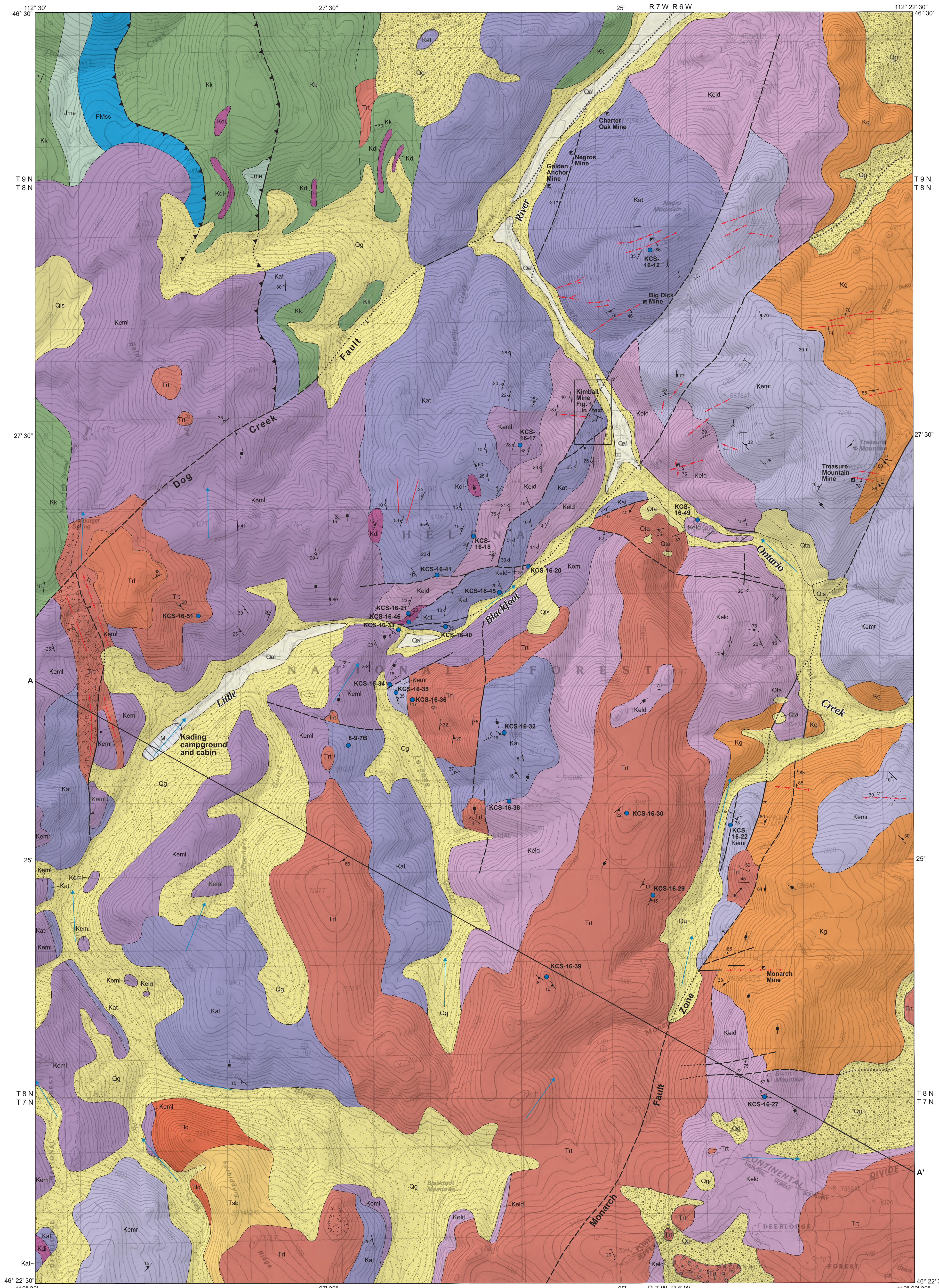


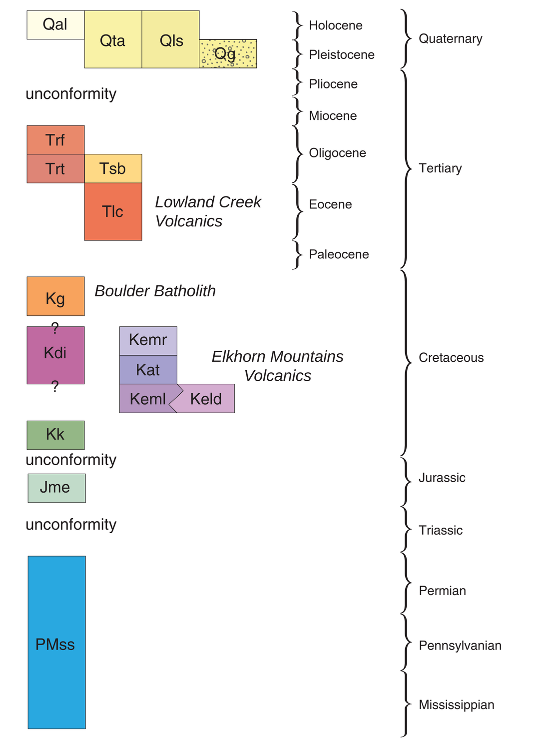
Base map produced by the United States Geological Survey
Bison Mountain 1:24,000-scale quadrangle map
Control by: USGS and NOS/NOAA
Compiled from aerial photographs taken 1980
Field checked: 1981 Map edited: 1985
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 1°02' West
1985 Magnetic North Declination: 17° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

Shaded relief created from 10 meter digital elevation model from U.S. Geological Survey National Elevation Dataset.

SCALE 1:24,000
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4174
http://mbmg.mtech.edu

CORRELATION DIAGRAM



MAP SYMBOLS

- Contact: dashed where approximately located (uncertainty >15 m); dotted where concealed
- Thrust fault: dashed where approximately located (uncertainty >15 m); dotted where concealed; teeth on upper plate
- High-angle fault: dashed where approximately located (uncertainty >15 m); dotted where concealed; arrow shows dip direction and magnitude
