GEOLOGIC MAP OF THE FAN MOUNTAIN, LONE MOUNTAIN, AND GALLATIN PEAK 7.5′ QUADRANGLES, MADISON RANGE MADISON AND GALLATIN COUNTIES, MONTANA

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*Compilation primarily from Kellogg and Williams (2000), Kellogg (1992), unpublished 1:24,000-scale field maps of the Lone Mountain and Gallatin Peak 7.5′ quadrangles by Karl S. Kellogg, and unpublished mapping by Roger S. Swanson and Larry N. Smith.

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GEOLOGIC MAP OF THE FAN MOUNTAIN, LONE MOUNTAIN, AND GALLATIN PEAK 7.5′ QUADRANGLES, MADISON AND GALLATIN COUNTIES, MONTANA

The geologic map of the Fan Mountain, Lone Mountain, and Gallatin Peak 7.5′ quadrangles was prepared to provide a 1:24,000-scale geologic map that transects the northern part of the north-trending Madison Range (Figure 1). The Montana Bureau of Mines and Geology STATEMAP Advisory Committee selected this area primarily because of proposed development and ongoing development in two adjacent, large ski resort areas—Moonlight Basin and Big Sky—which include ski lifts, housing developments, business facilities, and golf courses. The focus of the STATEMAP work in this area was to map potential geologic hazards such as landslides and Cenozoic faults. The STATEMAP field mapping built on previous published and unpublished geologic mapping. The Fan Mountain 7.5′ quadrangle was previously published at 1:24,000 scale (Kellogg, 1992). Additional landslide deposits and north-striking faults were added to the Madison Range part of that map based on field mapping through the STATEMAP Program. Mapping of the mountain front (Ruleman, 2002) was also incorporated. The Lone Mountain and Gallatin Peak 7.5′ quadrangles were mapped at 1:24,000 scale for incorporation into the 1:100,000-scale geologic map of the Ennis 30′ x 60′ quadrangle (Kellogg and Williams, 2000). Copies of 1:24,000-scale field maps were provided by Karl Kellogg which include detailed mapping that could not be shown on the 1:100,000 scale map. Some of that detailed mapping is included on the current 1:24,000-scale map with permission, supplemented by additional geologic mapping through the STATEMAP Program, and some alternate interpretations. Unpublished mapping by Roger W. Swanson in the Gallatin Peak 7.5′ quadrangle has also been incorporated. A separate map (Vuke, 2013) emphasizes landslide deposits in the Big Sky area, shown on a Light Detection and Ranging (LiDAR) bare earth hillshade base.

Laramide compression

Laramide compressional deformation began about 79 million years ago in the northern Madison Range (Kellogg and Harlan, 2007). Two major basement-involved structural systems developed during Laramide contraction: the Spanish Peaks Fault in the northern part of the map area, and the Hilgard thrust system in the western part of the map area (Figure 1).

The Spanish Peaks Fault is a major northwest-striking fault which was reactivated along Precambrian planes of weakness in the Archean basement (Garihan and others, 1983). Offset on the fault is at least 10,000 feet (Garihan, and others, 1983) (3050 m) and may be as much as 13,500 feet (McMannis and Chadwick, 1964) (4115 m). Northeast of the fault in the map area, the bedrock is Archean metasedimentary, meta-igneous, and plutonic rock. A band of footwall sedimentary rocks that strikes parallel to the fault, crops out on the southwest side of the fault. Beds generally dip moderately to steeply to the southwest and are locally overturned. Formations in this band range from the Cambrian Flathead Formation to the Cretaceous Frontier Formation in the map area.

The Hilgard thrust system is a zone of imbricate thrust faults along the western edge of the Madison Range that intersects but does not offset or deflect the Spanish Peak Fault (Tysdal and others, 1986; Kellogg and others, 1995). The units involved in thrusting include Archean metamorphic rocks, and sedimentary rocks from the Cambrian Flathead Formation to the Cretaceous Frontier Formation.

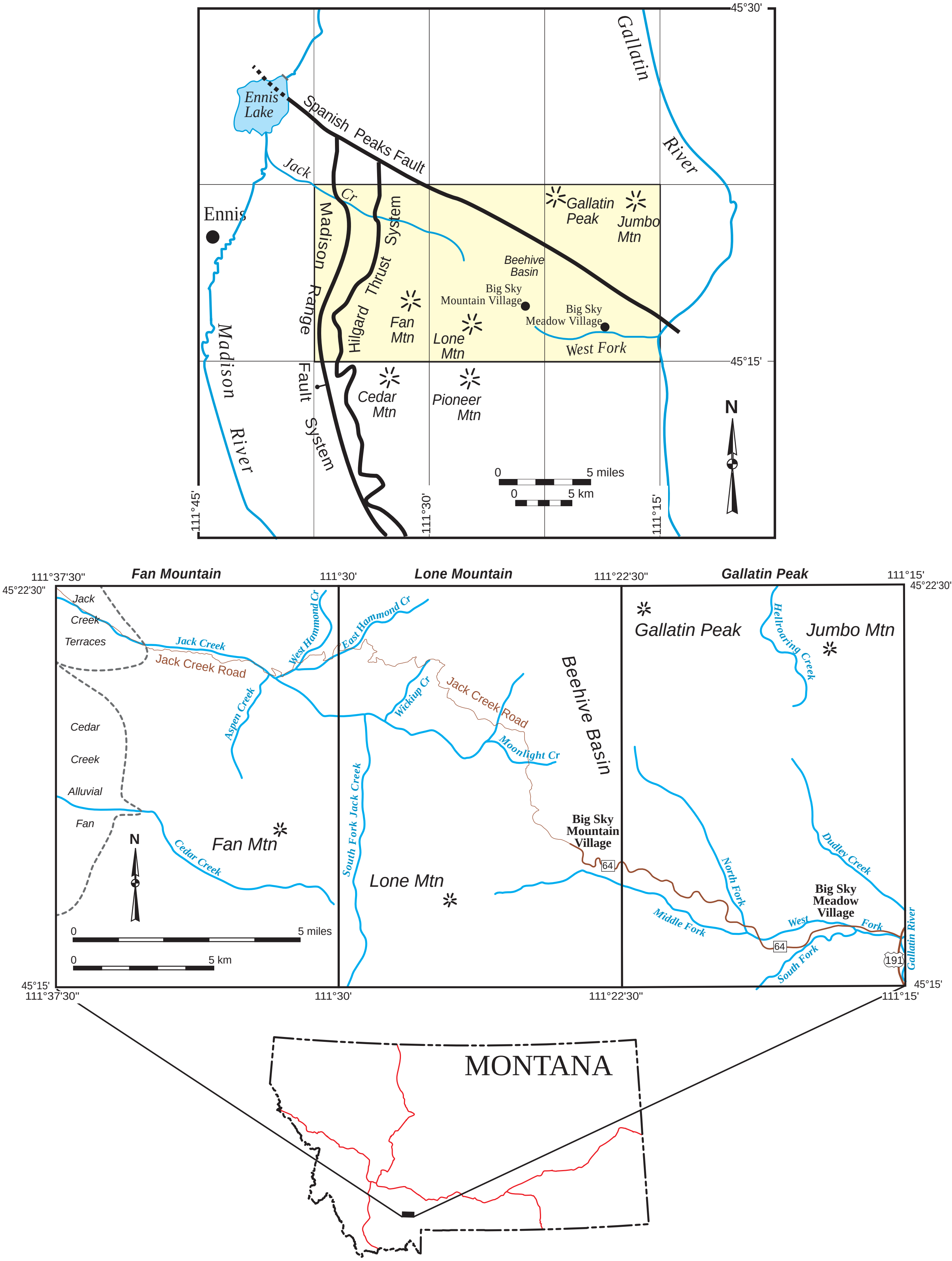

Figure 1. Location of map area showing major faults, rivers and streams, geographic, and geomorphic features.

Dacite porphyry intrusion (post-compression)

Laramide compression ended in the map area by about 69 million years ago, before the end of the Cretaceous Period (Kellogg and Harlan, 2007). Fan and Lone Mountains south of the Spanish Peaks Fault are intrusive centers in the map area that post-date Laramide movement on the Hilgard thrust system (Tysdal and others, 1986; Kellogg and Harlan, 2007). Two similar centers occur just south of the map area at Cedar Mountain and Pioneer Mountain (Figure 1). Gravity data suggest that Lone Mountain is the main intrusive center in the area, and that Fan, Cedar, and Pioneer Mountains are subsidiary centers (Tysdal and others, 1986). Numerous dacite porphyry sills characterize these mountains. Swanson (1950) interpreted the sills as parts of Christmas-tree laccolith complexes. (Cross section B-B′). Multiple, offset connections between sills have been interpreted in the Fan Mountain complex (Kellogg, 1992; Kellogg and others,1995), (Cross section A-A′). A smaller intrusion occurs along Jack Creek north of Fan and Lone Mountains between the mouths of Aspen and Hammond Creeks on the west, and Moonlight Creek on the east.

Cenozoic fault zones

Gravity and seismic data indicate that the east side of Madison Valley (west side of the map area) is bounded by a large, steep, generally north-trending, west-dipping fault zone, the Madison Range fault system (Pardee, 1950) (Figure 1). The faults of this system are interpreted as listric-normal, and many of the faults developed along fault planes of pre-existing, east-directed Laramide thrust faults (Kellogg and others, 1995). The subparallel Lost Lake fault zone was mapped about eight kilometers (five miles) east of the Madison Range fault system, and other subparallel faults, originally mapped by Swanson (1950), occur between the two zones along Jack Creek. The fault plane of one of the faults in the Lost Lake fault zone is well exposed near Wickiup Creek (Figure 2).

