of fine-grained, dark-gray, carbonaceous argillite, siltite, limy siltite, and silty limestone. Weathers dark brown, reddish brown, or dark gray. Much of sequence is graded and has abundant crossbedding, convolute structures, and prominent banded appearance. Measured section on north side of Pole Creek at confluence with Grand Prize Creek (43°56′ N., 114°41′ W.) at type locality in Hailey 1°×2° quadrangle is about 2,000 m thick, but neither top nor bottom is exposed. Conodonts collected by C. M. Tschanz from low in section at Pole Creek are reported to be Leonardian-Roadian (upper Lower Permian) by Bruce Wardlaw (written commun., 1979). On Pungo Mountain a sequence about 100 m thick of thin-bedded limestone and calcareous argillite that have been extensively metamorphosed to tremolite-actinolite is questionably assigned to this unit. Sequence forms black soil. Mapped to include clean, well-sorted quartzite on east side of Pungo Mountain

Wood River Formation

PPw **Upper part (Lower Permian to Upper Pennsylvanian)**—Includes units 5 and 6 of Hall and others (1974). Thick sequence of gray and light-brown, fine-grained, calcareous sandstone that weathers dark brown and dark reddish brown. Interbedded in calcareous sandstone are fine-grained sandy limestone, fine- to medium-grained bioclastic limestone, and brown, thick-bedded, fine-grained quartzite. Crossbedding and convolute structures are common. Unit is dated on basis of abundant fusulinids. Minimum thickness 3,400 m at type locality (Hall and others, 1974)

Pwl **Lower part (Upper to Middle Pennsylvanian)**—Includes units 1, 2, 3, and 4 of Hall and others (1974). Lower part of Wood River Formation is present only from Railroad Ridge (44°08.5′ N., 114°35.5′ W.) at Little Livingston and Hermit mines south to Livingston mine. Unit 1 is chert and quartzite conglomerate present as thin fault slivers at Little Livingston and Hermit mines. It is overlain by succession about 150 m thick of fine-grained limy sandstone, silty limestone, and limy siltstone that includes units 2, 3, and 4

Pzsr **Salmon River assemblage (Paleozoic)**—Medium- to dark-gray, thin- to thick-bedded, well-laminated argillite, siltstone, calcareous siltstone, and fine-grained calcareous sandstone; some local grit and nearly pure, medium-gray limestone. Weathers tan, medium brown to dark brown, and, locally, light gray, blue gray, and pink. Sandstone is predominantly very fine to fine grained; some medium sand and grit layers; localized thin beds of chertlike, very siliceous argillite. Rock composed of variable proportions of quartz (predominant), clay minerals, carbonaceous material, sericite, mica, feldspar (usually only few percent), lithic fragments (argillite, shale, chert, fine-grained quartzite), various accessory minerals, and carbonate. Faint to prominent lamination in most places; cross lamination, current bedding, and sole structures in many fine-grained, thin sandstone beds and laminae. Dark colors related to amount of carbonaceous material, which ranges from nil to nearly 100 percent in few impure, coaly seams. Age of this assemblage is poorly known. Megafossils recovered from blocks of float found near mouth of Mill Creek (44°15′ N., 114°33′ W.) were assigned a Mississippian age (Hobbs and others, 1975). Conodonts collected from lower Thompson Creek (44°16.5′ N., 114°31′ W.) and from Slate Creek (44°12′ N., 114°36′ W.) have Late Cambrian and Devonian ages (J. Repetski, written commun., 1984). Base of sequence as exposed in quadrangle is thrust fault; overthrust by Grand Prize Formation (Pg) between Warm Springs and Slate Creeks (44°13′ N., 114°38′ W.) and by Wood River Formation (PIPw and Pwl) near Washington Peak (44°01′ N., 114°00′ W.). Thickness and sequence of units indeterminate in most places because of isoclinal folding and thrust faulting. About 1,400 m is present along Last Chance Creek (44°11.5′ N., 114°37′ W.), but neither base nor top is exposed

Msuc **Surrett Canyon and South Creek Formations, undivided (Upper Mississippian)**—Gray, fossiliferous, pure, thick-bedded, cliff-forming limestone and grayish-red-purple, impure, thin-bedded, slope-forming limestone. Top not exposed in quadrangle. Thickness about 400 m in area to east (Mapel and others, 1965)

Msp **Scott Peak Formation (Upper Mississippian**—Medium-dark-gray, chert-bearing bioclastic limestone; weathers medium dark to medium light gray; chert medium dark to medium gray, weathers brownish tan, forms discontinuous thin layers and nodules scattered along bedding. Medium to thick bedded. Forms ledges. Contains much crinoidal debris, many corals, and brachiopods. Locally contains jasperoid (black silica as replacement of carbonate rocks). Evidence obtained elsewhere in region indicates that this material was formed during or after Eocene volcanism (B. A. Skipp, oral commun., 1983). Fragments of what appears to be this material within conglomerate at base of volcanic sequence (Tcg) suggest that jasperoid in this area may be both older than and penecontemporaneous with the volcanic rocks. Present only in southeast corner of quadrangle. Thickness about 750 m

Mmc **Middle Canyon Formation (Upper and Lower Mississippian)**—Succession of medium-bedded cherty limestone and impure limestone exposed as smooth, float-covered slopes in southeast corner of quadrangle. Upper half is impure, medium-dark-gray to medium-gray, cherty, micrograular limestone. Black chert abundant in layers and nodules. Weathers to medium- or light-gray, small, irregularly shaped blocks that have slight yellow or pink mottling. Lower half is very fine grained sandy limestone, silicified in part. Float in lower half is more brightly colored and more angular than that of upper part. Locally, limestone is replaced by jasperoid; see discussion under Scott Peak Formation (Msp), above. Thickness about 200 m

