

GEOLOGIC MAP OF THE DEER LODGE 15' QUADRANGLE SOUTHWEST MONTANA

By

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Geology and Mineral Resources of Deer Lodge Area, Montana

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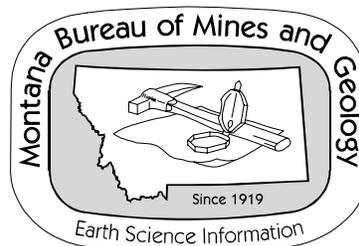
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INTRODUCTION

Between 1983 and 1988, four 7.5' quadrangles, Deer Lodge, Baggs Creek, Orofino Creek, and Sugarloaf Mountain (Fig. 1) were mapped separately at the 1:24,000-scale and subsequently were combined for the present report into a single 1:48,000-scale geologic map of the Deer Lodge area (Pl. 1). This map covers the same area as an earlier 1:48,000-scale reconnaissance map (Ruppel, 1961). The Deer Lodge area occupies approximately 520-km² (202 mi²) in Powell, Deer Lodge, and Jefferson Counties, Montana. The community of Deer Lodge, which is the county seat of Powell County, is located near the midpoint of the western margin of the map area. The small community of Racetrack is located in the southwestern corner of the area. Principal access is provided by Interstate 90 that extends north-south across the map area near the western map boundary. Secondary access is primarily by both public and private dirt roads. Much of the public land is part of the Deerlodge and Helena National Forests.

Topographic relief is about 1,146 meters (3,760 ft) with elevations ranging from slightly below 1,402 meters (4,600 ft) along the Clark Fork River at the extreme northwestern corner of the map area to about 2,549 meters (8,360 ft) along the eastern boundary of the map east of the Leadville mining district. The Continental Divide crosses the southeastern part of the Sugarloaf Mountain quadrangle near the Leadville mining district, separating the upper reaches of the Rock Creek drainage to the southeast from the Clark Fork drainage to the west and northwest.

Although the Deer Lodge area lies within the Montana Fold and Thrust Belt, the dominant geologic features in the eastern part of the area are more closely associated with the northwestern flank of the Cretaceous Boulder Batholith and the comagmatic Elkhorn Mountains Volcanics. Exposures of Mesozoic strata, the oldest rocks exposed in the area, are largely confined to the northeastern corner and the northwestern margin of the area. Tertiary sediments are present within the Deer Lodge structural basin in the western part of the map area where they are partly concealed beneath Quaternary deposits. Both Tertiary Lowland Creek Volcanics and Quaternary glacial deposits are locally abundant. The Emery mining district is near the center of the area and the Leadville mining district lies near the center of the southeastern quarter of the map area.

GENERAL STRATIGRAPHIC AND STRUCTURAL RELATIONSHIPS

Plate 2 provides five cross sections across the map area. Additionally, Figure 2 shows a generalized diagram of the vertical and lateral relationships of the Elkhorn Mountains Volcanics units recognized and mapped within the area.

Mesozoic sedimentary strata were folded and faulted prior to deposition of the Cretaceous Elkhorn Mountains Volcanics. Thus, Jurassic and Cretaceous sedimentary rocks (Swift, Kootenai, Blackleaf, and Carter Creek Formations, in ascending order) are exposed only in isolated areas where the volcanic cover has been removed by erosion. The Jurassic Swift Formation and the overlying Cretaceous Kootenai Formation are exposed in the northeastern part of the Baggs Creek quadrangle. Isolated exposures of Kootenai Formation thrust over Carter Creek Formation also occur in the northwestern corner of the Deer Lodge quadrangle. Lithologies of the Kootenai Formation in the Deer Lodge area include the lower calcareous, upper clastic, and gastropod-limestone members that correspond to the upper three members of Kootenai Formation of Kauffman (1963) in the Garnet Range 72 km (43.1 mi) northwest of the map area. Also exposed in the eastern Garnet Range to the north of the Deer Lodge area is a yellow-brown, well-indurated quartzite and quartz arenite above the gastropod limestone. We included this thin unit with the Kootenai Formation in the Deer Lodge area. The Carter Creek Formation, the uppermost formation of the Colorado Group in the map area, occurs in small fault slices along the northern margin of the Deer Lodge quadrangle. Mutch (1961) and Gwinn (1961) described a section of the Colorado Group, more than 3,000 m (9,840 ft) thick, just northwest of the Deer Lodge area in the northern Flint Creek Range and adjacent Garnet Range. A. B. French (personal communication, 1989) measured a similar thickness for the Colorado Group in the Garnet Range. The middle part of the

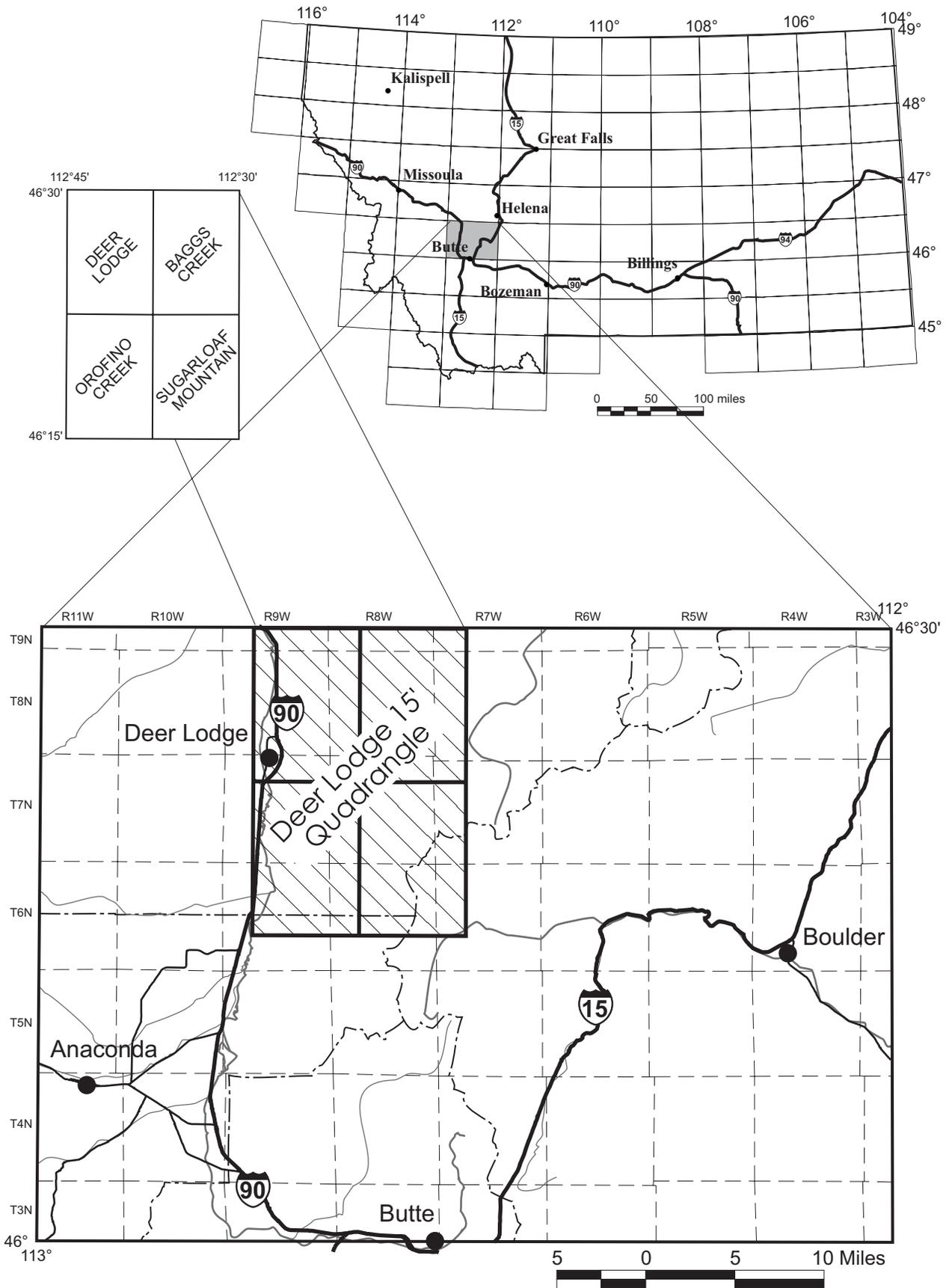


Figure 1. Location of Deer Lodge 15' quadrangle in southwest Montana, showing relationship of its four component 7.5' quadrangles.

Colorado Group is not exposed in the Deer Lodge area. The Blackleaf Formation, the basal formation of the Colorado Group, is represented only by limited exposures of contact-metamorphosed rock along the northwestern flank of the Boulder Batholith in the southeastern part of the Orofino Creek quadrangle, and by poor exposures in the northeastern part of the map. The Blackleaf Formation has been measured and described 32 km (19.2 mi) west of the map area at Drummond (Dyman and others, 1994) where it is more than 1,000 m (3,280 ft) thick.

In the Deer Lodge area, pre-Tertiary rocks also include Cretaceous Elkhorn Mountains Volcanics and intertongued basalt (Klepper and others, 1957; Ruppel, 1961, 1963; Smedes and others, 1988). The Elkhorn Mountains Volcanics are comagmatic with the Boulder Batholith. They thin and flatten northward (see cross section E-E', Pl. 2) and are exposed as a thick, generally northwestward-tilted sequence along the northwestern margin of the Boulder Batholith. The intertongued basalts are exposed in a broad, flat basin in the north-central portion of the area. A fringe of Elkhorn Mountains Volcanics is again exposed from the northern edge of the area northward into the adjacent Luke Mountain and Avon quadrangles (Peterson, 1985; Trombetta, 1987).