- Normal fault: dashed where approximately located (uncertainty >15 m); dotted where concealed; bar and ball on downthrown side
- Quartz veins, typically >0.5 m wide; arrow shows dip direction and magnitude
- Quartz stringers and veinlets, typically occur in zones <0.5 m wide
- Inferred direction of ice movement during the last Pleistocene glacial advance (Ruppel, 1962)
- Strike and dip of inclined flow banding
- Strike and dip of inclined compaction foliation
- Strike of vertically inclined compaction foliation
- Strike and dip of inclined rheomorphic foliation
- Bi-directional rheomorphic flow indicator
- Strike and dip of inclined joint
- Strike of vertically inclined joint
- Strike and dip of inclined bedding
- Sample location (see figs. 3 and 6, and table 1 in the pamphlet)
- Mine (see table 2 in the pamphlet)
- Adit
- Modified: Kading campground and cabin
- Breccia

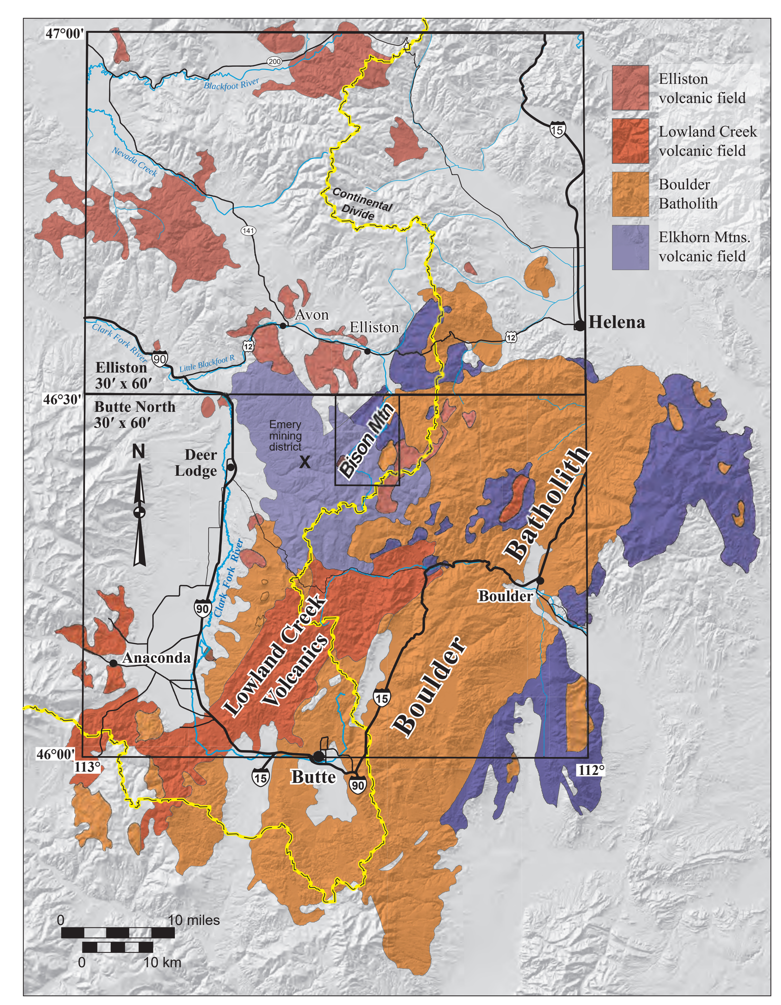
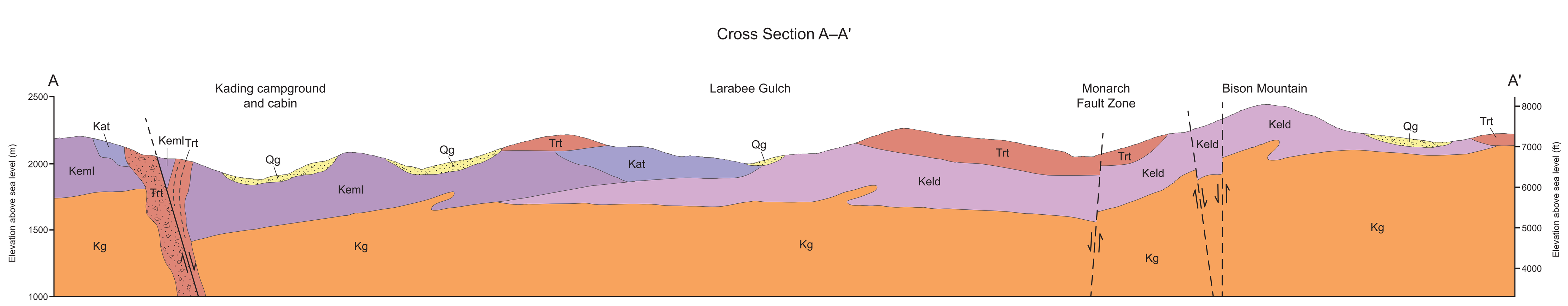


