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

# GEOLOGIC MAP OF THE SALMON NATIONAL FOREST AND VICINITY, EAST-CENTRAL IDAHO

Compiled by

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Geologic maps as follows:

Geologic map of the western part of the Salmon National Forest
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Geologic map of the eastern part of the Salmon National Forest
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## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

Qu **Alluvial, colluvial, landslide, and glacial deposits, undivided (Quaternary)**—Composite unit of unconsolidated gravel, sand, silt, and clay deposits of present streams, rivers, and washes; hillside colluvium; landslide material; and glacial moraines and outwash

### CENOZOIC SEDIMENTARY ROCKS

QT **Gravel, limestone, sandstone, and volcaniclastic sediments (Holocene to Oligocene(?))**—Composite unit of volcaniclastic sedimentary rocks, limestone, conglomerate, sandstone, shale, and mudstone, deposited as the present basin-range topography formed during extensional faulting. Unconsolidated and slightly consolidated boulder to pebble conglomerate is interbedded with sandstone and mudstone near top of unit where it accumulated as colluvium, landslide debris, and some glacial outwash. Limestones are laminated and platy, and formed in fresh-water lakes and hot springs. Tuffaceous sedimentary rocks and volcanic-derived conglomerates are dominant in lower part of unit. Well-exposed outcrops indicate that angular unconformities are common within unit (Lucchitta, 1966)

Ttu **Tuff and tuffaceous conglomerate (Pliocene to Miocene)**—Mainly very light gray, friable, vitric, well-sorted tuff in beds as much as 1 m thick, interbedded with very light grayish brown, medium-grained tuff and tuffaceous conglomerate, and very light gray, very finely crystalline to aphanitic limestone in beds 0.3–1 m thick. Unit is commonly veneered with angular chips of vitreous quartzite lag gravel derived from tuffaceous conglomerate and from sparse quartzite fragments scattered throughout tuff. Fossil vertebrate fauna, gastropods, and diatoms indicate an age span from Miocene to Pliocene (Ruppel and Lopez, 1988)

Ts **Sedimentary rocks—basin fill (Miocene(?) to Eocene)**—Tuffaceous, basin-fill strata, tentatively divided into two sequences (Ruppel and Lopez, 1988). Upper sequence consists of light-olive-gray and yellowish-gray to yellowish-brown or yellowish-orange, tuffaceous mudstone and shale; fine- to medium-grained, tuffaceous sandstone; and lenticular beds of conglomerate with a sandy, tuffaceous matrix. Shale and mudstone dominate base of upper sequence but decrease upsection where they are locally absent altogether. Upper sequence is at least 600–700 m thick. Lower sequence overlies the Challis Volcanic Group with angular unconformity and is predominantly olive-gray and yellowish-gray to grayish-orange, tuffaceous, bentonitic mudstone and shale with 2- to 15-cm-thick beds of lignite, lignitic mudstone, and beds with abundant woody fragments. This lower sequence also contains some interbeds of fine-grained to very fine grained, crossbedded sandstone as thick as 1 m and lenticular interbeds of comglomerate 1–8 m thick. The thickest unfaulted section of lower sequence is about 250 m but total thickness is unknown. Harrison (1985) interpreted the unit to represent eight depositional facies based on a transition from proximal alluvial fans to shallow lacustrine basins

Toc **Older colluvium of Panther Creek (Eocene)**—Poorly consolidated sandstone, mudstone, boulder conglomerate, and tephra that are locally carbonaceous; includes large landslide masses of variegated volcanic rocks. Unit was deposited in the rapidly subsiding Panther Creek graben during regional rifting concurrent with Challis volcanism. Strata are easily eroded and subject to a considerable degree of landsliding

### CENOZOIC VOLCANIC ROCKS

#### Challis Volcanic Group (Eocene)

Tc **Challis Volcanic Group, undivided**—Composite unit used in areas where the volcanic rocks have not been subdivided or where units have been combined in order to show at map scale. Most of the group was erupted from 45 to 51 Ma, although minor activity persisted to about 39 Ma (Fisher and Johnson, 1995)

*Tuffs and lavas of Thunder Mountain cauldron complex (southwestern part of Salmon National Forest)*—See Fisher and others (1992)

Tcs **Sunnyside tuff**—Rhyolitic tuff with multiple cooling units. Upper part of unit is a multiple-flow compound cooling unit of red-weathering, densely welded, devitrified rhyolite tuff; it contains lithic fragments and flattened pumice lapilli and has a black vitrophyre at its base.

Below this, megabreccia contains fragments of lower tuffs and probably formed from collapse of the Thunder Mountain caldera wall during eruption. Below the megabreccia the unit consists of (from top to bottom): (1) a single cooling unit of reddish-gray, densely welded rhyolite tuff; (2) at least two cooling units of red, flow-layered lava or ash-flow tuff with black vitrophyre and intercalated black vesicular latite flows; and (3) three or more cooling units of white to pink, only slightly welded, pumice-bearing, slightly porphyritic bases and gray, vertically jointed, densely welded, phenocryst-rich (as much as 50 percent) quartz latite tops. Leonard and Marvin (1982) reported K-Ar ages on biotite of 47.7±1.6 Ma, and on sanidine of 46.3±1.1 and 46.3±1.0 Ma. Total thickness is as much as 1,000 m. Unit constitutes most of the Thunder Mountain cauldron complex as subdivided by Fisher and others (1992); the name was originally an informal designation used locally by Shannon and Reynolds (1975) in the Thunder Mountain mining district

Tcp **Perlitic rhyolite**—Three rhyolite cooling units separated by green epiclastic sediments. Upper unit is an ash-flow tuff having a nonwelded top. All three units display devitrified, lavender to salmon, flow-layered lava or high-temperature, densely welded tuff at the top that grades downward into black vitrophyre at the base. Phenocryst content varies and assemblage includes alkali feldspar, plagioclase, hornblende, and trace clinopyroxene. Total thickness 0–300 m

Tct **Lapilli tuff**—Complex sequence of ash-flow tuff, commonly separated by beds of tuffaceous sandstone and siltstone, and locally by thin black latite lava. Greenish-gray or buff lapilli tuff is densely welded and contains conspicuous dark-green or brownish-green, 1- to 2.5-cm-long collapsed pumice lapillae. Phenocrysts (9–16 percent) in tuffs include as much as 5 percent quartz, 2–8 percent alkali feldspar, 70–83 percent plagioclase, as much as 2 percent biotite, as much as 4 percent hornblende, and as much as 16 percent (mostly altered) pyroxene. Tuffs have been pervasively propylitized, resulting in mafic minerals being altered to chlorite, calcite, and iron oxide. Eruption of unit associated with initial collapse of the Thunder Mountain cauldron complex. Total thickness 0–500 m

Tcll **Lower latite lava**—Dark-gray to dark-purplish-gray lavas consisting of interlayered crystal-poor latite and crystal-rich latite, dacite, and rhyodacite. Porphyritic flows contain 30–40 percent phenocrysts of biotite, hornblende, and pyroxene. Unit is found on margins of Thunder Mountain caldera and is more abundant to the west in Payette National Forest (Lund and others, 1998). Leonard and Marvin (1982) reported a sanidine K-Ar age of 50.8±1.7 Ma. Total thickness 0–500 m

*Tuffs of Castle Rock segment of Van Horn Peak cauldron complex (southwestern part of Salmon National Forest)*—See Ekren (1988)

Tcc **Tuffs of Castle Rock**—Five cooling units of reddish ash-flow tuff and thin interbeds of ash-fall tuff within the cauldron. Upper cooling unit is a cliff-forming, densely welded tuff about 228 m thick; beneath it are two thin, partly welded, lithic-rich cooling units each about 30 m thick; these are underlain by a cliff-forming, moderately welded cooling unit about 150 m thick; a lowermost slope-forming, partly welded cooling unit is rich in lithic fragments and about 190 m thick. Phenocryst assemblages are similar throughout but vary considerably in relative proportions; minerals include quartz, alkali feldspar, plagioclase, biotite, hornblende, and pyroxene. Quartz is slightly smoky in all cooling units and chatoyant alkali feldspar is common. Total thickness about 620 m

*Tuffs of Camas Creek–Black Mountain and related rocks of Van Horn Peak cauldron complex (southwestern part of Salmon National Forest)*—See Ekren (1988)

Tcb **Tuffs of Camas Creek–Black Mountain**—Cauldron-filling sequence of mostly very densely welded quartz latite to rhyodacite ash-flow tuff consisting of 10 or more separate cooling units that are characterized by small (about 2 mm) phenocrysts. Phenocryst content (11–40 percent) in upper part of unit consists of trace quartz and alkali feldspar, 65–75 percent plagioclase, as much as 10 percent biotite, trace altered hornblende, and 10–20 percent altered pyroxene. Phenocryst content (5–25 percent) in middle part of unit consists of trace quartz, as much as 20 percent alkali feldspar, 65–77 percent plagioclase, as much as 9 percent altered biotite, as much as 3 percent altered hornblende, and 3–10 percent altered pyroxene. Phenocryst assemblage (3–15 percent) in lower part of unit consists of 2–12 percent quartz, 2–8 percent alkali feldspar, 60–75 percent plagiclase, 2–10 percent altered biotite, as much as 3 percent altered hornblende, and as much as 10 percent altered pyroxene. Thickness from 0 to 3,000 m