Diamicton deposits

Diamicton deposits (Qd, QTdu, QTd) were mapped in the Fan Mountain quadrangle, the northwestern part of the Lone Mountain quadrangle (Kellogg, 1992; Kellogg and Williams, 2000), and elsewhere in much of the northern half of the Lone Mountain quadrangle. The deposits are unsorted, unstratified, unconsolidated and most are matrix-supported. Clasts are subangular to subround, as wide as 6½ ft (2 m), and composed of Archean metamorphic rocks with minor amounts of local sedimentary rocks admixed throughout. The matrix ranges from loose sandy loam to firm clayey loam. The Archean clasts originated from the hangingwall plate of the Spanish Peaks Fault.

Fabric analysis (Larry Smith, personal communication) suggests that the diamicton on the divide along the west side of Beehive Basin is till that is older than the Pinedale till in Beehive Basin (Figure 1). Fabric analysis of the matrix-supported diamicton at other locations in the Lone Mountain 7.5′ quadrangle shows moderate fabric development which was inconclusive in separating depositional mechanisms. Weathering rinds and decomposed clasts suggest that deposits could be as old as Tertiary. The diamicton is clast-supported near the Spanish Peaks Fault and along Moonlight and Jack Creeks (Figure 1). Some of the clast-supported deposits have a linear mound morphology.

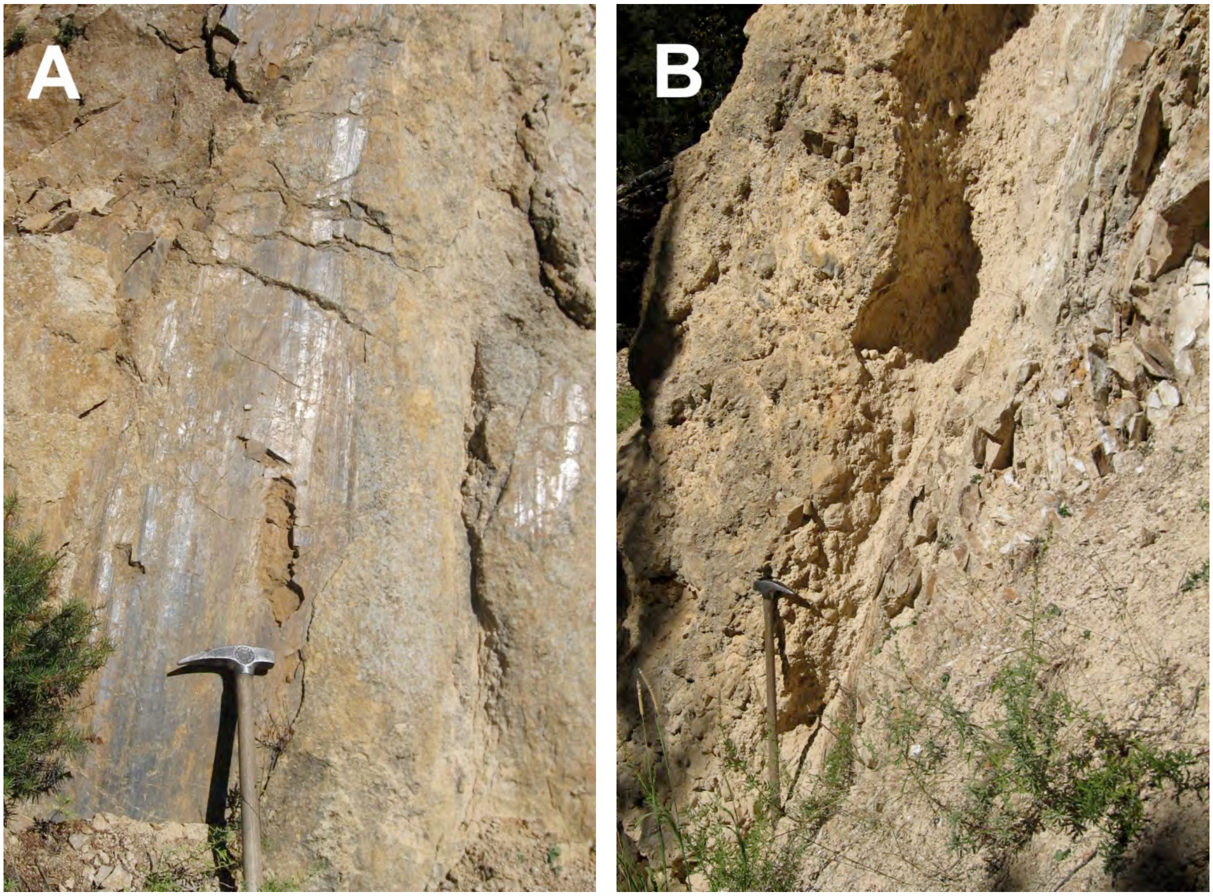

Figure 2. Slickenlines and polish (A), and fault gouge (B) on the Wickiup Creek Fault plane. Hammer for scale is 3 ft high.

Cedar Creek Alluvial Fan/Jack Creek Terraces

Cedar and Jack Creeks are adjacent drainages that have produced two distinct, prominent, and contrasting geomorphic features at the Madison Range front—the Cedar Creek alluvial fan and the Jack Creek alluvial terraces—both of which are partially within the map area (Figure 1). Deposits of both features primarily developed during the Pleistocene as a result of climate-induced aggradation during glaciation followed by entrenchment from interglacial climate-induced lowering of the Madison River base level (Bearzi and Locke, 1987; Ritter and others, 1995). Most of the entrenchment at Jack Creek is probably Holocene based on the lack of loess and minimal pedogenesis on the lower surfaces (Bearzi and Locke, 1987).

Landslide deposits

About forty percent of the map area southwest of the Spanish Peaks Fault and west of the Hilgard thrust system was mapped as landslide deposits. Steep slopes immediately southeast of the Spanish Peaks Fault and on the flanks of Lone and Fan Mountains, coupled with steeply dipping sedimentary beds, provide a setting conducive to mass movement, particularly within the shale-rich Cretaceous sedimentary rocks that underlie much of the map area. Bentonitic shale in the Vaughn Member of the Mowry Formation, and bentonite beds in the Frontier Formation increase susceptibility of the Cretaceous units to sliding.

In one area multiple landslides moved the Cretaceous Kootenai Formation downslope from about ¼ mi (.4 km) below the Spanish Peaks Fault to near the confluence of Moonlight Creek and Jack Creek, a distance of one mile (1½ km) from its source. The red mudstone and distinctive conglomerate and sandstone of the Kootenai Formation make it easier to distinguish in landslide deposits than the much more voluminous black shale and mudstone of younger Cretaceous units which have probably also moved downslope a comparable distance in many places.

Most of the landslide deposits are southwest of the Spanish Peaks Fault, but landslides also occur in the Archean metamorphic rocks northeast of the fault. Jumbo Mountain in the Spanish Peaks Wilderness is underlain by well-foliated metamorphic rock that dips toward Hell Roaring Creek Canyon, a major tributary of the Gallatin River. Well-developed scarps and crevasses along the top of Jumbo Mountain indicate a detached block that could break loose producing a huge landslide (Lageson and others, 1997).

Geologic hazards

The map area is within the Intermountain seismic belt, which is characterized by late Quaternary normal faulting, diffuse shallow seismicity, and episodic scarp-forming earthquakes of magnitude 6.5-7.5 (Smith and Arabasz, 1991). The largest historic earthquake in the northern Rocky Mountains occurred about thirty miles (50 km) south of the map area—the 1959 magnitude 7.3 Hebgen Lake earthquake (Witkind, 1960; Doser, 1985). The earthquake produced surface rupture along twenty-one miles (34 km) of the pre-existing Hebgen and Red Canyon Faults (part of the Madison Range fault system), and it produced numerous smaller scarps in the area. It triggered the Hebgen slide, a 28 million cubic meter rockslide—the largest historic rockslide in North America. Twenty-eight people lost their lives (Hadley, 1964). In addition, a climber who signed the register on the summit of Granite Peak in the Beartooth Mountains the day before the Hebgen Lake Earthquake, apparently fell to his death while descending, possibly as a result of the earthquake (McMillion, 2000).

The map area is about 25 miles (40 km) north of the Yellowstone seismic region, the most seismically active part of the entire intermountain seismic belt which extends from northern Arizona to northern Montana (Smith and Arabasz, 1991). The Centennial tectonic belt immediately west of the Yellowstone seismic region is the most tectonically and seismically active part of the northern intermountain seismic belt. Northwest of the map area in the Three Forks Basin, seismicity has been common (Qamar and Hawley, 1979), and a significant earthquake swarm occurred near the town of Norris in the summer of 1987 (Stickney, 1988). Proximity to these seismically active areas places the map area within a zone of potential strong to very strong ground shaking that may occur or be exceeded at a specified probability of two percent in fifty years or one chance in 2500 on an annual basis (Wong and others, 2005, Plate 17).

A study of tree rings was conducted on trees tilted or damaged by landslides in the eastern Gravelly Range along the southern Madison Valley southwest of the map area (Carrara and O'Neill, 2003). Multiple periods of movement during the twentieth century were documented based on the tree-ring patterns. A correlation was found between significant earthquakes (the 1983 Borah Peak, 1959 Hebgen Lake, 1935 Helena, 1925 Clarkston, and 1908 Virginia City earthquakes) and indications of landslide movement based on tree-ring indicators. The study suggests that many of the landslide movements were triggered by, or coincident with earthquakes as much as 200 km (125 miles) from the study area. Tree-ring studies have not been conducted in the current map area, but landslide movement was presumably triggered by these earthquakes in the region as well, and will likely continue to be triggered by future large earthquakes.

Although the map area is within the Intermountain seismic belt, historic data indicate seismic quiescence in the map area (Wong and others, 2005, Plate 1). Areas with large Holocene faults, yet with modern seismic quiescence, are common in the Intermountain seismic belt (Smith and Sbar, 1974; Smith and Arabasz, 1991; Stickney, 2007). Extensional stress may be relieved in these areas by major earthquakes, whereas nearby areas without large faults may experience lesser magnitude, but more abundant seismicity (Stickney, 1995).