The Elkhorn Mountains Volcanics, especially the basal units, are probably time-stratigraphic equivalents to the Upper Cretaceous Golden Spike Formation (Gwinn and Mutch, 1965). The Golden Spike Formation contains andesitic flows and tuff, limestone- and chert-pebble conglomerate, sandstone, and siltstone (Mutch, 1961; Gwinn, 1961). The classic exposures of the type locality are 6.4 km (3.83 mi) northwest of the Deer Lodge 7.5' quadrangle. The formation is exposed in the Luke Mountain 7.5' quadrangle (Peterson, 1985) that adjoins the northern border of the Deer Lodge 7.5' quadrangle, but nonvolcanic lithologies typical of the Golden Spike are not observed in the Deer Lodge 7.5' quadrangle or elsewhere in the present map area. The change from the 1,200-m- (3,937-ft)-thick Golden Spike Formation to the Elkhorn Mountains Volcanics in the Deer Lodge 7.5' quadrangle is probably the result of abrupt facies changes.

A series of basalt flows and flow breccias is interbedded with and overlies the Elkhorn Mountains Volcanics (Fig. 2). Robertson (1953) mapped these basalts as part of the Elkhorn Mountains Volcanics and Ruppel (1963), in the Basin quadrangle, included the basalts with the Elkhorn Mountains Volcanics, considering them the youngest phase of Late Cretaceous volcanism. In the Sugarloaf Mountain quadrangle, basalts are contact-metamorphosed adjacent to the Boulder Batholith, which supports the interpretation that the basalts are Late Cretaceous. Near the Emery mining district, the lowermost basalt flows appear to underlie the basal andesite unit of the Elkhorn Mountains Volcanics (Derkey, 1986) and, in the eastern part of the Baggs Creek quadrangle, basalt flows and flow breccias are intertongued with Elkhorn Mountains Volcanics, thus supporting the interpretation that the basalt is coeval with them. In this report the basalts are mapped separately from the Elkhorn Mountains Volcanics on the basis of their distinctive lithologies.

Erosional remnants of the early Eocene Lowland Creek Volcanics are most abundant in the south-central part of the area where they rest nonconformably on the Boulder Batholith and are overlapped by Paleogene sediments of the Deer Lodge basin sequence. The youngest unit (Tlcd) of the Lowland Creek Volcanics is probably equivalent to the fourth unit (Tda, aphanitic dacite) of Derkey and Bartholomew (1988) in the nearby Ramsay quadrangle. Our Tlca unit likely corresponds to their second unit (Trdp, porphyritic rhyodacite), and our lowermost exposed Tlct unit, which nonconformably overlies Kbqm, most likely correlates with their basal unit (Trt, rhyodacite tuff) that also nonconformably overlaps the Boulder Batholith.

Because of a lack of age determinations of specific units in the Deer Lodge area, correlations are based on lithology. Some units placed in the Lowland Creek Volcanics may be younger. The Trt unit in the northwest corner of the Deer Lodge quadrangle consists of tuff and tuffaceous, fossiliferous limestone, and is probably contemporaneous with late Eocene rhyolitic volcanic rocks in the Avon area 8 km (4.8 mi) east of these exposures (R. Chadwick, personal communication, 1984). Alternatively, the

Trt unit may be contemporaneous with early Eocene Lowland Creek Volcanics that crop out 22.5 km (13.5 mi) south of these exposures. Tuffaceous sandstone (Trt) near the southeast corner of the Deer Lodge quadrangle contains clasts (up to 15 cm in diameter) that are identical to a Lowland Creek Volcanics unit exposed in the adjacent Orofino Creek quadrangle. The tuff and tuffaceous, fossiliferous limestone (Trt) exposed in the northwest corner of the quadrangle is overlain by undifferentiated Oligocene to Miocene fluvial deposits (Fields and others, 1985) of the Deer Lodge basin sequence. Also, the lithologic similarity of the rhyolite (Tr) in a domal structure in the southeastern part of the Baggs Creek quadrangle, and its proximity to volcanics in the adjacent Avon quadrangle (Trombetta, 1987), suggest a correlation with Eocene rhyolites in the Avon Valley. Trombetta (1987) reported a K/Ar age (unpublished data of L. W. Snee, U.S. Geological Survey) of about 40 Ma for Avon volcanics from the Avon and Elliston quadrangles.

Tertiary sediments of the Deer Lodge basin sequence, veneered by Quaternary deposits, cover the western part of the area. These sediments have very gentle northwestward dips and generally appear to overlap the older rocks in the eastern part of the area. Although N20-30W-trending normal faults are common in this area, the bedrock/sediment contact does not appear to be fault-controlled along the eastern basin margin. Moreover, no N20-30W-trending faults were found offsetting the well-preserved Quaternary pediment surfaces or the Pleistocene fluvial and younger alluvial surfaces in the Deer Lodge Valley. Thus, the N20-30W-trending high-angle faults are inferred to be Tertiary.

GEOMORPHIC RELATIONS

Prominent dissected Pleistocene pediment surfaces are typically several hundred meters above the present level of the Clark Fork River. Where the pediment surfaces developed on Tertiary sediments, a 2- to 3-m (6.6 to 9.8-ft)-thick veneer of fluvial gravels caps the sediment; where the pediment surfaces developed on older igneous and metamorphic rocks, only scattered lag gravel remnants are typically preserved on the pediment surfaces. The oldest (highest) of these pediments appears to have developed prior to middle Pleistocene glaciation (Illinoian glaciation in continental glaciation terminology; Bull Lake glaciation in Rocky Mountain usage) because the terminal moraine appears to rest partly on top of parts of the oldest pediment surface near the center of the area. The intermediate pediment level appears to postdate the middle Pleistocene glaciation because it is several meters lower than remnants of middle Pleistocene outwash near the center of the map area. The youngest (lowest) of the pediment surfaces are incised into the intermediate pediment surface in the southeastern Deer Lodge quadrangle, but are still well above the oldest late Pleistocene (Wisconsin glaciation in continental glaciation terminology; Pinedale glaciation in Rocky Mountain usage) outwash gravel deposits. Thus, inferred relations among the glacial deposits and the younger two pediment levels are consistent with pediment development during the Sangamon interglaciation. The oldest pediment surface likely developed during the Yarmouth interglaciation.

The distribution of middle Pleistocene till suggests that alpine glaciers were present in the ancestral drainages of Baggs and Cottonwood Creeks and of Rock Creek in the central and southeastern parts, respectively, of the map area. The distribution of till in the Rock Creek drainage indicates that the Rock Creek glacier extended westward across the drainage divide and blocked Indian Creek during middle Pleistocene glaciation. In sec. 26 and 27, T. 8 N., R. 8 W., till extends northward from Baggs Creek across the drainage divide, suggesting that Fred Burr Creek received minor discharge from the Baggs Creek glacier during middle Pleistocene glaciation. The distribution of till suggests that the Baggs Creek and Cottonwood Creek glaciers merged near the center of the area and were contained by a single continuous terminal moraine.

In contrast, the distribution of late Pleistocene till suggests that late Pleistocene glaciation was less extensive than middle Pleistocene glaciation in the ancestral drainages of both Baggs and Cottonwood Creeks. The youngest terminal moraines in these creeks are located about 3 km (1.86 mi) upstream (east) from the middle Pleistocene moraine; lateral moraines are generally better preserved and occur at lower elevation than the relict middle Pleistocene moraines. Again, in sec. 26 and 27, discharge

from the Baggs Creek glacier was locally released into Fred Burr Creek. Only in sec. 30, T. 7 N., R. 7 W., is there any indication that heads of glaciers in Cottonwood and Rock Creeks may have merged. Thus, the late Pleistocene ice cap proposed by Ruppel (1962) did not extend as far westward as the Deer Lodge area where alpine glaciers carved the ancestral drainages of Baggs, Cottonwood, and Rock Creeks.

Outwash from late Pleistocene glaciation is represented by three distinct levels of glacio-fluvial deposits both from the Baggs Creek and Cottonwood Creek drainages and from drainages on the western side of the Deer Lodge basin that head in the Flint Creek Range. The youngest (lowest) outwash deposit from Baggs and Cottonwood Creeks still has a broadly convex-upward, lobate shape with well-preserved braided stream patterns on it and thus likely represents latest glaciation. The intermediate level is much more extensive in the Deer Lodge Valley and likely represents the peak of the late Pleistocene glaciation. Both geomorphic form and surface details are less well preserved on these intermediate outwash fans. Remnants of the oldest (highest) late Pleistocene outwash fan are preserved in the east-central part of the Deer Lodge quadrangle. Their height is well above the lowest and intermediate (both late Pleistocene) fans, yet significantly below the Sangamon pediments. Geomorphic form and surface details are generally lacking as well, suggesting these highest outwash deposits may be relicts of an early Wisconsin (pre-Pinedale) glaciation.