Figure 1. Location map. Geology after Vuke and others (2007), Elliston volcanic fields from Mosolf (2015).

Cross Section A–A'



No vertical exaggeration
Orientation of igneous compaction foliation

SCALE: 1:24,000

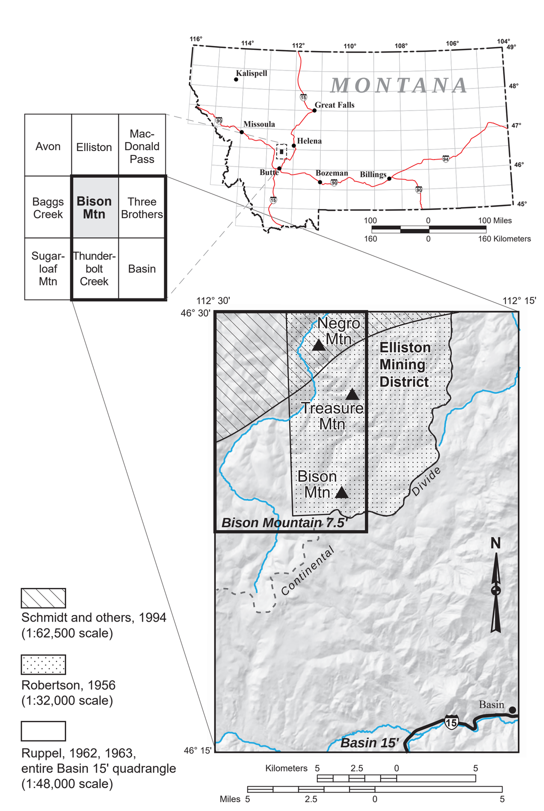


Figure 2. Index to previous mapping.

INTRODUCTION

The Bison Mountain 7.5' quadrangle is located in the Boulder Batholith along the Continental Divide 30 km (18 mi) west of Helena, and about 10 km (6 mi) south of Elliston in southwestern Montana (figs. 1 and 2). Late Cretaceous–Tertiary igneous rocks (fig. 3), including the Elkhorn Mountains Volcanic field (EMVF) (fig. 4), are exposed throughout the quadrangle. Steep-sided forested mountains with broad, gently sloping tops are conspicuous elements of the landscape. The quadrangle is accessed by the Little Blackfoot River Road, which follows the Little Blackfoot River drainage south from Highway 12 just east of Elliston (pop. 225). Most of the quadrangle lies in the Helena and Deer Lodge National Forests. Topographic elevation increases steadily from north to south, rising from less than 1,580 m (5,184 ft) along the Little Blackfoot River to greater than 2,335 m (7,661 ft) at the Continental Divide in the southwestern corner of the map.