Paleoseismic activity also apparently decreased northward along the Madison Range fault system. That may be because the southern area displacements occurred along a principal basement-involved normal fault whereas to the north in the map area, there are multiple normal faults that exploit the hanging wall of older thrust faults. The individual shorter faults have less displacement (Ruleman and Lageson, 2002). Alternatively, the lesser amount of late Quaternary displacement northward along the Madison Range fault system may result from its greater distance from the Yellowstone volcano-tectonic province (M. Stickney, written communication, 2009).

Even without a seismic trigger, the potential for landslide movement is high in the map area. Slope undercutting for roads and buildings and addition of water for lawns, septic systems, and golf courses are likely to enhance landslide development. Several significant landslides occurred along Jack Creek Road during the spring of 2008, probably promoted by above average (although not record-setting) spring precipitation. The toe of several landslides that developed in Cretaceous shale on the upslope side, spread onto the road requiring excavation. Elsewhere, landslides soled in Cretaceous shale, down-dropped the downslope side of the road along the headwall scarp (Figure 3). In all observed cases, the landslides developed where older landslide deposits had been mapped. The landslides along Jack Creek Road are probably representative of landslides that developed along many roads in the area following the relatively high precipitation.

The slopes of steeply dipping Cretaceous sedimentary rocks on the flanks of Fan and Lone Mountains and south of the Spanish Peaks Fault in the map area are especially susceptible to mass gravitational movement. In addition, Jumbo Mountain in the Spanish Peaks Wilderness has been identified as having the potential to produce a catastrophic, large-volume rockslide that could potentially impede Hell Roaring Creek and the Gallatin River. Breaching of a landslide-generated dam could be disastrous to downstream residents (Lageson and others, 1997).

Figure 3. Landslide along Jack Creek Road, promoted by cut-and-fill in an older landslide deposit, coupled with relatively heavy precipitation. Photo taken July 10, 2008.

DESCRIPTION OF MAP UNITS

Qal **Alluvium of modern channels and flood plains (Holocene)**—Unconsolidated silt- to boulder-size, subangular to rounded clasts, moderately sorted to well sorted in flood plains; includes fine-grained overbank deposits. Larger clasts are moderately rounded to well rounded. Maximum thickness greater than 15 ft (6 m).

Qpa **Paludal deposits (Holocene)**—Sand, silt, and organic matter deposited in natural or man-made swamp environment or standing body of water.

Qafh **Youngest alluvial fan deposit of Madison Range Front (Holocene)**— Poorly sorted pebble and cobble gravel with subangular to rounded clasts in a matrix of sand and silt. Includes debris flow deposits consisting of angular to subangular, poorly sorted, pebble- to boulder-size clasts in a clay-rich matrix. Restricted to the mountain-piedmont junction along ephemeral drainage channels. Form fresh, steep alluvial cones along the mountain front. Deposited by intermittent streams and debris flows onto older alluvial surfaces. Lacks substantial soil development and includes fine-grained alluvial deposits at toe of cone. Description from Ruleman (2002).

Qta **Talus deposit (Holocene and upper Pleistocene?)**—Angular and subangular cobble- to boulder-size clasts at base of steep valley walls or cliffs. Boulders generally as large as 2 ½ ft (2 m), although in places as large as 30 ft (10 m). Locally includes minor alluvial deposits and rock-glacier deposits. Maximum thickness greater than 65 ft (20 m).

Qrg **Rock glacier deposits (Holocene and upper Pleistocene?)**—Hummocky, lobate deposits of angular boulders that have a frontal slope near the angle of repose; locally active. In places, grade into and include some talus deposits. As much as 66 ft (20 m) thick.

Qat **Alluvial terrace deposit of Jack Creek (Holocene and upper Pleistocene)**—Well-rounded to subrounded gravel in sandy matrix. Forms two small deposits about 200 ft (60 m) above Jack Creek in the Fan Mountain 7.5′ quadrangle. Most clasts composed of Archean gneiss. As much as 30 ft (10 m) thick.

Qc **Colluvium (Holocene and upper Pleistocene)**—Unconsolidated to slightly indurated, mostly massive, dark brown to light grayish brown deposits that mantle gently to moderately sloping surfaces; sediment types are intermixed by down-slope movement. Colluvium contains cobbles and pebbles derived from weathering of bedrock. Locally includes loess that is very fine grained sand, silt, and minor clay. Commonly contains poorly to moderately developed soil profile in upper part. Includes alluvium in small channels and sheetwash on steeper hillsides. Unmapped in many areas, particularly where deposit is thin and forms discontinuous veneer. On flanks of Lone Mountain colluvium dominantly consists of angular blocky or platy clasts of dacite porphyry primarily cobble size, but as large as boulder size. Maximum thickness probably less than 30 ft (10 m).

Qaf **Alluvial fan deposits (Holocene and upper Pleistocene)**—Deposits east of Big Sky Meadow Village along Michener Creek and the West Fork of the Gallatin River. Deposits have fan morphology and consist of stratified alluvial deposits and poorly sorted debris-flow deposits.

Qac **Alluvium and colluvium (Holocene to middle Pleistocene)**—After Ruleman (2002). Poorly to moderately sorted, slopewash colluvium, stream alluvium, and fan alluvium along the mountain front. Includes local slumps and rockfall deposits. Mantles surfaces. Description from Ruleman (2002).

Qls **Landslide deposit (Holocene and Pleistocene)**—Mass-wasting deposits that include slides of nearly intact rotated concave slump blocks to greatly deformed masses, earthflows, debris slides, and debris avalanches. Many smaller landslide deposits not mapped, and areas of relatively accelerated creep may not be included. Thickness from about 30 ft (10 m) to greater than 165 ft (50 m) thick.

Qatp **Alluvial terrace deposit of Pinedale glaciation (upper Pleistocene)**—Silt- to boulder-size, moderately sorted to well sorted, unconsolidated sediments; sub-angular to rounded clasts (Ruleman, 2002). Ten geomorphic surfaces at different elevations on unit along Jack Creek (Bearzi, 1987). Mantled by less than 6½ ft (2 m) of loess at most places, although loess on many higher surfaces is thick enough to support cultivation. Mostly less than 30 ft (10 m) thick.

Qafp **Alluvial fan deposit of Pinedale glaciation (late Pleistocene)**—Moderately well sorted to well-sorted, cobble and boulder gravel with subrounded to rounded clasts, locally mantled by loess less than 1 m thick. Modern channel of Cedar Creek incised about 30 ft (10 m) into fan deposits near mouth of creek, indicating that proximal fan deposits are presently eroding. In part, deposit forms the southern part of the Cedar Creek alluvial fan. Description from Ruleman (2002).

Qatb **Alluvial terrace deposit of Bull Lake glaciation (middle Pleistocene)**—Silt- to boulder-size alluvium covered by loess about 1 m thick. Surface characterized by a lack of large boulders and subdued bar-and-swale micro-topography. This alluvium represents deposition at the maximum fill level within the basin and the highest (oldest) terrace level along Jack Creek. Description from Ruleman (2002).

Qafb **Oldest alluvial fan deposit of Madison Range front (upper to upper-middle Pleistocene)**—Moderately to well-sorted cobble and boulder gravel with rounded to well-rounded clasts in a sand and silt matrix. Surface of deposits smooth and subdued. Unit includes loess cap that ranges from 1½ ft (0.5 m) to 6½ ft (2.0 m) in swales. In part, deposit forms the northern part of the Cedar Creek alluvial fan. Coeval with Bull Lake glaciation and older alluvial period. Description from Ruleman (2002).

Qgt **Glacial till deposit (Pleistocene)**—Unsorted, unstratified, unconsolidated, subangular to subrounded boulders in an unsorted matrix with clasts as fine as silt. Most till deposited during Pinedale glaciations (about 20-14 ka), but till of Bull Lake glaciation (about 140-100 ka) also included. Pinedale-age till preserved in hummocky deposits that contain numerous closed depressions and have a thin or non-existent soil profile; deposits of Bull Lake-age till have more rounded topography, are more dissected, and generally exhibit a well-developed soil profile. As much as about 165 ft (50 m) thick.

Qgo **Glacial outwash deposit (Pleistocene)**—Cobble-pebble gravel with matrix of sand, silt, and clay. Dominant clast composition dacite porphyry with subordinate clasts of lower Thermopolis Formation quartz arenite and other Cretaceous sandstone. Matrix includes lenses of clay. South of West Fork of Gallatin River interpreted as glacial outwash deposit with fan-form morphology that is notably devoid of Archean metamorphic clasts except along the south margin of the river (Walsh, 1971). Glacial outwash deposits were also mapped in the Big Sky Mountain Village area (Montagne, 1971; Walsh, 1971), but they are no longer exposed because of development. Thickness about 15 ft (4.5 m).

QTdu **Diamicton deposit, undivided (Pleistocene and/or Pliocene)**—Northern Fan Mountain 7.5′ quadrangle and along Hammond Creek in the Lone Mountain 7.5′ quadrangle: Unsorted, unstratified, unconsolidated matrix-supported deposit composed of angular to subangular clasts of Archean metamorphic rocks as much as 6½ ft (2 m) wide. Fabric analysis (L. Smith, personal communication) suggests that the diamicton in this area may be glacial till.

