Geologic Map of the

Austin 7.5´ Quadrangle

Central Montana

Mapped and Compiled

by

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Introduction

The Austin 7.5´ quadrangle is situated northwest of Helena and east of the Continental Divide, adjacent to the recently released Black Mountain 7.5´ quadrangle (Berg, 2009). Some of the bedrock geology for the southern part of the Austin quadrangle was taken directly from Knopf (1963) and from Schmidt and others (1994). Some structural interpretations differ from previous geologic maps with a reinterpretation of the stratigraphy of units in the Belt Supergroup and more detailed examination of several areas. Plutonic units are those described and mapped by Knopf with changes in names where appropriate to those now in common usage (Streckeisen, 1976). Colors are reported using the Munsell color scheme (Geological Society of America, 1995). Descriptions of Phanerozoic sedimentary rocks apply to those exposed in this quadrangle, which are almost without exception metamorphosed by plutons of the Boulder batholith.

Geologic Summary

The oldest rocks in this quadrangle are metasedimentary rocks of the Mesoproterozoic Belt Supergroup. In ascending order, the formations are the Spokane, Empire, Helena, Snowslip, Shepard, Informal Member 2 of the Mount Shields, and Informal Member 3 of the Mount Shields. The greenschist facies metamorphism recognized in these formations is thought to be regional metamorphism and not contact metamorphism caused by the Boulder batholith plutons. In ascending order, the Phanerozoic section consists of the Flathead Formation, Wolsey Shale, Meagher Formation, Park Shale, Hasmark Formation, Red Lion Formation, Jefferson Formation, Three Forks Formation, Madison Group, and Cretaceous and Jurassic sedimentary rocks undivided. The Flathead Formation rests on the Mount Shields Formation, Member 3, in the central part of the quadrangle and on the Shepard Formation in the southern part.

Structural geology within the Austin quadrangle is complex. The quadrangle lies within the north-trending, late Cretaceous to early Tertiary Sevier thrust belt, although only one short, east-directed thrust fault segment has been recognized in the quadrangle. An unusual west-directed reverse fault in the southeastern part of the map is probably also related to the thrust belt; it contains west-overturned beds in its footwall on the south adjacent Black Mountain quadrangle (Berg, 2009). Many west-northwest-striking faults cross the quadrangle and are thought to be related to the Lewis and Clark Line, a sinistral transpressive structure that formed

synchronously with Sevier thrusting and was later reactivated during Tertiary extension (Sears and Hendrix, 2004). The Bald Butte and Cherry Creek faults are representative of faults of the Lewis and Clark Line. Across the Cherry Creek fault, offset of the Flathead Formation is relatively minor in comparison to that of the Belt units. On the north side of the fault, the Flathead rests on the Mount Shields Informal Member 3, while on the south side it lies on the Shepard Formation. Therefore, the Cherry Creek fault must be a reactivated down-to-the-north Neoproterozoic or early Cambrian fault that was active before deposition of the Flathead Formation. Winston (1986) has proposed an east-west, down-to-the-north Mesoproterozoic growth fault for this area that explains the pre-Flathead movement on the Cherry Creek fault as well as the southward thinning of the Mesoproterozoic Shepard Formation (see Descriptions of Map Units).

Descriptions of Map Units in the Austin 7.5´ Quadrangle

M **Modified land** – Tailings along Silver Creek from past milling upstream

Qal **Alluvium of modern channels and flood plains –** Gravel, sand, silt, and clay along active streams that consists of locally derived clasts.

Qac **Alluvium and colluvium, undivided –** Mainly soil containing poorly sorted clasts from local formations that were deposited by sheetwash and to a lesser extent fluvial processes. Generally insufficient concentration of lithologies to make an inference as to underlying bedrock.

Qls **Landslide deposit –** Only one landslide has been recognized in this quadrangle and it is situated in sec. 21, T. 11 N., R. 5 W. where it was mainly developed on Mount Shields Member 3 and Mount Shields Member 2.

QTgr **Gravel deposits –** Remnants of what may have been widespread gravels, possibly of Tertiary age, that are preserved in some active stream valleys and on several ridges in the northern part of the quadrangle. Recognized in some areas by the occurrence of rounded cobbles scattered on the surface. Placer mining of this gravel for gold was accomplished along the north side of Greenhorn Creek.

Ts **Sediment or sedimentary rocks, undivided –** Poorly exposed tan mudstone, siltstone, and soft sandstone.

Tda **Dacite –** Dikes and large intrusive body north of Skelly Gulch. Crumbly exposures weather reddish brown with sparse quartz and K-feldspar phenocrysts in dense, fine-grained groundmass.

Klmo **Priest Pass leucomonzonite –** Monzonite that is almost devoid of quartz and contains about 9 percent hornblende and biotite.