Previous mapping

Previous workers examined all, or part, of the Bison Mountain 7.5' quadrangle (fig. 2). Robertson (1953) mapped the distribution of rock types and veins in the Elliston mining district. Ruppel (1962, 1963) mapped Pleistocene glacial deposits and geology of the Basin 15' quadrangle, respectively. Schmidt and others (1994) mapped the northwestern corner of the Bison Mountain 7.5' quadrangle during a study of fold-thrust belt deformation. In the late 1980s through the 1990s Homestake Mining Co. and Phelps-Dodge Co. contracted geologic mapping of mine workings at the Kimball Mine (fig. 4 in pamphlet), located north of the confluence of Ontario Creek with the Little Blackfoot River. The entire quadrangle is included on the 1:250,000 scale map by Lewis (1998).

See the pamphlet for the geologic summary, pamphlet figs. 1, 2, 3 and 4, tables 1 and 2, and references cited.

DESCRIPTION OF MAP UNITS

Sediments

Qal **Alluvium (Holocene)**—Well-sorted gravel, sand, silt, and clay along modern streams and floodplains. The unit is typically less than 3 m (10 ft) thick.

Qta **Talus alluvium (Holocene–Pleistocene)**—Rock fragments, usually coarse and angular, found at the base of cliffs and steep slopes.

Qls **Landslide deposits (Holocene–Pleistocene)**—Mass wasting deposits of clay- to boulder-size sediment. Includes rotated or slumped blocks of bedrock and surficial sediment, soils, and mudflow deposits. Thickness undetermined.

Qg **Glacial deposits (Pleistocene)**—Glacial deposits consist primarily of till and minor outwash deposits, probably of early Wisconsin age (about 25 Ka). These deposits were left by valley glaciers that occupied the Little Blackfoot River and Ontario Creek drainages. Since glaciation ended, frost action, mass-wasting, and related erosive processes have produced a variety of colluvial and residual accumulations including creep-and-solifluction deposits, stone-banked terrace deposits, protalus ramparts and associated rock streams, talus, landslides, and related forms (Ruppel, 1962).

Eocene–Oligocene volcanic and related rocks

Trf **Rhyolite flows (Oligocene)**—Grayish red purple to medium gray, very fine-grained to aphanitic, flow-banded rhyolite lavas. The lavas contain 10–15 percent crystals consisting of 1 to 2-mm-long sanidine, quartz, and sparse biotite. The lava sequence is exposed north and west of the Kading campground and cabin, in the west-central portion of the quadrangle. The lavas occur adjacent to a N–S-striking fissure characterized by coarse breccia and quartz veining. The fissure is continuous for about 3 km (2 mi) and may be the source of the lavas. The lava sequence is about 85 m (279 ft) thick.

Trt **Rhyolite tuff (Oligocene)**—White and gray to pink red purple, crystal-rich (10–30 percent) and glass-rich, non-welded to welded, rhyolite (76.81–80.35 wt. percent SiO_2; fig. 3, table 1 in pamphlet) tuff. The base of the tuff contains subangular to subrounded accidental and accessory lithic fragments up to 6 inches in diameter (Ruppel, 1963). The welded tuff north of the Blackfoot Meadows (sample KCS-16-39; fig. 2A in pamphlet) is moderate red or grayish red to light brown, contains about 5–10 percent smoky quartz in bipyramidal crystals and crystal fragments 1–2 mm long and a few percent sanidine in broken crystals 1–3 mm long, and is characterized by abundant completely flattened, crenulated pumiceous fragments and glass shards typically no more than 1 mm thick and 1 cm long (Ruppel, 1963). The tuff resembles a 39.2 Ma to 39.8 Ma (U-Pb on zircon) rhyolite described by Mosolf (2015) in the Elliston Volcanic field, located about 20 mi (32 km) north of the quadrangle (fig. 1). $^{40}Ar/^{39}Ar$ plateau ages of 37.43 ± 0.05 Ma (KCS-16-30) and 37.42 ± 0.05 Ma (KCS-16-36) were obtained for the vent (figs. 3A, 3B in pamphlet). A bi-directional rheomorphic flow lineation of N45°E was obtained from an outcrop of the tuff in the Monarch Fault zone, about 0.5 mi (0.8 km) north of the Monarch Mine (see map). The tuff is exposed over vast portions of the southern half of the quadrangle where it typically exhibits a gentle (~10°), south-dipping, compaction foliation (fig. 2A in pamphlet). The tuff sequence is up to 250 m (820 ft) thick.

Tsb **Breccia and coarse-grained sandstone (Oligocene)**—Dark greenish gray, poorly sorted fine-grained breccia and coarse-grained sandstone composed of angular fragments of Cretaceous and Tertiary volcanic rocks (Ruppel, 1963). The breccia is exposed at Forbidding Ridge, located in the southwestern corner of the map, where it is about 150 m (492 ft) thick.

