GEOLOGIC MAP OF THE HEBGEN LAKE 30' x 60' QUADRANGLE, BEAVERHEAD, MADISON, AND GALLATIN COUNTIES, MONTANA, PARK AND TETON COUNTIES, WYOMING, AND CLARK AND FREMONT COUNTIES, IDAHO

by
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Revisions:
8/03 Map edge-matched and text revised to provide continuity with adjacent Ennis and Gardiner 30' x 60' quadrangles.

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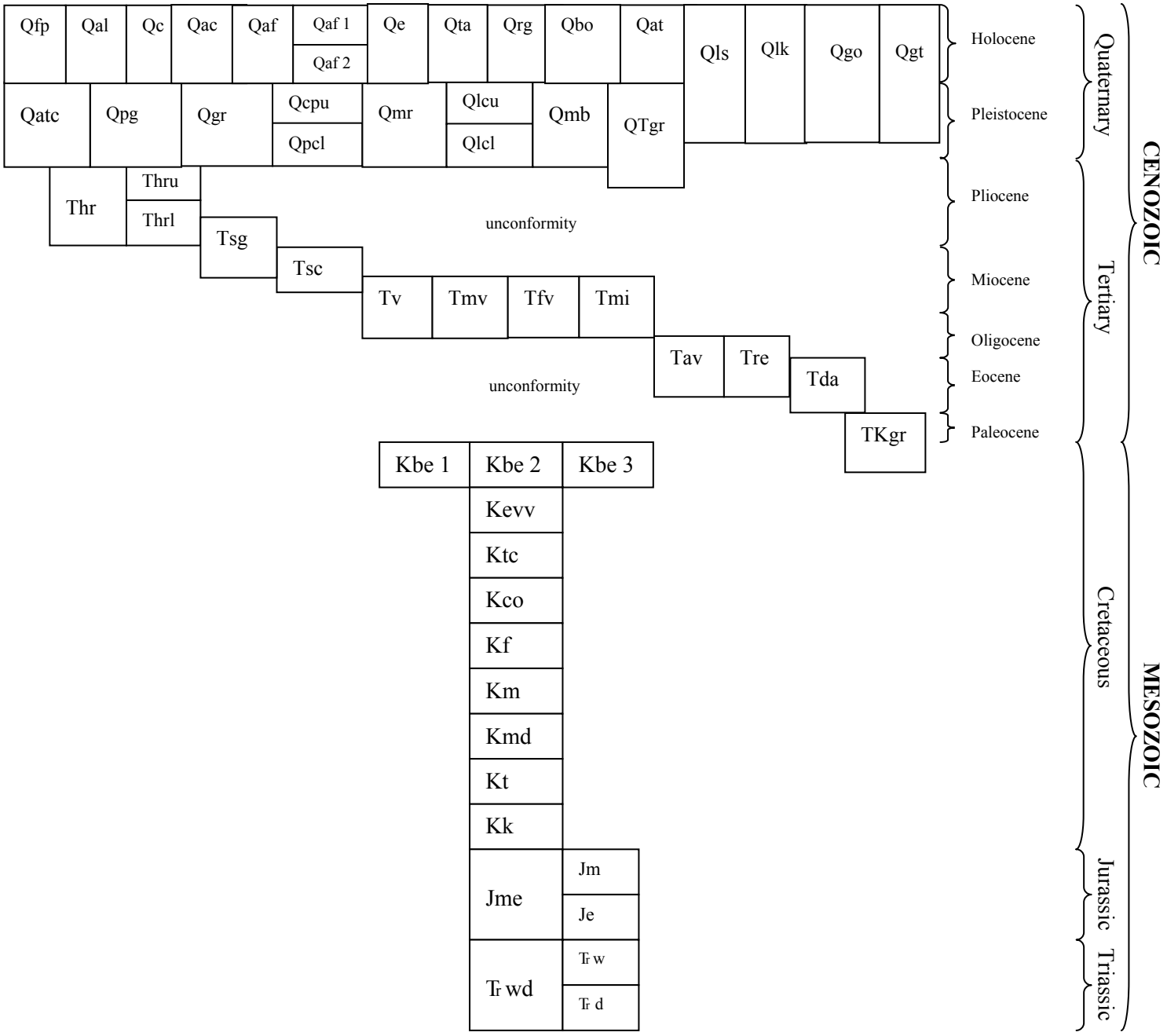
This report has had preliminary reviews for conformity with Montana Bureau of Mines and Geology's technical and editorial standards