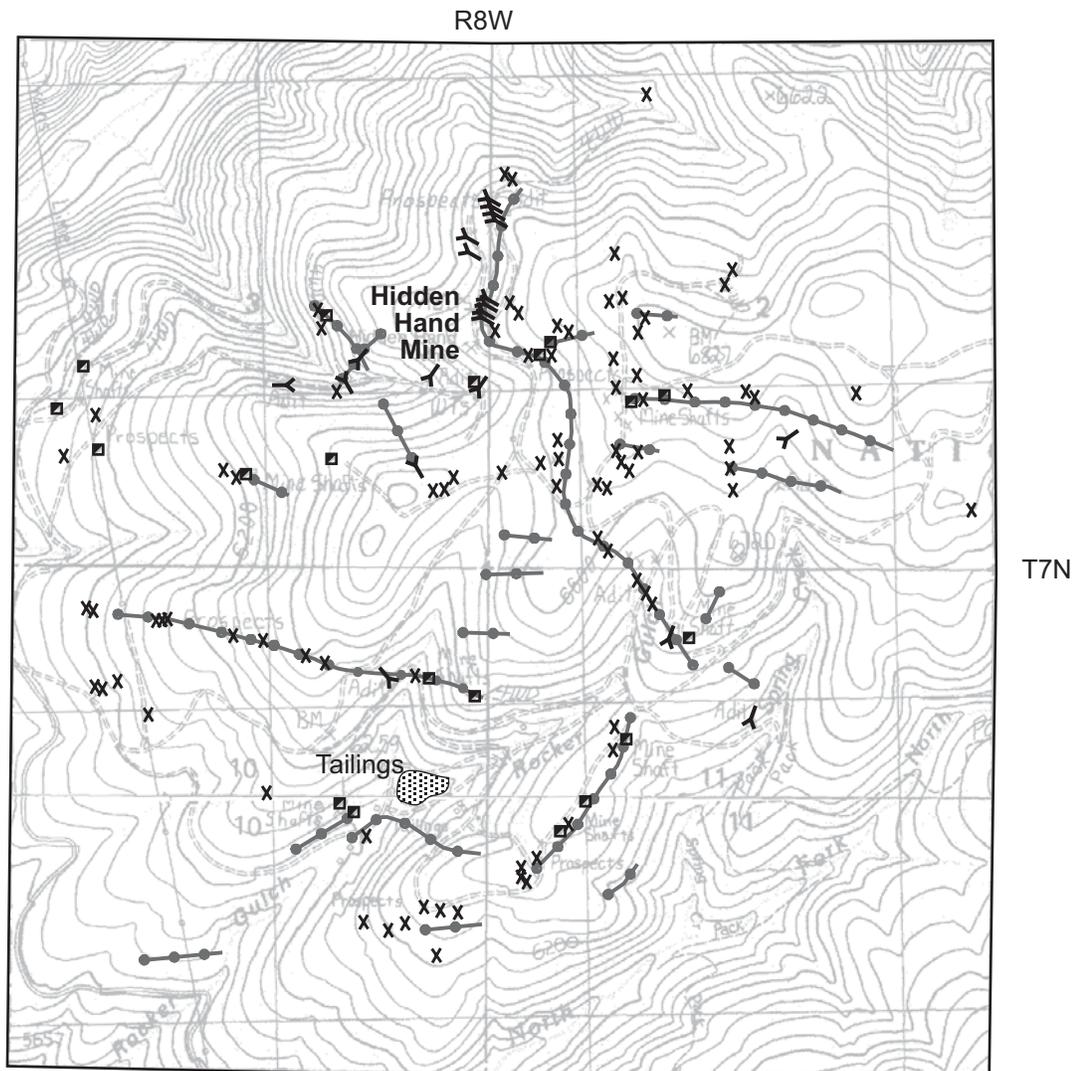
The Pleistocene glacio-fluvial deposits were incised by Holocene streams that are represented by successive, generally unpaired, levels of terrace deposits. The distribution of these numerous Holocene terrace deposits suggests a considerable narrowing of floodplain widths, inferred to accompany reduced stream flow, compared to the older Pleistocene floodplains. Mount Mazama ash (approximately 6,800 years BP) is preserved at one locality, several meters below the surface in an intermediate-level Holocene fan in the northwestern corner of the Orofino Creek quadrangle.

MINERAL RESOURCES

The Emery mining district contains the principal economic ore deposits in the Deer Lodge area (Fig. 3, and Pl. 1). It is located near the center of the area along the boundary between the Baggs Creek and Sugarloaf Mountain quadrangles, primarily in sec. 2, 3, 10, and 11, T. 7 N., R. 8 W. Derkey (1986) summarized the literature and history of this district and compiled a map showing locations and names of all mines and veins. All of these mines and veins, as well as prospects, are shown on Figure 3 of the present report. Derkey (1986) recognized four stages of mineralization as follows: 1) low-temperature minerals -- quartz, pyrrhotite, pyrite, and sphalerite; 2) high-temperature minerals -- arsenopyrite, tourmaline, quartz, and gold; 3) low-temperature minerals -- sphalerite, galena, boulangerite, tetrahedrite, and chalcopyrite; and 4) calcite and ankerite.

As part of the U.S. Bureau of Mines' Mineral Lands Assessment Program, Federspiel and Mayerle (1988) mapped and described the Leadville area (Fig. 4), located about 7 km (4.3 mi) southeast of the Emery district near the center of the Sugarloaf Mountain quadrangle, primarily in sec. 36, T. 7 N., R. 8 W. and sec. 1, T. 6 N., R. 8 W. Again, many of the mines, prospects, and veins are shown on Plate 1, without names for readability. Federspiel and Mayerle (1988) provided data from many new assays and concluded that the Leadville area is a subeconomic deposit containing gold, silver, lead, copper, zinc, and antimony.

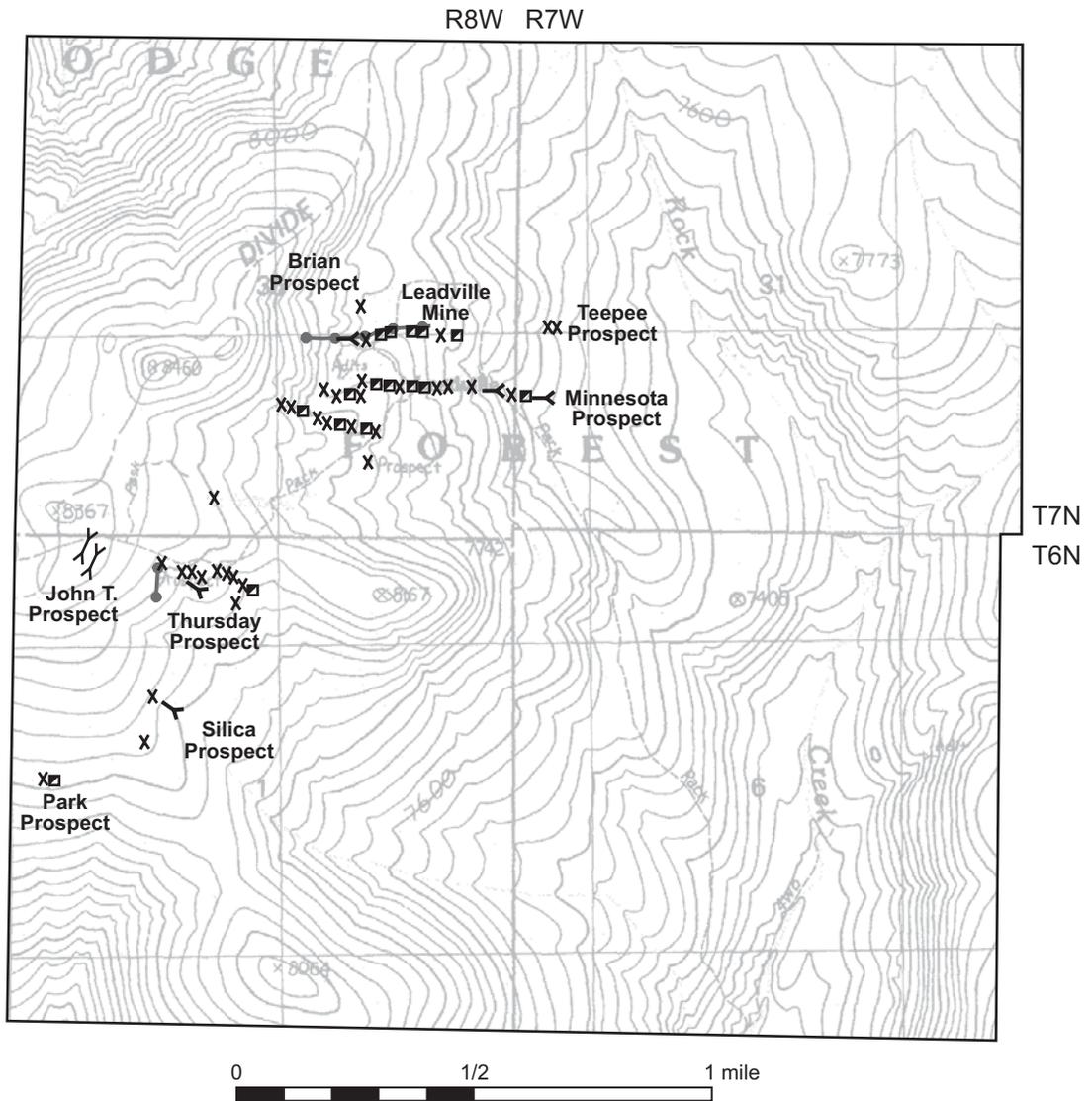
Derkey (1987) mapped and described the Burnt Hollow area in sec. 20 and 29, T. 7 N. R. 8 W., about 6 km (3.7) southwest of the Emery district along the eastern flank of the Deer Lodge basin where Tertiary sediments overlap Cretaceous volcanic rocks (Pl. 1). Along the overlap, Derkey (1987) recognized three small areas with sericitic alteration. Assays from the Burnt Hollow area show low-grade gold and silver mineralization (Derkey, 1987).



- x Prospect pit
- ▣ Abandoned shaft
- ↘ Mine adit
- Chalcedony and quartz veins and zones of silicified rock
- ↗ Trench



Figure 3. Emery mining district.



- x Prospect pit
- ▣ Abandoned shaft
- ↘ Mine adit
- Chalcedony and quartz veins and zones of silicified rock
- ↗ Trench



Figure 4. Leadville mining district.

Williams (1951) described the mines and ore deposits in the Champion Pass area that adjoins the south-central part of the Deer Lodge area. The Elk Mine, in the Orofino Creek quadrangle (Fig. 1), was included in his report.