Tcl **Intermediate and mafic lavas**—Andesitic to basaltic lava flows that are predominantly aphyric, reddish-brown weathering, gray and greenish gray, brittle, columnar jointed, and blocky to platy; locally interbedded with oxidized flow breccias. Pyroxene phenocrysts are visible in some specimens; microphenocrysts include olivine, clino- and orthopyroxene, and common xenocrystic quartz. Groundmass is rich in trachytic and pilotaxitic plagioclase and may contain reddish-brown, strongly pleochroic mica and considerable apatite. Thickness from 0 to 700 m

Tcem **Tuff of Eightmile Creek**—Light-gray and greenish-gray, massive-weathering, partly welded and densely welded quartz latite to rhyodacite. Unit is megascopically similar to unit Tce but is distinguished by presence of alkali feldspar, more quartz, and less biotite and hornblende. Phenocryst assemblage (25–35 percent of rock) consists of 13–17 percent quartz, 12–16 percent alkali feldspar, 45–55 percent plagioclase, 9–12 percent biotite, as much as 2 percent hornblende, and trace clinopyroxene. K-Ar biotite analysis yields age of 48.4±1.7 Ma (Fisher and others, 1992). Thickness from 0 to 300(?) m

Tce **Tuff of Ellis Creek**—Light-greenish-gray, massive-weathering, densely welded, crystal-rich rhyodacite ash-flow tuff. Unit represents outflow from major collapse of the Van Horn Peak cauldron complex. Phenocrysts (36–50 percent) consist of 4–15 percent quartz (as long as 4 mm and “worm-eaten”), 60–75 percent plagioclase (as long as 6 mm), 12–20 percent biotite, 8–16 percent hornblende, and trace clinopyroxene. Unit contains abundant pumice lapilli. K-Ar biotite analysis yields age of 48.4±1.6 Ma (Fisher and others, 1992). Thickness from 0 to 300 m

## TERTIARY TO CRETACEOUS INTRUSIVE ROCKS

Ti **Mafic to felsic intrusions, undivided (Eocene)**—Small, poorly exposed basaltic, andesitic, and granitic plutons scattered throughout eastern part of Salmon National Forest. Most abundant in Lemhi Range and along Salmon River north of Salmon

Tgp **Gray porphyry (Eocene)**—Mixed sequence of gray and greenish-gray extrusive and intrusive rocks of intermediate composition exposed in Camas Creek drainage at southwestern margin of Salmon National Forest. Some exposures display flow layering indicating that they are lavas; most are massive with crystalline groundmasses. Phenocrysts constitute 30–45 percent of the rock and have the following proportions: quartz, as much as 5 percent; plagioclase, 60–75 percent; biotite, 1–12 percent; hornblende, as much as 25 percent; pyroxene, as much as 20 percent (Ekren, 1988). Intrusive contacts of the massive rock with lavas of the Challis Volcanic Group suggest an age for the unit of 48–51 Ma or less

Tg **Granite (Eocene)**—Medium- to coarse-grained, phaneritic to porphyritic hornblende-biotite syenogranite and gray monzogranite that occur predominantly as large plutons in western part of Salmon National Forest. Pink to tan syenogranite is composed of 45–55 percent alkali feldspar, 15–20 percent plagioclase, 15–20 percent quartz, 5–8 percent biotite, 3–5 percent hornblende, and accessory magnetite (Schmidt and others, 1994). Gray monzogranite is composed of 35–40 percent alkali feldspar, 25–30 percent plagioclase, 25–30 percent quartz, 5–8 percent biotite, and minor hornblende. Weathering produces exfoliated outcrops and coarse grus. This unit includes parts of the Painted Rocks pluton (Lund, Rehn, and Holloway, 1983), the Casto pluton (Cater and others, 1973), and the Chamberlain Basin pluton (Lund and others, 1998) whose easternmost extension is known as the Bighorn Crags pluton (Cater and others, 1973; Lund and others, 1998). K-Ar biotite ages range from 44 to 49 Ma (recalculated from Armstrong, 1974)

Tgd **Granite, granodiorite, and quartz monzodiorite (Eocene)**—Discrete plutons in the Lemhi Range west and southwest of Leadore ranging in composition from monzogranite to granodiorite and quartz monzodiorite (Ruppel and Lopez, 1988). Granite is medium-light-gray to medium-dark-gray, porphyritic biotite monzogranite with subhedral phenocrysts (4–6 mm long) of plagioclase, alkali feldspar, quartz, biotite, and hornblende set in a fine-grained groundmass. Granite in core of the Big Eightmile stock, southeast of Big Eightmile Creek, has been intensely hydrothermally altered. Granodiorite is commonly medium dark gray and porphyritic with phenocrysts (2–3 mm long) of plagioclase, hornblende, and biotite set in a fine-grained groundmass. Quartz monzodiorite is medium dark gray to medium gray and porphyritic with phenocrysts (1–3 mm long; rarely 8 mm) of plagioclase, hornblende, biotite, and pyroxene set in a very fine grained to fine-grained groundmass. K-Ar biotite data suggest an age of about 50 Ma (Ruppel and Lopez, 1988)

Tir **Intrusive rhyolite (Eocene)**—Dikes and plugs of light-gray, dense, phenocryst-poor rhyolite. Locally, unit has conspicuous phenocrysts of sanidine as long as 8 mm and sparse phenocrysts of quartz. Unit crops out in southwestern part of Salmon National Forest

TKi **Intrusions, mostly intermediate and felsic (Tertiary to Cretaceous)**—Mostly composite plutons of the Carmen stock in the headwaters of Carmen Creek in the northern Beaverhead Mountains, and the Chief Joseph plutonic complex near Lost Trail Pass, Idaho-Montana. Carmen stock is mostly granite, granodiorite, and quartz monzodiorite; Ar ages about 48–55 Ma; eastern part of stock is more mafic and yields ages of about 80–83 Ma (Kilroy, 1981). Chief Joseph plutonic complex is located mostly outside the Salmon National Forest in Montana, and includes granite, hornblende-biotite granodiorite, biotite granodiorite, and tonalite. K-Ar, U-Pb zircon, and fission track ages indicate an age range of about 43–78 Ma (Desmarais, 1983)

Kt **Hornblende-biotite tonalite (Cretaceous)**—Dark-gray, slightly foliated, medium-grained, phaneritic hornblende-biotite tonalite with local mafic enclaves; poorly exposed in northwestern part of Salmon National Forest. Pluton is 40–50 percent feldspar (<5 percent alkali feldspar), 15–20 percent quartz, 5–10 percent hornblende, 15–20 percent biotite, and less than 5 percent brown pyroxene(?) (Schmidt and others, 1994). Unit Kt is intruded by unit Tg and intrudes Kpg and Ybgn, suggesting a Cretaceous age similar to that of tonalitic rocks in the Payette National Forest to the west (Lund and others, 1998)

Kg **Biotite-muscovite granite (Cretaceous)**—Light-gray, nonfoliated, medium-grained, phaneritic two-mica granite in upper Owl Creek, west of Shoup and north of Salmon River. Rock consists of 20–30 percent alkali feldspar, 30–40 percent plagioclase, 25–30 percent quartz, 5–10 percent muscovite (euhedral books), and less than 5 percent biotite (Schmidt and others, 1994). Outcrops tend to exfoliate and weather to a coarse, light-gray grus. Pluton intrudes units Ybgn, Ymg, and Kgd with sharp contacts. Unit Kg commonly crops out to the west in the Payette and Nez Perce National Forests, Idaho, where it has been dated by $^{40}Ar/^{39}Ar$ method at about 74 Ma (Lund and others, 1986)

Kpg **Porphyritic granite and granodiorite (Cretaceous)**—Light-gray, nonfoliated to weakly foliated, medium-grained, porphyritic granite and granodiorite exposed within Salmon River canyon at northwest margin of Salmon National Forest and along Camas Creek in southwestern part of forest. Similar in composition to unit Kgd but contains pink alkali feldspar phenocrysts generally 5–7 cm in length. Weathering characteristics are similar to those of unit Kgd

Kgd **Biotite granodiorite (Cretaceous)**—Light-gray, nonfoliated to weakly foliated, medium-grained, phaneritic biotite granodiorite in western part of Salmon National Forest; forms plutons, dikes, and sills within Mesoproterozoic units. Made up of 20–25 percent alkali feldspar, 45–55 percent plagioclase, 15–25 percent quartz, and 3–10 percent biotite, with accessory sphene and magnetite (Schmidt and others, 1994). Locally, near contacts with Proterozoic rocks, unit Kgd can contain as much as 10 percent muscovite. Outcrops weather to a light-gray, coarse grus. Unit Kgd is a major component of the Idaho batholith to the west in the Payette National Forest (Lund and others, 1998)