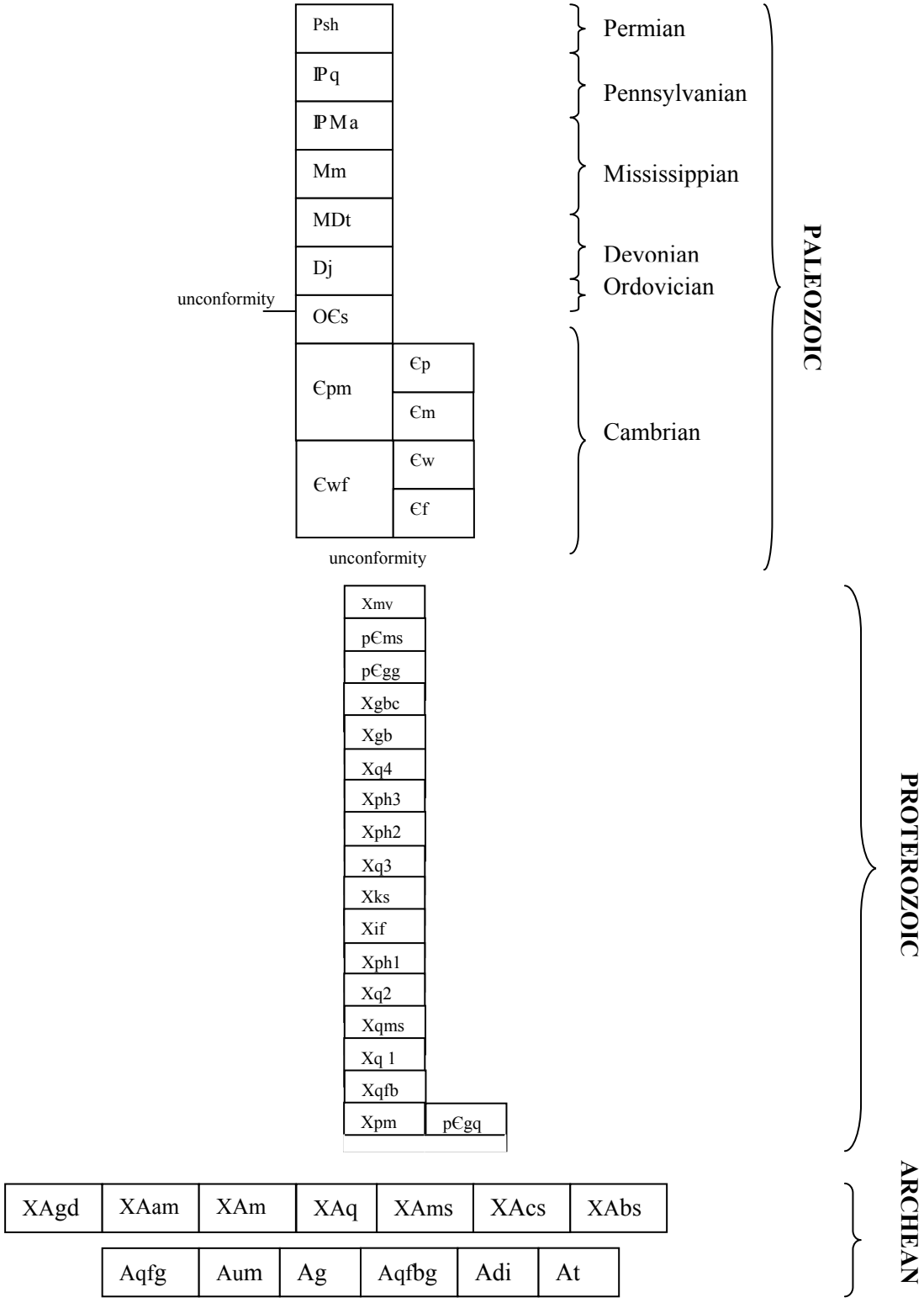
CORRELATION OF MAP UNITS
HEBGEN LAKE 30 x 60 QUADRANGLE

CENOZOIC and MESOZOIC

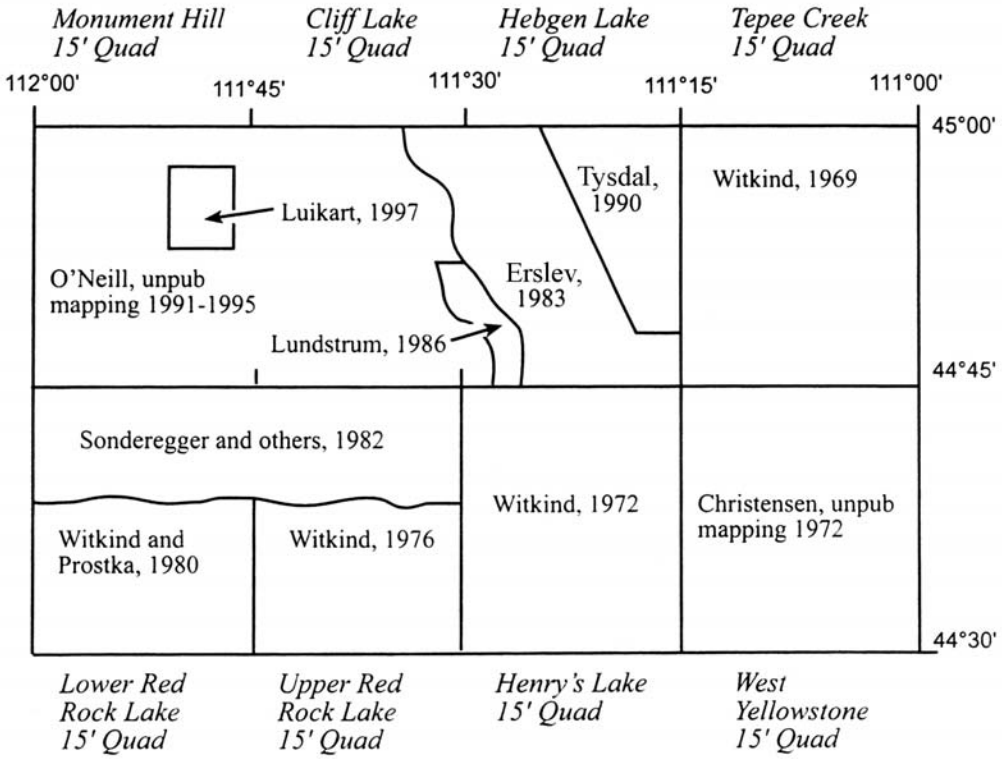


CORRELATION OF MAP UNITS
HEBGEN LAKE 30' x 30' QUADRANGLE

PALEOZOIC and PRECAMBRIAN



Index to Sources of Mapping Data
for the Hebgen Lake 30' x 60' Quadrangle



DESCRIPTION OF MAP UNITS
HEBGEN LAKE 30' x 60' QUADRANGLE

SEDIMENT AND SEDIMENTARY ROCKS

Qfp **Floodplain deposits (Holocene)—**Sand, silt, and clay deposited in broad, open stream valleys and in confined ephemeral stream channels. Maximum thickness unknown.