Mw **White Knob Limestone (Upper Mississippian)**—Chiefly gray, ledge-forming, thick- to thin-bedded fossiliferous limestone; locally sandy, variably cherty, but in middle part also includes gray to yellowish-brown chert and quartzite granule to cobble conglomerate, sandstone, siltstone, and mudstone. Locally, limestone is replaced by jasperoid; see discussion under Scott Peak Formation (Msp), above. Thickness about 1,150 m

Mmg **McGowan Creek Formation (Lower Mississippian)**—Poorly exposed unit of mudstone (or argillite), subordinate siltstone, partly calcareous claystone, sandstone, and minor pebble conglomerate. Extensively sheared; formation sustains steep slopes covered by slabby or platy, locally finely blocky or pencil-like fragments; weathers medium light gray, yellowish gray, or light olive gray. Measured thickness 1,100 m in Lost River Range, east of quadrangle (Mapel and others, 1965; Sandberg, 1975)

Mcb **Copper Basin Formation, lower part (Lower Mississippian)**—Light-gray to black, medium- to thick-bedded conglomerate, sandstone, siltstone, and mudstone. Conglomerate contains clasts as much as 20 cm in diameter of chert, quartzite, quartz, and argillite in sandstone matrix. Unit is series of proximal to distal turbidites (Nilsen, 1977). Crops out chiefly near southeast corner of quadrangle. An isolated outcrop at confluence of Herd Creek and Lake Creek (44°07′ N., 114°14.5′ W.) is questionably assigned to this formation. Thickness more than 300 m

Dgj **Grand View and Jefferson Dolomites, undivided**

Dg **Grand View Dolomite (Upper Devonian)**—Includes microgranular, medium-dark- to medium-light-gray dolomite that weathers medium light gray and lighter and much recrystallized medium-light-gray to very light gray, fine- to coarse-grained dolomite that weathers grayish orange or pale yellowish brown. Scattered sandy intervals; a few shaly beds. Beds thick, commonly laminated. Formation moderately to highly resistant; forms blocky ledges and, locally, cliffs. At south end of, and southwest of, Grand View Canyon (44°21.5′ N., 114°3.5′ W.) map unit includes small patches of calcareous shale and dolomite elsewhere assigned to overlying Three Forks Formation (Hays and others, 1978). Thickness about 365 m

Dj **Jefferson Dolomite (Upper and Middle Devonian)**—Resistant, well-exposed unit of medium-dark-gray to medium-gray and subordinate dark-gray dolomite. Weathers to similar dark colors, partly mottled, commonly having brown cast; a few beds weather medium light gray. Grain size ranges from microgranular to fine; little silt or sand; commonly fetid. Beds thick to very thick (0.3–1.5 m); some thin, regular lamination. Highly resistant, forms ledges and cliffs. Thickness about 300 m

Dab **Informal units B (Middle? and Lower Devonian) and A (Lower Devonian) of Hays and others (1978, 1980) and Beartooth Butte Formation (Lower Devonian), undivided**—Unit B contains dark-gray to olive-gray, medium-bedded to very thick bedded dolomite and minor dolomitic sandstone; unit A contains dark- to light-gray, medium- to thick-bedded, moderately silty dolomite; Beartooth Butte Formation contains gray and brownish-gray, medium- to thick-bedded, very fine grained quartzite, sandstone, and siltstone

Sl **Laketown Dolomite (Silurian)**—Strikingly light colored dolomite that commonly forms ridges and peaks. Dolomite is predominantly medium light to light gray, mostly very fine to fine grained, and almost pure. Few scattered sandy intervals. Beds medium to very thick, mainly 0.3–1 m; locally, rock is massive and bedding is obscure. Joints common. Resistance to erosion high; forms rounded, light-gray to very light gray ledges and cliffs. Thickness 215–395 m

Srm **Roberts Mountains Formation (Silurian)**—Medium-dark- to medium-gray, carbonate-bearing, fine-grained detrital rocks and impure carbonate rocks. Most are mudstone, siltstone, and very fine silty sandstone, mainly dolomitic, partly calcareous; less abundant and irregularly distributed are muddy, silty, or finely sandy microgranular to very fine grained limestone and dolomite; small amount of siltite and quartzite. Beds medium to very thick. Regular lamination, 3 mm or less thick, and cleavage that may be parallel or oblique to bedding common. Resistance to erosion moderate to weak. Upper part contains fossils of late Wenlock and probable Ludlow age. Thickness about 800 m in Lone Pine Peak quadrangle (Hays and others, 1978)

Op **Black, carbonaceous, graptolite-bearing shale and argillite (Ordovician)**—Black, fissile, carbonaceous shale; bedding obscured by cleavage. Exposures totalling less than 1 km^2 along lower reaches of Big Lake Creek and Pine Creek (44°09′ N., 114°23′ W.), tributaries to East Fork of Salmon River. Generally deformed, especially in highest exposures beneath thrust contact with Salmon River assemblage (₽zsr). Tentatively correlated with Ordovician Phi Kappa Formation to south, as suggested by Dover and others (1980). Maximum of 35 m of unit exposed, total thickness unknown