Northern half of Lone Mountain 7.5′ quadrangle: Unsorted, unstratified, unconsolidated matrix-supported deposit composed of subangular to subrounded clasts, as large as 6½ ft (2 m wide), of Archean metamorphic rocks with lesser amounts of sedimentary rocks at the base of the deposit, and minor amounts admixed throughout. Matrix ranges from loose sandy loam to firm clayey loam. Fabric analysis (L. Smith, personal communication) suggests that the diamicton on the divide along the west side of Beehive Basin is till that is older than the till (Qgt) in Beehive Basin. Fabric analysis (L. Smith, personal communication) of the matrix-supported diamicton at other locations in the Lone Mountain 7.5′ quadrangle showed moderate fabric development. Weathering rinds and decomposed clasts suggest that deposits could be as old as Tertiary (L. Smith, personal communication). The Archean clasts must have originated from north of the Spanish Peaks fault and are likely periglacial. The diamicton is clast-supported near the Spanish Peaks fault and along Moonlight and Jack Creeks. Some of the clast-supported deposits have a distinct linear mound morphology. Maximum thickness greater than 65 ft (20 m).

Qd **Younger diamicton deposit (Pleistocene)**—Unsorted, unstratified, unconsolidated matrix-supported deposit which is mostly composed of angular to subangular clasts of Archean metamorphic rocks as much as 6½ ft (2 m) wide, and lesser amounts of sedimentary rocks concentrated at the base of the deposit. Matrix ranges from loose sandy loam to firm clayey loam. Deposits have a topographically lower surface than QTd and appear incised into QTd. Fabric analysis (Larry Smith, personal communication) showed moderate fabric development.

QTd **Older diamicton deposit (Pleistocene and/or Pliocene)**—Unsorted, unstratified, unconsolidated matrix-supported deposit composed of subangular to subrounded clasts, as much as 6½ ft (2 m) wide, which are mostly Archean metamorphic rocks with lesser amounts of sedimentary rocks concentrated at the base. Matrix ranges from loose sandy loam to firm clayey loam. Fabric analysis (L. Smith) showed moderate fabric development. Weathering rinds and decomposed clasts suggest that deposits could be as old as Tertiary (L. Smith, personal communication). Deposits have a topographically higher surface than Qd.

Thr **Huckleberry Ridge Tuff (Pliocene)**—Light brown to gray, massive welded tuff that contains sparse phenocrysts of sanidine, quartz, and plagioclase. Matrix is mostly devitrified glass shards, opaque minerals, and aphanitic minerals. Contains sparse pumice fragments. Age of unit is 2.0 Ma and source is Yellowstone caldera (Christiansen and Blank, 1972). Thickness 100 ft (30 m).

Ts **Sediment, undivided (Pliocene?)**—Poorly consolidated to unconsolidated, bedded to massive silt, sand, and gravel with well-rounded pebble and cobble clasts. Exposed thickness about 100 ft (30 m).

Tgr **High-level gravel deposits (Pliocene?)**—Cobble gravel that underlies the Huckleberry Ridge Tuff (Thr) near the mouth of the West Fork of the Gallatin River and includes clasts of Archean metamorphic rocks, dacite porphyry, and Cretaceous sandstone. Faint clast imbrication suggests transport to the east (Walsh, 1971). Thickness 80-100 ft (24-30 m).

TKga **Gabbro sills (Eocene to Upper Cretaceous)**—Black, medium-grained plagioclase-clinopyroxene gabbro that typically weathers into spheroidal blocks. In places completely weathered into orange-brown grus and soil. Several larger sills contain irregular dikes, as wide as 2 m, of fine-grained, pinkish gray, inequigranular clinopyroxene-biotite syenite, in which the clinopyroxene forms conspicuous rods as long as 1 cm. Syenite, in turn, contains thin aplitic dikes. Unit crops out in Big Sky area where it intruded Thermopolis, Muddy, Mowry, and Frontier Formations. Thickness variable.

Kdap **Dacite porphyry of Fan and Lone Mountains (Upper Cretaceous)**—Gray to greenish-gray porphyritic dacite and subordinate andesite that weathers to a very light gray or tan. Euhedral to subhedral phenocrysts comprise 30-50 percent of the rock; phenocrysts are 70-90 percent zoned plagioclase crystals (An_{25-30}) as long as 2 cm, trace to 15 percent green hornblende crystals as long as 6 mm, 0-15 percent biotite flakes as long as 3 mm, and 0-10 percent equant quartz crystals as long as 5 mm. Mafic minerals are commonly altered to chlorite and epidote; plagioclase is sericitized. Matrix is very fine grained and dense, and contains about 5 percent opaque minerals. Fine-grained chill zone extends inward several centimeters from contacts. Commonly contains mafic autoliths as large as about 0.5 m. Forms sills, some greater than 80 m thick, in intrusive centers underlying Lone Mountain and a subsidiary intrusive center, Fan Mountain. Dacite porphyry sills also underlie Andesite Mountain. Cretaceous beds dip away from the central peaks at Lone, Fan, and Andesite Mountains. Intruded rocks range from Middle Cambrian to Late Cretaceous. Where less than about 20 m thick, unit is indicated on map by a single red line. Potassium-argon (K-Ar) and $^{40}Ar/^{39}Ar$ ages from hornblende indicate ages of about 68-69 Ma (Kellogg and Harlan, 2007; Tysdal and others, 1986). Thickness highly variable.

Kevt **Everts Formation (Upper Cretaceous)**—Thin- to medium-bedded, light gray to dark gray, poorly to moderately sorted, quartz-rich sandstone intercalated with thin-bedded, greenish gray to dark gray mudstone and siltstone. Contains a few thin beds of dense limestone, porcellanite, and coal. Contains about equal amounts of sandstone and finer-grained sedimentary rocks. Conformably overlies Virgelle Sandstone. About 490 ft (150 m) exposed in map area.

Kvi **Virgelle Sandstone (Upper Cretaceous)—**Thin- to thick-bedded, medium- to coarse-grained, light brown to yellowish brown, trough-crossbedded quartz sandstone that forms prominent white-weathering ledges. Conformably overlies Telegraph Creek Formation. Thickness 75-165 ft (23-50 m).

Ktc **Telegraph Creek Formation (Upper Cretaceous)**—Light gray to dark brown, thin- to medium-bedded, feldspathic, calcite-cemented sandstone and interbedded dark gray siltstone and mudstone. Middle marker sequence is a 20-m-thick white tuffaceous siltstone and sandstone visible from the Madison Valley as a white stripe on the western side of Fan Mountain. Contains thin flaggy sandstone beds in lower part. Conformably overlies Cody Shale. Thickness about 330-490 ft (100-150 m).

Kco **Cody Shale (Upper Cretaceous)**—Upper part consists of thin-bedded black fissile shale that is interbedded with minor amounts of thin-bedded, brown, commonly bioturbated calcareous, fine-grained sandstone. Lower part consists of black, fissile shale and minor siltstone that weathers dark gray. Conformably overlies Frontier Formation. Thickness about 820 ft (250 m).

Kf **Frontier Formation (Upper Cretaceous)**—Dominantly alternating black shale and light gray to yellowish tan, thin-bedded to very thick bedded, cross-bedded sandstone. Sandstone ledges are as much as 3 m thick; ratio of sandstone to shale is about 1:3. Shale is locally carbonaceous or coaly. Shale sequences are as thick as about 20 m and commonly contain equally spaced 5- to 10-cm-thick sandstone beds, spaced 10-20 cm apart. Contains several white porcellanite and bentonite beds; one prominent porcellanite bed, about 5 m thick, is about 15 m above base of sequence and displays well-developed ball-and-pillow structures. Conformable with underlying Mowry Shale. Thickness about 490-655 ft (150-200 m).

Km **Mowry Formation (Upper and Lower Cretaceous)**—Mostly brownish gray and greenish gray tuffaceous mudstone and shale. Upper part contains abundant thin sandstone beds. Lower Vaughn Member in the map area consists of light gray, green, yellow, brown, light red, and cream-colored bentonitic mudstone, and porcellanite, siltstone, and minor interbedded quartz sandstone. Poorly exposed in most places. Unconformable above Muddy Formation. Thickness 295-590 ft (90-180 m).

Kmd **Muddy Sandstone (Lower Cretaceous)**—Thin- to medium-bedded, medium- to coarse-grained, brown to brownish gray, poorly to moderately indurated, clayey, ledge-forming salt-and-pepper sandstone; locally contains mud chips as long as 1 cm. In map area, formation typically exposed as upper and lower sandstone sequence interrupted by central, poorly exposed shaly sequence. Thickness about 65-150 ft (20-45 m).

Kt **Thermopolis Formation, undivided (Lower Cretaceous)**

Ktu **Upper Thermopolis Formation (Lower Cretaceous)**—Black to dark gray, locally carbonaceous, fissile shale and poorly indurated, thin-bedded, silty brown sandstone. Thickness about 165-200 ft (50-60 m).

Ktl **Lower Thermopolis Formation (Lower Cretaceous)**—Thin- to medium-bedded, fine-grained, white to tan quartz arenite that contains black, fissile shale interbeds; Sandstones contain ripple marks, crossbedding, Liesegang bands and other iron-stains, and may be speckled with rust-colored clots. Unconformable contact with underlying Kootenai Formation. Fissile shale locally underlies the sandstone. Sharks teeth were found in this shale near Cedar Creek (Roger Swanson, unpublished notes). Thickness about 50-60 ft (15-20 m).

Kk **Kootenai Formation, undivided (Lower Cretaceous)**

Kku **Upper Kootenai Formation (Lower Cretaceous)**—Upper 30-50 ft (10-15 m) is medium-bedded light-gray, micritic, oolitic limestone that contains abundant gastropod fossils. Lower 115-230 ft (35-70 m) is variegated red, purple, yellow, and gray shale, mudstone, siltstone, sandstone, and locally, nodular freshwater limestone. Lower part typically weathers to a reddish soil.

Kkl **Lower Kootenai Formation (Lower Cretaceous)**—Medium- to coarse-grained, gray, well-indurated, ledge-forming salt-and-pepper sandstone that contains a basal coarse-grained sandstone or chert-pebble conglomerate as much as 3 ft (1 m) thick. Lower contact is unconformable. Thickness (30-130 ft) 10-40 m (Kellogg, 1992).