Kgdf **Foliated biotite granodiorite (Cretaceous)**—Light-gray, medium-grained, foliated biotite granodiorite in southwestern part of Salmon National Forest along and near Middle Fork Salmon River. Ekren (1988), based on one thin section, described a composition of about 11 percent alkali feldspar, 51 percent plagioclase, 28 percent quartz, and 10 percent biotite. Although exposures underlie only a small part of Salmon National Forest, unit Kgdf is widespread west of the Thunder Mountain caldera in Payette National Forest (Lund and others, 1998)

## MESOZOIC TO PROTEROZOIC SEDIMENTARY ROCKS

₨d **Dinwoody Formation (Lower Triassic)**—Yellow-brown-weathering, dark-gray, fissile shale and calcareous shale, with interbeds of medium-gray and brownish-gray limestone and calcareous sandstone; present in Beaverhead Mountains southeast of Leadore. Coarse-grained recrystallized limestone contains distinct, abundant fossil debris. Spaced cleavage is prevalent and locally obscures bedding. Upper contact is disconformable and lower contact with the Phosphoria Formation (Pp) is abrupt. Unit poorly exposed. Although structurally deformed, formation is probably about 300 m thick (Lucchitta, 1966)

Pp **Phosphoria Formation (Lower Permian)**—Crops out in Beaverhead Mountains; definition follows usage of Lucchitta (1966). Upper part is bedded black chert with thin beds of dolomite and limestone. Bluish-white phosphatic spots are found in chert beds. Chert is about 50 m thick and is equivalent to the Tosi Chert Member (McKelvey and others, 1959). Lower part is dark-gray dolomite and minor limestone with dark-gray to black, ropy chert nodules (mapped as Phosphoria and Park City Formations, undivided, by

Lucchitta, 1966). Lower part may belong to the upper Juniper Gulch Member of the Snaky Canyon Formation, but structural complexity and lack of definitive age information make it difficult to assign these beds. Lowest part exposed is a bluish siltstone less than 30 m thick. Upper contact, with the Dinwoody Formation (₮d), is abrupt; lower contact with the undivided Snaky Canyon and Bluebird Mountain Formations (PMs), where preserved, is gradational. Thickness difficult to measure but probably about 260 m (Lucchitta, 1966)

PMs **Snaky Canyon (Lower Permian to Upper Mississippian) and Bluebird Mountain (Upper Mississippian) Formations, undivided**—Combined unit present in Beaverhead Mountains in southeastern part of Salmon National Forest. The upper member of the Snaky Canyon (Juniper Gulch Member) is medium-bluish-gray, sandy dolomite with interbedded quartz sandstone layers. Amount of interbedded sandstone decreases upward so that light- to medium-gray cherty dolomite predominates. The underlying Gallagher Peak Sandstone Member of the Snaky Canyon Formation is similar to the Bluebird Mountain strata but has more calcareous cement. The lower member of the Snaky Canyon Formation (Bloom Member) is medium- to dark-gray, cherty limestone with common chert nodules and interbedded thin quartz sandstone similar to Bluebird Mountain sandstone. Sandstone of the Bluebird Mountain Formation is light-brown-weathering, fine-grained, light-gray quartzitic sandstone and minor quartzite. Unit PMs totals about 560 m thick (Lucchitta, 1966). Type section for these units is south of Salmon National Forest in extreme southern Beaverhead Mountains, where total thickness is 1,350 m (Skipp, Hoggan, and others, 1979). Upper contact is gradational and some cherty dolomite beds included in the Phosphoria Formation (Pp) on this map may belong to the upper part of the Snaky Canyon Formation. Lower contact is abrupt. Intense structural disruption is common in this unit

Mu **Surrett Canyon(?), South Creek(?), and Scott Peak Formations (Upper Mississippian) and Middle Canyon (Upper and Lower Mississippian) Formation, undivided**—Combined unit of limestones in Beaverhead Mountains that are either so brecciated or sheared that original bedding characteristics are obscured and strata cannot be assigned to particular formations. This unit may include strata correlative with the South Creek and Surrett Canyon Formations, although these two units have not been recognized in this part of Beaverhead Mountains

Mss **Surrett Canyon, South Creek, and Scott Peak Formations (Upper Mississippian) and Middle Canyon (Upper and Lower Mississippian) Formation, undivided**—Combined unit of limestone and silty limestone that crops out low on eastern side of southern Lemhi Range. Shaly beds at top of unit may be equivalent to the Railroad Canyon Formation. Underlying minor thin-bedded silty limestone, preserved locally above massive limestone, is probably equivalent to parts of the South Creek and Surrett Canyon Formations. Thickest part of unit is massive cherty bioclastic limestone that is equivalent to the Scott Peak Formation. Lower part of unit is thin-bedded, cherty, yellow- to red-weathering silty bioclastic limestone that is highly cleaved and deformed. Although not mapped separately, these lower rocks are equivalent to the Middle Canyon Formation. Originally mapped as the White Knob Limestone (Hait, 1965), the rocks were subsequently subdivided and renamed (Huh, 1967; Skipp, Sando, and Hall, 1979). Total thickness about 700 m (Hait, 1965)

Mr **Railroad Canyon Formation (Upper Mississippian)**—Dark-gray, pink-, and yellow- to orange-weathering shale, mudstone, silty limestone, and calcareous siltstone present in Beaverhead Mountains north and east of Leadore. Strata are mostly thin bedded and flaggy, though some dark shale is fissile and flaggy. Dark shale and siltstone have a musty odor. Unit is poorly exposed and underlies swales and valleys, where springs and slumps are preferentially located in it. Shaly strata commonly act as locus for faults that in many places excise all or part of formation. Slivers of unit Mr are preferentially silicified along fault zones; narrow zones of silicified siltstone are common indicators of low-angle faults. Formation was mapped previously as Big Snowy Group (Lucchitta, 1966) and Big Snowy Formation (Skipp and others, 1984). Unit Mr is 205 m thick at type section on west side of upper Railroad Canyon northeast of Leadore and is considered equivalent to the Surrett Canyon and Arco Hills Formations of the foredeep carbonate bank sequence of Idaho (Wardlaw and Pecora, 1985; Skipp, Sando, and Hall, 1979). Upper and lower contacts are conformable

Ms **Scott Peak Formation (Upper Mississippian)**—Medium-dark-gray, medium- to thick-bedded, mostly pure limestone with bedded chert horizons in Beaverhead Mountains in vicinity of Leadore and in Lemhi Range near Gilmore. Much of unit contains orange-weathering, wispy and bedded, dark-gray chert. Beds are fossiliferous with corals and brachiopods dominant; encrinite layers are common but not diagnostic. Unit typically forms cliffs.

Thin-bedded strata, recognized in the upper part by Lucchitta (1966) but not mapped separately, may be correlative with the South Creek and Surrett Canyon Formations. Near low-angle normal faults, unit is brecciated and recemented with calcite. Throughout study area the Scott Peak is strongly cleaved as a result of deformation associated with thrust faulting. Although commonly thinned by low-angle normal faults, unit may be as much as 700 m thick (Skipp and others, 1984)

Mm **Middle Canyon Formation (Upper and Lower Mississippian)**—Medium- to dark-gray, thin-bedded cherty limestone and silty limestone in southeastern part of Salmon National Forest. Bedding is commonly 0.5–5 cm thick. Silty interbeds weather tannish orange and give unit a tannish-gray appearance. Unit forms smooth slopes and generally only crops out on canyon walls. Exposures in range front north of Leadore indicate that strata are strongly ductilely deformed, having undergone multiple deformations. In Lemhi Range west of hamlet of Lemhi, near junction of Hayden and Basin Creeks, unit Mm forms prominent outcrops in footwall of Poison Creek thrust fault. Some of these strata are silicified adjacent to rocks of the Eocene Challis Volcanic Group and locally were misinterpreted as Beaverhead Conglomerate (now Beaverhead Group) (Cretaceous and Paleocene) by Anderson (1961). Total thickness about 160 m (Lucchitta, 1966)

Mg **McGowan Creek Formation (Lower Mississippian)**—Gray to pink calcareous siltite, argillite, and shale poorly exposed in Lemhi Range in southeastern part of Salmon National Forest. Thickness about 200 m in southern part of Lemhi Range (Hait, 1965)

Du **Three Forks and Jefferson Formations, undivided (Upper Devonian)**—Widespread in Lemhi Range and Beaverhead Mountains in southeastern part of Salmon National Forest. Uppermost part of unit locally includes limey siltstone beds that were not mapped separately, but which may correlate with the McGowan Creek Formation. The Three Forks Formation consists of dark-gray siliceous mudstone, tan to gray to pink siltstone, and platy fine-grained dark-gray limestone. The underlying Jefferson Formation is primarily dark-gray dolomite with lesser amounts of limestone, limestone evaporite-solution breccia, and sandy dolomite. Strong tectonic brecciation of unit in most locations makes identification of bedding difficult. Beneath (east of) the Hawley Creek thrust (east-southeast of Leadore) in Beaverhead Mountains, base of unit is an angular unconformity with underlying Ordovician and Mesoproterozoic strata. Above (west of) the Hawley Creek thrust in Lemhi Range and north of Leadore in Beaverhead Mountains, the unconformity is less profound and Silurian and Upper Ordovician rocks are present. Ruppel and Lopez (1988) reported a maximum thickness in Lemhi Range, near Gilmore, of about 825 m of Jefferson and 90 m of Three Forks strata, but both units (especially the Jefferson) thin rapidly to the south and east