Qal **Alluvial and fluvial channel deposits (Holocene)—**Sand, silt, clay, and pebble to cobble gravel deposited in narrow stream channels and on broad alluvial slopes at base of low hills and mountain fronts. Locally includes thin colluvial deposits. Generally less than 5 m thick.

Qc **Colluvium (Holocene)—**Unconsolidated deposits of silt, sand, angular pebbles and cobbles formed by mass movement downslope. Thickness generally less than 2m.

Qac **Alluvial and colluvial deposits, undivided (Holocene)**

Qaf **Alluvial fan deposits, undivided (Holocene)—**Poorly sorted silty sand and gravel deposited in small alluvial fans along valley margins and around hills and mountains. Maximum thickness unknown.

Qaf 1 **Young alluvial fan deposits (Holocene)—**Active, small to large alluvial fans along valley margins.

Qaf 2 **Old alluvial fan deposits (Holocene)—**Inactive, generally large alluvial fans, most of which were deposited along the east side of the Madison Valley; fans are weakly dissected and locally cut by Holocene fault scarps.

Qe **Eolian deposits (Holocene)—**Translucent tan to brown, well-sorted, moderately frosted quartz sand grains comprise sand dune field in northern Centennial Valley. Maximum thickness (dune height) about 10 m.

Qta **Talus deposits (Holocene)—**Unsorted, unstratified angular clasts and slabs as much as 2 m across that accumulate at the base of cliffs and very steep slopes.

Qrg **Rock glaciers deposit (Holocene)—**Lobate to elongate, unconsolidated deposits of coarse gravel and boulders in glacial cirques or at the base of cliffs above timberline. Older deposits are locally covered by thin soil and vegetation. Thickness generally less than 20 m.

Qbo **Boulder fields (Holocene)—**Unsorted accumulation of angular boulders on steep slopes.

Qat **Aluvium of alluvial terrace deposits, undivided (Holocene)—**Pebble- to boulder-size gravel and sand on low terraces adjacent to major streams. Maximum exposed thickness about 5 m.

Qls **Earth flow and landslide deposits (Holocene and Pleistocene)—**Coarse, unconsolidated deposits of locally derived, angular pebbles, cobbles, and boulders associated with fine-grained matrix of silt and sand. On south and east sides of Gravelly Range, huge landslides where length and width are measured in km include large toreva blocks of Huckleberry Ridge Tuff (Thr) deposited on unconsolidated sand and silt of the Neogene Six Mile Creek Formation (Tsc); on the west side of the Gravellys, landslides of similar size reflect massive dip-slip slope failure of clay-rich, tuffaceous, weakly indurated Cretaceous formations. Maximum thickness probably near 60 m.

Qlk **Lacustrine deposit (Holocene and Pleistocene)—**Light-brown to brown, well-sorted, unconsolidated sand, silt, and clay veneer on undissected surfaces underlain mainly by basin-fill deposits. Marked, in part, by multiple strand lines that outline limit of dwindling glacial lake. Thickness unknown; probably less than 2 m.

Qgo **Glacial outwash deposits (Holocene and Pleistocene)—**Generally poorly sorted, bouldery, layered sand and gravel deposited by glacial meltwater.

Qgt **Glacial till and related deposits (Holocene and Pleistocene)—**Poorly sorted, unconsolidated deposits of silt, sand, gravel, and boulders within, commonly adjacent to, and locally at the mouths of major alpine valleys. Deposits are both Pinedale and Bull Lake in age; cirque moraines and protalus ramparts are Holocene in age. Maximum thickness is unknown.

Qatc **Alluvial terrace deposit of the Cameron Bench (Pleistocene)—**Moderately sorted, moderately rounded to well-rounded sand and gravel.

Qpg **Pediment deposits (Pleistocene)—**Weakly dissected deposits of pebbles and cobbles of generally angular to subrounded, unsorted and unconsolidated sedimentary and crystalline rocks in a fine-grained, pale-yellowish-brown matrix. Deposited on gently dipping surfaces related to the development of the Madison Valley. Maximum thickness about 5 m.

Qgr **Gravel deposit (Pleistocene)—**Sand and pebble- to boulder-size gravel deposit underlying several terrace levels along the Ruby River at elevations as much as about 100 m above the river.

Qpcu **Plateau Rhyolite, Central Plateau Member, upper part (Pleistocene)—**Rhyolitic flows erupted from vents in the Yellowstone Caldera; flows contain abundant phenocrysts of mainly quartz and sanidine; plagioclase phenocrysts are conspicuous in their absence. Maximum thickness about 300 m.