JŦ md **Morrison Formation, Ellis Group, and Dinwoody Formations, undivided (Upper and Middle Jurassic and Lower Triassic)**—Combined thickness of units about 935 ft (285 m).

Jm **Morrison Formation (Upper Jurassic)**—Upper 65-100ft (20-30 m) is mostly black and locally purple shale that contains minor intercalated thin- to medium-bedded, rusty-brown and gray quartz sandstone that is lensoidal in places. Lower, thicker part is composed of thin-bedded, gray, yellow, orange, red, and green shale and siltstone interbedded with lesser amounts of gray quartz arenite and thin-bedded, brown limestone. Unconformable above Ellis Group. Thickness about 250-300 ft (75-100 m).

J̄R ed **Ellis Group and Dinwoody Formation, undivided (Upper and Middle Jurassic and Lower Triassic)**—Combined thickness of units about 600 ft (185 m).

Ellis Group (Middle Jurassic)—Included in units J̄Rmd and J̄Red

Swift Formation—Brown, medium- to coarse-grained glauconitic calcareous sandstone that locally contains abundant chert pebbles, and minor olive-green shale; glauconite commonly weathered to orange limonitic clots. Unconformably overlies Rierdon Formation. Less than 40 ft (12 m) thick.

Rierdon Formation—Thin- to thick-bedded, yellowish-gray to brownish-gray, fine-grained oolitic limestone; contains a few calcareous siltstone interbeds; locally very argillaceous. Bivalves *Camptonectes* sp. and *Gryphea* sp. locally abundant. Thickness about 25-150 ft (8-45 m).

Sawtooth Formation—Interbedded limestone and shale; weathers yellowish brown and is very poorly exposed. Unconformably overlies Dinwoody Formation. Thickness 80-180 ft (25-55 m).

Dinwoody Formation (Lower Triassic)—Included in J̄Rmd and J̄Red. Upper part: gray mudstone that overlies thin-bedded platy-weathering, light yellowish brown, fine-grained silty sandstone and siltstone. Lower part: Thin-bedded brown limestone, fine-grained, yellowish brown, limy siltstone, and fine-grained quartz sandstone. Formation poorly exposed. Unconformable on Shedhorn Sandstone. Thickness about 100 ft (30 m).

Psh **Shedhorn Sandstone (Lower Permian)**—Mostly medium- to massive-bedded, gray, fine- to coarse-grained, very well indurated quartz-rich sandstone that contains white cherty stringers and nodules. Thin, shaly phosphorite beds in middle of formation are rarely exposed. Dolomitic near base. Conformably overlies Quadrant Formation. About 165 ft (50 m) thick in map area.

IPMqsr **Quadrant Formation and Snowcrest Range Group, undivided (Pennsylvanian and Upper Mississippian)**

IPq **Quadrant Formation (Pennsylvanian)**—Medium- to thick-bedded, white to yellowish tan, well-sorted, fine- to medium-grained, dolomite-cemented quartz arenite; crossbeds common. Lower half and at least upper 15 m of formation contain medium-bedded, light yellowish tan dolostone beds that alternate with the sandstone beds. The upper dolostone beds in the upper part contain chert. Conformable contact with underlying Amsden Formation. Thickness about 245 ft (75 m).

IPMsr **Snowcrest Range Group, undivided (Lower Pennsylvanian and Upper Mississippian)**

Amsden Formation—<u>Upper part:</u> limestone interbedded with shale overlain by sandstone. The basal limestone of this unit is commonly thin bedded and fossiliferous with abundant cup corals and brachiopods. <u>Lower part:</u> Poorly resistant brick red, reddish-brown, and pink calcareous siltstone, shale and some limestone and sandstone. Thickness 295 ft (90 m).

Lombard Limestone—Mostly thin- to medium-bedded, gray limestone that becomes more dolomitic and shaly toward base. Thickness 180 ft (55 m).

Kibbey Sandstone—Thin- to medium-bedded, yellowish-gray to maroon, friable, dolomitic sandstone, sandy dolostone, and siltstone. Unconformable contact with underlying Mission Canyon Limestone. Thickness 245 ft (75 m).

Mm **Madison Group, undivided (Upper and Lower Mississippian)**

Mmc **Mission Canyon Limestone (Upper and Lower Mississippian)**—Medium- to massive-bedded, light-gray, gray, and brownish-gray, medium-crystalline limestone and minor dolostone. Weathers light gray. Chert stringers and nodules common, locally fossiliferous; solution breccias in uppermost part. Prominent ridge-forming unit. Conformable with underlying Lodgepole Limestone. Thickness about 790 ft (240 m).

Ml **Lodgepole Limestone (Lower Mississippian)**—Thin- to medium-bedded, gray to brownish gray, finely crystalline limestone that commonly grades into silty limestone interbeds several centimeters thick. Locally cherty; upper half is profusely fossiliferous. Conformable with underlying Three Forks formation. Thickness about 590 ft (180 m).

Mississippian and Devonian

MDt **Three Forks Formation**—Mostly thin-bedded, yellowish orange to yellowish tan siltstone and silty limestone that weathers light yellowish tan and contains a few thin interbeds of brick-red-weathered siltstone. Contains a medium gray irregularly bedded, approximately 40-ft-thick (12 m), rough-weathered limestone about 80 ft (25 m) above base of unit (Logan Gulch Member). Formation poorly exposed; forms slopes and swales. Unconformably overlies Jefferson Formation. Thickness 130-165 ft (40-60 m).

Dj **Jefferson Formation**—Thin- to thick-bedded, black, brown, dark gray, and light gray, petroliferous, locally fossiliferous, medium-crystalline to coarsely crystalline dolostone; colors vary considerably over short stratigraphic intervals. Weathers mostly brown, and outcrops are typically knobby and irregular; forms conspicuous brown hoodoos. At least upper 50 ft (15 m) is thick- to massive-bedded, gray sucrosic dolostone solution breccia (Birdbear Member). Thickness about 360 ft (110 m).

Ꞓrlp **Red Lion and Pilgrim Formations, undivided (Upper Cambrian)**

Red Lion Formation (Upper Cambrian)—Thin-bedded medium gray to tan, siliceous dolomite that contains conspicuous orange tan to reddish tan, cherty stringers as much as 1 inch (2.5 cm) thick; lower 23 ft (7 m) contains intraformational clasts as wide as ¼ inch (5 mm). Unconformably overlies Pilgrim Formation. Thickness about 130-195 ft (40-60 m).

Pilgrim Formation (Upper Cambrian)—Gray, light gray, and brownish gray, medium- to massive-bedded, locally oolitic, medium-crystalline dolomite. Weathers light gray and contains irregularly shaped darker gray mottles. Conformably overlies Park Shale. Forms conspicuous crags. Thicknesses about 100 ft (30 m) (Kellogg, 1992).

Ꞓp **Park Shale (Middle Cambrian)**—Greenish gray to tan, fissile shale. Poorly exposed, slope-forming unit that conformably overlies Meagher Limestone. Thickness about 100-165 ft (30-50 m) in map area.

Ꞓm **Meagher Limestone (Middle Cambrian)**—Thin- to massive-bedded, light gray to brownish gray, finely crystalline limestone. Locally oölitic, especially in upper part. Upper 100 ft (30 m) is thin-bedded, gray limestone that contains conspicuous orange mottles; upper few meters contains fissile grayish green shale. Middle 165 ft (50 m) is medium- to massive-bedded limestone, locally mottled tan that contains small silicic limestone stringers. Lower 100 ft (30 m) is thin- to medium-bedded, tan-mottled, gray limestone that contains a few intercalated micaceous shale beds in lower part. Forms cliffs. Conformably overlies Wolsey Shale. Thickness about 330-490 ft (100-150 m) (Kellogg, 1992).

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

Wolsey Shale—Mostly thin-bedded, greenish gray, olive drab, gray, and grayish brown micaceous sandstone, siltstone, and shale. Sandstone beds are wavy and bioturbated, contain green, and gray-and-green mottled shale interbeds, and generally weather brown; animal trails are common; locally glauconitic. Near middle of unit is a 10- to 15 m-thick section of thin-bedded, dark gray, brown-weathered argillaceous limestone interbedded with lesser amount of sandstone and shale. Upper 5 m is interbedded wavy-laminated, thin-bedded, gray limestone and gray, micaceous siltstone. Conformable with underlying Flathead Sandstone. Forms slopes and swales. Thickness 100-215 ft (30-65 m).

Flathead Sandstone—Thin- to medium-bedded, medium- to coarse-grained, reddish brown, tan, and purplish tan, quartz-rich, feldspathic sandstone; locally weathers to rusty red. Two thin zones of fine-grained, micaceous, greenish gray, argillaceous sandstone near top of formation. Basal part of formation contains rounded pebbles of metamorphic rock. Unconformably overlies Archean crystalline rock. Thickness ranges from 50-245 (15-75 m).

Ᵽdb **Diabase dike (Proterozoic)**—Black to dark greenish gray, fine- to medium-grained, equigranular, well indurated diabase in steeply dipping, northwest-striking dikes as wide as 30 m (most are considerably thinner). Contains about 30-50 percent euhedral labradorite, 30-60 percent augite, 0-30 percent hornblende (inverted from augite), 0-10 percent potassium feldspar, 5-8 percent opaque minerals, 1-3 percent apatite, 0-5 percent biotite, 0-3 percent quartz, and from trace to 1 percent epidote. Diabase dikes in southwest Montana emplaced during two periods, about 1,455 Ma and 750-780 Ma (Harlan and others, 1990).