Ose **Saturday Mountain Formation, Kinnikinic Quartzite, and Ella Dolomite, undivided (Ordovician)**—Upper and Middle Ordovician Saturday Mountain Formation is predominantly medium-dark- to medium-gray, microgranular to very fine grained, fairly pure dolomite that contains abundant (as much as 50 percent), irregular layers of medium-dark-gray chert in uppermost part of exposed section; some chert color laminated. Weathered surfaces medium light gray with yellowish cast. Forms blocky outcrops strongly ribbed by brownish-weathering chert. Contains considerable limestone, siltstone, and black shale in Squaw Creek area (44°18′ N., 114°29′ W.). Uppermost part of Saturday Mountain Formation may be Silurian. Middle Ordovician Kinnikinic Quartzite is fine-grained quartzite that is mainly light to very light gray with yellowish or brownish cast; locally as dark as medium gray or mottled medium dark and lighter gray; very fine to fine grained, contains some medium-size rounded grains; clean. Medium to thick bedded (maximum 1 m), bedding commonly obscured by shearing and partial recrystallization; local faint lamination. Middle Ordovician Ella Dolomite is medium- to dark-gray or brownish-gray, medium- to thick-bedded dolomite that contains thin laminae of silt and sand. Sequence in extreme northeastern part of quadrangle at

Rattlesnake Creek (44°58′ N., 114°0.5′ W.) includes quartzite that possibly is older than Ella Dolomite. Upper 30 m or so consists of medium-gray, fine-grained, mostly foliated dolomite, locally massive. Lower 10 m includes foliated dolomitic quartzite, which grades downward to massive, cliff-forming, white to light-gray quartzite about 200 m thick consisting of virtually pure quartz in two size fractions, a framework fraction 0.4–0.6 mm in diameter and a matrix fraction 0.1–0.2 mm in diameter. Landreth (1964) noted a few pale-red-purple beds near lower part of unit and considered entire sequence to be Kinnikinic Quartzite. Dolomite sampled by P. J. Modreski from upper 30 m contains conodonts of Middle or Late Ordovician age (J. Repetski, written commun., 1983) and an orthoid brachiopod identified by J. T. Dutro, Jr., (written commun., 1983) as probably genus *Valcourea*. Dutro further suggests that the collection might well represent Ella Dolomite. This allows possibility that quartzite is older than Kinnikinic and equivalent to Lower Ordovician Summerhouse Formation (Ruppel and others, 1975; McCandless, 1982). Total thickness about 1,450 m

Oc **Upper carbonate unit (Ordovician)**—Heterogeneous sequence of dolomite, silty dolomite, and dolomitic sandstone that crops out in Squaw Creek drainage basin, northwest of Clayton. Estimated thickness about 150 m

OЄrr **Siltstone, sandy siltstone, and quartzite of Rob Roy mine area (Ordovician? or Cambrian?)**—Thickness of at least 600 m exposed only near Kinnikinic Creek north of Clayton. Top eroded; thrust fault at base

OЄq **Quartzite (Lower Ordovician or older)**—Divided into five map units by Hobbs and others (1975). Over most of its outcrop area, consists mostly of Clayton Mine Quartzite (Middle Ordovician or older), which is poorly sorted, coarse- to medium-grained, feldspathic quartzite that, in upper two-thirds of section, includes conglomerate layers, pebbly quartzite, and scattered pebbles. Very thin shale partings throughout. More than 1,000 m thick

Or **Ramshorn Slate (Ordovician?)**—Gray, greenish-gray, purple, thin-bedded, well-laminated slate, locally phyllitic. Commonly shows well-developed cleavage at angle to bedding. Includes thin beds of sandstone toward top. Thick lens of conglomerate at base in outcrops west of Challis. Thickness about 800 m

OЄb **Bayhorse Dolomite (Lower Ordovician and Upper Cambrian)**—Light-gray to yellowish-gray, medium-bedded to very thick bedded dolomite in upper part and medium- to dark-gray, thin-bedded, fine-grained limestone in lower part. Dolomite contains dark-gray, silicified oval structures resembling pisolites in several layers as much as 9 m thick. Both upper and lower parts locally contain thin interbeds of siltstone, argillite, or fine-grained sandstone. Top of unit is erosional disconformity characterized by zone of probable paleokarst topography. Minimum thickness about 400 m

Єg **Garden Creek Phyllite (Cambrian(?))**—Dark-gray to black, slightly calcareous phyllite. As shown, includes small area of dolomite beneath phyllite, which is exposed in bed of Bayhorse Creek west of Bayhorse. Estimated thickness is 150–300 m

Єcqs **Quartzite, shale, and carbonate rocks of Squaw Creek area (Cambrian)**—Includes fossiliferous upper Middle Cambrian shale and underlying sequence of quartzite and carbonate rocks of Cambrian or older age (Hobbs and others, 1968). Mapped as four separate units by Hobbs and others (1975)

PALEOZOIC(?) AND PROTEROZOIC(?) ROCKS

OЄZl **Interbedded quartzite, dolomite, and argillite of Leaton Gulch and Pennal Gulch areas (Ordovician?, Cambrian?, Late Proterozoic?)**—Sequence of predominantly quartzitic strata containing subordinate dolomite interbeds and some thin argillitic interbeds and locally thicker argillite intervals. Quartzite generally deep red to dark purplish gray to medium gray; some thick zones of light pinkish or tannish gray and very light gray to white; medium grays and purplish grays predominate. Thin to medium bedded, platy, laminated; some massive units are thick bedded and structureless; mostly medium to fine grained, locally coarse grained and pebbly; lamination prominent in some thick layers; includes several zones of very coarse conglomerate or intraformational breccia. Much of thin-bedded platy quartzite shows ripple marks, flute casts, worm trails; abundant magnetite in parts of section. Dolomite very fine grained to dense, light to medium tan on fresh surface, weathers rich reddish tan to brown; beds dispersed in quartzite and range from 0.2 m to several meters in thickness; restricted to area within 1 km east from Beardsley Hot Springs (44°31′ N., 114°10′ W.). Argillite occurs as laminae or thin interbeds in much of quartzite sequence and locally forms continuous sequence as much as 100 m thick; generally thin bedded, fissile; dark gray or purplish gray, in places altered to deep gray green. Many argillaceous layers metamorphosed to phyllite close to thrust faults. Sequence of rock types is indeterminate because of complex structure and discontinuity of exposures. General characteristics of strata and structural relations to Swauger Formation suggest possible correlation with Late Proterozoic Wilbert and (or) Lower Ordovician Summerhouse Formations (Ruppel, 1975) or with formation of Tyler Peak of Early Cambrian age (McCandless, 1982)