The only known nonmetallic mineral production from the Deer Lodge quadrangle is sand and gravel (labeled **sg** on map) from numerous pits located in the western half of the area adjacent to the interstate highway, the railroads, and the city of Deer Lodge, and near small ranches in the Deer Lodge Valley. The larger gravel pits are generally in late Pleistocene outwash gravels (sec. 4, T. 6 N., R. 9 W.; sec. 5 and 33, T. 7 N., R. 9 W.; sec. 21, 27, and 35, T. 8 N., R. 9 W.; sec. 33, T. 9 N., R. 9 W.) and locally, where these gravels were reworked by the Clark Fork River and Cottonwood Creek, in older Holocene terrace deposits (sec. 9, T. 7 N., R. 9 W.; sec. 21, 28, and 33, T. 8 N., R. 9 W.).

Two small pits are in middle Pleistocene pediment gravel deposits (sec.10, T. 7 N., R. 9 W.; sec. 17, T. 8 N., R. 9 W.). However, compared to late Pleistocene deposits, middle Pleistocene deposits, which have been subjected to a much longer period of weathering, typically have a higher percentage of clasts that are significantly altered and more friable. These older deposits also are capped by thick zones of significant carbonate buildup in the matrix between clasts, and generally contain more clay than less weathered deposits. Because of the greater degree of weathering, middle Pleistocene, and the oldest late Pleistocene gravel deposits are less suitable than younger late Pleistocene deposits as sources of sand and gravel.

Sand and gravel have also been obtained from Holocene deposits (sec. 29, T. 8 N., R. 8 W.; sec. 34, T. 9 N., R. 9 W.). These Holocene deposits, however, contain a higher proportion of finer-grained sediment (silt and clay) and are less suitable than the youngest late Pleistocene deposits as a source of sand and gravel. During the 1980s, sand was also obtained locally from three small borrow pits in Tertiary sediments south of Deer Lodge (sec. 2 and 33, T. 7 N., R. 9 W.) and from one pit prior to that time (sec. 17, T. 8 N., R. 9 W.). Crushed stone was obtained from Elkhorn Mountains Volcanics (sec. 28, T. 7 N., R. 8 W.) for local use as gravel on Forest Service roads.

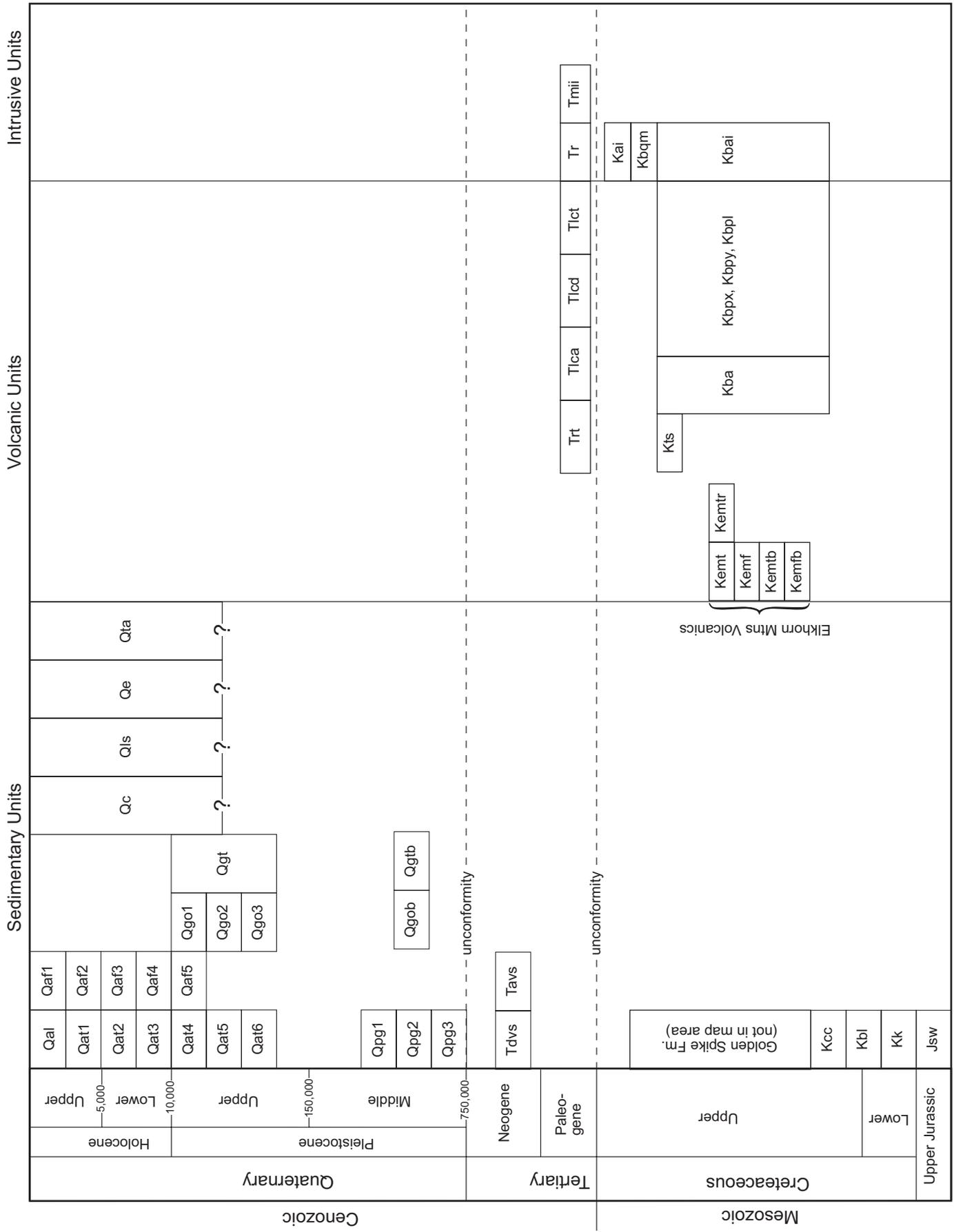


Figure 5. Correlation chart of map units of the Deer Lodge 15' quadrangle.

DESCRIPTION OF MAP UNITS

NOTE: Map unit thicknesses, where given, are in metric units. To convert meters to feet (the contour interval unit on the topographic map base), divide the meters by 0.3048. To convert centimeters to inches, divide the centimeters by 2.54. To convert millimeters to inches, divide the millimeters by 25.4.

Where reference is made to height above modern rivers and flood plains, measurements are given in both metric and English units.

QUATERNARY

Holocene Epoch

In the following descriptions of Quaternary deposits, Munsell color designations and the ISCC-NBS system of color names are used for deposits where well-exposed profiles were observed and described. If profiles suitable for description were not observed, more generalized terms are used for deposit descriptions. All measurements are given in metric units, but for heights above river or stream levels, English units are included in parentheses because the topographic contour interval used on the map is in English units.

- Qa1 **Alluvium of modern stream channels and floodplains**
Qaf1 **Alluvium of modern alluvial fan deposit**

Deposits of modern channels, floodplains, terraces, and fans. Stratified, unconsolidated deposits of grayish-brown (5 YR 3/2) sandy gravel, with rounded to subangular clasts as much as 10 cm long, interbedded with dark yellowish-brown (10 YR 4/2) sand and silty sand. On floodplain, sediment is covered by 5-10 cm of dark yellowish-brown (10 YR 4/2) sand and sandy loam O/A soil horizon.

- Qat1 **Alluvial terrace deposit, youngest**
Qaf2 **Alluvial fan deposit, second youngest**

Lowest alluvial deposits above modern floodplain. Deposits on irregularly shaped, unpaired terraces and in fans, 1-2 m (3-6 ft) above the modern floodplain, that consist of 1-2 m of stratified, unconsolidated deposits of grayish-brown (5 YR 3/2) sandy gravel interbedded with dark-yellowish-brown (10 YR 4/2) sand and silty sand and containing dusky-yellowish-brown (10 YR 2/2) sandy loam Ab horizons 2-15 cm thick. Detrital material consists of well to poorly sorted, rounded to subangular rock clasts derived from Tertiary and older strata. Deposits covered by 10-20 cm of dark yellowish-brown (10 YR 4/2) sandy loam O/A soil horizon.

- Qat2 **Alluvial terrace deposit, second youngest**
Qaf3 **Alluvial fan deposit, third youngest**

Deposits in intermediate Holocene position above modern floodplain. Deposits on irregularly shaped, unpaired terraces and in fans, 2-5 m (6 to 16 ft) above modern floodplain, that consist of 1-3 m of stratified, unconsolidated deposits of grayish-brown (5 YR 3/2) sandy gravel interbedded with dark yellowish-brown (10 YR 4/2) sand and silty sand and containing numerous 2-15 cm thick, dusky-yellowish-brown (10 Yr 2/2) sandy loam AB horizons. Detrital material is similar to that in lower alluvial terrace and fan deposits. Deposits covered by 15-20 cm of dark-yellowish-brown (10 YR 4/2) sandy loam O/A horizon locally overlying 5-10 cm moderate-yellowish-brown (10 YR 5/4) sandy loam E horizon. A 5-7 cm thick bed of Mount Mazama ash (6800 years BP) lies about 2-3 m beneath the surface of a large fan (Qaf3) in the northeastern corner of the Orofino Creek Quadrangle.

- Qat3 **Alluvial terrace deposit, third youngest**
 Qaf4 **Alluvial fan deposit, fourth youngest**

Deposits located at highest Holocene level above modern floodplain. Deposits on irregularly shaped, unpaired terraces and in fans, 7-10 m (20-30 feet) above modern floodplain, that consist of 1-3 m of stratified, unconsolidated deposits of grayish-brown (5 YR 3/2) sandy gravel interbedded with dark-yellowish-brown (10 YR 4/2) sand and silty sand and containing numerous 2-15 cm thick, dusky-yellowish-brown (10 Yr 2/2) sandy loam AB horizons. Detrital material is similar to that in lower alluvial terrace and fan deposits. Deposits covered by 15-20 cm of dark-yellowish-brown (10 YR 4/2) sandy loam O/A horizon locally overlying 5-10 cm of moderate-yellowish-brown (10 YR 5/4) sandy loam E horizon overlying 20-25 cm of yellowish-brown (10 YR 5/4) K horizon with stage I carbonate buildup.