<u>Igneous and Meta-igneous rocks</u>

Agp **Granite porphyry**—Pink, coarse-grained, massive to slightly foliated biotite monzogranite porphyry. Contains about 20 percent conspicuous euhedral to subhedral potassium-feldspar phenocrysts as long as ½ inch (1.5 cm); matrix contains about 30 percent quartz, 35 percent plagioclase, 15 percent potassium feldspar and about 20 percent biotite. Locally sheared to form well-developed, pinkish gray augen gneiss.

Agog **Granitic orthogneiss**—Light gray to light pinkish gray, generally tan-weathered, medium-grained, hypidioblastic, weakly to moderately foliated orthogneiss that generally ranges in composition from tonalite to monzogranite. Biotite is almost exclusively the only mafic mineral (trace to 15 percent), may contain as much as 5 percent almandine and rarely, 5 percent hornblende, 2 percent augite, and 2 percent muscovite; also contains traces of zircon, epidote, allanite, and opaque minerals. One unusual occurrence is a pluton near Summit Lake in the northeast part of the Lone Mountain quadrangle; the pluton is a discordant body composed of massive to weakly foliated, very light gray biotite tonalite.

Amb **Metabasite**—Black and commonly speckled with white feldspar and pink garnet, fine-grained, equigranular, granoblastic, weakly foliated to massive hornblende-augite-almandine metabasite. Composition variable; contains 15-45 percent plagioclase (mostly andesine), 10-60 percent yellowish green to brown hornblende, 2-20 percent augite, 0-20 percent almandine, 0-5 percent reddish brown biotite, 1-3 percent opaque minerals, and trace apatite. In some places, relict porphyritic texture is preserved as white clusters of fine-grained plagioclase crystals as long as 1 cm. Mostly occurs as sills as wide as about 165 ft (50 m) concordant to foliation; in some places sills show pinch-and-swell structure and boudinage. Commonly enveloped in medium-grained amphibolite margins as wide as 30 ft (10 m) that indicate post-emplacement metasomatism at amphibolite grade.

Ahgs **Hornblende-biotite granodiorite orthogneiss of Summit Lake**—Light to medium gray, medium-grained, hypidiomorphic, poorly to well foliated hornblende-biotite granodiorite orthogneiss. Contains 30-40 percent plagioclase, 10-20 percent potassium-feldspar, 15-25 percent quartz, 10-20 percent hornblende, and about 10 percent biotite. Most rock is highly strained and shows well developed foliation with mafic minerals concentrated in ribbon-like layers 2-5 mm thick. Contains numerous, thin (3-10 mm) feldspar-quartz migmatitic layers. Cut by sills and dikes with at least three periods of intrusion; sills and dikes locally so closely spaced that they form an agmatite. Locally cut by granitic orthogneiss.

Amum **Meta-ultramafic rocks**—Black to dark greenish gray, fine- to medium-grained, well-foliated to massive, variably serpentinized ultramafic rocks of wide-ranging composition; includes olivine websterite, lherzolite, and olivine clinopyroxenite. Accessory minerals include olive-green spinel, magnetite, and apatite. Commonly contains secondary amphibole (anthophyllite or actinolite) serpentine, talc, dolomite, magnesite, and/or mica. Occurs in lenses, pods, and small irregularly shaped masses, rarely more than 30 ft (10 m) in diameter. Probably tectonically incorporated into country rock.

Gneissic rocks of unknown origin

Aqfg **Quartzofeldspathic gneiss**—Mapped where rocks are heterogeneous, generally layered, light to medium gray microcline-plagioclase-quartz-biotite gneiss. Commonly migmatitic and blastomylonitic.

Aga **Hornblende-plagioclase gneiss and amphibolite**—Dominantly gray to black, medium-grained, hypidioblastic, equigranular, moderately foliated to well-foliated hornblende-plagioclase gneiss and amphibolite; contains as much as 5 percent quartz and traces of zircon, opaque minerals, and apatite; locally garnetiferous. Plagioclase is typically An_{30} and weathers white. Commonly contains white, migmatitic leucosomes of anorthosite as thick as 4 inches (10 cm). Amphibolite envelopes around some metabasite intrusive bodies indicate at least some amphibolite was derived from intrusive rocks. Unit may include minor amounts of other Archean units.

Abs **Biotite schist**—Black, dark gray, and gray, fine- to medium-grained biotite-plagioclase-quartz, ± hornblende, ± microcline schist. Interpreted to be sheared mafic rock that equilibrated at lower amphibolite facies; not studied in detail.

Abhg **Biotite-hornblende gneiss**—White, light gray, dark gray, and black, medium-grained, well-foliated and well-layered gneiss. Leucosomes contain plagioclase, quartz, biotite, ± potassium feldspar, ± garnet, and a trace of opaque minerals. Commonly migmatitic. Melasomes contain biotite, hornblende, plagioclase, quartz, ± garnet, and trace of opaque minerals. Contains rare quartzite layers and sillimanite-bearing gneiss. Layers are typically ½-8 inches (1-20 cm) thick. Injected by numerous sills of metabasite.

<u>Metasedimentary rocks</u>

Aags **Aluminous gneiss and schist**—Gray to dark brownish gray, medium-grained, inequigranular, generally well foliated, commonly micaceous gneiss and schist that contains aluminosilicate (mostly sillimanite and rarer kyanite). Unit contains 5-90 percent anhedral quartz with undulatory extinction, 0-30 percent microcline, 0-35 percent plagioclase, 0-30 percent almandine, 0-20 percent muscovite, trace to 15 percent sillimanite or kyanite, 0-10 percent reddish brown biotite, 0-2 percent opaque minerals, including graphite, and trace of zircon. Commonly rich in quartz and locally grades into quartzite.

Abmg **Biotite-muscovite gneiss**—Light- to medium-gray, medium-grained, poorly foliated to well-foliated quartz-feldspar gneiss that contains abundant thin schistose layers containing both biotite and muscovite. Aluminosilicate-bearing lenses are common, and one prominent 65- to 165-ft-thick (20-50 m) schistose horizon contains as much as 50 percent coarse-grained biotite, about 20 percent quartz, 0-10 percent gedrite, 5 percent plagioclase, 5 percent sillimanite, 3 percent kyanite (as large blue blades), 3 percent garnet, and 3 percent muscovite. Mapped on north side of Hell Roaring Creek Valley in Spanish Peaks.

Aq **Quartzite**—White, medium- to coarse-grained inequigranular, moderately foliated to massive quartzite; locally bright green where trace amounts of chromium-bearing mica (fuchsite) are present. In most places, unit is composed entirely of anhedral quartz grains having undulatory extinction, but locally contains as much as 30 percent microcline, 20 percent muscovite, 15 percent sillimanite, 10 percent cummingtonite, 8 percent almandine, 2 percent actinolite, and trace of zircon and opaque minerals. Commonly forms prominent ridges. Unit is interlayered in many places with mafic amphibolite.

Am **Marble**—White, coarse-grained, massive to moderately well foliated, dolomitic marble that contains as much as 3 percent quartz grains. Weathers orange brown.

Sources of Geologic Map Information

Fan Mountain 7.5′ Quadrangle	Lone Mountain 7.5′ Quadrangle	Gallatin Peak 7.5′ Quadrangle
1, 2, 4, 7	3, 4, 6, 7	3, 4, 5, 6, 7

Additional: 5, 6, 7

Additional: 1, 7

1. Ruleman, 2002, scale 1:24,000.
2. Kellogg, 1992, scale 1:24,000.
3. Kellogg, K.S., USGS, unpublished mapping 1994-1996, scale 1:24,000.
4. Kellogg and Williams, 2000, scale 1:100,000.
5. Smith, L.N., MBMG, unpublished mapping 2007, scale 1:24,000.
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7. Vuke, S.M., MBMG, unpublished mapping 2007, scale 1:24,000.

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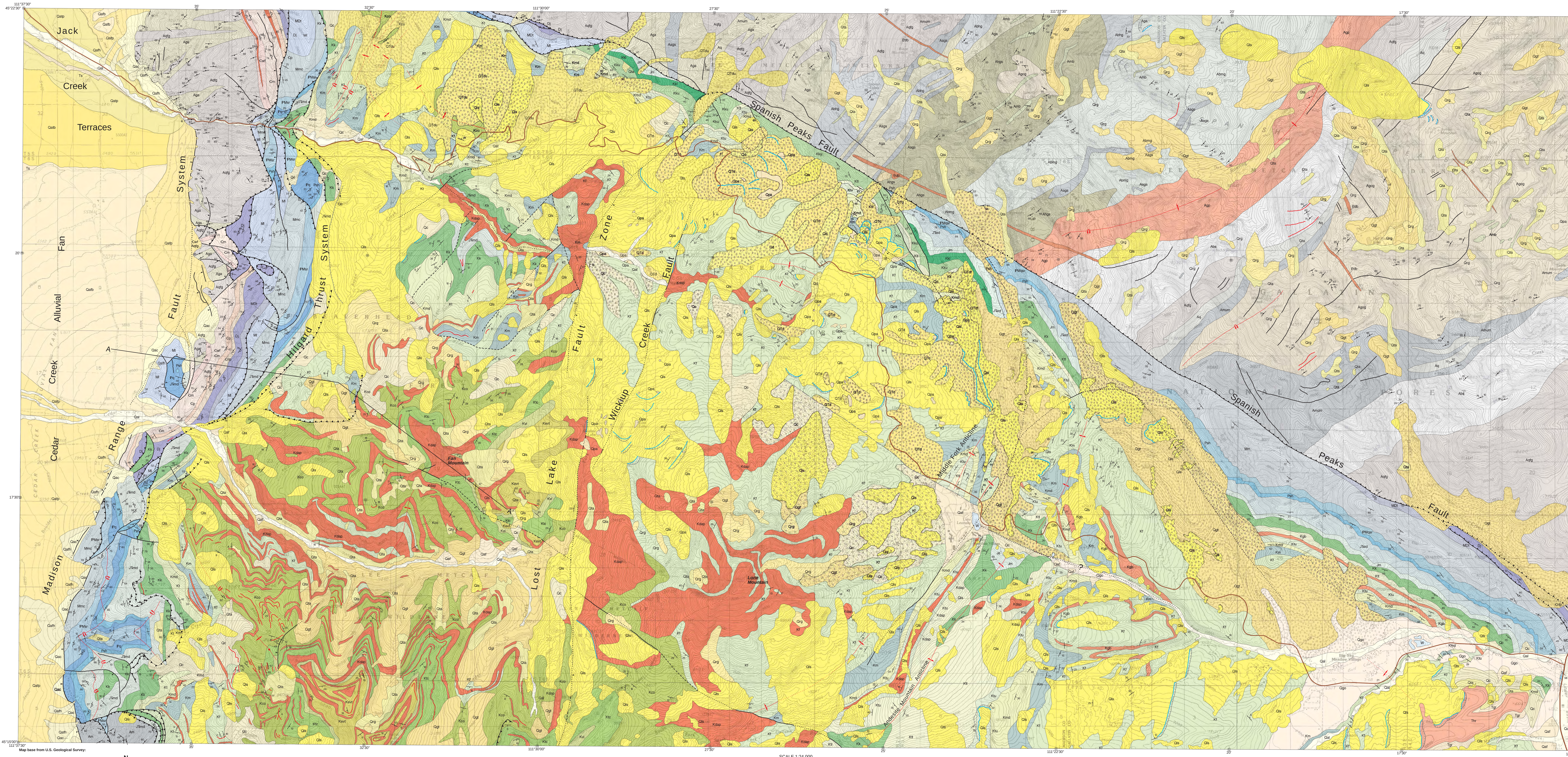