Tlc **Rhyodacite lavas of the Lowland Creek volcanics (Eocene)**—Grayish red purple to medium gray, quartz-rich lavas and glasses that are thinly laminated and commonly interbedded with layers of breccia less than 1 m thick. Ruppel (1963) assigned these volcanic deposits to the 53–49 Ma Lowland Creek volcanics (Smedes, 1962; Smedes and Thomas, 1965; Dudas and others, 2010). The lava sequence is exposed at Forbidding Ridge in the southeastern corner of the quadrangle where it is about 100 m (328 ft) thick.

Late Cretaceous volcanic rocks and intrusions

The Boulder Batholith

Ruppel (1963) divided granitic rocks in the quadrangle into northern and southern masses based on subtle differences in mineralogy and grain size, differences that were not recognized here. The absolute age of the granite masses is unknown and both resemble Butte granite (Kg), which crystallized about 74 Ma to 76 Ma. Porphyritic diorite intrusive rocks (Kdi) predate the Butte granite (Kg), and postdate andesite–dacite rocks of the lower member EMVF (Keml and Keld). A diorite dike south of the Emery mining district has an age of 79.8 ± 1.9 Ma (Korzeb and others, 2018), and diorite sills on the east side of the batholith, near Boulder (fig. 1), are 80.0 ± 0.4 Ma (Olson and others, 2016) and 78.6 ± 0.17 Ma (Scarberry, 2016).

Kg **Butte granite (Late Cretaceous)**—Light to medium gray, or light brownish gray with a tint of pink. Outcrops are typically massive and jointed. Contains normal-zoned plagioclase (45–50 percent), orthoclase (20–30 percent), and quartz (5–10 percent) (Berg and Hargrave, 2004). Hornblende and biotite generally make up 15–20 percent of the rock and occur at a 1:1–1:2 ratio. The mafic minerals are largely altered to chlorite and epidote. Accessory minerals include apatite, chlorite, epidote, magnetite, sphene, and zircon (Ruppel, 1963). The granite occurs in the eastern half of the quadrangle and is discontinuously exposed, from north to south. Ruppel (1963) suggested that the northern granite mass is coarser (grain size of 0.5–2.0 mm vs. 0.5–1.5 mm) and lacks alkali feldspar crystals, 2–4 mm in length, which rarely occur in the southern granite mass. The granite near Butte has reported ages of about 74.5 Ma (Lund and others, 2002) and 76.3 Ma (Martin and Dilles, 2000).

Kdi **Diorite intrusive rocks (Late Cretaceous)**—Dark greenish gray or greenish gray to medium gray, and fine- to medium-grained, diorite intrusions. An andesitic sill (sample KCS-16-46; fig. 3, table 1 in pamphlet) exposed north of the Little Blackfoot River Road, near the center of the quadrangle, has conspicuous hornblende phenocrysts up to 3 cm long (fig. 2B in pamphlet) Some of the intrusive rocks contain 1 to 2-mm-long pyroxene phenocrysts. The unit also includes "oatmeal basalts" (e.g., Robertson, 1953) with oriented and rounded 2 to 5-mm-wide plagioclase phenocrysts that are up to 1 cm long (unit Kvbi of Ruppel, 1963). Plagioclase alignment in these rocks records flow during emplacement. A hornblende-bearing diorite intrusion located near the center of the quadrangle (KCS-16-46) has an age of 81.77 ± 0.12 Ma (fig. 3C in pamphlet).

The Elkhorn Mountains volcanic field

The EMVF (Klepper and others, 1957) covers 25,000 km^2 (9,650 mi^2) along the flanks and top of the Boulder Batholith north of Butte (fig. 1). The EMVF once formed a 4.6-km (2.9 mi) volcanic plateau at the height of Late Cretaceous volcanism (Smedes, 1966). Regional studies identified lower, middle, and upper EMVF sequences (Klepper and others, 1957; Smedes, 1966; Klepper and others, 1971). The lower EMVF is primarily basaltic andesite and dacite porphyry lavas and dome complexes (Olson and others, 2016). The middle EMVF consists of andesite pyroclastic deposits and several large-volume rhyolite ignimbrites (Scarberry and others, 2016; Smedes, 1966). The upper sequence contains volcanogenic sediments, interstratified tuff and tuff breccia, and pyroclastic water-laid deposits of volcanic origin. Only the lower and middle EMVF successions are exposed in the quadrangle.