rp **Roof pendants and xenoliths of metamorphic rock in Idaho batholith, undivided (Paleozoic? or Proterozoic?)**—Includes schist, quartzite, and calc-silicate rocks. At some places graphite is common constituent of rocks. Includes Thompson Peak Formation of Reid (1963)

rps **Schist roof pendant**—Exposures of these rocks east of Big Baldy Lookout (44°47′ N., 114°13′ W.) are principally staurolite-muscovite-biotite-quartz schist and locally, according to B. F. Leonard (written commun., 1983), contain garnet and andalusite

rpq **Quartzite roof pendant**

rpc **Calc-silicate rock roof pendant**

MIDDLE PROTEROZOIC SEDIMENTARY AND METAMORPHIC ROCKS

Yl **Lawson Creek Formation**—Thin- to medium-bedded and interbedded fine-grained, platy, pink to greenish-gray quartzite and dark-purplish-gray quartzitic phyllite containing some zones of laminated purple, sandy argillite. Quartzite is feldspathic, locally containing much coarse mica on bedding planes, and has conspicuous ripple marks and other sedimentary structures. Some thicker quartzite beds similar to Swauger Formation in general characteristics. Base of sequence is gradational through distance of a few meters with the Swauger Formation on which it lies; top not known; minimum thickness about 1,300 m (Hobbs, 1980)

Ys **Swauger Formation**—Light-pink, pinkish-tan, purplish-gray to locally red, medium- to coarse-grained, fairly pure, well-sorted quartzite; commonly contains several percent feldspar; medium to thick bedded, locally prominent cross-lamination; few very thin shaly partings. Base not exposed; top seems to grade over several meters into Lawson Creek Formation (Yl). Minimum thickness about 3,000 m

Yg **Gunsight Formation**—Light-brownish-gray, fine- to medium-grained (0.3–0.6 mm diameter), thin- to thick-bedded, sericitic quartzite; typically contains about 60–65 percent quartz, 30 percent sericite, 2–4 percent orthoclase and perthite, 3–6 percent microcline, 0.4–0.6 percent plagioclase. Rock is not well sorted; mostly well rounded quartz "berries" as large as 0.7 mm commonly occur in matrix of grains averaging about 0.3 mm diameter. Some exposures contain only trace amounts of alkali feldspar and plagioclase and considerably less than 15 percent sericite, and appear to be gradational with overlying Swauger Formation. Thickness 400 m (incomplete)

Ya **Apple Creek Formation**—Mainly siltstone and fine-grained sandstone; medium-greenish-gray to grayish-red-purple to dark-gray, thin-bedded, laminated siltstone containing irregular streaks and lenses of light-gray, pinkish- to pale-brown sandstone cemented by ferrodolomite. Sandstone lenticles are typically a few millimeters to several centimeters thick and 1 m, more or less, long, although much longer lenses are known. Medium-gray to brownish-gray to light-gray or pale-red, feldspathic, fine-grained quartzite beds several centimeters in thickness occur in what appear to be stratigraphically higher parts of unit. Ripple marks and other sedimentary structures are abundant, and many bedding surfaces are coated with detrital mica; lamination and cross-lamination in fine-grained sandstone common. Disconnected exposures and complex structure prevent accurate correlation of beds and determination of thickness. No base or top exposed in quadrangle. It is possible that upper part of section mapped as Yellowjacket Formation (Yy) east and north of Iron Lake (44°54.5′ N., 114°11.5′ W.) and north of Iron Creek (44°56′ N., 114°04′ W.) actually is Apple Creek Formation

Yb **Big Creek Formation**—Light-greenish-gray, thin- and thick-bedded, fine- to medium-grained, micaceous and feldspathic quartzite; thicker beds are conspicuously cross bedded; magnetite grains are abundant in some laminae and scattered through rock. In some exposures greenish-gray quartzite grades upward to reddish-gray feldspathic quartzite that weathers brown and brownish gray. Some thinner bedded exposures contain more siltite and show rather pronounced slaty cleavage, obscure current ripple marks, and some load casts. Typical rocks contain 45–57 percent quartz (0.1–0.3 mm long), 10–20 percent orthoclase and microcline, 10–20 percent plagioclase, and 7–20 percent sericite, biotite, and iron oxide. Abundance of plagioclase is distinctive. Thickness 600 m (incomplete)