Kqmo **Quartz monzonite –** Biotite adamellite of Knopf (1963). The plagioclase content is approximately equal to the K-feldspar content of this rock, which also contains biotite.

Kgdp **Porphyritic granodiorite –** The northernmost part of a large pluton that occupies much of the Black Mountain 7.5´ quadrangle to the south (Berg, 2009) is exposed in the southwestern part of the Austin 7.5´ quadrangle. This granodiorite is characterized by prominent euhedral K-spar megacrysts that range up to 3 cm in length. The average modal composition for this rock is 40 percent plagioclase, 24 percent alkali feldspar (K-feldspar), 24 percent quartz, 7 percent biotite, 3 percent hornblende, and a total of one percent for the accessory minerals magnetite, titanite, apatite, and zircon (Smedes and others, 1988).

Kng **Nonporphyritic granodiorite –** This rock type, similar in composition to the porphyritic granodiorite, is considered to be an equigranular equivalent of the prophyritic granodiorite (Knopf, 1963).

Kdi **Diorite –** Small diorite plug exposed on the north side of Greenhorn Creek that in part exhibits rhythmic layering in which hornblende layers up to 5 mm thick alternate with plagioclase-rich layers of similar thickness.

KJs **Cretaceous and Jurassic sedimentary rocks undivided –** Metamorphosed sedimentary rocks considered to be Jurassic and Cretaceous on the basis of comparison to unmetamorphosed rocks of this age to the east (Knopf, 1963). Light olive gray (5Y 5/2) to light gray (N6) medium-grained, feldspathic quartzite with prominent biotite porphyroblasts forms ledges and is the most prominent lithology of this unit. Subrounded detrital quartz grains are generally recognizable and fine-grained intergranular material is probably chlorite. Hornfels generally occurs only as float.

Mm **Madison Group, undivided –** The Madison Group is 400 m (1,300 ft) thick in this area and consists mainly of limestone (Knopf, 1963). Contact metamorphism has produced a crumbly sucrosic marble that forms gray to white (N8 to N9) outcrops. Actinolite is reported in the lower unit that is 90 m (300 ft) thick (Knopf, 1963).

MDt **Three Forks Formation –** The Three Forks Formation is 105 m (350 ft) thick and consists in ascending order of 75 m (240 ft) of green shale, 8-15 m (25-50 ft) of limestone, 10-30 m (35-90 ft) of blue-black shale, and 15 m (50 ft) of light-bluish-gray scapolite-diopside hornfels (Knopf, 1963). The most distinctive lithology is the scapolite - diopside hornfels that forms a low ridge composed of blocky outcrops with small grooves several millimeters thick and weathers orange (10R 6/6) to very pale orange (10YR 8/2). A fresh surface of this hard, flinty hornfels is very light gray (N 8). Dark gray (N3) chips of the blue-black shale poorly exposed next to this hornfels appear to lack evidence of metamorphism.

Dj **Jefferson Formation –** The Jefferson Formation is 230 m (750 ft) thick and consists of interbedded limestone and dolomite. Periclase and brucite formed by contact metamorphism in some of the dolomite has weathered out leaving many small cavities several millimeters across (Knopf, 1963). Coarsely crystalline calcitic marble weathers medium dark gray (N4) to dark gray (N3), forms rounded outcrops, and in some exposures contains light gray and dark gray streaks. The dolomitic marble is yellowish gray (5Y 8/1) and also forms rounded outcrops with local development of dolomite sand. The calcitic marble has a slightly fetid odor on a fresh fracture and the dolomitic marble has a stronger fetid odor.

Ꞓrl **Red Lion Formation -** The Red Lion Formation is 50 m (160 ft) thick and consists in ascending order of 6 m (20 ft) of thin-bedded calc-hornfels, 15 m (45 ft) of cordierite hornfels, and 305 m (100 ft) of interbedded limestone and dolomite. Crinkly filaments of chert occur in a zone 8-15 m (25-50 ft) thick in the upper limestone and dolomite unit (Knopf, 1963).

Ꞓh **Hasmark Formation –** The Hasmark Formation is 140 m (450 ft) thick and is an unusually pure dolomite as determined by 29 chemical analyses (Knopf, 1963). Contact metamorphism of the Hasmark Formation has produced sugary marble that forms rounded outcrops with splotchy gray and white surface; on a fresh surface marble is white (N9).

Ꞓp **Park Shale –** The Park Shale is 55-60 m (180-200 ft) thick (Knopf, 1963) and has been metamorphosed to a very hard cordierite-bearing hornfels that breaks with a conchoidal fracture. Color on a fresh surface is brownish black (5YR 2/1) and it is medium dark gray (N4) on a weathered surface. This formation is easily recognizable in outcrop in this area because of the small (several millimeters), white cordierite porphyroblasts in contrast to the dark hornfels.