Qpcl **Plateau Rhyolite, Central Plateau Member, lower Buffalo Lake flow (Pleistocene)—**Rhyolitic ash-flow tuff, light-gray, dense, fine-grained to aphanitic with angular to rounded phenocrysts of quartz, sanidine, pyroxene, and olivine that make up as much as 25 percent of volume of rock.

Qmr **Madison River Basalt (Pleistocene)—**Medium- to light-gray, dense basalt that contains moderately abundant plagioclase phenocrysts and rare olivine phenocrysts; occurs as scattered, thin flows in the vicinity of West Yellowstone.

Qlcu **Lava Creek Tuff, upper member, informal (Pleistocene)**—Light-gray, locally pale-red, fine-grained to aphanitic, densely welded ash-flow tuff, with phenocrysts composing as much as 20 percent of rock. Thickness to east of map area ranges from 180 to 300 m.

Qlcl **Lava Creek Tuff, lower member, informal (Pleistocene)—**Ash-flow tuff lithologically similar to overlying upper member; the two members are separated by a partially welded tuff locally associated with a sorted and bedded crystal ash several cm thick.

Qmb **Mount Jefferson Rhyolite, Big Bear Lake flow (Pleistocene)—**Light-gray rhyolite flows conformably underlying Lava Creek Tuff; rhyolite is variable in appearance but contains conspicuous phenocrysts of sanidine, quartz, and plagioclase that make up 30-50 percent of the volume of the rock. Maximum thickness to east of map area is 450 m.

QTgr **Gravel deposit (Pleistocene and Pliocene)—**Isolated sand and pebble- to boulder-size gravel deposits at high elevations in the Gravelly and Centennial Ranges.

Thr **Huckleberry Ridge Tuff, undivided (Pliocene)—**Tuff, mapped in the Gravelly Range, where it thins dramatically to less than 1 m in the north, and in the northern Gallatin Mountains in the northeast part of the quadrangle.

Thru **Huckleberry Ridge Tuff, upper member, informal (Pliocene)**—Pinkish-gray, gray, to brown welded tuff containing abundant phenocrysts of sanidine and quartz (25 and 10 percent, respectively); uppermost part is locally nonwelded, light pink on weathered surfaces, and contains noncompacted pumice fragments.

Thrl **Huckleberry Ridge Tuff, lower member, informal (Pliocene)—**Medium- to dark-gray welded tuff with sparse (less than 5 percent) phenocrysts; base of the unit is a vitrophyre overlain by densely welded tuff that becomes only partly welded at the top.

Tsg **Sand and gravel (Pliocene and Miocene)—**Thin alluvial and fluvial sand and pebble-size gravel deposits restricted to abandoned stram valleys in the Gravelly Range.

Tsc **Six Mile Creek Formation (Miocene)—**Weakly consolidated. tan to light-orange-brown, laminated, tuffaceous mudstone, siltstone, sandstone, and lithic pebble conglomerate; maximum exposed section along the West Fork of Madison River is about 70 m.

Tv **Volcanic rocks, undivided (Miocene and Oligocene)—**Rocks of a volcanic vent, located along north map border in northwest part of map.

Tmv **Mafic volcanic rocks (Miocene and Oligocene)—**Dark-gray to black, dense, fine-grained flow rock, commonly vesicular or columnar jointed, and containing sparce olivine phenocrysts. Maximum thickness in southern Gravelly Range along the West Fork of the Madison River is near 120 m. In Centennial Range, divided into two similar mafic flow sequences separated by rhyolitic flows (Tfv). Upper flows are basalt to basaltic andesite, sparsely porphyritic, and interlayered

with thin, discontinuous beds of mudflow breccia; lower sequence consists of lava flows and flow breccias of dark-gray to brownish-black basalt, basaltic andesite, and gray, brown, and yellowish-brown andesite with fewer mafic flows lowermost in the sequence. All rocks are porphyritic; basaltic rocks contain plagioclase and olivine phenocrysts whereas andesite contains sparse to abundant phenocrysts of plagioclase and at least one mafic mineral in a glassy to aphanitic groundmass. Total thickness about 870 m.

Tfv **Felsic volcanic rocks (Miocene and Oligocene)—**In Centennial Mountains, consists of two units: upper sequence consists of light-gray, yellowish-gray, and brown porphyritic dacite and rhyodacite flows and flow breccias interlayered with thin, discontinuous beds of mudflow breccia; maximum thickness about 350 m; lower sequence is light- to brownish-gray mudflow breccia and mudstone containing poorly sorted volcanic rock fragments in an ashy matrix; lower sequence ranges in thickness from 0 to 60 m.

Tmi **Mafic intrusive rocks (Miocene and Oligocene)—**Large to small plugs and sills of basalt and basaltic andesite exposed in western part of map area; largest plug is Black Butte in the Gravelly Range. In eastern part of map area includes sills of dacite porphyry and minor shoshonite.

Tav **Absaroka Supergroup volcanic rocks, undivided (Oligocene and Eocene)—**In Centennial Mountains consists of dark-gray to black, fine-grained to aphanitic pyroxene trachyte porphyry; augite, olivine, and andesine are common phenocrysts. Thickness unknown.

Tre **Renova Formation (Oligocene and Eocene)—**Weakly consolidated, cream-colored, tuffaceous mudstone commonly containing calcareous concretions, interlayered with lesser amounts of sandy siltstone and granule-pebble conglomerate; maximum exposed thickness at Lion Mountain at the crest of the Gravelly Range, is about 260 m.