Yy **Yellowjacket Formation**—Mostly medium-gray and light-bluish-gray to greenish-gray, thin- and thick-bedded, argillaceous quartzite and siltite grading downward to thin- and thick-bedded, light-gray quartzite that is indistinguishable from underlying Hoodoo Quartzite (Yh, see below). Upper sequence of Yellowjacket Formation (above Hoodoo) along north border of quadrangle at long 114°27′ W. is of uncertain thickness but probably has preserved thickness of several hundred meters. Overall, it is cleaner and lighter colored than Yellowjacket that underlies Hoodoo. Incomplete sequence below Hoodoo in Yellowjacket area (44°59′ N., 114°30′ W.) consists of 2,340 m of dark-gray, argillaceous, thin- and thick-bedded quartzite and siltite that tend to weather to hackly chips. Ross (1934) and our work show that quartzite beds are composed of 55–70 percent quartz grains having average diameter of 0.1 mm, about 30 percent biotite, chlorite, sericite (formed from originally argillaceous material), and magnetite. Some beds are sufficiently rich in magnetite to strongly attract pencil magnet. Argillaceous quartzite grades downward locally to varicolored calcareous rocks. According to Carter (1981), calcareous rocks occur as discrete lenses in argillaceous quartzite. Thin quartzite beds throughout Yellowjacket display fine-scale, cross-laminated layers, oscillatory ripple marks, and current ripple marks. Excellent mud cracks were found in siltite or very thin quartzite layers just east of Yellowjacket Creek, along Hoodoo Creek (44°57.5′ N., 114°35′ W.), and at mouth of Musgrove Creek (45°01′ N., 114°19′ W.) in Elk City 1°×2° quadrangle. These occurrences confirm conclusion of Ross (1934) that Yellowjacket was deposited under shallow marine conditions, at least in area near Yellowjacket mining district (44°59′ N., 114°30′ W.). Base of formation has not been identified in Challis quadrangle. Lower sequence of Yellowjacket in Iron Creek area (44°55′ N., 114°06′ W.) is more than 3,500 m thick; thickness of entire Yellowjacket at principal reference section (Ekren, 1988) is greater than 4,000 m (including Hoodoo Quartzite)

Yh **Hoodoo Quartzite**—White, off-white, and light-brownish-gray, massive-weathering, thin- and thick-bedded, clean quartzite. Except for outcrops at top and base, bedding is obscure; crossbedded in beds 0.5–1.0 m thick; contact at base and top transitional with subjacent and superjacent Yellowjacket. Intensely fractured and sheared in most places. Quartz averages about 85 percent; feldspar averages 5–15 percent and consists of microcline, non-perthitic orthoclase, and sparse albite. Rocks near base and top contain as much as 10 percent biotite, sericite, and iron oxide formed from original clay-rich cement. Thickness 0–1,100 m

INTRUSIVE ROCKS OF UNCERTAIN AGE

dr **Diorite, quartz diorite, and syenite**—In Yellowjacket area corresponds to "hornblende quartz diorite" of Ross (1934), who considered rock to be Tertiary in age. This unit is mixed sequence of mostly gray, melanocratic rock ranging in composition from reconstituted gabbro to mafic-rich quartz monzonite. Composition of gabbro from near Middle Fork Peak (44°58′ N., 114°39′ W.): pf (1–10 mm long), 34.4; b, 2.8; hb (mostly after px), 18.4; fibrous actinolite-tremolite, 5.2; nonfibrous actinolite-tremolite, 15.1; chlorite, 7.6; black opaque oxides, 10.8; apatite, 5.7. According to Ross (1934, p. 58), typical hornblende quartz diorite is nearly white and contains the following minerals: q, trace–5 (locally as much as 20);

af, trace–10; pf, 60; hb and b (mostly intergrown), 20–40 (locally hb, 43; b, 38). Rock commonly is altered to epidote, chlorite, sericite, and calcite. Cater and others (1973) considered these rocks to be Precambrian in age, and Peale (1982, p. 58) considered them to be Cambrian(?) to Ordovician(?). Diorite and quartz diorite are part of composite mass that includes syenite (sr, see below). Gabbro and diabase may be as old as Precambrian, but ages of other rocks of this unit clearly are uncertain. Karl Evans (written commun., 1984) obtained an Ordovician age on zircons from syenite in this map unit from a locality a few kilometers east of Middle Fork Peak (44°58′ N., 114°39′ W.)

sr **Quartz syenite, syenite, and granite**—A composite mass, considered by Ross (1934) to be Tertiary in age. According to Peale (1982, p. 61–62), rocks all contain quartz except for syenite, which is rare. Mode: q, 5–32; af (mostly microcline-microperthite), 37–85; pf, 1–28; b, 0–5; ferrohastingsite, 0–15. Much of rock in this unit is remarkably fresh and postorogenic; it intrudes highly deformed Precambrian rocks. Rock resembles syenite of known Tertiary age elsewhere in quadrangle; in particular, it resembles syenite that is part of intrusive mass at Jackson Peak (Tdc), which intrudes Idaho batholith and has an Eocene potassium-argon age (see page 20). It also closely resembles "hornblende granite" of Ross (1934), which intrudes Challis Volcanics. These rocks presumably are same age as syenite mapped within unit dr (see p. 27)

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Table 1. *Potassium-argon ages of the Eocene Challis Volcanic Group and intrusive rocks*

[All ages calculated using constants of Steiger and Jaeger (1977); ages published prior to 1977 have been recalculated; do., ditto]

Locality No. on map	Map unit symbol	Map unit name (page number)	K-Ar age (m.y.)	Material dated	Sample locality	Sources of data (see list of references)
				Intrusive rocks		
1	(*)	Hornblende latite dike--	36.7±1.5	Hornblende-	Thunder Mtn. cauldron complex--	Leonard and Marvin (1982).
2	Tdb, Tdbi	Rhyodacite domes and plugs at Bradbury Flat (p. 15).	39.7±1.2	Plagioclase---	Southeastern part of quadrangle--	Armstrong (1975).
3	Trd	Rhyolite dikes (p. 2)----	39.8±0.9	Whole rock--	Thunder Mtn. cauldron complex--	Leonard and Marvin (1982).
4	Trd	----------do-----------------	41.1±0.9	Sanidine------	----------------do-----------------------	Do.
5	Trd	----------do-----------------	42.4±1.5	Sanidine------	----------------do-----------------------	Do.
6	Tg	Granite (p. 5)-------------	43.9±1.3	Biotite--------	Northern part of Van Horn Peak cauldron complex.	Armstrong (1975).
			47.8±1.9	Biotite--------	--------------do-------------------------	Leonard and Marvin (1982).
7	Tg	Granite (p. 19)-----------	44.3±1.3	Hornblende-	South-central part of quadrangle.	R.J. Fleck, written commun., 1984.
8	Tqp*	Quartz porphyry intrusions (p. 4).	44.4±1.0	Sanidine------	Panther Creek graben---------------	R.F. Marvin, written commun., 1981.
9	Tr	Rhyolite intrusions (p. 2).	44.6±1.5	Sanidine------	Thunder Mtn. cauldron complex--	Leonard and Marvin (1982).
10	Tr	Rhyolite intrusions (p. 4).	44.6±1.5	Sanidine------	Panther Creek graben---------------	R.F. Marvin, written commun., 1981.
11	Tg	Granite (p. 5)-------------	45.1±1.6	Biotite--------	Northern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1984.