Middle member of the Elkhorn Mountains volcanic field

Kemr **Rhyolite tuff and lava (Late Cretaceous)**—Rhyolite (77.53–77.65 wt. percent SiO_2; fig. 3, table 1 in pamphlet) deposits are crystal-rich (about 30 percent) ignimbrite that contains about 25 percent small, broken plagioclase crystals, and up to 5 percent, 1 to 2-mm-long, euhedral biotite crystals. South of Treasure Mountain, in the northeastern corner of the map, the unit is moderately welded and recognized by conspicuous 1 to 10-cm-long fiammé (fig. 2C in pamphlet). Ignimbrite is exposed in the Monarch Fault Zone, located about 1 km northwest of the Monarch Mine (see map, sample KCS-16-22). North of the Monarch Mine, a 1.3 km^2 (0.5 mi^2) ignimbrite roof pendant sits on Butte granite (Kg) and is cross-cut and brecciated by quartz veins. The ignimbrite unit may contain several discrete sheets, but they are difficult to recognize due to discontinuous exposure and alteration, particularly where they are intruded by granite (Kg). The ignimbrite is tentatively correlated with rhyolite ignimbrite B (Kemb), which is exposed on the east flank of the Boulder batholith (Prostka, 1966; Olson and others, 2016; Scarberry and others, 2017) and has an age of about 81.7 ± 0.8 Ma (Olson and others, 2016).

South of the Little Blackfoot River, near the mouth of Larabee Gulch (see map, sample KCS-16-35), blocks of pyroxene andesite (Keml) 2 m wide (fig. 2D in pamphlet) are entrained in a rhyolite lava flow. The size of the Keml blocks suggests that these rhyolite lavas are part of a small lava dome complex. The sequence is up to 300 m (984 ft) thick in the quadrangle.

Kat **Basaltic andesite–dacite breccia and welded tuff (Late Cretaceous)**—Greenish gray to black, poorly to moderately welded basaltic andesite–dacite (54.37–62.15 wt. percent SiO_2; fig. 3, table 1 in pamphlet) breccia, tuff, and minor debris flow deposits. Debris flow deposits contain chaotic, unsorted and dense, angular to subangular fragments of andesite and dacite clasts in an ash matrix. Breccia, tuff, and debris flows are laterally discontinuous. The base of the sequence is breccia that thins, from about 500 m (1,640 ft) at Negro Mountain (fig. 2), to about 300 m (984 ft) north of the Little Blackfoot River. The unit tapers out completely to the south and west (Robertson, 1956). At Negro Mountain, >10-cm-long breccia clasts (fig. 4A) are common. North of the Little Blackfoot River, towards Kading campground and cabin, breccia clasts are no longer than 5 cm and typically only 1 to 2-mm-long, and recognizable only with a hand lens. To the south and west, breccia clasts are sand-pebble size and reworked. These observations taken together suggest that Negro Mountain was a topographic high, perhaps a vent, where the breccia formed and fanned outwards to the south. The tuff sequence is moderately welded near its base and contains 30 percent broken plagioclase crystals and 5 percent altered mafic minerals. Conspicuous flattened pumice 7–10 cm long occur near the base of the unit. The tuff sequence is 100–200 m (328–658 ft) thick. Including breccia and tuff, the unit is about 550 m (1,804 ft) in total thickness.

Lower member of the Elkhorn Mountains volcanic field

Keld **Dacite lavas and dome complexes (Late Cretaceous)**—Dark brown to green, and white to medium gray andesite–dacite (62.44–65.40 wt. percent SiO_2; fig. 3, table 1 in pamphlet) lavas and domes, autobreccia lava flow margins, vitrophyre, and intercalated volcanogenic sediments. These rocks are often yellowish orange, and iron-oxide stained, due to either oxidation of disseminated fine-grained pyrite, or pyrite, along fractures. The texture of the rock varies considerably, from coarse-grained, porphyritic, and crystal-rich (30–35 percent) to fine-grained, and crystal-poor (<10 percent). Phenocrysts include plagioclase, augite, hornblende, minor biotite, and Fe-Ti oxides. Autobreccia occurs locally and is characterized by subangular dacite clasts that regularly transition abruptly to subrounded volcanogenic conglomerates, sands, and muds. Dacite units occur in the hills north and west of the Little Blackfoot River at its confluence with Ontario Creek. Dacite vitrophere is exposed along the southern half of Bison Mountain (see map, sample KCS-16-27) and along Ontario Creek near its confluence with the Little Blackfoot River (sample KCS-16-49). Plagioclase is typically 1–3 mm long and euhedral in the lavas, domes, and vitrophyre. Phenocrysts are broken and abraded in the fine-grained, intercalated sediments. This unit was mapped as a sill by Robertson (1956) but the presence of autobrecciated flow margins, ramp structures (fig. 3E in pamphlet), volcanogenic sediments, and vitrophyre indicate an extrusive origin. Trace fossils of what may be molds of incinerated, laterally transported tree trunks (fig. 2F in pamphlet) provide more evidence for an extrusive origin. The unit is at least 450 m (1,476 ft) thick.