Tda **Dacite, intrusive (Eocene)**—Light- to medium-gray and brownish-gray, dense, porphyritic dacite. Phenocrysts are euhedral plagioclase, hornblende, and biotite.

TKgr **Gravel and conglomerate (Paleocene and Upper Cretaceous)—**Unconsolidated cobbles and boulders of subrounded metamorphic rock in scattered exposures along the crest of the Gravelly Range; maximum preserved thickness about 10 m.

Beaverhead Group (Upper Cretaceous) lithologies (numbers do not imply relative age or stratigraphic position):

Kbe 1 **Limestone and conglomerate—**Limestone and limestone conglomerate interbedded with varying amounts of siltstone and sandstone. Best exposures are at Red Hill in the Gravelly Range where basal siltstone and limestone conglomerate are interlayered with lenses of well-rounded quartzite gravel in an angular quartz sand matrix; gravel is similar to underlying stream gravel deposits (Kbeg) and may have been derived, in part, from these fluvial deposits. The lacustrine limestone consists of medium- to coarse-crystalline, light-gray limestone locally containing abundant snails, stromatolites, and oncolites; also commonly interlayered with coarse-grained sandstone, siltstone, and intraformational limestone rip-up conglomerate. Many of the conglomerate lenses consist of

clasts of locally derived Paleozoic rocks upon which these rocks rest; they are confined to paleovalleys that, in the Gravelly Range, drained from west to east. Maximum thickness is about 20 m.

Kbe 2 **Gravel and sand, Beaverhead Group (Upper Cretaceous)—**Unconsolidated, well-rounded pebble- to cobble-size stream deposits composed chiefly of quartzite derived from Mesoproterozoic Lemhi Group and Belt Supergroup exposed to the northwest and west of Gravelly Range, beyond the borders of the Hebgen Lake quadrangle; thickness about 10 m or less.

Kbe 3 **Sandstone of Beaverhead Group (Upper Cretaceous)**—Poorly exposed buff to brown, silty sandstone interlayered with lenses of well-rounded to subrounded cobbles and boulders of metamorphic rock; present in the northern Centennial Valley and southernmost Gravelly Range; thickness may be as much as 725 m.

Kevv **Everts(?) Formation and Virgelle Sandstone (Upper Cretaceous)**

Everts(?) Formation—Light- to dark-gray, thin- to thick-bedded, fine- to medium-grained, quartz-rich sandstone and interbedded siltstone; includes sparse mudstone, porcellanite, and dark gray limestone. Lower 60-90 m are thinly interbedded mudstone, siltstone, shale, coal, and minor crossbedded sandstone. Formation is about 425 m thick.

Virgelle Sandstone—Thin- to thick-bedded, medium- to coarse-grained, crossbedded sandstone forming prominent white-weathering ledges. Thickness ranges from 23 to 50 m.

Ktc **Telegraph Creek Formation (Upper Cretaceous)—**Upper half consists of light-brown-weathering mudstone and siltstone with thin interbeds of light-gray sandstone that locally contain chert-pebble lags and glauconite. Middle 20 m consists of conspicuous white-weathering, finely laminated tuffaceous siltstone. Lower 75 m consists of slope-forming siltstone and mudstone in upper part that overlies lowermost "salt and pepper", ripple-marked sandstone. Total thickness about 206 m.

Kco **Cody Shale (Upper Cretaceous)—**Dark-gray, thin-bedded, locally micaceous and silty mudstone with thin interbeds of gray-green siltstone and fine-grained sandstone. About 300 m thick.

Kf **Frontier Formation (Upper Cretaceous)—**Interbedded sandstone, siltstone, mudstone, carbonaceous shale and coal seams, and minor limestone. Sandstone is predominantly medium light gray to yellowish or greenish gray, very fine to medium grained and commonly calcareous. Coarse-grained varieties include subangular lithic sand grains of chert, feldspar, and biotite; locally conglomeratic, containing well-rounded pebbles of quartzite and chert. Sandstone beds generally less than 1 m, but occur in layered units as much as 7 m in thickness. Siltstone and mudstone are olive gray and medium to dark gray and are bentonitic and porcellanitic. Limestone is thin-bedded to nodular, light to medium gray, and micritic. Thickness ranges from about 870 m directly north of the Gravelly Range, to 2100 m near the southern part of the Gravellys, and thins to 120 m in the Madison Range.

Km **Mowry Formation (Lower Cretaceous)—**Slope-forming dark-gray mudstone and silty mudstone interbedded with minor siltstone, sandstone and bentonite with organic-rich shale in the upper part. Lower part is light colored pink, gray green, green, and orange-cream colored mudstone, bentonitic mudstone, and porcellanite interlayered with welded tuff, mudstone, siltstone, and minor quartz sandstone. Generally poorly exposed because of slumping; in the Gravelly Range the Mowry is the site of pronounced landsliding. Formation is about 150 to 180 m thick.

Kmd **Muddy Formation (Lower Cretaceous)—**Formation consists of three parts: upper part consists of light-gray, thin- to medium-bedded, fine- to coarse-grained quartz sandstone, feldspathic sandstone, and arkose; middle part is dark-gray, thin-bedded siltstone, sandstone, and shale; lower part is greenish-gray to tan, fine- to medium-grained sandstone. The middle member thins to the west and is absent in the Gravelly Range. Thickness ranges from 0 to about 110 m.

Kt **Thermopolis Shale (Lower Cretaceous)—**Dark-gray to black, fissile, organic-rich shale in the upper part overlies light- to dark-brown-weathering, thin- to medium-bedded, fine- to medium-grained sandstone. Thickness ranges from about 50 to 75 m.