SOu **Laketown Dolomite (Silurian) and Saturday Mountain Formation (Lower Silurian to Middle Ordovician), undivided**—Where present in Lemhi Range south of Poison Creek, the Laketown Dolomite is too thin to show separately and has been combined with the underlying Saturday Mountain Formation (see description of unit SOs). The Laketown Dolomite is a light-olive-gray to medium-light-gray and light-gray, fine- to medium-crystalline dolomite in beds 0.6–3 m thick. Fresh surfaces of the Laketown are characterized by a sparkling appearance, in contrast to the Saturday Mountain Formation. Vugs (1–2 mm in diameter) are moderately abundant but fossils are rare. Thickness of the Laketown Dolomite in central Lemhi Range is about 60 m; total thickness of unit Sou as much as 430 m

SOs **Saturday Mountain Formation (Lower Silurian to Middle Ordovician)**—Medium-light- to medium-dark-gray, very fine grained dolomite located in Poison and Warm Spring Creeks area of Lemhi Range and in Beaverhead Mountains near Leadore. South of Poison Creek in Lemhi Range, unit has been combined with the overlying Laketown Dolomite into unit SOu. Unit SOs consists of four members (Ruppel and Lopez, 1988). Uppermost member consists of medium-gray to medium-light-gray, finely crystalline, thick- to massive-bedded dolomite that weathers to a mottled appearance. Black chert nodules are present but notably less abundant than in lower members; however the member is quite fossiliferous. Underlying this is medium-dark-gray to medium-gray, finely crystalline dolomite that weathers to distinctly mottled lighter gray colors; black chert nodules are also common as well as numerous beds with abundant fossils and fossil fragments. This grades downward into yellowish-gray to medium-gray, finely crystalline dolomite characterized by a network of irregular, interlaced, hairlike wisps and veinlets of white dolomite and locally by abundant black chert nodules. The basal Lost River Member consists of interbedded clastic deposits of generally dark-colored sandstone, quartzite, shale, and mudstone. Ruppel and Lopez (1988) reported fossil data that indicate an age in central Lemhi Range of mostly Ordovician with the top part being Lower Silurian; in southern Lemhi Range, however, unit is wholly Ordovician. It is overlain along a deeply weathered, erosional unconformity by the Silurian Laketown Dolomite. Maximum thickness of unit **SOs** in central Lemhi Range is about 370 m, but it thins to the south and east

Ok **Kinnikinic Quartzite (Middle Ordovician)**—White to light-gray, fine- to medium-grained, vitreous quartzite present in Beaverhead Mountains and Lemhi Range. Unit is compositionally supermature and well sorted with tightly cemented subrounded grains; as a result, bedding is usually difficult to identify. Lower contact is conformable with the underlying Summerhouse Formation (Os), although locally the Kinnikinic rests unconformably on Mesoproterozoic strata (Ruppel, 1980). Thickness about 300 m in Lemhi Range (Ruppel, 1980)

Os **Summerhouse Formation (Lower Ordovician)**—White and light-gray to pale-yellowish-orange, fine- to coarse-grained (locally bimodal) quartzite and dolomitic quartzite; locally includes an uppermost unit of massive dolomite. Unit exposed in Rattlesnake Creek area of Salmon River Mountains. Bedding is commonly 50–100 cm thick. Beds virtually identical to those of the Kinnikinic Quartzite (Ok) are intercalated with medium- to coarse-grained, locally bimodal quartzite with dolomitic cement, consistent with relationships in the type section of unit Os in central Lemhi Range (Ruppel and others, 1975; McCandless, 1982). Quartzites grade upward through an approximately 10-m-thick transition zone of dolomitic quartzite into about 30 m of medium-gray, fine-grained, locally massive dolomite (which in this study has been included in map unit Os). Conodonts and brachiopods from the dolomite suggest an age of Middle or Late Ordovician, possibly equivalent in part to the Middle Ordovician Ella Dolomite of the Challis area (Ekren, 1988). This is in accord with the interpretation that the quartzites are pre-Kinnikinic and best correlated with the Summerhouse Formation. Because the dolomite is too thin to show at the scale of the map and because regional relationships of the Ella Dolomite and the Summerhouse Formation are undefined (McCandless, 1982; Hobbs and Hays, 1990), the dolomite is tentatively mapped as part of the Summerhouse Formation. In Rattlesnake Creek area, the dolomite is truncated upward by the Poison Creek thrust but the base of the quartzites is thrust onto the Gunsight Formation (Yg) along one of several imbricate faults below the Poison Creek thrust. Total thickness about 230 m

Oks **Kinnikinic Quartzite (Middle Ordovician) and Summerhouse Formation (Lower Ordovician), undivided**—Map unit used only in northern Lemhi Range where poor exposure and map scale used for compilation prevented the two units from being shown separately. In Goldbug Ridge area north of the Poison Creek thrust fault, dolomite is overlain (conformably?) by the Kinnikinic Quartzite but unfoliated quartzite of the basal Summerhouse rests unconformably on locally strongly cleaved Swauger Formation. Further south near Poison Peak and the thrust fault, coplanar cleavage presumably produced by thrusting occurs in both quartzites and post-unit Ok carbonates. Total thickness about 530 m

₵Zw **Wilbert Formation (Lower Cambrian to Neoproterozoic?)**—Predominantly quartzite pebble to cobble conglomerate and quartzite with minor carbonate-cemented sandstone and sandy dolostone. Unit crops out in small area in Beaverhead Mountains north of Leadore. Most recognized exposures are quartzite with interbedded conglomerate, but where conglomerate is lacking parts of this unit may include some underlying Gunsight Formation (Yg). Quartzite shows bimodal grain size distribution, and is cemented by silica in lower part of unit. Conglomerate layers are as thick as 2 m; cobbles derived primarily from quartzite of the Mesoproterozoic Swauger (Ys) and Gunsight Formations; minor clasts of vein quartz and rare chips of light-colored siltite. Amount of carbonate cement increases upward where the carbonate-cemented sandstone is interbedded with sandy dolomite. Unit is probably correlative with the Wilbert Formation as defined in Lemhi Range (Ruppel and others, 1975; McCandless, 1982). Total thickness of unit **₵Zw** is unknown because it only crops out in fault slivers; maximum thickness observed is about 10 m

## PALEOZOIC TO PROTEROZOIC VOLCANIC ROCKS

PzZv **Metavolcanic and metasedimentary strata (lower Paleozoic(?) to Neoproterozoic)**—Greenschist facies mafic and felsic metavolcanic rocks with minor volcaniclastic conglomerate, graywacke, and quartzite. Occurs as roof pendant in batholithic rocks along and near Middle Fork Salmon River in southwest corner of map area. Mafic volcanic rocks are amphibolites with relict plagioclase and pyroxene phenocrysts; felsic volcanic rocks contain relict potassium feldspar, plagioclase, and quartz phenocrysts. Minor associated sedimentary strata include amphibolite conglomerate with heterogenous lithic clasts, biotitic-feldspathic metasandstone, and quartzite. Rocks in roof pendant along Middle Fork Salmon River are probably equivalent to lithologically similar pendants better exposed along strike to the west in Payette National Forest, where mafic volcanic unit is about 500 m thick (Leonard, 1962; Lund and others, 1997, 1998; Lund, 1998). Felsic metavolcanic strata from a pendant near Big Creek, Idaho (Payette National Forest) has been dated using SHRIMP U-Pb methods on zircon to be 684±4 Ma (Lund and others, 2003; date slightly revised from Evans and others, 1997)

PALEOZOIC INTRUSIVE ROCKS

O€i **Mafic to predominantly felsic alkalic intrusions (Ordovician to Cambrian)**—Medium-grained, phaneritic to porphyritic, alkali-feldspar syenite, alkali-feldspar quartz syenite, and alkali-feldspar granite with generally lesser amounts of gabbro and mafic-rich quartz syenite. Crops out in Beaverhead Mountains (Beaverhead pluton of Scholten and Ramspott, 1968; Skipp, 1984), west of Salmon (Deep Creek and Arnett Creek plutons, Evans and Zartman, 1988), and near Yellowjacket and Middle Fork Peak (Ekren, 1988). U-Pb zircon dates indicate an age of about 490 Ma, in contrast to compositionally similar alkalic plutons to the west in Payette National Forest (Lund and others, 1998), where preliminary data indicate an age of about 650 Ma (Evans and Zartman, 1988; J.N. Aleinikoff and K.V. Evans, unpub. data, 2003)

PALEOZOIC TO PROTEROZOIC METAMORPHIC ROCKS

PzZgm **Gray marble (lower Paleozoic(?) to Neoproterozoic)**—Greenschist facies marble and calc-silicate marble locally preserved as isolated blocks in intrusive rocks along Middle Fork Salmon River in southwest corner of map area. Silicate minerals present in calc-silicate rocks include tremolite, actinolite, and chlorite. Unit probably correlates with similar strata preserved as roof pendants to the west in Payette and Nez Perce National Forests (Lund, 1998)