Map base from U.S. Geological Survey:

Fan Mountain 7.5' topographic quadrangle
Map date: 1988
Projection: Lambert Conformal Conic
UTM zone 12; 1927 NAD
UTM Grid Declination: 0°24' West
1988 Magnetic North Declination: 15°30' East

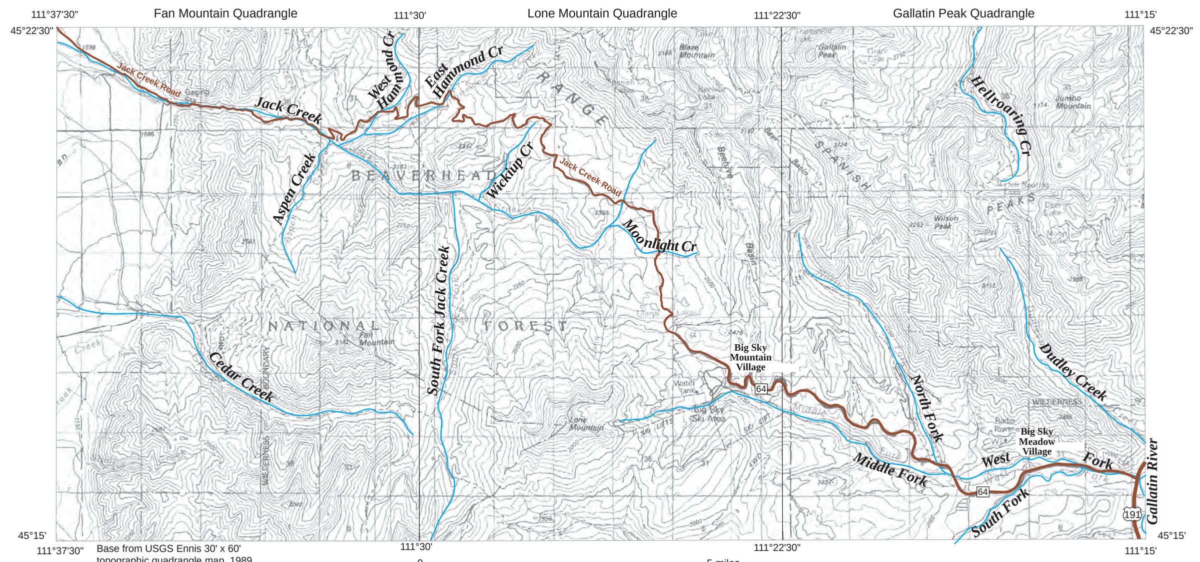
Lone Mountain 7.5' topographic quadrangle
Map date: 1988
Projection: Lambert Conformal Conic
UTM zone 12; 1927 NAD
UTM Grid Declination: 0°19' West
1988 Magnetic North Declination: 15°30' East

Gallatin Peak 7.5' topographic quadrangle
Map date: 1988
Projection: Lambert Conformal Conic
UTM zone 12; 1927 NAD
UTM Grid Declination: 0°13' West
1988 Magnetic North Declination: 15°30' East

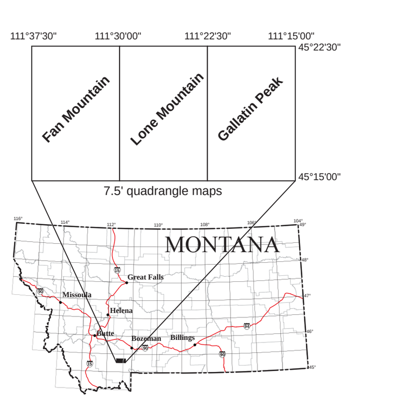
MAP UNITS

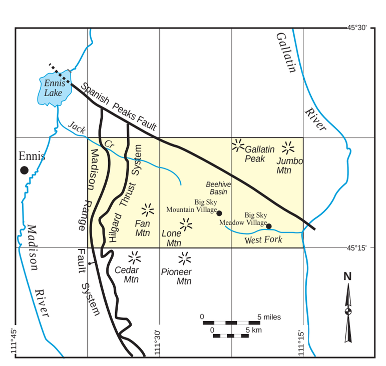
Qal Alluvium
Qpa Paludal deposit
Qafh Alluvial fan, Holocene
Qta Talus deposit
Qrg Rock glacier deposit
Qat Alluvium of alluvial terrace
Qc Colluvium
Qaf Alluvial fan deposit
Qac Alluvium and colluvium, undivided
Qls Landslide deposit
Qatp Alluvial terrace deposit, Pinedale equivalent
Qafp Alluvial fan, Pinedale equivalent
Qatb Alluvial terrace deposit, Bull Lake equivalent
Qafb Alluvial fan, Bull Lake equivalent
Qgt Glacial till
Qgo Glacial outwash deposit
QTdu Diamicton, undivided
Qd Diamicton
QTd Older diamicton
QTdf Debris flow deposit
Thr Huckleberry Ridge Tuff
Ts Sediment, undivided
Tgr Gravel
Kgb Gabbro sills
Kdap Dacite porphyry
Kevt Everts Formation
Kvi Virgelle Sandstone
Ktc Telegraph Creek Formation
Kco Cody Shale
Kf Frontier Formation
Km Mowry Shale
Kmd Muddy Sandstone
Kt Thermopolis Formation
Ktu Thermopolis Formation, upper shale member
Ktl Thermopolis Formation, lower sandstone member
Kk Kootenai Formation
Kku Kootenai Formation, upper member
Kkl Kootenai Formation, lower member
JTrmd Morrison through Dinwoody Fms., undivided
Jm Morrison Formation
Je Ellis Group, undivided
JTrwd Ellis Gp., Woodside and Dinwoody Fms., undivided
Psh Shedhorn Sandstone
PMqsr Quadrant Formation and Snowcrest Range Group, undivided
PPq Quadrant Formation
PMsr Snowcrest Range Group
Mm Madison Group, undivided
Mmc Mission Canyon Limestone
Ml Lodgepole Limestone
MDt Three Forks Formation
Dj Jefferson Formation
Crp Red Lion and Pilgrim Formations, undivided
Cp Park Shale
Cm Meagher Limestone
Cwf Wolsey and Flathead Formations, undivided
Ydb Diabase dike
Agp Granite porphyry of Hell Roaring Creek
Agog Granite orthogneiss
Amb Metabasite
Ahgs Hornblende-biotite granodiorite orthogneiss of Summit Lake
Amum Meta-ultramafic rock
Aqfg Quartzofeldspathic gneiss
Aga Amphibolite and gneiss
Abs Biotite schist
Abhg Biotite-hornblende gneiss
Aags Aluminous gneiss and schist
Abmg Biotite-muscovite gneiss
Aq Quartzite
Am Marble
W Water

For a more detailed description of the map units and symbols, please refer to the text accompanying this map.



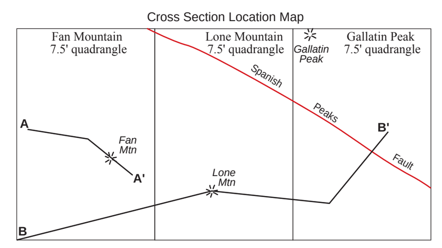
Location map





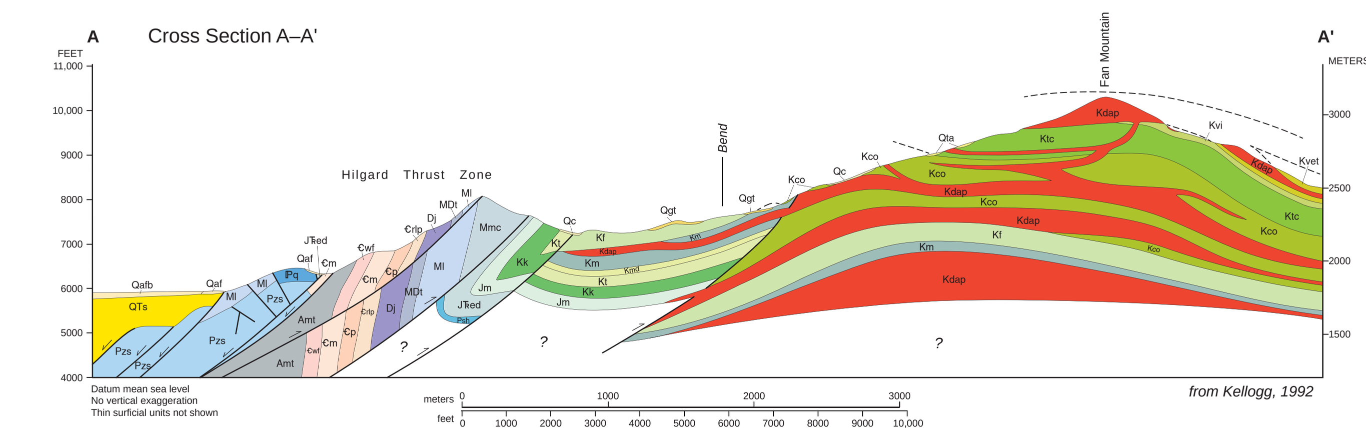
Major fault zones, peaks and rivers in map area and vicinity.