Kk **Kootenai Formation (Lower Cretaceous)—**Upper 15 m consists of conspicuous, ledge-forming, medium- to thick-bedded, light-gray fresh water limestone that contains abundant gastropods. Middle part is a slope-forming gray, maroon, yellow, red, and purple mudstone with siltstone, sandstone, and, in the lower part, minor limestone. Lower part is thick-bedded, cherty, crossbedded, quartz-rich sandstone and minor, well-rounded chert-pebble conglomerate. Thickness about 125 m.

Jme **Morrison and Ellis Formations, undivided (Upper and Middle Jurassic)**

Jm **Morrison Formation (Upper Jurassic)—**Interbedded red, green, gray, and yellowish siltstone, mudstone, and shale locally interlayered with thin beds of dense, fine-grained limestone; in Madison Range the upper part includes yellowish-tan, medium-bedded sandstone lenses as much as 20 m thick; formation is generally poorly exposed and forms reddish-colored slopes. Maximum thickness is about 100 m.

Je **Ellis Group (Upper and Middle Jurassic)**

Swift Formation—Thin- to medium-bedded, medium- to coarse-grained, calcareous, locally chert-bearing quartz sandstone that contains abundant ooids and shell fragments; lowermost part is olive-green shale and claystone. The Swift is the only formation of the Ellis Group exposed in the western part of the map area. Thickness ranges from about 1 to 30 m.

Rierdon Formation—Light-gray to pale brown, thin- to thick-bedded, dense, oolitic limestone locally containing sparse chert pebbles. Formation is absent in western part of map area; maximum thickness is about 30 m.

Sawtooth Formation—Thin-bedded, light- to dark-gray limestone with local shaly to silty limestone interbeds; locally fossiliferous and oolitic. Formation absent in western part of map area; maximum thickness about 55 m.

Trwd **Woodside and Dinwoody Formations, undivided (Lower Triassic)**

Trw **Woodside Formation (Lower Triassic)—**Brick-red to orange-red, thin-bedded siltstone and mudstone interbeded with gypsum and thin, discontinuous limestone beds; uppermost strata are silty and locally crossbedded. Thickness ranges from 0 to about 220 m.

Trd **Dinwoody Formation (Lower Triassic)—**Tan to pale-brown-weathering, finely laminated, calcareous siltstone in the upper part; grades downward into chocolate-brown-weathering gray to tan limestone, silty limestone and siltsone. Thickness is variable, ranging from about 20 to 80 m.

Psh **Shedhorn Sandstone (Permian)—**Uppermost medium-bedded, fine- to coarse-grained sandstone with minor chert lenses grades downward into yellowish- to dark-brown, thin-bedded chert with silty, locally phosphatic partings; lower part is brown to gray, thin- to medium-bedded sandstone that grades downward into yellowish-gray, medium-bedded dolomite and sandy dolomite locally containing abundant chert fragments. Equivalent to Phosphoria Formation. Thickness is variable, ranging from about 35 to 70 m.

IPq **Quadrant Sandstone (Pennsylvanian)—**White to tan, medium- to thick-bedded, clean, well-sorted quartz sandstone; lower part contains thin interbeds of pale-brown dolomite and gray limestone. Thickness is 60-100 m.

IPMa **Amsden Formation (Lower Pennsylvanian and Upper Mississippian)—**Dark-red, gray-red, and pinkish-red, thin-bedded, calcareous siltstone, silty shale, and shale; upper part of formation contains interbeds of medium- to coarse-grained, calcareous sandstone whereas the lower part is interbedded with thin-bedded limestone, limestone-pebble conglomerate, and dolomite. Thickness ranges from about 10 to 50 m.

Mm **Madison Group, undivided (Upper and Lower Mississippian)—**Group ranges in thickness from about 400 to 700 m.

Mission Canyon Limestone (Upper and Lower Mississipian)—Commonly cliff-forming, thick-bedded, light-gray-weathering, cherty, fine-grained limestone and minor dolomite; uppermost few meters of formation contain prominent orangish-gray-weathering solution breccia.

Lodgepole Limestone (Lower Mississippian)—Slope- to ledge-forming, thin- to medium-bedded, light-gray, finely crystalline, fossiliferous limestone with brownish silty limestone partings.

MDt **Three Forks Formation (Lower Mississippian and Upper Devonian)—**Consists of three members, from top to bottom: Yellowish-tan calcareous siltstone and silty limestone (Sappington Member, maximum thickness 25 m); gray-green, fissile, micaceous shale (Trident Member, maximum thickness 6 m); yellowish-grey vuggy limestone and dolomite underlain by olive-green micaceous shale (Logan Gulch Member, maximum thickness 12 m).

Dj **Jefferson Formation (Upper Devonian)—**Light-gray, tan, yellowish-brown, and dark-gray, fine-crystalline to sucrosic dolomite locally interbedded with 1-m-thick silty, shaly, laminated dolomite; in Madison Range, includes uppermost, massive, ledge-forming dolomite breccia (Birdbear Member). Maximum thickness about 100 m.

OЄs **Sedimentary rocks, undivided—Bighorn(?) Dolomite, Snowy Range Group, and Pilgrim Limestone, undivided (Ordovician and Upper Cambrian)**

Bighorn(?) Dolomite (Ordovician)—Light-gray, thin-bedded, dense cryptocrystalline dolomite. About 11 m thick.