PROTEROZOIC SEDIMENTARY ROCKS

[Mesoproterozoic sedimentary rocks of the region have been metamorphosed to greenschist facies. The term “quartzite” historically has been applied to these strata even though feldspar and other grains may be equally abundant in a rock. Further, silt-size grains constitute the common (or only) grain size for rocks of many stratigraphic units. Hence, we use the term *metasandstone* to denote a rock composed chiefly of sand-size grains, reserving *quartzite* for sandstone that is greater than 90 percent quartz. Siltite is used for those rocks composed chiefly of silt-size grains, regardless of composition]

Ylc **Lawson Creek Formation (Mesoproterozoic)**—Intercalated siltite and metasandstone to orthoquartzite. Strata are gray to grayish green and bluish green, and range from near equal parts quartz and feldspar in a fine-grained chloritized matrix to orthoquartzite. Beds are 1 cm to 1.5 m thick and planar to crosslaminated, and locally contain “floating” rip-up clasts of argillite. A few beds are light-gray, fine-grained metasandstone with fine laminations and dark-gray, heavy-mineral laminae 1–2 grains thick. Other metasandstones are poorly sorted with well-rounded, medium- to coarse-grained quartz, minor plagioclase, and medium- to coarse-grained silt. Siltite is medium to dark gray and forms sequences as thick as 10 m in which siltite and metasandstone are interlayered in beds 0.5–5 cm thick. These strata are planar to ripple crosslaminated and show abundant flaser and lenticular bedding, as well as cut and fill structures. Hobbs (1980) named the unit for strata in Lost River Range, and Tysdal (1996a) and Tysdal and Moye (1996) extended the term to rocks in fault slivers south of the Lem Peak fault in Lemhi Range. The description is from Tysdal (1996a) and applies only to Lemhi Range. Tysdal (2000a) interpreted the unit to have formed in an intertidal environment. Total thickness in type section is about 1,200 m, but only about 300 m is preserved in Salmon National Forest due to thinning by faults

Ys **Swauger Formation (Mesoproterozoic)**—Light-gray, pale-green, and pale-red-purple, medium- to coarse-grained quartzite. Unit is widespread in Lemhi Range and present in Beaverhead Mountains near Leadore and in Salmon River Mountains west of Salmon. Quartz content typically ranges from 90 to 95 percent; well-rounded, well-sorted, tightly cemented, and glassy grains. Feldspar content seldom exceeds 5–10 percent. A speckled appearance is quite common and results from 0.5- to 3-mm-diameter (usually reddish) spots of hematite, local limonite, and rare chlorite commonly concentrated along crosslaminae. Beds are 0.5–2 m thick and commonly show trough crosslaminations and lesser herringbone crosslaminae. Two-dimensional ripples and subaqueous dunes are quite well developed in places; dunes have wavelengths of 4–8 m and heights of 0.7–1 m and ripples have wavelengths of 2–15 cm and heights of 0.3–3 cm. Tysdal (2000a) interpreted the bulk of the Swauger to have been deposited in a tidal environment, based on compositional maturity of quartzites, presence of herringbone crossbeds, subordinate current cap deposits (de Mowbray and Visser, 1984) on some dunes, rare antidunes, and local flaser and lenticular bedding. The Swauger grades upward into the Lawson Creek Formation. Total thickness about 3,100 m

Yg **Gunsight Formation (Mesoproterozoic)**—The Gunsight Formation was defined by Ruppel (1975) for rocks at Gunsight Peak in Lemhi Range west-southwest of Leadore, Idaho. McBean (1983) further studied the type section and much of the following description for the Gunsight south of Lem Peak fault is taken from his work. North of Lem Peak fault and in Beaverhead, Salmon River, and Clearwater Mountains, strata previously mapped as the upper unit of the Yellowjacket Formation (unit Yyu of Evans, 1998) are now correlated with the Gunsight (Tysdal, 2000b). Accordingly, the Gunsight is separately described as follows: south of Lem Peak fault (that is, type section) and north of Lem Peak fault (that is, mostly former unit Yyu).

South of Lem Peak fault—Pale-brown to gray, very fine grained to medium-grained metasandstone typifies most of type section. Quartz and feldspar are dominant components, with feldspar content ranging from 25 to 50 percent; matrix content is 0–8 percent. Sedimentary structures include trough and planar crossbeds; parallel ripple and climbing ripple crosslaminations; ripple and climbing ripple laminations; straight-crested, asymmetrical and oscillation ripples; and dewatering structures. In uppermost 100+ m, where unit is transitional into the compositionally mature Swauger Formation (Ys), quartz content increases to 80–90 percent. Lower 450 m of unit consist of interbedded siltite, argillite, and very fine grained metasandstone transitional into the underlying siltite of the Apple Creek Formation. Matrix content in this lower part can reach 40 percent. Total thickness is 1,700+ m. McBean (1983) interpreted the formation to have been deposited in a shallow marine setting, but Tysdal (2000a) considered most of unit to be fluvial. Trough crossbedded metasandstone (as thick as 1–2 m) that fines upward into siltite is indicative of channel and overbank deposits and strongly supports Tysdal's reevaluation. Upper part of formation may be shoreface deposits transitional into marine deposits of the Swauger (Tysdal, 2000a). Lower part of formation, with its intercalated siltite and argillite, probably formed in an intertidal to subtidal environment transitional into the turbidites of the Apple Creek Formation.

North of Lem Peak fault—Light- to dark-gray, very fine grained to medium-grained, feldspathic metasandstone (arkose) typifies this unit in northern Lemhi Range and Salmon River Mountains. Bed thickness ranges from 10 to 100 cm. Decimeter-thick trough and planar crossbeds are typical; hummocky cross-stratification is present locally in Salmon River Mountains. Conglomeratic beds exist locally, containing clasts that are angular and rounded. Deposition was in fluvial environment, but hummocky, crossbedded rocks in Salmon River Mountains are interpreted as marine. Total thickness probably exceeds 4,000 m. In Salmon River Mountains, unit is transitional downward into the banded siltite unit of the Apple Creek Formation (Yab), and upward into the Swauger Formation (Ys) (Tysdal, 2003)

Ya **Apple Creek Formation, undivided (Mesoproterozoic)**—The Apple Creek Phyllite was defined by Anderson (1961) for foliated rocks near Hayden Creek in central Lemhi Range. Ruppel (1975) redefined the unit as the Apple Creek Formation and Tietbohl (1981, 1986) studied a diamictite unit within the formation. Tysdal (1996a, b, c, 2000a, b; Tysdal and Moye, 1996) slightly redefined and subdivided the formation into mappable informal subunits, described below. On our geologic map, Tysdal's subunits are used where recent mapping is available; where it is not available or distinctions could not be made in the field, the undivided designation (Ya) is used. In Beaverhead Mountains south of Kenney Creek, unit Ya consists mostly of coarse siltite unit (Yac) but units were not mapped separately (K.I. Lund, unpub. data, 2002)

Yab **Banded siltite unit**—Centimeter-scale layers of light-gray siltite to very fine grained metasandstone alternating with black siltite or argillite characterize the easily identified banded member. Thickness of layers and percentage of metasandstone versus siltite/argillite vary considerably. Layers range from 0.5 to 10 cm thick and percentages of metasandstone to siltite/argillite range from equal to 95 percent dominance by either component. These couples and couplets of the unit are interpreted to be turbidites (Sobel, 1982; Tysdal, 2003). In addition to the visually striking light and dark layering, argillite beds in virtually any outcrop exhibit predominantly (but not exclusively) downward-penetrating dikelets of coarser sediment from the overlying layer.

Commonly the dikelets are "ptygmatically" folded due to compaction of the originally very water laden argillaceous layers. Unit is widespread in Salmon River Mountains northeast of Iron Lake fault, and reaches a thickness of at least 2,000 m. Unit apparently thins to the southeast due to erosion so that only a thin sliver is preserved in footwall of Poison Creek thrust in Lemhi Range. Unit is primary host for the stratabound Blackbird Co-Cu-Au deposit. Base of unit is gradational downward into the coarse siltite unit (Yac), and top grades upward through a relatively abrupt transition into the overlying Gunsight Formation (Yg). As previously noted, in Lemhi Range unit Yab thins below the Gunsight due to erosion.