Map area



The original map for Cross Section A–A' is a 1:24,000-scale geologic map of the Fan Mountain 7.5' quadrangle (Kellogg, 1992). The line for the cross section is indicated on the current map and on the inset map above. The cross section scale is 1:24,000.

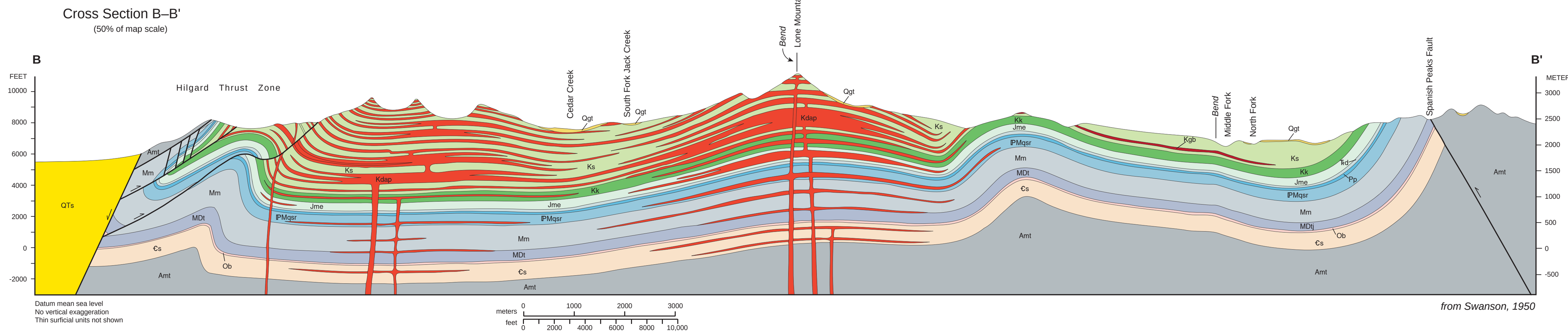
The original map for Cross Section B–B' is a 1:36,360-scale geologic map of part of the Virginia City and Eldridge 15' quadrangles (Swanson, 1950). The line for the cross section is only indicated on the inset map above, because the cross section (1:48,000 scale) is not necessarily coincident with the current geologic map.



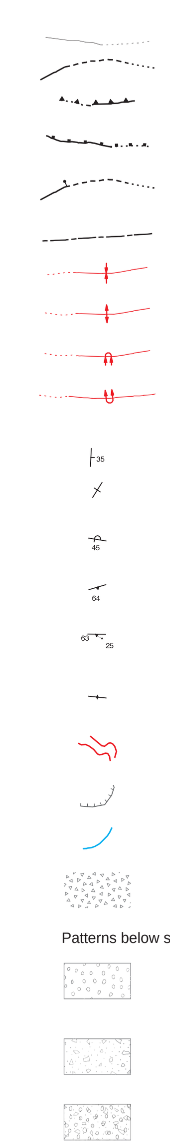
CROSS SECTION EXPLANATION

Qc Colluvium
Qta Talus
Qgt Glacial till
QTs Basin-fill sediment
Kdap Dacite porphyry and related compositions
Ks Everts through Thermopolis Formations
Kevt Everts Formation
Kvi Virgelle Formation
Ktc Telegraph Creek Formation
Kco Cody Formation
Kf Frontier Formation
Km Mowry Formation
Kmd Muddy Formation
Kt Thermopolis Formation
Kk Kootenai Formation
Jm Morrison Formation
JTred Ellis Group and Dinwoody Formation
Psh Shedhorn Sandstone
PPq Quadrant Formation
PMqsr Quadrant Formation and Snowcrest Range Group
Mm Madison Group, undivided
Mmc Mission Canyon Limestone
Ml Lodgepole Limestone
MDtj Three Forks and Jefferson Formations
MDt Three Forks Formation, undivided
Dj Jefferson Formation
Db Beartooth Butte Formation
Cs Sedimentary rock, undivided
Crp Red Lion and Pilgrim Formations
Cp Park Shale
Cm Meagher Formation
Cwf Wolsey and Flathead Formations
Ps Paleozoic sedimentary rock
Amt Archean metamorphic rock, undivided

Cross Section B–B'
(50% of map scale)



MAP SYMBOLS



Contact—Dotted where concealed.
Fault—Dotted where concealed fault inferred.
Thrust fault—Dotted where concealed fault inferred. Teeth on upthrown hangingwall side.
Reverse fault—Dotted where concealed fault inferred. Boxes on upthrown hangingwall side.
Normal fault—Dotted where concealed fault inferred. Ball and bar on downthrown hangingwall side.
Linear feature—May represent a fault.
Syncline—Showing axial trace and plunge direction where known. Axial trace dotted where concealed.
Anticline—Showing axial trace and plunge direction where known. Axial trace dotted where concealed.
Overturned Syncline—Showing axial trace and plunge direction where known. Axial trace dotted where concealed.
Overturned Anticline—Showing axial trace and plunge direction where known. Axial trace dotted where concealed.
Strike and dip of bedding
Vertical bedding
Overturned bedding
Strike and dip of foliation
Strike and dip of foliation, showing lineation—Direction and plunge of lineation indicated by arrow and associated value.
Vertical foliation
Dikes or sills
Landslide scarp (not all are shown)
Top of landslide (the highest line of contact between the disturbed material and main scarp, not all are shown)
Breccia zone

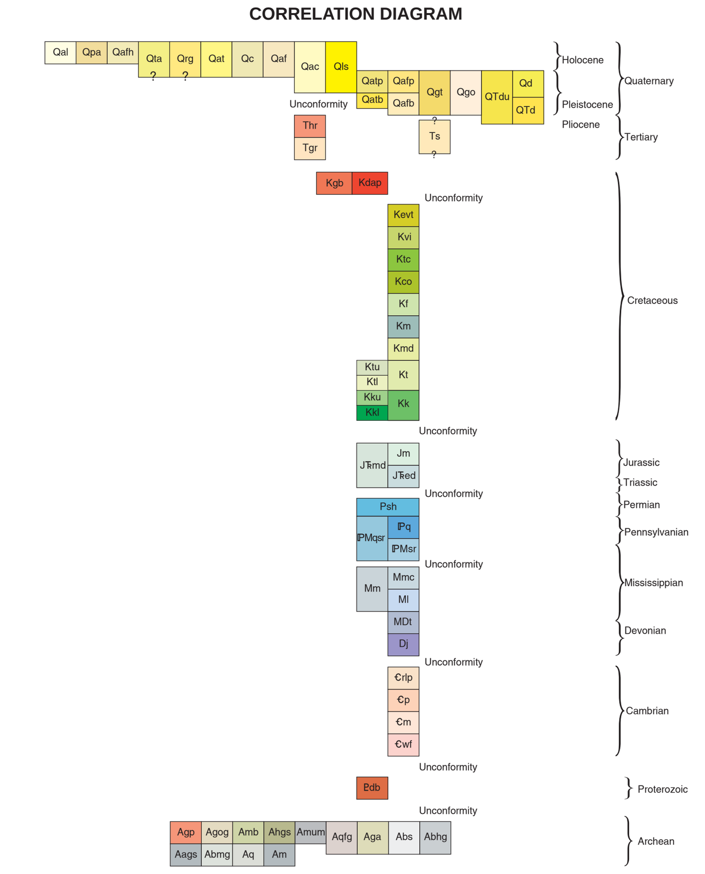
Patterns below shown only in selected areas

Deposits with abundant spheroidal to oblong, subangular to subrounded boulders and cobbles composed of Archean metamorphic rocks, relatively few Mesozoic and/or Paleozoic sedimentary rocks, and rare dacite porphyry clasts.

Deposits with platy angular and lesser spherical, rounded clasts composed of dacite porphyry and subordinately of Cretaceous sedimentary rocks. Deposits devoid of Archean metamorphic clasts.

Deposits with clasts that include both Archean metamorphic rocks and dacite porphyry.

CORRELATION DIAGRAM



Montana Bureau of Mines and Geology
Open-File Report 633

Geologic Map of the Fan Mountain, Lone Mountain, and Gallatin Peak 7.5' Quadrangles, Madison Range, Madison and Gallatin Counties, Montana

Compiled* and mapped by Susan M. Vuke

2013

*Compilation primarily from Kellogg and Williams (2000), Kellogg (1992), unpublished 1:24,000 scale field maps of the Lone Mountain and Gallatin Peak 7.5' quadrangles by Karl S. Kellogg, and unpublished mapping by Roger S. Swanson and Larry N. Smith

Maps may be obtained from: Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4167
Fax: (406) 496-4451
http://www.mbmg.mtech.edu

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GIS production: Paul Thale, MBMG. Map graphics and layout: Susan Smith, MBMG.