Snowy Range Group (Upper Cambrian)—Tan, thin-bedded limestone with reddish mottles underlain by greenish, thin-bedded dolomite and dolomitic mudstone that grades downward into red, calcareous siltstone and green sandy shale. Formation is about 300 m thick.

Pilgrim Formation (Upper Cambrian)

Єpm **Park, and Meagher Formations, undivided (Upper Cambrian)**

Єp **Park Shale (Middle Cambrian)—**Greenish-gray to reddish-gray, fissile, locally waxy-looking shale interbedded with minor limestone, limestone-pebble conglomerate, and oolitic limestone. Poorly exposed everywhere and perhaps locally missing in the Gravelly Range. Locally included with the underlying Meagher Formation where too thin to show on map. Thickness 0 to 30 m.

Єm **Meagher Formation (Middle Cambrian)**—Light-gray to brownish-gray, thin to medium-bedded, finely crystalline limestone with thin partings of calcareous shale in upper and lower parts; characteristically contains irregular orange-yellow silty mottles; locally interbedded with cm-thick oolitic limestone. Basal few meters of formation in the Gravelly Range, where it directly overlies Paleoproterozoic metasedimentary rocks, are characterized by calcareous-cemented lag gravel deposits. In Gravelly Range, locally includes thin, unmapped deposits of Wolsey and Flathead Formations. Maximum thickness about 150 m.

Єwf **Wolsey and Flathead Formations, undivided (Middle Cambrian)**

Єw **Wolsey Formation (Middle Cambrian)—**Gray-green to dark-gray, fissile, micaceous shale interbedded with minor, thin limestone beds similar to mottled limestone of the overlying Meagher Formation as well as thin, glauconitic, quartzose sandstone similar to underlying Flathead Sandstone. Locally missing in the Gravelly and Centennial Ranges. Thickness 0 to 60 m.

Єf **Flathead Sandstone (Middle Cambrian)—**White, tan to reddish-brown, hematitic, thin- to medium-bedded, fine- to medium-grained quartz to feldspathic sandstone; interlayered with greenish shale in upper part; glauconitic locally. Where unmapped in the Centennial and Gravelly Ranges, formation may be missing or so thin that it is included in the overlying Meagher Formation. Thickness 0 to 30 m.

PALEOPROTEROZOIC ROCKS

Late Paleoproterozoic tectonites, metasedimentary rocks, and associated igneous rocks. Relative ages as listed, youngest to oldest. Exposed only in Gravelly Range. Rocks have been divided into 12 sedimentary members that have been intruded by gabbro sills and small plugs and, in the north, a granitic stock. The weakly metamorphosed rocks are interpreted to represent a sequence of late Paleoproterozoic clastic foreland basin deposits (O'Neill, 1999) consisting mainly of sandstone and shale; sedimentary iron formation occurs in the middle of the sequence and is a marker horizon throughout the Gravelly Range. Gabbroic intrusive rocks are weakly tectonized and are associated with contact metamorphic aureoles marked by porphyroblasts of andalusite or staurolite or both in pelitic rocks around their perimeters. Mylonitization of rocks occurred about 1.8 Ga, coeval with the mylonitic rocks to the east, in the Madison Range.

Xmy Mylonite

pЄms Mylonitic schist (carried into Hebgen Lake quadrangle from north-adjacent Ennis 30'x60' quadrangle)

[Xg Granite] Changed to **pЄgg** (granite, migmatite, pegmatite, and granitic orthogneiss) to agree with north-adjacent Ennis 30'x 60 quadrangle)

Xgbc Gabbro, chloritized

Xgb Gabbro

Xq4 Quartzite member 4

Xph3 Phyllite member 3

Xph2 Phyllite member 2

Xq3 Quartzite member 3

Xks Knotted mica schist

Xif Iron formation

Xph1 Phyllite member 1

Xq2 Quartzite member 2

Xqms Quartz-mica schist

Xq1 Quartzite member 1

Xqfb Quartz-feldspar-biotite gneiss.

Changed to **pЄms** (mylonitic schist) along north map border in Gallatin Range to agree with north-adjacent Ennis quadrangle.

Xpm Pegmatite and metasedimentary rocks, undivided

Changed to **pЄgq** (biotite gneiss, quartzite, and hornblende gneiss) along north map border in Gallatin Range to agree with north-adjacent Ennis 30' x 60' quadrangle)

EARLY PALEOPROTEROZOIC?–ARCHEAN SUPRACRUSTAL METASEDIMENTARY AND META-IGNEOUS ROCKS

Amphibolite-grade metasedimentary rocks are strongly deformed and show abundant evidence of internal thickening and thinning; original thickness of the metamorphic units is not known. These supracrustal rocks, originally called the Cherry Creek Metamorphic Suite for exposures in the Gravelly Range along Cherry Creek, directly north of the map area (Heinrich, 1960), have traditionally been accepted as being Late Archean in age. Erslev and Sutter (1990) obtained latest Archean (2.53 Ga) cooling ages from gneissic rocks interlayered with metasedimentary rocks directly west of Henrys Lake; however, it is not clear how the gneissic rocks are related to the enclosing metasediments. Given the strongly folded and thrust faulted-nature of these rocks, the likely imbricate stacking of Archean crustal rocks with overlying, younger supracrustal rocks in a fold-and-thrust belt, and the fact that supracrustal rocks are virtually unknown from Archean basement rocks of North America, we tentatively suggest the possibility of an early Paleoproterozoic age for these metasediments.