Unit was called the "middle subunit of the Yellowjacket Formation" by Connor and Evans (1986), but because the unit lies conformably above the coarse siltite unit of the Apple Creek Formation, Tysdal (2003) assigned it to the Apple Creek Formation. The "banded siltite" name resurrects an informal name that was used originally by Connor and Evans (1986)

Yac **Coarse siltite unit**—Grayish-green, medium- to coarse-grained siltite and fine-grained quartzite (metasandstone) best preserved between Bear Valley Lakes and Basin Lake in Lemhi Range. In Salmon River Mountains southwest of town of Salmon, strata previously mapped as the lower unit of the Yellowjacket Formation (unit Yyl of Evans and Connor, 1993) are now identified as the coarse siltite member of the Apple Creek Formation (Tysdal, 2000a, b; Tysdal and others, 2000). Unit is named for distinctive light-gray, quartz-rich graded beds of coarse-grained siltite to fine-grained quartzite that are most abundant in lower part of this member. Light-gray beds have erosional bases, show Bouma sequences ($T_{b-c}$, $T_{b-c-d}$, locally also $T_a$), and grade upward into gray-green medium siltite. Graded beds commonly are 10–30 cm thick but are as thick as 1 m. Upper part of unit is dominated by graded beds of grayish-green siltite and minor beds of argillite and fine-grained quartzite. Bedding ranges from 1 to 100 cm; most about 10–25 cm thick. Magnetite bands are present both in Lemhi Range where this unit was defined by Tysdal (1996a, b, c, 2000a) and in the redefined strata (formerly lower Yellowjacket Formation) in Salmon River Mountains (Nash, 1989). Soft-sediment deformation structures are common in this unit, including convolute lamination, dish, pillar, and flame structures, syneresis cracks, and ball-and-pillow structures. Unit Yac is interpreted to be primarily a turbidite deposit with minor debris flows indicated by rare pebbly beds. Total thickness about 2,000–2,500 m. Unit grades upward through a transition into the Gunsight Formation (Tysdal, 2000a)

Yad **Diamictite unit**—Grayish-green argillite, argillaceous siltite, and fine- to medium-grained siltite forms the matrix and interbeds to matrix-supported, poorly sorted conglomerate, first characterized as diamictite by Tietbohl (1981). Unit is generally intensely cleaved, obscuring sedimentary features; however, graded beds are commonly recognized in those siltite beds that are less pervasively deformed. Conglomeratic beds are tabular in shape with thicknesses of as much as several meters and lateral extent of several tens of meters. Clasts in conglomeratic beds are subangular to well rounded and commonly 1–5 cm in long dimension; locally, some clasts are 20–25 cm long and one observed clast was 50 cm. Matrix material is composed of sericite, muscovite, chlorite, and silt of quartz and plagioclase. Tietbohl (1986) indicated that about 90 percent of clasts are detrital rock fragments ranging from argillite to fine-grained metasandstone. Tysdal (2000a) described sparse laminae and beds (≤1 cm) of magnetite locally present in Lemhi Range. He interpreted graded bedding in the siltite beds to indicate an origin by turbidity currents, and attributed conglomeratic beds that lack grading to subaqueous debris flows. Thickness estimates are complicated by deformation but unit is about 600 m thick on west side of Lemhi Range and 1,000–1,500 m on east side. Unit grades upward into the conformably overlying coarse siltite member (Yac) (Tysdal, 2000a)

Yaf **Fine siltite unit**—Greenish-gray to olive-gray, planar-laminated and ripple-crosslaminated, fine-grained siltite and argillaceous siltite well exposed in upper reaches of Bear Valley Creek drainage in Lemhi Range. Some beds contain planar laminations that grade upward to small-scale (1–3 cm) sets of ripple-crosslaminated siltite. Planar-laminated strata locally developed water-escape structures. Beds commonly grade from 1- to 2-cm-thick, light-gray, medium- to fine-grained siltite upward into dark-gray, fine-grained siltite. Upper part of fine siltite member contains sparse, local, matrix-supported, gravel-size argillite clasts in horizons 1–2 clast diameters thick. Fine silt and clay content also is more abundant in upper part of unit. Graded beds with Bouma sequences and sedimentary structures indicate most of unit consists of turbidites, with lesser debris flows and some reworking by bottom currents (Tysdal, 2000a). Base of unit is unconformable on the Big Creek Formation (Yb) and top is conformably overlain by abrupt appearance of the diamictite member (Yad). Total thickness about 1,000 m (Tysdal, 2000a)

Yb **Big Creek Formation (Mesoproterozoic)**—Big Creek strata are primarily exposed in Lemhi Range and Beaverhead Mountains. In Lemhi Range, the Lem Peak (normal) fault separates somewhat different sequences of unit Yb; the following descriptions from Tysdal (2000a) focus on these two areas (Tysdal, 1996a, b, c; Tysdal and Moye, 1996).

North of Lem Peak fault—Light-gray, coarse-grained siltite to medium-grained quartzite (metasandstone); prominent silty laminae of rusty-brown-weathering carbonate and dark-gray, heavy-mineral laminae. Quartzite is composed of 50–60 percent quartz, 10–20 percent feldspar, 5–15 percent matrix, and as much as 5 percent heavy-mineral laminae, including such minerals as tourmaline, zircon, and ilmenite. Beds commonly are composed of two-dimensional, subaqueous dunes (megaripples) with planar crosslamination in sets 0.5–1 m high; dune wavelengths as much as 3 m, and dune heights 0.3–0.5 m. Other beds show three-dimensional dunes with trough crosslaminae; dune wavelengths 3–5 m, and dune heights 0.3–0.5 m. In upper part of formation, dark-gray argillaceous siltite in sequences less than 5 m thick is intercalated with light-gray, coarse-grained siltite and fine-grained quartzite. Locally, double clay drapes and reactivation surfaces are developed, indicating deposition by tidal current processes. Other sedimentary features indicating or consistent with bipolar tidal currents include herringbone crosslamination, flaser and lenticular bedding, interbedded dunes and mudstone lenses, and tidal channel deposits. Locally, an amygdaloidal andesite flow is 2–4 m thick in upper Big Creek strata. Thickness about 2,700 m. Bottom of the Big Creek is not exposed in Salmon National Forest and top is unconformably overlain by the Apple Creek Formation (Tysdal, 2000a).

South of Lem Peak fault—Light-gray, coarse-grained siltite to medium-grained quartzite is also the dominant lithology south of Lem Peak fault, including the area designated the type section by Ruppel (1975). Upper part of the Big Creek in the type area consists of stacked two-dimensional dunes with heights of 0.5–1.5 m and wavelengths of 2–3 m. Reactivation surfaces and double clay drapes indicate deposition in a tidal environment with bipolar currents trending northeast-southwest (present coordinates). Lower part of formation is typified by heavy-mineral laminae commonly as thick as 3 cm and extending laterally in gently inclined crossbeds for as much as 100 m. These strata have been interpreted as beach deposits (Tysdal, 2000a). Total thickness about 3,100 m

Yu **Lawson Creek Formation, Swauger Formation, and (or) Lemhi Group, undivided (Mesoproterozoic)**—Composite unit generally used for areas where Mesoproterozoic strata were mapped prior to the definition of current stratigraphic nomenclature, and have not been reexamined during this mapping and compilation effort

Yaq **Argillaceous quartzite, unnamed (Mesoproterozoic)**—Predominantly dark gray (but ranging from light to dark gray), thin- and thick-bedded, fine-grained and very fine grained, feldspathic and micaceous quartzite interlayered with lesser amounts of medium-gray argillaceous siltite (Ekren, 1988; Tysdal, 2000b); crops out in and near upper Shovel Creek in southwestern part of map area. Sedimentary structures include abundant crossbeds, ripple crosslaminations, and local rip-up clasts. Unit grades downward through a conformable transition zone into the Hoodoo Quartzite (Yh), as noted by Ross (1934), Ekren (1988), Evans and Connor (1993), and Tysdal and others (2000). An intertidal depositional environment is suggested by sedimentary structures and alternating lithologies, which reflect contrasting energy conditions. Top of unit not exposed; minimum thickness 500 m.

Unit Yaq was recognized by Ross (1934) as a separate unit from the Yellowjacket Formation (Yy), which occurs below the Hoodoo, but he did not assign a stratigraphic name. Ekren (1988) also did not assign a formal name to the unit, preferring instead to use the informal “argillaceous quartzite.” Evans and Connor (1993), following the lead of Evans and Ekren (1985), included both Ross’ Yellowjacket below the Hoodoo Quartzite and the argillaceous quartzite above the Hoodoo in their “lower Yellowjacket.” This tentative correlation implied that the Hoodoo could be a tongue of clean white quartzite interfingering with the “expanded” Yellowjacket. To further complicate the issue, Evans and Connor (1993), as well as other workers, also extended use of their “lower Yellowjacket” to include rocks to the east now interpreted to be Lemhi Group (see Yellowjacket Formation description). Subsequent work indicates that the sequence Yellowjacket Formation (as defined by Ross)–Hoodoo Quartzite–argillaceous quartzite reflects a genetically related package of shallow-water strata that occur in a thrust plate which has later been cut by high-angle faults. This package is fault bounded and, as shown on geologic map, is structurally isolated from Lemhi Group strata to which it has been correlated previously. Tysdal (2000b) provided a detailed account of the geology and history of correlations relevant to this stratigraphic package