Keml **Basaltic andesite–andesite lava flows and autobrecciated flow margins (Late Cretaceous)**—Dark brown to dark greenish gray basaltic andesite–andesite (62.44–65.40 wt. percent SiO_2; fig. 3 on map, table 1 in pamphlet) lavas and autobreccia. The lavas commonly form steep, resistant hillslopes. Two-pyroxene andesite lavas are most common. They contain 30–40 percent plagioclase phenocrysts, 1–3 mm long, and 5–10 percent pyroxene phenocrysts, 3–5 mm long. Sparse olivine (<1 mm) altered to fibrous amphibole (antigorite) was reported by Robertson (1953). Magnetite and apatite are the important accessory minerals. Amygdaloidal layers (fig. 4B) occur adjacent to, and within, autobrecciated flow margins. The lava sequence is exposed between Connors Gulch and Larabee Gulch, and to the north across the Little Blackfoot River road. The unit is at least 450 m (1,476 ft) thick.

Sedimentary rocks (Paleozoic–Mesozoic)

Sedimentary rocks are poorly exposed in the quadrangle, but occur over an area of about 8 km^2 (3 mi^2) in the northwestern corner of the map. The sedimentary rocks are mostly concealed by surficial debris and their thicknesses are not well known (Ruppel, 1963). Descriptions of these rocks and estimates of their thicknesses are compiled from Schmidt and others (1994) unless otherwise noted.

Kk **Kootenai Formation (Early Cretaceous)**—Red and green shale, siltstone, and feldspathic and lithic, coarse-grained sandstone that contains thin, discontinuous beds of light gray-weathering micrite, biomicrite, and biosparite. Discontinuous beds of pebble conglomerate occur at the base of the unit.

Jme **Morrison Formation (Late Jurassic) and Ellis Group, undivided**—Generally recessive, marine and locally non-marine succession characterized by a lower portion of thin-bedded, calcite-cemented, lithic arenite, sandy siltstone, siltstone, and shale yielding orange, red, tan, and dark gray, sandy siltstone regolith and an upper portion of thin- to medium-bedded, orange to red quartz arenite, thin-bedded siltstone, shale, and sandy micrite (Schmidt and others, 1994). Also contains discontinuous beds of light gray-weathering limestone. Rocks assigned to the Morrison Formation may consist entirely of olive gray and grayish olive mudstone (Ruppel, 1963). Total thickness is around 150 m (492 ft).

PMss **Shedhorn Formation and Phosphoria and Park City Formations (Permian), Quadrant Quartzite (Pennsylvanian) and Snowcrest Range Group (Early Pennsylvanian and Late Mississippian), Mission Canyon Formation (Mississippian), undivided**—May include gray and brownish gray, fine- to medium-grained quartzarenite at top; gray, dark gray, brownish gray, and pale brown, thinly interbedded oolitic phosphorite, phosphatic sandstone and shale and chert in middle; and gray, brownish gray, and yellowish gray limestone, cherty limestone, siltstone, and quartzarenite at bottom (Shedhorn Formation and Phosophoria and Park City Formations), Gray, tan, and rusty orange, thickly bedded, vitreous, fine-grained quartzarenite. Thin interbeds of light gray and tan siltstone, sandstone, and dolomite occur in lower part (Quadrant Quartzite), Red, reddish gray, and purplish gray shale, pinkish gray and tan siltstone, tan and pinkish weathering dolomite, and gray limestone. Locally has a red or yellow argillaceous, dolomitic breccia at base (Snowcrest Range Group). Thick to massively bedded, medium to dark gray, fossiliferous (rugose corals, sponges, and bioclastic hash) wackestone, packstone, and locally rudstone (Schmidt and others, 1994). Total thickness is around 75 m (246 ft).