- Qc **Colluvial deposit** -- Nonstratified, unconsolidated, irregularly-shaped deposits of unsorted, generally angular, unsorted, coarse-grained, locally derived detrital material in a variable matrix of sand, silt, and clay. Colluvium covered by 15-20 cm of moderate brown (5 YR 3/4) sandy loam O/A horizon with abundant weathered cobbles and pebbles overlying 15 to 20 cm of moderate-yellowish-brown (10 YR 5/4) sandy loam E horizon overlying 20-25 cm yellowish-brown (10 YR 5/4) K horizon with stage I carbonate buildup.

Holocene and Pleistocene Epochs

- Qls **Landslide deposits** -- Mass wasting deposits that retain relict geomorphic form indicative of either deep-seated or shallow-seated landslides. Color, texture, and lithology of clasts reflect locally derived rock types. Geomorphic forms are best preserved in younger (Holocene) landslides. Abundant large landslides are associated with both Mesozoic sedimentary rocks and Pleistocene glacial deposits. Abundant smaller landslides and some large landslides are associated with both Tertiary sedimentary strata and Cretaceous volcanic rocks.
- Qta **Talus** -- Unconsolidated, unsorted, angular deposits of locally derived cobble- to boulder-size debris generally lacking finer-grained matrix detritus. Larger mapped deposits associated with Cretaceous volcanic rocks.
- Qe **Eolian deposits** -- Unstratified, well-sorted, light-brown (5 YR 6/4) deposits of wind-blown silt and fine-grained sand. Large deposit mapped in southwest part of map area in the Orofino 7.5' quadrangle.

Pleistocene Epoch

- Qgt **Glacial till of Pinedale Glaciation** -- Nonstratified, unconsolidated, poorly sorted, generally gray to brownish-gray deposits containing subangular to rounded, cobble- to boulder-size, matrix-supported clasts in a medium-brown to grayish-brown, clayey matrix; clasts are predominantly derived from both abundant Cretaceous and sparse Tertiary volcanic rocks along the Baggs and Cottonwood Creeks, but include some granitic rocks in the Rock Creek drainage; clasts have thin weathering rinds; generally covered by 10-20 cm A/O soil horizon over poorly developed B horizon; carbonate buildup is generally lacking. Remnants of terminal moraines are found in sec. 34 and 35, T. 8 N., R. 8 W along Baggs Creek, sec. 15, T. 7 N., R. 8 W. along Cottonwood Creek, and sec. 19 and 20, T. 6 N., R. 7 W. along Rock Creek; geomorphic form of both terminal and lateral moraines is commonly well preserved.
- Qgo1 **Glacial outwash gravel**
 Qat4 **Alluvial terrace deposit**
 Qaf5 **Alluvial fan deposit, oldest**

Lowest glacial deposits within valley. Outwash gravels are poorly stratified, unconsolidated deposits, 10-15 m (35-45 ft) above modern floodplain; consist of poorly to moderately sorted subrounded to well-rounded cobbles and pebbles with an olive-gray (5 Y 4/1), gravelly coarse sand matrix. Deposits covered by 10-15 cm dark-yellowish-brown (10 YR 4/2) loam O/A horizon over 5-10 cm dark-yellowish-brown (10 YR 5/2) sandy loam E horizon overlying 25-100 cm olive-gray (5 Y 4/1) K horizon with stage I carbonate buildup. Relict braided stream pattern discernable on lobate outwash deposit between Baggs and Fred Burr Creeks. Alluvial terrace deposits, preserved on paired terraces above modern drainages, and glacial alluvial fan deposits are moderately to well stratified, moderately to well sorted deposits with a higher percentage of coarse sand beds and coarse sand matrix than in outwash deposits. These fans appear to be older than the oldest Holocene fans (Qaf4)

Qgo2 **Glacial outwash gravel**
Qat5 **Alluvial terrace deposit**

Glacial deposits at intermediate level within valley. Outwash gravels are poorly stratified, unconsolidated deposits 16-20 m (50 to 65 ft) above modern floodplain; consist of poorly to moderately sorted, subrounded to well-rounded boulders, cobbles, and pebbles with a very pale-orange (10 YR 8/2) sandy gravel matrix (40 %). Coarser detrital material ranges from equal proportions of granitoid and quartzite plus hornfels material west of the Clark Fork River to predominantly Cretaceous volcanic rock fragments east of the river, covered by 10 cm of dark-yellowish-brown (10 YR 4/2) sandy loam O/A horizon with 20-30 % weathered pebbles; overlying 10-20 cm of moderate-yellowish-brown (10 YR 5/4) sandy loam E horizon with 40-50 % weathered cobbles and pebbles; overlying 20-30 cm very pale-orange (10 YR 8/2) K horizon with stage III carbonate buildup; overlies 50-100 cm grayish-orange (10 YR 7/4) C horizon with 40 % matrix-supported clasts in sandy silt matrix with stage I carbonate buildup extending more than 2 m below K horizon. Alluvial terrace deposits are more stratified and better sorted than glacial outwash deposits and contain more fine-grained material as both matrix in conglomerates and as discrete beds of medium to coarse sand; alluvial deposits occur primarily on paired terraces.

Qgo3 **Glacial outwash gravel**
Qat6 **Alluvial terrace deposit**

Higher glacial deposits within valley. Poorly exposed, poorly stratified, unconsolidated deposits 24-35 m (75-105 ft) above modern floodplain; consists of poorly to moderately sorted, subrounded to well rounded boulders, cobbles, and pebbles with a pale orange sandy gravel matrix; covered by 10-20 cm brownish-gray A/O soil horizon over 30-50 cm orangish-gray K horizon with stage III carbonate buildup. Alluvial terrace deposits are better stratified and sorted than glacial outwash deposits and contain a greater percentage of sand, as both matrix in conglomerates and as discrete beds, than that in glacial outwash deposits.

Qpg1 **Younger pediment gravel deposits** – Two to 3 m of poorly stratified, unconsolidated, deposits 50-135 m (150-400 ft) above modern river level; consist of boulder-, cobble-, and pebble-size, grain-supported clasts with a grayish-orange (10 YR 7/4) to very pale-orange (10 YR 8/2) coarse sand matrix of quartz and lithic detritus; coarse detrital lithic clasts consist of weathered volcanic rock, granitoid rock, quartzite, and hornfels; covered by 15 cm A/O horizon of moderate (10 YR 5/4) to dark (10 YR 4/2) yellowish-brown loamy sand over 40-50 cm very pale-orange (10 YR 8/2) K horizon with stage IV carbonate buildup; stage I carbonate buildup extends more than 2 m below K horizon.

Qpg 2 **Intermediate pediment gravel deposits** – Two to 3 m of poorly exposed, moderately stratified, unconsolidated, grain-supported deposits 135-200 m (400-600 ft) above modern river level; consist of poorly to moderately sorted, subrounded to rounded, boulder-, cobble-, and pebble-size, grain-supported clasts with grayish-orange to reddish-brown, coarse sand matrix of quartz

and lithic detritus; lithic material generally derived from volcanic rocks; covered by 10-20 cm of dark-orangish-brown A/O soil horizon over 0.5-1.5 m K horizon with stage III to IV carbonate buildup and carbonate accumulation extending at least 2 m below K horizon.

- Qgtb Glacial till of Bull Lake Glaciation** -- Poorly exposed, nonstratified, unconsolidated, poorly sorted, generally reddish-brown deposits containing subangular to rounded cobble- to boulder-size, matrix-supported clasts in a clayey to silty sand matrix; clasts are primarily derived from volcanic rocks and most clasts are deeply weathered (easily broken with a hammer or even by hand); covered by up to 0.5 m generally grayish-brown A/O soil horizon over 1+ m orangish – reddish-brown B horizon over deeply weathered till extending to depths of several meters; carbonate buildup is generally lacking. Remnants of a deeply dissected terminal moraine occur near the junction of Cottonwood and Baggs Creeks near the center of the map area; remnants of lateral moraines, with little preserved geomorphic form, occur at higher elevations along both creeks and along the lower part of Indian Creek in the southeastern part of the Sugarloaf Mountain quadrangle.
- Qgob Glacial outwash of Bull Lake Glaciation** -- Poorly exposed, poorly stratified, unconsolidated, poorly sorted, generally reddish-brown deposits containing subangular to rounded cobble- to boulder-size clasts in a clayey to silty sand matrix; highly dissected remnant outwash fans occur adjacent to the western flank of the Qgtb terminal moraine noted above. A thick, generally grayish-brown A/O horizon at least locally overlies 0.5-1 m K horizon with stage III to IV carbonate buildup and with carbonate accumulation extending at least several meters into deeply weathered deposits similar to Qgtb. Preserved deposits probably include considerable colluvial material produced by mass wasting of both Qgtb and Qgob .
- Qpg 3 Older pediment gravel deposits**– One to 3 m, poorly exposed, poorly to moderately stratified, unconsolidated, moderately sorted, generally reddish- or grayish-brown deposits 165-260 (500-800 ft) above modern river level; deposits contain subrounded to rounded, cobble- to boulder-size, grain-supported clasts with a sandy matrix; covered by 15-20 cm, generally gray A/O soil horizon over 1-2 m-thick zone of stage IV carbonate buildup that commonly extends to the base of these thin gravel deposits.