Table 1. *Potassium-argon ages of the Eocene Challis Volcanic Group and intrusive rocks*--Continued

Locality No. on map	Map unit symbol	Map unit name (page number)	K-Ar age (m.y.)	Material dated	Sample locality	Sources of data (see list of references)
12	Trd	Rhyolite dikes (p. 2)----	45.2±1.5	Sanidine------	Thunder Mtn. cauldron complex--	Leonard and Marvin (1982).
13	Tdc	Diorite complex (p. 20)-	46.0±1.7	Whole rock--	Western part of quadrangle--------	R.J. Fleck, written commun., 1984.
14	Tdi	Dikes and plugs of intermediate composition (p. 10).	46.0±1.7	Biotite--------	Southern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1983.
			48.9±2.9	Hornblende-	----------------do-----------------------	Do.
15	Tdc	Diorite complex (p. 20)-	46.2±0.9	Biotite--------	Western part of quadrangle--------	R.J. Fleck, written commun., 1984.
			47.7±1.1	Hornblende-	----------------do-----------------------	Do.
16	Trf	Rhyolite dikes, plugs, and flows (p. 10).	46.5±1.7	Sanidine------	Southern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1984.
17	Tdc	Diorite complex (p. 20)-	46.6±0.5	Biotite--------	Western part of quadrangle--------	R.J. Fleck, written commun., 1984.
			48.2±3.0	Hornblende-	----------------do-----------------------	Do.
18	Tg	Granite (p. 5)-------------	46.6±1.6	Biotite--------	Northern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1981.
19	Til	Potassium-rich andesite, latite, and basalt intrusions (p. 16).	48.2±1.4	Whole rock--	Southeastern part of quadrangle--	Armstrong (1975).
20	Tgp	Gray porphyry (p. 10)---	48.6±1.4	Biotite--------	Southern part of Van Horn Peak cauldron complex.	Armstrong (1975).
21	Tdi	Dikes and plugs of intermediate composition (p. 16).	50.0±1.8	Biotite--------	Southeastern part of quadrangle--	R.F. Marvin, written commun., 1982.

Table 1. *Potassium-argon ages of the Eocene Challis Volcanic Group and intrusive rocks*--Continued

Locality No. on map	Map unit symbol	Map unit name (page number)	K-Ar age (m.y.)	Material dated	Sample locality	Sources of data (see list of references)
			Extrusive rocks			
22	Tvr	Rhyolite flows (p. 20)---	37.6±2.1	Sanidine------	Western part of quadrangle--------	R.J. Fleck, written commun., 1984
23	Tcr	Tuff of Challis Creek (p. 16).	45.0±1.3	Sanidine------	Southeastern part of quadrangle--	Armstrong (1975).
24	Tss	Sunnyside tuff (p. 2)-----	46.3±1.0	Sanidine------	Thunder Mtn. cauldron complex-	Leonard and Marvin (1982).
25	Tss	----------do-----------------	46.3±1.1	Sanidine------	----------------do-----------------------	Leonard and Marvin (1982).
			47.7±1.6	Biotite--------	----------------do-----------------------	Do.
26	Trb	Rhyolite of Red Butte (p. 13).	46.9±1.6	Biotite--------	Southern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1980.
27	Tgp	Gray porphyry (p. 10)---	46.9±2.8	Hornblende-	----------------do-----------------------	R.F. Marvin, written commun., 1983.
			49.5±1.4	Biotite--------	----------------do-----------------------	Do.
28	Tem	Tuff of Eightmile Creek (p. 15).	47.5±1.3	Biotite--------	Custer graben-----------------------	R.F. Marvin, written commun., 1984.
29	Ttm	Tuff of Table Mountain (p. 8).	47.8±1.7	Biotite--------	Corral Creek cauldron segment---	R.F. Marvin, written commun., 1982.
30	Th	Tuff of Herd Lake (p. 17).	48.1±1.7	Biotite--------	Southeastern part of quadrangle--	Do.
31	Tem	Tuff of Eightmile Creek (p. 13).	48.4±1.7	Biotite--------	Southern part of Van Horn Peak cauldron complex.	Do.
32	Te	Tuff of Ellis Creek (p. 8).	48.4±1.6	Biotite--------	Panther Creek graben---------------	Do.