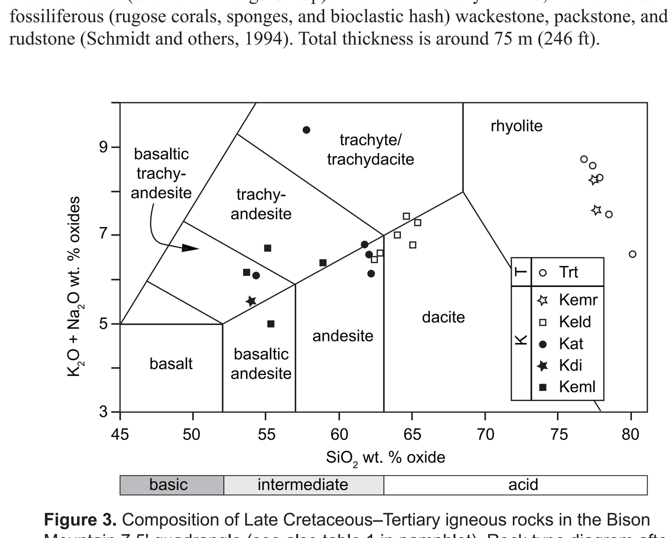


Figure 3. Composition of Late Cretaceous–Tertiary igneous rocks in the Bison Mountain 7.5' quadrangle (see also table 1 in pamphlet). Rock type diagram after classification by Le Bas and others (1986).

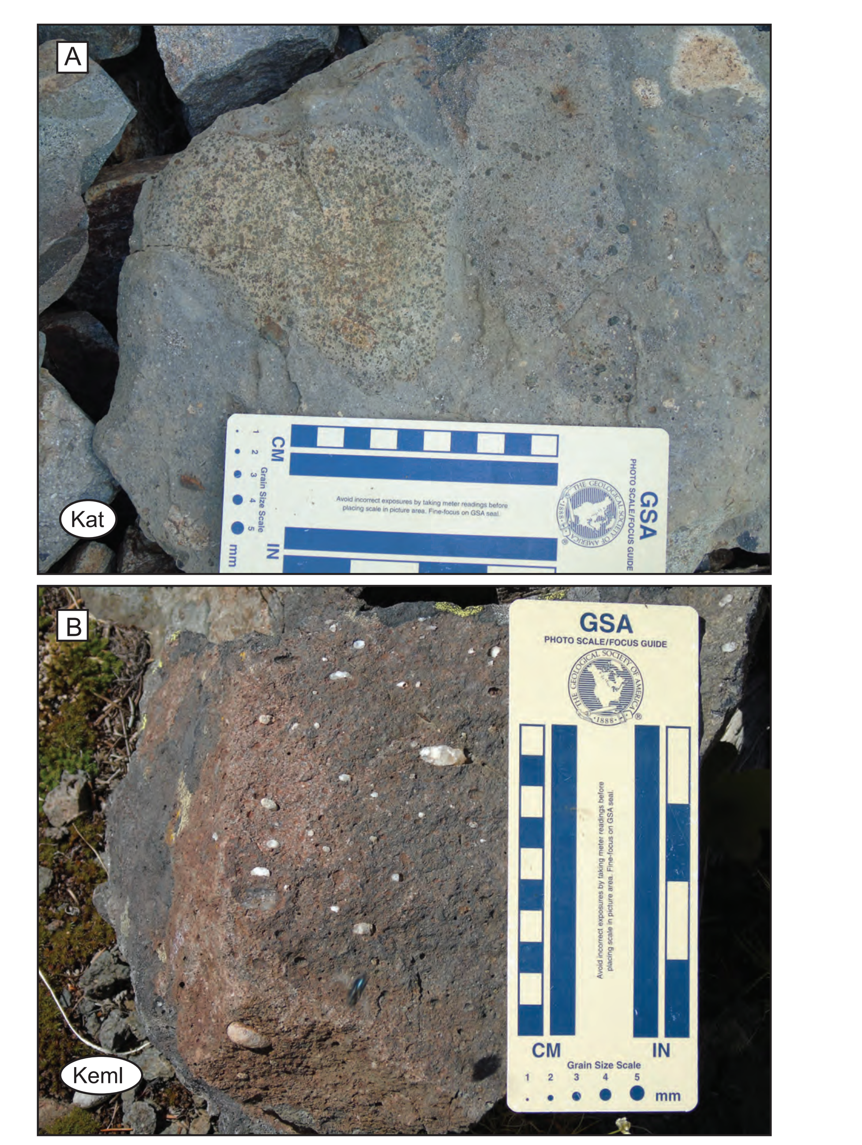


Figure 4. Rocks from the Late Cretaceous Elkhorn Mountains Volcanic field. **(A)** Coarse breccia deposits in the lower EMV (Kat). **(B)** Amygdaloidal lavas from the lower EMV (Keml).

Montana Bureau of Mines and Geology

Geologic Map 71

Geologic Map of the Bison Mountain 7.5' Quadrangle, Powell and Jefferson Counties, Montana

Kaleb C. Scarberry, Ethan L. Coppage, and Alan R. English

2018

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