TERTIARY

Sedimentary Rocks

- Tdvs Deer Lodge Valley basin sequence** -- Stratified, cross-bedded or thickly bedded, lenticular, poorly lithified, light-gray (N 7) to light-brown (5 YR 6/4), matrix-supported, fluvial deposits with yellowish-gray (5 Y 7/2), medium- to coarse-grained quartz-mica and volcanoclastic sand with lenses of dusky yellow (5 Y 6/4), medium-grained sand and light-brown (5 Y 6/4), fine-grained, silty sand interbedded with yellowish-gray (5 Y 7/2), coarse-grained conglomeratic sand and sandy pebble conglomerate.
- Tavs Avon Valley basin sequence** -- Stratified, thickly bedded or cross-bedded, poorly lithified, light-gray (N 7) to light-brown (5 YR 6/4), matrix-supported, fluvial deposits composed of interbedded coarse-grained conglomeratic sandstone lenses and fine-grained sandstone, siltstone and tuffaceous beds occurring in the northeast corner of the quadrangle at the southern end of the Avon Valley.

Intrusive Igneous Rocks

- Tr Rhyolite** -- Light- to medium-gray or pinkish, with 5-10 % phenocrysts of plagioclase (1-2 mm) and quartz (1 mm) in a fine-grained siliceous groundmass. Locally abundant flow banding. Occurrence limited to a single body in southeastern corner of the Baggs Creek quadrangle.

Tmi **Mafic to intermediate dikes** – Dark-gray, aphanitic, alkalic dikes that intrude the Carter Creek Formation in northwestern part of map area. May be equivalent to Lowland Creek Volcanics (Tertiary) or Elkhorn Mountains Volcanics (Cretaceous).

Extrusive Igneous Rocks

Trt **Rhyolite tuff, tuffaceous sediments and fossiliferous limestone** --White to buff, tuffaceous rocks with sparse coarser-grained, well-indurated tuff-breccia lenses containing darker volcanic fragments. Fossiliferous limestone interbedded with siliceous tuff crops out near the northwestern corner of the Deer Lodge quadrangle. Near the southeast corner of the Deer Lodge quadrangle, the tuffaceous sandstone contains cobbles and boulders similar to Lowland Creek Volcanics rocks exposed in the adjacent Orofino Creek quadrangle.

Lowland Creek Volcanics

Includes aphanitic dacite flows (Tlcd), crystal-rich, quartz-latic, welded ash-flow tuff (Tlca), and crystal-rich, quartz-latic tuff (Tlct).

Tlcd **Dacite flows, aphanitic** -- Medium- to dark-gray aphanitic sills or flows with well-developed columnar jointing and closely spaced platy horizontal jointing. Contains 20-25 % plagioclase, 2-3 % clinopyroxene, 1-2 % hornblende, and 1 % quartz phenocrysts set in a microcrystalline groundmass. Flows cap prominent small butte near the center of the boundary between the Orofino Creek and Sugarloaf Mountain quadrangles.

Tlca **Quartz-latic, welded ash-flow tuff, crystal-rich** -- Pale-red, reddish-orange, and light-gray, well-indurated, crystal-rich, massive to flow-foliated ash-flow tuff. Locally contains lithic fragments. Contains 10-25 % plagioclase (An₃₁), 1-5 % quartz, 2-7 % biotite, 1-5 % hornblende, and 1 % pyroxene crystals set in a microcrystalline to glassy groundmass. Crystals are commonly broken; large plagioclase phenocrysts are zoned, and some quartz crystals have resorption boundaries. Forms moderately smooth slopes and resistant cliffs; may exhibit steep and contorted flow-foliation in outcrop, perhaps due to rheomorphic flow following deposition. A 1.5-5 m thick vitrophyre (typically perlitic) occurs at the base of the unit with similar phenocryst abundance. The welded tuff unit occurs as small remnants in the Sugarloaf Mountain and Orofino Creek quadrangles and the thickness ranges to as much as 65-95 m.

Tlct **Quartz-latic tuff, crystal-rich** -- Very light-gray to yellowish- and greenish-gray, massively bedded air-fall and ash-flow tuff that is poorly to moderately indurated, easily eroded, crystal-rich, with sparse, moderately flattened pumice lumps. Small exposures of thinly bedded and cross-bedded water-laid tuff that occur at the same stratigraphic position are considered part of this unit. The unit contains as much as 20 % plagioclase (An₃₂), as much as 5 % potassium feldspar, 5 to 10 % quartz, 5 to 10 % biotite, and 1% hornblende crystals set in a microcrystalline groundmass.

CRETACEOUS

Intrusive Rocks

Kbqm **Butte quartz monzonite and aplite of the Boulder Batholith** -- Coarse- and fine-grained, light-gray to pink to bluish quartz monzonite (Watson, 1987; Smedes and others, 1988). Composed of normally zoned plagioclase (45-50 %) crystals that range in composition from An₄₀ to An₆₀, orthoclase (20-30 %) in anhedral masses, quartz (5-10 %) as abundant, irregular granules within the groundmass or as interstitial masses, biotite (as much as 15 %) as irregular books up to 5 mm in length, and hornblende (5-15 %) as euhedral to subhedral phenocrysts and as irregular masses clustered with biotite and opaque minerals. Contains numerous quartz and aplite veins that range

in width from a few centimeters to several meters. Intrudes the basal part of the Elkhorn Mountains Volcanics and interbedded basalt flows (Kba) that were both locally metamorphosed by the quartz monzonite.

- Kai **Aplite, intrusive** -- Dikes of mappable extent, associated with the Boulder Batholith; located primarily in the southern map area.
- Kbai **Basalt and basalt breccia, intrusive** -- Brecciated equivalents of the three basalt flow types (Kbpl, Kbpy and Kbpx) found in small, probably intrusive, bodies that locally cross cut other contacts in the northern part of the Sugarloaf Mountain quadrangle.

Extrusive rocks

- Kts **Tuff, siliceous.** Light-green to pale-greenish-gray to light-gray, fine-grained, locally thinly bedded tuffs resembling chert and consisting of quartz with accessory plagioclase and hematite. The well-indurated rocks within approximately 1.6 km of exposures of the Boulder Batholith (Kbqm) are contact-metamorphosed.
- Kba **Basalt flows and flow breccias** -- Because of poor exposure, basalt was mapped as a single lithologic, but probably not stratigraphic, unit in the Deer Lodge and Baggs Creek quadrangles, while farther south it is subdivided into three lithologic types that may be stratabound, and a basalt breccia unit that is a brecciated equivalent of the three basalt types.

The three main basalt types recognized in the field by Derkey (1986) are: (1) dark-gray porphyritic basalt that contains 5-7 mm-long plagioclase (An50-60) and 1-3 mm augite phenocrysts (Kbpl), (2) medium-green porphyritic basalt that contains 1-3 mm augite phenocrysts (Kbpy), and (3) dark-green porphyritic basalt with large augite phenocrysts up to 1 cm (Kbpx). The basalts are quite variable in appearance. The dark-gray porphyritic basalt, which is most common in the Emery mining district in the adjacent Baggs Creek quadrangle, is distinguished by distinct, light-gray plagioclase phenocrysts that are especially visible on weathered surfaces. It is also found in the east-central portion of the Deer Lodge quadrangle. The medium-green porphyritic basalt is most prevalent in the adjacent Baggs Creek quadrangle. It is readily distinguished by its fine-grained, medium- to dark-green matrix with 3-5 % augite phenocrysts. The dark-green porphyritic basalt contains the large pyroxene phenocrysts in a dark-green matrix that has a distinct hackley fracture. The dark-green porphyritic basalt makes up most of the basalt exposed in the Deer Lodge quadrangle. All three basalt types contain olivine (as much as 10 %) and also have widespread amygdaloidal zones. Generally, olivine is altered to a varying mesostasis of serpentine, chlorite, fibrous amphibole, calcite, and epidote or clinozoisite. Augite is also altered to these minerals but much less extensively than the olivine. Amygdaloidal zones seldom crop out but are well exposed in a 2-m-deep trench that was cut across the quadrangle during construction of a natural gas pipeline. Amygdules consist of chalcedony and lesser amounts of calcite.

- Kbpl **Basalt flows and flow breccias, plagioclase basalt** -- Dark-gray porphyritic basalt containing 5- to 7-mm-long light-gray plagioclase phenocrysts (An50 to An60) that are especially distinct on weathered surfaces, and 1- to 3-mm in diameter phenocrysts of augite.
- Kbpy **Basalt flows and flow breccias, small-pyroxene basalt** -- Medium- to dark-green, fine-grained (sugary) matrix that contains 1- to 3-mm-diameter augite phenocrysts (3 to 5 %).
- Kbpx **Basalt flows and flow breccias, large-pyroxene basalt** -- Dark-green porphyritic basalt contains large augite phenocrysts (as much as 1 cm in the Deer Lodge quadrangle. The dark-green matrix has a distinct hackley fracture. Plagioclase phenocrysts are An 50-60.

Elkhorn Mountains Volcanics (Kem)

The Elkhorn Mountains Volcanics are comagmatic with the Boulder Batholith (Figure 2) and consist, from bottom to top, of: (1) two laterally equivalent lower units of andesite flows, flow breccia and tuff breccia; (2) a unit of crystal-rich ash-flow tuff and tuff breccia and (3) an upper unit of andesite flows with a densely welded ash-flow tuff at the top of the andesite flows unit and laterally equivalent, thick welded ash-flow tuff in the Rock Creek area. Probable depositional relations between volcanic units and underlying sedimentary units in the Deer Lodge and adjacent quadrangles are shown in Figure 2.