XAgd **Granodioritic gneiss (Early Paleoproterozoic(?) - Late Archean)—**Foliated granodiorite occurs as intrusive sills that locally show crosscutting relationships and chilled margins. The rock is equigranular and composed of plagioclase, quartz, microcline, hornblende, and biotite.

XAam **Amphibolite (Early Paleoproterozoic(?) - Late Archean)**—Amphibolite dikes and sills in the Madison Range range from infolded, disjointed units to tabular sheets with sharp, planar contacts; mapped units were probably originally grabbroic intrusive rock. In the Centennial Range and Horn Mountains, amphibolite is green to greenish brown, schistose to massive, generally fine grained, and locally porphyroblastic; actinolite makes up as much as 50-90 percent of rock.

XAm **Marble (Early Paleoproterozoic(?) - Late Archean)—**Massive, light-gray to cream-colored dolomitic marble interlayered with thin quartzite bands; schistosity defined by aligned chlorite and phlogopite, and flattened dolomite grains. In thin section, dolomite dominates the marble; calcite is associated with quartzite layers only; quartz is present generally as granular bands within marble.

XAq **Quartzite (Early Paleoproterozoic(?) - Late Archean)—**Light-green, poorly banded quartzite interfingers with adjacent biotite schist and marble; quartzite has been completely recrystallized and does not show clastic textures or graded bedding.

XAms **Mica schist (Early Paleoproterozoic(?) - Late Archean)—**Interlayered rusty-yellow-weathering, quartz-rich muscovite schist and thin quartzite; locally contains abundant magnetite, chlorite, biotite, and poikiloblastic garnet.

XAcs **Chlorite-biotite schist (Early Paleoproterozoic(?) - Late Archean)—**Well-banded chlorite-biotite schist and gneiss containing variable amounts of quartz and epidote are interlayered with green phyllonite, chloritic schist with quartz augen, and granulated amphibolite.

XAbs **Biotite schist and gneiss (Early Paleoproterozoic(?) - Late Archean)—**Compositional layering of biotite-rich metamorphic rocks is defined by relative proportions of quartz, biotite, garnet, and muscovite. One- to 3-m-thick beds of biotite-rich

metasandstone with well-preserved clastic textures separated by thinner beds of metapelite are common. Biotite schist is also interlayered with marble and is associated with chlorite-quartz schist and well-banded quartzite similar to banded cherts associated with iron formation.

MIDDLE ARCHEAN ROCKS

Middle Archean amphibolite- to granulite-grade metamorphic tectonites and associated igneous rocks; relative ages uncertain. That these rocks are Middle Archean (> 3.1 Ga) has been confirmed by U-Pb zircon ages from crystalline rocks collected from the southern Madison Range (Shuster and others, 1987).

Aqfg **Quartzofeldspathic gneiss (Middle Archean)—**Heterogeneous , generally layered, light- to medium-gray microcline-plagioclase-quartz-biotite gneiss.

Aum **Ultramafic rock (Middle Archean)**—Pods and lenses of hornblende-rich rock consisting mainly of, from rim to core, hornblende and biotite, actinolite and biotite, chlorite, talc and carbonate, anthophyllite, and a core of serpentine.

Ag **Granite and granitic gneiss (Middle Archean)**—Pink, foliated granitic rocks show weakly to strongly discordant contacts with adjacent rocks. Rock composition and texture is variable, ranging from medium-grained and equigranular with faint layering defined by aligned biotite, to highly folded and contorted leucogranite enclosing granodioritic xenoliths, to mafic, folded granite and granite gneiss.

Aqfbg **Quartz-feldspar-biotite gneiss and migmatite (Middle Archean)**—Similar in composition to augen gneiss (Aa) but lacks tectonite fabric; similar in texture to granite gneiss (Ag) but is less mafic and generally concordant.

Adi **Dioritic gneiss (Middle Archean)**—White-and-green-spotted, well-foliated plagioclase-hornblende-quartz rock occurs as thin sills and small stocks. Sills typically consist of 60-80 percent plagioclase, hornblende, and minor quartz; stocks are more felsic and include biotite and as much as 30 percent quartz.

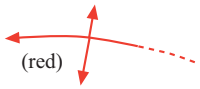
At **Tonalitic gneiss (Middle Archean)**—Tonalitic migmatite-gneiss and tonalitic biotite gneiss are highly variable both texturally and compositionally; gneiss includes amphibolitic migmatite breccia, leucotonalite gneiss, and dark-gray tonalitic biotite gneiss with moderate migmatite banding. Locally tonalite gneiss is interlayered with a mixed gneiss composed of green quartzite, biotite-garnet gneiss, amphibolite and garnet amphibolite, and gedrite-cordierite-bearing gneiss. All tonalitic rocks consist of essential plagioclase, quartz, hornblende, and biotite with a granoblastic texture. Also included with these rocks is migmatitic granite gneiss characterized by granite leucosomes containing abundant microcline between thin layers enriched in plagioclase, biotite and, locally, hornblende.

MAP SYMBOLS

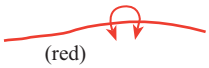
Contact—Dashed where approximately located, dotted where concealed

Normal Fault—Dotted where concealed

Thrust Fault—Teeth on upper plate; dotted where concealed



Anticline—Dotted where concealed



Overturned Anticline

Syncline—Dotted where concealed

Overturned Syncline

Monocline

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