Table 1. *Potassium-argon ages of the Eocene Challis Volcanic Group and intrusive rocks*--Continued

Locality No. on map	Map unit symbol	Map unit name (page number)	K-Ar age (m.y.)	Material dated	Sample locality	Sources of data (see list of references)
33	Trm	Rhyolite of Mill Creek Summit (p. 17).	48.5 ± 1.2	Biotite--------	Southeastern part of quadrangle--	Marvin and Dobson (1979).
34	Tdf	Dacitic and rhyodacitic lava (p. 8).	48.6 ± 1.7	Biotite--------	Panther Creek graben--------------	R.F. Marvin, written commun., 1980.
35	Tvs	Volcaniclastic and sedimentary rocks (p. 18).	49.0 ± 1.8	Biotite--------	Southeastern part of quadrangle--	R.F. Marvin, written commun., 1982.
			49.0 ± 2.9	Hornblende-	---------------do----------------------	Do.
36	Tdf	Dacitic and rhyodacitic lava (p. 18).	49.2 ± 1.2	Biotite--------	---------------do----------------------	Marvin and Dobson (1979).
37	Tdf	----------do----------------	49.3 ± 1.4	Plagioclase--	---------------do----------------------	Armstrong (1975).
38	Tbal	Mafic lava (p. 18)--------	50.3 ± 1.5	Whole rock--	---------------do----------------------	Do.
39	Tdf	Dacitic and rhyodacitic lava (p. 14).	50.4 ± 1.8	Biotite--------	Twin Peaks caldera area-----------	R.F. Marvin, written commun., 1982.
40	Tll	Lower latite lava (p. 4).	50.8 ± 1.7	Sanidine------	Thunder Mtn. cauldron complex--	Leonard and Marvin (1982).
41	Tdf	Dacitic and rhyodacitic lava (p. 8).	51.1 ± 1.8	Biotite--------	Northern part of Van Horn Peak cauldron complex.	R.F. Marvin, written commun., 1982.
42	Tdf	Dacitic and rhyodacitic lava (p. 18).	51.1 ± 1.7	Biotite--------	Southeastern part of quadrangle--	McIntyre and others (1976).

*Not shown at this map scale.

Table 2. *Potassium-argon ages of Cretaceous granitic rocks of the Idaho batholith*

[All ages calculated using constants of Steiger and Jaeger (1977). Many of these potassium-argon ages do not represent ages of pluton emplacement. Many are younger because of prolonged residence of the rocks at temperatures above the argon blocking temperature and because of reheating associated with Eocene plutonism (see Criss and others, 1982); do, ditto]

Locality letter on map	Map unit symbol	Map unit name	K-Ar age (m.y.)	Material dated	Sample locality and comments	Sources of data (see list of references)
A	Klg	Leucocratic granite.	63.6±1.4	Biotite--------	Greenback Mine, southwest of Stanley.	R.F. Marvin, written commun., 1980.
B	Klg	----------do-----------	65.1±0.8	Biotite--------	Warm Spring Guard Station, southwest of Stanley.	R.J. Fleck, written commun., 1984.
C	Klg*	----------do-----------	70.3±2.5	Biotite--------	Northeast of Paddy Flat, near northwest corner of quadrangle.	R.F. Marvin, written commun., 1982.
D	Klg	----------do-----------	72.1±1.7	Biotite--------	Southeast of Landmark; dike (not shown on map).	R.F. Marvin, written commun., 1980.
E	Klg	----------do-----------	72.6±2.5	Biotite--------	Northeast of Landmark; dike (not shown on map).	Do.
F	Klg	----------do-----------	75.0±2.7	Muscovite----	Lost Packer Mine, near Casto; dike (not shown on map).	R.F. Marvin, written commun., 1985.
G	Kg	Muscovite-biotite granodiorite and granite.	65.3**	Biotite--------	Southeast of Deadwood Reservoir.	Criss and others (1982).
H	Kg	----------do-----------	66.2±0.9	Biotite--------	Northeast of Deadwood Reservoir.	R.J. Fleck, written commun., 1984).
			68.8±0.2	Muscovite----	-----------------do------------------	Do.
I	Kg	----------do-----------	68.0**	Biotite--------	Near southwest corner of quadrangle.	Criss and others (1982).

Table 2. *Potassium-argon ages of Cretaceous granitic rocks of the Idaho batholith*--Continued

Locality letter on map	Map unit symbol	Map unit name	K-Ar age (m.y.)	Material dated	Sample locality and comments	Sources of data (see list of references)
J	Kg	----------do-----------	68.6**	Biotite--------	West of Deadwood Reservoir.	Do.
K	Kg	----------do-----------	69.5±2.3	Biotite--------	West of Yellow Pine-----------	R.F. Marvin, written commun., 1974.
			70.7±2.3	Muscovite----	-----------------do-----------------	Do.
L	Kg	----------do-----------	72.1±2.6	Biotite--------	West of Yellow Pine-----------	R.F. Marvin, written commun., 1982.
			72.2±1.7	Muscovite----	-----------------do-----------------	Do.
M	Kg	----------do-----------	69.8±2.3	Biotite--------	West of Yellow Pine-----------	R.F. Marvin, written commun., 1974.
			74.1±1.7	Muscovite----	-----------------do-----------------	Do.
N	Kg	----------do-----------	73.1±2.6	Biotite--------	East of Paddy Flat, near northwest corner of quadrangle.	R.F. Marvin, written commun., 1982.
			74.7±2.7	Muscovite----	-----------------do-----------------	Do.
O	Kg	----------do-----------	73.9±2.7	Biotite--------	East of Warm Lake, in northwest part of quadrangle.	Do.
			75.8±2.7	Muscovite----	-----------------do-----------------	Do.
P	Kgd	Biotite granodiorite	61.5**	Biotite--------	South Fork Payette River, southwest of Stanley.	Criss and others (1982).
Q	Kgd	----------do-----------	62.0**	Biotite--------	East of Lowman----------------	Do.
R	Kgd	----------do-----------	62.4**	Biotite--------	West of Lowman----------------	Do.
S	Kgd	----------do-----------	63.4**	Biotite--------	South Fork Payette River, northwest of Jackson Pk.	Do.