Where exposed at the northern boundary of the Baggs Creek quadrangle, andesites of the basal unit of the Elkhorn Mountains Volcanics (Kemfb) contain flat, irregularly shaped plagioclase phenocrysts. These phenocrysts, which average about 3 mm in diameter, resemble rolled oats, hence the field name "oatmeal" andesite. The overlying green, crystal-rich ash-flow tuff and tuff breccia unit (Kemt看) is characterized by abundant blocky, white, 1- to 2-mm-diameter plagioclase that generally comprises 20-40 % of the rock. Where bedrock is not exposed, this unit can be traced by the abundant white plagioclase crystals in the soil. This unit also contains pumice fragments generally less than 1 cm in diameter and breccia fragments ranging only up to 8 cm. This unit is locally absent along the northern map boundary and thickens southward from about 60 m to about 650 m in the Sugarloaf Mountain quadrangle.

Andesite flows composing the upper unit are fine-grained, phenocryst-poor andesite. Two large, representative exposures of the unit crop out in the Luke Mountain quadrangle, just north of the Deer Lodge quadrangle, and on Black Mountain in the Sugarloaf Mountain quadrangle. The rock breaks with a conchoidal fracture. In thin section, sparse plagioclase (most are extensively altered) and pyroxene phenocrysts occur in a matrix of interlocking, subrounded microlites. The unit thickens dramatically eastward and interfingers with both pyroxene basalt flows and the Golden Spike Formation (?) in the northeastern portion of the Baggs Creek quadrangle

Densely welded ash-flow tuff containing abundant lithic fragments overlies the upper fine-grained andesite in the northern part of the area, but because of poor exposures, similarity in color, and paucity of phenocrysts, it is mapped as part of the upper unit in the northern part of the area. Lithologically similar densely welded ash-flow tuffs are mapped as a distinct unit where one or more ash-flow tuffs are apparently interlayered with the poorly exposed basalt in the Deer Lodge and Baggs Creek quadrangles. In sec. 9, T. 8 N., R. 8 W., the approximately 40-m-thick ash-flow tuff unit is divided by a distinct broken and fractured subhorizontal zone. This belt of ash-flow tuff is laterally discontinuous but definitely lies stratigraphically above the ash-flow tuff in sec. 14 and 22, T. 8 N., R. 8 W. Small islands of ash-flow tuff that overlie basalt in the Baggs Creek quadrangle also have a pronounced fracture cleavage especially near their basal contacts with the basalt. In the Sugarloaf Mountain quadrangle, the ash-flow tuff unit contains relatively few lithic fragments and is distinguished from the basalts by (1) its red, brown, and gray colors versus the dark-gray and green of the basalts, (2) the presence of lithic fragments, and (3) rare pumice. Inferred relationships between the welded ash-flow tuff(s) and other volcanic units in the quadrangle are shown in Figure 2. An alternative explanation is that, where two distinct beds of welded ash-flow tuff occur at different stratigraphic/structural levels, they are a single 20-m-thick ash-flow tuff repeated by shallow-seated thrusts such as might occur as localized syndepositional slides with a detachment zone near the base of the ash-flow tuff.

Elkhorn Mountains Volcanics in the Deer Lodge quadrangle are extensively altered: plagioclase and pyroxene phenocrysts and crystals are altered to sericite, calcite, and chlorite. Plagioclase crystals are sparse in all units except the green crystal tuff. Albite twinning in sparse plagioclase crystals indicate an intermediate An content. Chemically, all of the Elkhorn Mountains Volcanics units are andesite except for the ash-flow tuff that is generally dacitic in the Deer Lodge and Baggs Creek quadrangles, but is more silicic in the Sugarloaf Mountain quadrangle. Although

ash-flow tuff samples selected for analysis appeared to be free of lithic fragments, analytical results suggest some accidental material from the underlying andesite and basalt units modified the chemistry.

- Kemtr Welded ash-flow tuff of Rock Creek** -- Consists of light-grayish-white tuff with dark-gray fiamme, medium-gray tuff with light-gray fiamme, and dense reddish-brown tuff in which fiamme are generally not discernable. All contain 4- to 5-mm-long plagioclase phenocrysts (generally 5-10 %, but may range up to 20 %) that average An₂₅ and are frequently fractured. Subhedral sanidine crystals (less than 5 %) are locally present and are as much as 3 mm long. Angular or bent anhedral crystals of biotite and a trace of hornblende form a small percentage of the phenocrysts. Eutaxitic texture is well developed. Rare lithic fragments may be as much as 1 cm in diameter. Fiamme which average 2 cm long and 0.5 mm thick, are commonly draped around crystal and lithic fragments and are recrystallized to quartz and feldspar intergrowths. Groundmass consists of a very fine-grained mosaic of intergrown quartz and feldspar that, in plane-polarized light, is darker than is the quartz-feldspar groundmass of pumice fragments. Contacts with overlying units are not exposed; however, the unit is more than 300 m thick.
- Kemt Welded ash-flow tuff** -- Brown to red-brown to red-gray to dark gray, crystal-poor (<5 %) containing abundant lithic fragments of the underlying andesite units. Variable colors are due to intensity or degree of welding. The welded ash flow tuff ranges up to 15-18 m thick. Where mapped as a separate unit, it appears to be a repeated section suggesting possible gravity sliding within the interval. Near the rarely exposed base of the tuff the unit has a well-developed eutaxitic structure and contains abundant, collapsed white pumice in a medium-gray matrix. Central parts of the tuff, which are reddish-brown to brown, are massive and lack eutaxitic structure. Exposures of the ash-flow tuff unit in the Deer Lodge and adjacent Baggs Creek quadrangles are densely welded. Identification of individual cooling units, if present, is not possible because of poor exposures and alteration. Collapsed pumice fragments occur as irregular white streaks in less densely welded portions near the base, below the densely welded portion of the unit. Because of limited exposures and the similarity of the welded ash-flow tuff to the fine-grained andesitic lava flows that crop out in the north-central and northeastern part of the map area, the two units are mapped together as Kemf in that part of the map area. Where the welded ash-flow tuff overlies basalt, the welded ash-flow tuff is mapped as a separate unit. Where two distinct beds of welded ash-flow tuff occur in the east-central part of the map area, they may be repeated by thrust faulting. A distinct broken and fractured zone is exposed between the two welded ash-flow tuff units.
- Kemf Andesitic lava flows, fine-grained** -- Medium- to dark-brown, dark-gray and dark-green, fine-grained, nearly aphyric lava flows. Limited exposures plus faulting precluded determination of the thickness of this unit in the Deer Lodge and adjacent quadrangles. Steep dips in flow-folded sections of the unit are common in some exposures, but the majority of attitudes indicate the unit was folded into relatively broad, north-south-trending, south-plunging folds. Dips of flow banding and the plunge of folds are generally <10 degrees. The contact with overlying basalts (Kba) in the northern part of the map area reflects these broad folds. Because of a paucity of phenocrysts and similarity in densely welded sections of welded tuff (Kemt), the fine-grained andesitic lava flows unit is mapped together with the welded ash-flow tuff unit. These two units immediately underlie basalt (Kba) in the north-central and northeastern part of the map area.
- Kemtb Tuff and tuff breccia** -- Dark-gray to green groundmass in a crystal lithic tuff that is easily distinguished by its 1- to 2-mm equidimensional, white plagioclase phenocrysts. Locally contains abundant lithic fragments up to 7 cm in diameter. Only limited exposures of this unit are found in the Deer Lodge quadrangle and the thickness is less than 60 m in this and immediately adjacent quadrangles. A unique feature of this unit is the occurrence of locally well-indurated and brecciated exposures in the north-central part of the area. The brecciation probably occurred following deposition, and in these well-indurated rocks, the breccia fragments are tuff with equidimensional white plagioclase phenocrysts. Matrix between fragments of the brecciated tuff

is similar but finer grained and almost completely lacking in equidimensional white plagioclase phenocrysts.

Brecciated, green, crystal-rich tuff crops out in small isolated exposures in the north-central part of the Deer Lodge quadrangle. The breccia fragments, which range up to 15 cm in diameter, are blocky, white plagioclase-crystal tuff surrounded by a tuff matrix containing smaller, less abundant, blocky, white plagioclase crystals. The origin of the tuff breccia is unknown although, because of the abundant plagioclase crystals similar to those in the green crystal tuff and its presence in the same stratigraphic position as the green crystal tuff, it is included in that unit.

Kemfb Andesite flows, flow breccia and tuff breccia – Dark-gray to purplish-gray, irregularly distributed, containing locally distributed white plagioclase phenocrysts that are typically flattened and irregular in shape and resemble rolled oats resulting in the field name "oatmeal andesite". Unconformably overlies the Kootenai Formation near the contact between the Tertiary Deer Lodge Valley sequence and the Cretaceous volcanic rocks in the north-central to northwestern part of the map area. The unit typically is deeply weathered and altered. The best exposures are found in the north-central to northwestern part of the map area. The matrix typically is dark-gray and sugary and it is difficult to distinguish volcanoclastic rocks from lava flows. Breccias within this unit are difficult to distinguish from the flows, and because of limited exposures, the relative proportions of flows to flow breccia and tuff breccia are unknown. Breccia fragments are volcanic with rare fragments from the underlying sedimentary units found near the basal contact. In the SE1/4 of sec. 35, T. 9 N., R. 9 W., cobbles as much as 15 cm in diameter from the lower limestone member of the Kootenai Formation exhibit baked margins where Kootenai Formation is unconformably overlain by the lower andesite member of the Elkhorn Mountains Volcanics.

Sedimentary Rocks

Kcc Carter Creek Formation -- Local exposures in small fault slices within the northern part of the Deer Lodge quadrangle. Consists of coarse-grained, salt-and-pepper, cross-bedded sandstone, white to pale-green tuffaceous beds, and beds of fine-grained, gray to brownish-gray limestone lenses up to 45 cm thick containing no visible fossils. Thickness is more than 500 ft.