Yh **Hoodoo Quartzite (Mesoproterozoic)**—White to light-gray (locally brownish gray), medium-grained, thin- to thick-bedded quartzite composed of about 80–90 percent well-rounded quartz, 5–10 percent feldspar (orthoclase, microcline, and albite), and 5–10 percent biotite, chlorite, sericite, and iron oxide (Ekren, 1988). Unit is generally massive, making identification of bedding difficult where fracturing is well developed. Crosslamination is locally distinct and oscillatory and current ripples are present throughout unit. Marble and calcareous quartzite are irregularly present in basal part of formation (Ekren, 1988; Evans and Connor, 1993). Total thickness estimated at about 1,100 m (Ekren, 1988). The Hoodoo Quartzite grades downward into the Yellowjacket Formation (Yy) through a thickness of about 200 m, with thin-bedded white Hoodoo strata intercalated with thin-bedded, dark-gray argillaceous metasandstone and gray, fine-grained metasandstone typical of the Yellowjacket. Transitional zone is reasonably well exposed in upper Lake Creek (about 7 km west of townsite of Yellowjacket) and in cirque wall about 0.7 km north of McEleny Mountain (Ekren, 1988; Evans and Connor, 1993). Upper contact is gradational into unit Yaq. The Hoodoo Quartzite is interpreted to be a shallow subtidal to intertidal deposit, winnowed under high-energy conditions as evidenced by lack of silt and clay and common presence of high-angle crosslaminations

Yy **Yellowjacket Formation (Mesoproterozoic)**—Unit (as defined by Ross, 1934, and Tysdal, 2000b; see discussion below) consists of 518 m of calcareous strata, with no base exposed, overlain by 2,225 m of quartzitic clastic rocks. Calcareous beds are gray to dark green and black, containing varying amounts of carbonate and calc-silicate minerals in lenses that intertongue with quartzite. Upper greenschist metamorphism resulted in beds that are banded or mottled, depending on presence of dark metamorphic minerals. Presence of metamorphic scapolite indicates some of beds were formerly evaporite horizons (Tysdal and Desborough, 1997). Upper quartzitic part of section is dark-gray, dark-bluish-gray, or locally white, generally thin bedded quartzite, with lesser intercalations of thin-bedded, dark gray siltite and argillite. Metasandstone commonly consists of about 70 percent quartz, 15 percent biotite (or chlorite altered from biotite), and 15 percent feldspar (Ekren, 1988). Common sedimentary structures include ripple crosslamination, mudchips, fluid-escape structures, local herringbone crosslamination, climbing ripples, mudcracks, and millimeter-scale load casts (Ekren, 1988; Tysdal, 2000b). Some argillite layers show "pull apart" structures probably formed as clay layers dried and shrank. Locally, mudchips are imbricated in opposite directions, indicating reversal of current directions. These features are most consistent with deposition in a tidal environment, confirming the original shallow-water interpretation of Ross (1934) and later Ekren (1988). Yellowjacket strata grade upward into the conformably overlying Hoodoo Quartzite (Yh) (Ross, 1934; Ekren, 1988; Evans and Connor, 1993)

Because this report uses a revised definition of unit Yy that differs from most recent applications [summarized to 1993 by Evans (1998)], a short summary of the nomenclatural history of this unit is required. Ross (1934) originally included gray, slightly calcareous, shallow-water deposits of metasandstone and siltite near townsite of Yellowjacket in his description of the reference section (technically, there is no formal type section). Subsequent workers extended use of the Yellowjacket name to other gray quartzites and siltites that are widespread in eastern Salmon River Mountains and northern Lemhi Range (Vhay, 1948; Ruppel, 1975; Bennett, 1977; Lopez, 1981; Hughes, 1983; Connor and Evans, 1986; Ekren, 1988; Evans and Connor, 1993; Evans, 1998). Recent detailed mapping and stratigraphic studies indicate that the term Yellowjacket Formation should be restricted to the genetically related shallow-water strata originally designated by Ross (1934), which are preserved in a fault-bounded structural block (Tysdal, 2000b; Tysdal and others, 2000). Similar, though not identical, conclusions have been reached by D. Winston (University of Montana) and P.K. Link (Idaho State University) in their attempt to relate the Mesoproterozoic strata of east-central Idaho to the classic Belt Supergroup (Winston and others, 1999). Other rocks to which the Yellowjacket name had been extended (see references cited above) are now correlated with formations of the Lemhi Group (Tysdal, 2000a, b)

Yfm **Feldspathic metasandstone (Mesoproterozoic)**—White to light-gray, medium- to coarse-grained feldspathic metasandstone; feldspar is 15–45 percent of rock; quartz grains are generally subangular to subrounded. Dark-gray heavy-mineral laminae are common in lower parts of beds; mud chips of siltite are present in some beds. Beds commonly range from 30 to 100 cm thick and are trough crossbedded, with troughs in sets that decrease in size upward in each bed. Local 1- to 25-cm-thick, discontinuous interbeds of medium-gray siltite. Unit present only northwest of Carmen Creek in northwestern part of Beaverhead Mountains and in eastern part of Clearwater Mountains. Unit displays characteristics of fluvial strata in both areas (R.G. Tysdal, unpub. data, 2002). Neither top nor bottom of unit is exposed. Total thickness unknown, but greater than 2,000 m

Ym **Missoula Group, undivided (Mesoproterozoic)**—Light-gray, fine- to coarse-grained, arkosic metasandstone composed chiefly of quartz and feldspar (both microcline and plagioclase); matrix ranges from 1 to 10 percent. Dark-gray heavy minerals are abundant and are concentrated in basal laminae of beds; some heavy-mineral laminae are so concentrated as to form sags and convolute layers. Beds composed of trough crosslaminae are abundant, and commonly are overlain by beds of planar to ripple crosslaminated metasandstone. Fragments of dark-gray siltite (mudchips) occur at base of some beds, some forming lenses as thick as 1 m and extending along strike for several meters. Climbing ripples were observed in a few beds. Pebble conglomerate layers occur at base of some beds, forming lenses as thick as 10 cm, and extend at least 50 m along strike. Pebbles commonly are rounded and are1–4 cm in diameter. Clast compositions are mainly vein quartz, but include crystalline metamorphic rocks, granite, and metasandstone. Water-escape structures occur locally. Unit is interpreted as fluvial (R.G. Tysdal, unpub. data, 2002). Unit is present only along northeast flank of northwestern part of Beaverhead Mountains. Unit is more than 5,000 m thick. Unit was assigned to the Mount Shields Formation (Ruppel and others, 1993)

Yhe **Helena and Empire Formations, undivided (Mesoproterozoic)**—Alternating sequence of quartzitic and calc-silicate strata. A basal, upward-fining, fine-grained, and laminated metasandstone grades upward into calc-silicate argillite, siltite, and quartzite. Basal quartzitic units vary in thickness from 0.1 to 2 m; capped by thin-bedded calc-silicate units 0.1–1 m thick. Calc-silicate rocks are medium to dark green and contain abundant porphyroblasts of actinolite and tremolite. Exposure of this unit is poor but the strata have been correlated to clastic and calcareous units of the Helena and Empire Formations of the Belt Supergroup as exposed in Anaconda Range, Mont., east of Salmon National Forest (Ruppel and others, 1993)

Ysg **Spokane and Greyson Formations, undivided (Mesoproterozoic)**—Dark-gray to dark-greenish-gray, well-laminated argillite and silty argillite in uneven beds generally less than 5 cm thick; commonly contains uneven, parallel laminations of white to tan, very fine grained quartzite and siltstone. Apparently overlying is a unit of light-gray to white, fine- to medium-grained quartzite interlayered with minor dark-gray argillite and siltite. Ruppel and others (1993) interpreted these strata as being correlative to the Spokane and Greyson Formations of the Belt Supergroup as seen in Highland Mountains, Mont., to the east. Unit is poorly exposed at northern end of Salmon National Forest but appears to underlie the strata mapped as undivided Helena and Empire Formations (Yhe)

## PROTEROZOIC INTRUSIVE ROCKS

Zm **Mafic intrusive rock (Neoproterozoic?)**—Dark-gray-green to grayish-blue-green rock; cleaved; metamorphosed to lower greenschist facies. Some intrusions are diabase, but others are so well cleaved that classification is uncertain. Some of the rock contains yellowish-brown carbonate clots that weather readily, leaving a vuggy surface texture. Forms sills, dikes, and in western part of Lemhi Range, a small plug-like intrusion. Thickness of tabular bodies ranges from 1 to 30 m, generally too thin and discontinuous to show on map; only a very few are shown. Present mainly in Lemhi Range and eastern part of Salmon River Mountains. Age uncertain

Ymg **Megacrystic granite and augen gneiss (Mesoproterozoic)**—Pink and light-gray, medium- to coarse-grained, porphyritic to coarsely porphyritic, slightly peraluminous granite and augen gneiss underlying large areas in north-central part of Salmon National Forest. Composed of 20–40 percent alkali feldspar, 15–25 percent plagioclase, 20–40 percent quartz, 20–30 percent biotite, and locally minor muscovite. Microcline phenocrysts are commonly 1–4 cm long in the strongly foliated augen gneiss but generally range from 4 to 10 cm in the less foliated granite; locally, as long as 15 cm. Phenocrysts typically are rounded oblate spheroids with rapakivi texture and internal growth rings commonly defined by small biotite inclustions. Unit occurs both as plutonic bodies and as sills ranging from 1 to 1,000 m thick. Outcrops weather to spheroidal shapes studded with gray or pink microcline phenocrysts and produce coarse grus with whole microcline phenocryts and augen typically preserved. U-Pb zircon dates yield an age of about 1,370 Ma (Evans and Zartman, 1990; Doughty and Chamberlain, 1996)