Table 2. *Potassium-argon ages of Cretaceous granitic rocks of the Idaho batholith*--Continued

Locality letter on map	Map unit symbol	Map unit name	K-Ar age (m.y.)	Material dated	Sample locality and comments	Sources of data (see list of references)
T	Kgd	----------do----------	68.5**	Biotite--------	South of Landmark--------------	Do.
U	Kgd	----------do----------	72.5**	Biotite--------	Northeast of Stanley------------	Do.
V	Kgd	----------do----------	72.7±2.6	Biotite--------	North of Warm Lake-----------	R.F. Marvin, written commun., 1982.
W	Kgd	----------do----------	73.0±2.5	Biotite--------	Gold Fork River, in northwest part of quadrangle.	R.F. Marvin, written commun., 1981.
X	Kgd	----------do----------	74.9±2.5	Biotite--------	East of Landmark---------------	R.F. Marvin, written commun., 1980.
Y	Kgd	----------do----------	76.3±2.6	Biotite--------	Northeast of Seafoam Ranger Station.	R.F. Marvin, written commun., 1981.
Z	Kgd	----------do----------	78.9±2.8	Biotite--------	Southwest of Eagle Nest Lookout, near west edge of quadrangle.	R.F. Marvin, written commun., 1982.
AA	Kgd	----------do----------	81±2	Biotite--------	North of Robinson Bar Ranch	Armstrong (1975).
BB	Kgd	----------do----------	81.3±2.9	Biotite--------	North of Sunbeam---------------	R.F. Marvin, written commun., 1985.
CC	Kgd	----------do----------	81±2	Biotite--------	Hw. 93, northeast of Stanley---	Armstrong (1975).
DD	Kgd	----------do----------	83.2±2.8	Biotite--------	White Cloud Stock, southeast of Stanley.	R.F. Marvin, written commun., 1981.
EE	Kgd	----------do----------	84.7±1.9	Biotite--------	White Cloud Stock; sample somewhat porphyritic.	Do.

Table 2. *Potassium-argon ages of Cretaceous granitic rocks of the Idaho batholith*--Continued

Locality letter on map	Map unit symbol	Map unit name	K-Ar age (m.y.)	Material dated	Sample locality and comments	Sources of data (see list of references)
FF	Kgd	----------do----------	85.6±2.1	Biotite--------	White Cloud Stock-------------	Marvin and Dobson (1979).
GG	Kgd	----------do----------	88.9±3.1	Biotite--------	Pat Hughes Stock, Thompson Creek.	Marvin and others (1973).
HH	Kgd	----------do----------	96.9±3	Biotite--------	Northeast of Robinson Bar Ranch.	Armstrong (1975).
II	Kgd	----------do----------	98.1±3.3	Biotite--------	Juliette Stock, west of Bayhorse.	McIntyre and others (1976).
JJ	Kgdp	Porphyritic biotite granodiorite and granite.	62.6**	Biotite--------	Northwest of Stanley-----------	Criss and others (1982).
KK	Kgdp	----------do----------	77.9±2.8	Biotite--------	South of Yellow Pine----------	R.F. Marvin, written commun., 1985.
LL	Kgdp	----------do----------	79.8±2.7	Biotite--------	West of Sunbeam---------------	R.F. Marvin, written commun., 1980.
			84.7±2.9	Hornblende--	----------------do-----------------	Do.
MM	Kgdp	----------do----------	84±2	Biotite--------	West of Sunbeam---------------	Armstrong (1975).
NN	Kt	Tonalite and granodiorite.	71.9±2.5	Biotite--------	North of Paddy Flat, near northwest corner of quadrangle.	R.F. Marvin, written commun., 1974.
OO	Kt	----------do----------	81.2±2.9	Biotite--------	Southeast of Stanley; unmapped patch of Kt in Kgdp.	R.F. Marvin, written commun., 1985.
PP	Kt	----------do----------	81.6±2.9	Biotite--------	Gold Fork River, near west edge of quadrangle.	R.F. Marvin, written commun., 1982.

*Not shown at this map scale.
**No value for standard error provided by Criss and others (1982).

Table 3. *^{40}Ar-^{39}Ar age determinations on sanidine, tuff of Challis Creek, Challis Volcanic Group*

[L. W. Snee, written commun., 1984]

Locality letter on map	Map unit symbol (page number)	Map unit name	Age (m.y.)
C1	Tcru (p. 11)	Tuff of Challis Creek, upper unit-----	45.5±0.3
C2	Tcrl (p. 12)	Tuff of Challis Creek, lower unit-----	45.8 ±0.2
C3	Tcrm* (p. 12)	Tuff of Challis Creek, middle unit----	45.9 ±0.2
C4	Tcr* (p. 12)	Tuff of Challis Creek, outflow unit---	46.3 ±0.2
C5	Tcrl* (p. 12)	Tuff of Challis Creek, lower unit-----	46.5 ±0.1

*Rock matrix is zeolitized.

Table 4. *Summary of cauldron-related volcanic events, Eocene Challis Volcanic Group, Challis quadrangle*

[Leaders (---), no data]

Subsidence feature	Tuff eruption that triggered subsidence (page number)	Time of initial subsidence (m.y.)
Corral Creek cauldron segment.	Lithic tuff of Corral Creek (p. 9)-	---
Van Horn Peak cauldron complex.	Tuff of Ellis Creek (p. 8)-----------	48.4
Custer graben and part of Van Horn Peak cauldron complex.	Tuff of Eightmile Creek (p. 15)---	47.5
Thunder Mountain cauldron complex.	Dime- and quarter-size lapilli tuff (p. 4).	---
Castle Rock cauldron segment.	Quartz-biotite tuff (p. 6)------------	---
Twin Peaks caldera----	Tuff of Challis Creek (p. 11)-------	46.5

INDEX

Map unit symbol	Page