Kbl Blackleaf Formation -- Fine- to medium-grained quartzose sandstone and quartz-pebble conglomerate exposed only along the western flank of the Boulder Batholith in the southeastern part of the Orofino Creek quadrangle where unit is metamorphosed. Contact-metamorphic minerals include minor amounts of skarn minerals suggesting this unit contained carbonate cement. Locally, hematite-rich pods and veins occur. Thickness is more than 200 ft.

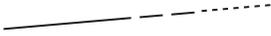
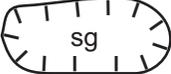
Kk Kootenai Formation -- Four recognizable lithologic units in the Deer Lodge quadrangle from the lowermost upward consist of (1) the lower calcareous member: dark-gray, white- and buff-weathering, micrite and minor dolomite; (2) the upper clastic member: interbedded green- to gray siltstone and shale and maroon siltstone and shale with interbedded lenses of micritic, dark-gray limestone; (3) the gastropod limestone member: a distinct gastropod limestone bed (only one bed was distinguished in any area and shale interbeds were not distinguished from the clastic member); and (4) an upper quartzite: a yellow-brown, medium- and fine-grained vitric quartzite and quartz arenite (A. B. French, personal communication, 1989). This uppermost unit is now considered to be the basal part of the Flood Member of the Blackleaf Formation (Dyman and others, 1994). Thicknesses of individual units were not determined.

JURASSIC

Jsw Swift Formation -- Medium- to light-gray, tan and pink chert-clast-rich sandstone that contains scattered chert pebble conglomerate lenses and beds with pebbles up to 2-3 cm in diameter. Contains secondary quartz veins that locally make up over 50% of the rock, particularly near

faults. The thickness of the Swift Formation was not determined. Thickness of the undivided Kootenai and Swift formations is about 800 ft.

MAP SYMBOLS

| | |
|---|--|
|  | Contact – dashed where approximately located, dotted where concealed |
|  | Fault – dashed where approximately located, dotted where concealed; ball and bar on downthrown side; dip of fault plane, where measured, shown as short tick line |
|  | Strike and dip of bedding planes in sedimentary rock or of foliation, such as flow banding or eutaxtic structure, in volcanic rocks; also includes closely spaced shear surfaces |
|  | Strike of vertical beds in sedimentary rocks or of foliation, such as flow banding or eutaxtic structure, in volcanic rocks |
|  | Horizontal bedding in sedimentary rocks |
|  | Strike and dip of joints |
|  | Strike of vertical joints |
|  | Occurrence of Mount Mazama ash (6,800 years old) |
|  | Younger pediment surfaces |
|  | Intermediate pediment surfaces |
|  | Older pediment surfaces |
|  | Mafic to intermediate dikes |
|  | Aplite dikes |
|  | Chalcedony and quartz veins and zones of silicified rock-- primarily from Derkey (1986 & 1987); Federspiel and Mayerle (1988); and Ruppel (1961) |
|  | Alteration zone |
|  | Gold placer tailings |
|  | Sand and gravel pit |

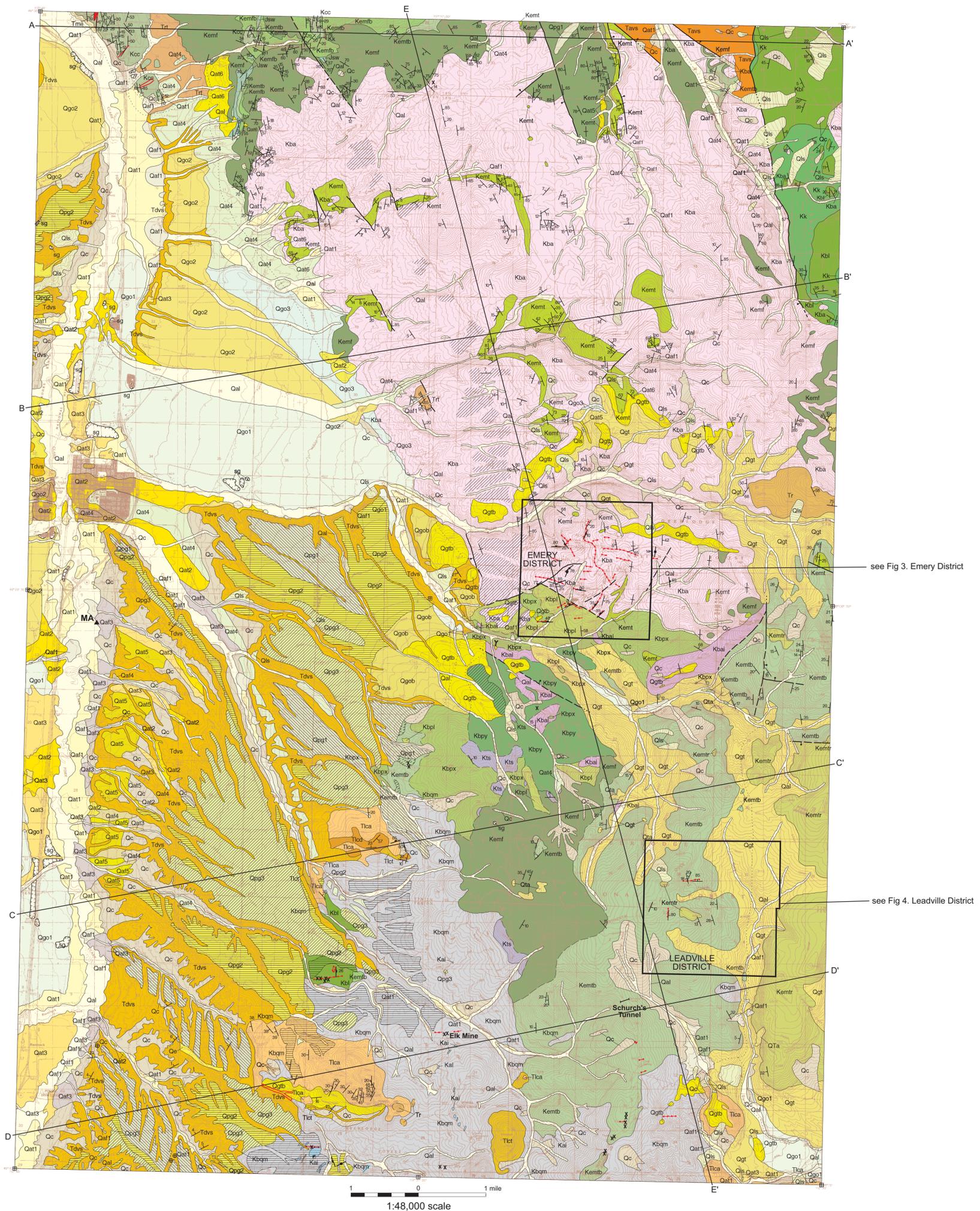
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see Fig 3. Emery District

see Fig 4. Leadville District

LEGEND

- MA** Occurrence of Mount Mazama ash (6,800 years old)
- Younger pediment surfaces
- Intermediate pediment surfaces
- Older pediment surfaces
- Mafic to intermediate dikes
- Aplite dikes
- Chalcedony and quartz veins and zones of silicified rock
- Placer gold workings
- Prospect pit
- Abandoned shaft
- Mine adit
- Sand and gravel pit

MAP UNITS

- | | | |
|---|---|--|
| Qal Alluvium of modern channels and flood plains | Qat6 Glacial channel deposit, third youngest | Kbqm Butte quartz monzonite and apfite |
| Qaf1 Alluvial fan deposit, youngest | Qgo3 Glacial outwash deposit, third youngest | Kts Tuff, siliceous |
| Qat1 Alluvium of youngest alluvial terrace level | Qgt Glacial till | Kba Basalt |
| Qat2 Alluvial fan deposit, second youngest | Qgp1 Pediment gravel deposit, youngest | Kbpx Basalt flows and flow breccias, large pyroxene basalt |
| Qat3 Alluvium of second youngest alluvial terrace level | Qgp2 Pediment gravel deposit, second youngest | Kbpy Basalt flows and flow breccias, small pyroxene basalt |
| Qaf3 Alluvial fan deposit, third youngest | Qgob Glacial outwash of Bull Lake glaciation | Kbpl Basalt flows and flow breccias, plagioclase basalt |
| Qat4 Alluvium of third youngest alluvial terrace level | Qgtb Glacial till of Bull Lake glaciation | Kbal Basalt flows and flow breccias, intrusive |
| Qaf4 Alluvial fan deposit, fourth youngest | Qgp3 Pediment gravel deposit, third youngest | Kemt Welded ash-flow tuff |
| Qc Colluvium | Tdvs Deer Lodge Valley basin sequence | Kentr Welded ash-flow tuff of Rock Creek |
| Qls Landslide deposit | Tavs Avon Valley basin sequence | Kerf Andesitic lava flows, fine-grained |
| Qe Eolian deposit | Trt Rhyolite tuff | Kemb Tuff and tuff breccia |
| Qta Talus deposit | Tlca Lowland Creek Volcanics, ash flow tuff | Kerf Andesite flows, flow breccia and tuff breccia |
| Qat4 Glacial channel deposit, youngest | Tlcl Lowland Creek Volcanics, dacite flows | Koc Carter Creek Formation |
| Qat5 Alluvial fan deposit, fifth youngest | Tlct Lowland Creek Volcanics, tuff | Kbl Blackleaf Formation |
| Qgo1 Glacial outwash deposit, youngest | Tr Rhyolite or rhyolitic sediment | Kk Kootenai Formation |
| Qat5 Glacial channel deposit, second youngest | Tm Mafic to intermediate intrusive rocks | Jw Swift Formation |
| Qgo2 Glacial outwash deposit, second youngest | Kai Aplite, intrusive | |

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Geologic Map of the Deer Lodge 15' Quadrangle, Southwest Montana

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