Yam **Amphibolite and magnetite-hornblende gneiss (Mesoproterozoic)**—Dark-gray to black, fine- to medium-grained amphibolite and magnetite-hornblende gneiss in north-central part of Salmon National Forest and extending to the north into Montana (Berg, 1977). Composed of 40–70 percent hornblende, 20–50 percent plagioclase, 5–40 percent biotite, and less than 5 percent quartz (Schmidt and others, 1994). Typically, amphibolite occurs as 1- to 15-m-thick sills with foliation defined by hornblende and biotite; magnetite-hornblende gneiss probably was comagmatic with amphibolite. Magnetite-hornblende gneiss contains 55–70 percent feldspar, 20–30 percent quartz, 10–20 percent hornblende, and 3–5 percent magnetite (Schmidt and others, 1994). Outcrops of unit Yam are uncommon and weathering produces a dark micaceous soil. Field relations between unit Yam and the megacrystic granite (Ymg) indicate mingling of the two magmas; U-Pb isotopic dating of both units confirms a comagmatic relationship at about 1,370 Ma (Berg, 1977; Evans and Zartman, 1990; Doughty and Chamberlain, 1996)

## PROTEROZOIC METAMORPHIC ROCKS

Ybgn **Biotite gneiss (Mesoproterozoic)**—Medium- to dark-gray, fine- to medium-grained, thinly layered biotite gneiss well exposed in lower Middle Fork Salmon River and along main Salmon River west of Shoup (Maley, 1974). Composed of 50–90 percent subrounded to subangular quartz, 5–50 percent biotite, and 0–20 percent feldspar (Schmidt and others, 1994; Lund, Evans, and Esparza, 1983). Biotite-rich and quartz-rich layers alternate and range from 0.5 to 10 cm thick. Metamorphism reached garnet and sillimanite grade with migmatization common along Middle Fork Salmon River. Locally, gneiss interfingers with unit Yq and is cut by sills of units Ymg and Yam. Some biotite-rich layers contain greater than 50 percent biotite and are similar to biotitites associated with the cobalt-deposit at Blackbird mine (Evans, 1998), suggesting at least part of unit Ybgn is equivalent to identifiable lower-grade strata

Yq **Quartzite (Mesoproterozoic)**—Light-gray to white, fine- to medium-grained quartzite present in both walls of Salmon River canyon west of Shoup and northeast of Papoose Creek. Compositionally 80–100 percent subrounded quartz, 0–5 percent biotite, and 0–10 percent feldspar, with local concentrations (≤5 percent) of muscovite (Schmidt and others, 1994). Bedding commonly massive except where biotite-rich laminae define thin layers. Rare tourmaline breccias are present as 0.5- to 3-m-thick concordant lenses with angular quartzite clasts surrounded by a matrix of tourmaline. Units Ymg and Yam intrude the quartzite, as do deformed and undeformed pegmatite and aplite. Unit interfingers with unit Ybgn at both outcrop and map scale.

The stratigraphic relationship of units Yq and Ybgn is similar to that of the much less metamorphosed Hoodoo Quartzite and Yellowjacket Formation at their reference section near Yellowjacket (Ross, 1934; Tysdal and others, 2000). In addition, local tourmaline breccias are present in the Hoodoo Quartzite (Evans and Connor, 1993), possibly strengthening the argument for such a correlation. However, if biotitite layers are present in unit Ybgn, this suggests correlation with rocks at Blackbird mine (formerly considered Yellowjacket Formation, but now correlated with the Apple Creek Formation (compare, Evans, 1998; Tysdal, 2000b). In such a case, unit Yq may correlate with part of the Gunsight Formation (Yg)

Ycsq **Calc-silicate quartzite (Mesoproterozoic)**—Medium-gray to green, medium-grained sphene-hornblende(?)-biotite-diopside quartzite in a limited area in northwestern Salmon National Forest. Centimeter-scale compositional layering is well developed and accentuated by differential erosion (Schmidt and others, 1994). Dikes and sills of intrusive rocks have obscured the contact relationships with unit Ybgn. Possible correlatives may be calcareous strata of the Yellowjacket Formation or Lemhi Group

Xg **Basement gneiss (Paleoproterozoic)**—Predominantly light-gray to red-brown, coarse-grained granite gneiss locally present near Deadman Pass in Beaverhead Mountains, but widely exposed in Montana immediately east of Salmon National Forest in Maiden Peak spur area northeast of Leadore (M'Gonigle, 1994). Average composition is 38 percent microcline, 25 percent quartz, 12 percent orthoclase, 11 percent plagioclase, 12 percent hornblende and (or) biotite, and 2 percent apatite, zircon, ilmenite, and leucoxene. Preliminary U-Pb zircon data suggested an Archean age (reported in M'Gonigle, 1994), but recent work suggests a Paleoproterozoic age of about 2,450 Ma (Kellogg and others, 1999)

## INTRODUCTION

The Salmon National Forest occupies about 1.8 million acres of land, primarily in Lemhi County but also including minor parts of Idaho and Valley Counties, Idaho. Much of the forest lies within the dissected plateau of the Clearwater and Salmon River Mountains, but the eastern part includes the basin-range topography of the Lemhi Range and Beaverhead Mountains. The Salmon River and its major tributaries drain the forest. Land use activities vary from restricted, in the Frank Church–River-of-No-Return Wilderness on the western side of the forest, to multiple use (recreation, grazing, logging, mining) in the majority of the forest. In addition, segments of the Salmon River and the Middle Fork Salmon River are designated as "wild-and-scenic," catering to thousands of rafters every year.

### PREVIOUS INVESTIGATIONS

The geologic map comprises recent published and unpublished mapping, primarily by members of the U.S. Geological Survey (USGS); older maps were used only where recent coverage was lacking. Since the mid-1980's, several research projects of the USGS yielded new maps for large areas of the Salmon National Forest. Not all questions of map relations could be adequately resolved with existing data, so careful users of the map will note a few areas of apparent geologic and geometric problems. This is particularly true for the northwestern part of the Beaverhead Mountains and the northeastern part of the Clearwater Mountains. Almost no field work was undertaken in these areas and satisfactory reconciliation of previous, differing map interpretations was not readily accomplished. Some interpretation in the westernmost part of the western map sheet is speculative. Such areas and problems should be viewed as opportunities for future research.

### DATA SOURCES, PROCESSING, AND ACCURACY

The geology of large parts of the Salmon National Forest and vicinity was mapped from 1990 to 2002, and was compiled by the authors from 1997 to 2002. New published and unpublished maps by members of the USGS, particularly Karl V. Evans, Karen Lund, Russell G. Tysdal, and Gary R. Winkler, were integrated with maps from numerous published contributions (see "Index to sources of geologic mapping"). The geology was compiled onto 1:100,000-scale topographic base maps for input into a Geographic Information System (GIS). Digital base map data files, including the Bighorn Crags, Borah Peak, Challis, Leadore, Nez Perce Pass, Salmon, and Wisdom quadrangles, are available at url http://pubs.usgs.gov/imap/2003/i-2765/. This database is not meant to be used or displayed at any scale larger than 1:100,000 (for example 1:62,500 or 1:24,000).

Clear-film positives of the 1:100,000-scale geologic map compilation were electronically scanned to create raster digital images, converted to vector, polygon and point GIS layers, and attributed by a contractor (Geologic Data Systems, Inc., Denver, Colo.). The digital files were further attributed and edited, and then plotted and compared to the original film positive of the geologic map to check for digitizing and attributing errors. All processing by the USGS was done in Arc/Info version 7.2.1 installed on a Sun Ultra workstation.

## GEOLOGY

### REGIONAL GEOLOGIC SETTING

The Salmon National Forest is in both the northern Basin and Range province and the adjacent upland plateau of east-central Idaho. Mesoproterozoic metasedimentary rocks underlie large areas of the forest. Paleozoic and Mesozoic sedimentary strata are mostly restricted to the Lemhi Range and Beaverhead Mountains in the southeastern part of the forest. Intrusions throughout the area are predominantly granitoid and are Mesoproterozoic (1,370 Ma), Cambrian and Ordovician, Cretaceous (Idaho batholith), and Eocene. Eocene extrusive rocks of the Challis Volcanic Group are widespread but are most common in the southern part of the forest. Tertiary and Quaternary sedimentary strata dominate the Lemhi Valley, which is mostly outside the boundary of the forest. The map area lies within the Cordilleran thrust belt and was translated to the east in Cretaceous to Paleocene time. At least three major thrust faults—the Iron Lake, Poison Creek, and Brushy Gulch faults—are present in the forest and broadly separate the geology into three tectonostratigraphic packages. Several episodes of Tertiary extensional faulting further complicated the structural setting, and Miocene to Pleistocene(?) basin-range faulting produced the current topography of the eastern half of the forest.

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