Ꞓm **Meagher Formation –** The Meagher Formation is 195 m (640 ft) thick and where unmetamorphosed consists of pure limestone 85 m (280 ft) thick in the upper part and 110 m (360 ft) of thin-bedded siliceous dolomitic limestone below this (Knopf, 1963). Where metamorphosed, the lower diopside-calcite marble forms a distinctive surface where calcite has weathered out leaving lenticular solution pits 1-2 cm wide. Diopsidic layers are greenish gray (5G 6/1) and calcitic layers are very light gray (N8).

Ꞓw **Wolsey Shale –** The Wolsey Shale is estimated to be 40 m (130 ft) thick along the ridge between Nelson and Colorado Gulches in the Black Mountain quadrangle (Berg, 2009) where it is a hornfels, but not nearly as hard as the hornfels produced by metamorphism of the Park Shale. Color on a fresh surface is from greenish black (5GY 2/1) to brownish black (5Y 2/1).

Ꞓf **Flathead Formation –** The Flathead Formation ranges in thickness from 26 to 63 m (86 to 206 ft) in the Helena area (Knopf, 1963). Where metamorphosed, outcrops are strongly joint controlled and the weathered surface appears somewhat greasy. Individual rounded quartz grains are easily recognizable on both weathered and fresh surfaces; cross stratification is common. Color is grayish orange pink (5YR 7/2) to light brown (5YR 5/6) on a weathered surface and white (N9) on a fresh surface.

Yms3 **Mount Shields Formation, Informal Member 3 –** Red quartzite to argillite couples and couplets with abundant mudcracks, mudchips, and diagnostic, well-formed cubic salt casts. Includes green interbeds and some red microlaminae. Complete section not exposed in the map area, but as much as 220 m (700 ft) thick. Not present in southern part of the map area where the Cambrian Flathead Formation rests on units beneath the Mount Shields Formation.

Yms2 **Mount Shields Formation, Informal Member 2 –** Pink to gray, flat-laminated to crossbedded, fine- to medium-grained quartzite. Contains some tan-weathering dolomite lenses. Mostly flat laminated, but contains some cross beds. Thickness 0-180 m (0-580 ft). Not present in the southern part of the map area where Cambrian Flathead Formation rests on units beneath the Mount Shields Formation.

Ysh **Shepard Formation –** Dolomitic and non-dolomitic, dark green siltite and light green argillite in microlaminae and couplets, and lenticular couplets of white quartzite and green siltite. Poorly exposed, but weathers into thin plates. Dolomitic beds have a characteristic orange brown weathering rind. Ripples and load casts are common, and mudcracks are rare. In the northern part of the map area, the upper half contains intervals of pink to gray fine-grained feldspathic quartzite. Top 50 m (160 ft) contains distinctive rose-colored dolomitic siltite-argillite couplets. Thickness varies from approximately 250 m (800 ft) in the southern part of the map area to 830 m (2700 ft) in the north, possibly as a result of an east-west-striking Mesoproterozoic growth fault (Winston, 1986). In the southern part of the map area, pre-middle Cambrian erosion has removed the upper part of this formation.

Ysn **Snowslip Formation –** Interbedded intervals of quartzite to red argillite couplets, and dark green siltite to light green argillite couplets and microlaminae. Desiccation cracks and mud rip-up clasts are common throughout. Contains beds and lenses of distinctive white quartzite that consists of well-sorted, well-rounded, coarse, frosted quartz grains. Lower 50 m (160 ft) dominated by microlaminated green dolomitic siltite and argillite. Faulting precludes thickness estimate of total thickness, but at least 685 m (2,180 ft) thick.

Yh **Helena Formation –** The upper 300 m (1,000 ft) consists of dark gray limestone interbedded with dark gray calcareous argillite. Below this interval, the Helena Formation is characterized by cycles consisting of a basal clastic zone of tan to gray siltite and fine-grained quartzite, overlain by tan dolomite, and capped by dark gray argillaceous limestone (Schmidt and others, 1994). Molar-tooth structure, non-polygonal crinkle cracks, and recessive weathering calcitic pods are common. The Helena Formation is reported to be 1,220 m (3,900 ft) thick in this area (Schmidt and others, 1994).

Ye **Empire Formation –** Consists of calcareous and dolomitic grayish green, medium green, and light green argillite and siltite. Some calcareous and dolomitic beds contain stromatolites. Thickness is reported to be 300 m (1,000 ft) (Schmidt and others, 1994).

Ys **Spokane Formation –** Grayish red, dark greenish red, and purplish red argillite and siltite in microlaminae and couplets. Dessication cracks and mud rip-ups are common. Thickness is 1,000 m (3,200 ft) (Schmidt and others, 1994).

Acknowledgments

Reviews by Phyllis Hargrave, Katie McDonald, Colleen Elliot, John Metesh, and Ed Deal have improved both map and text and are appreciated.

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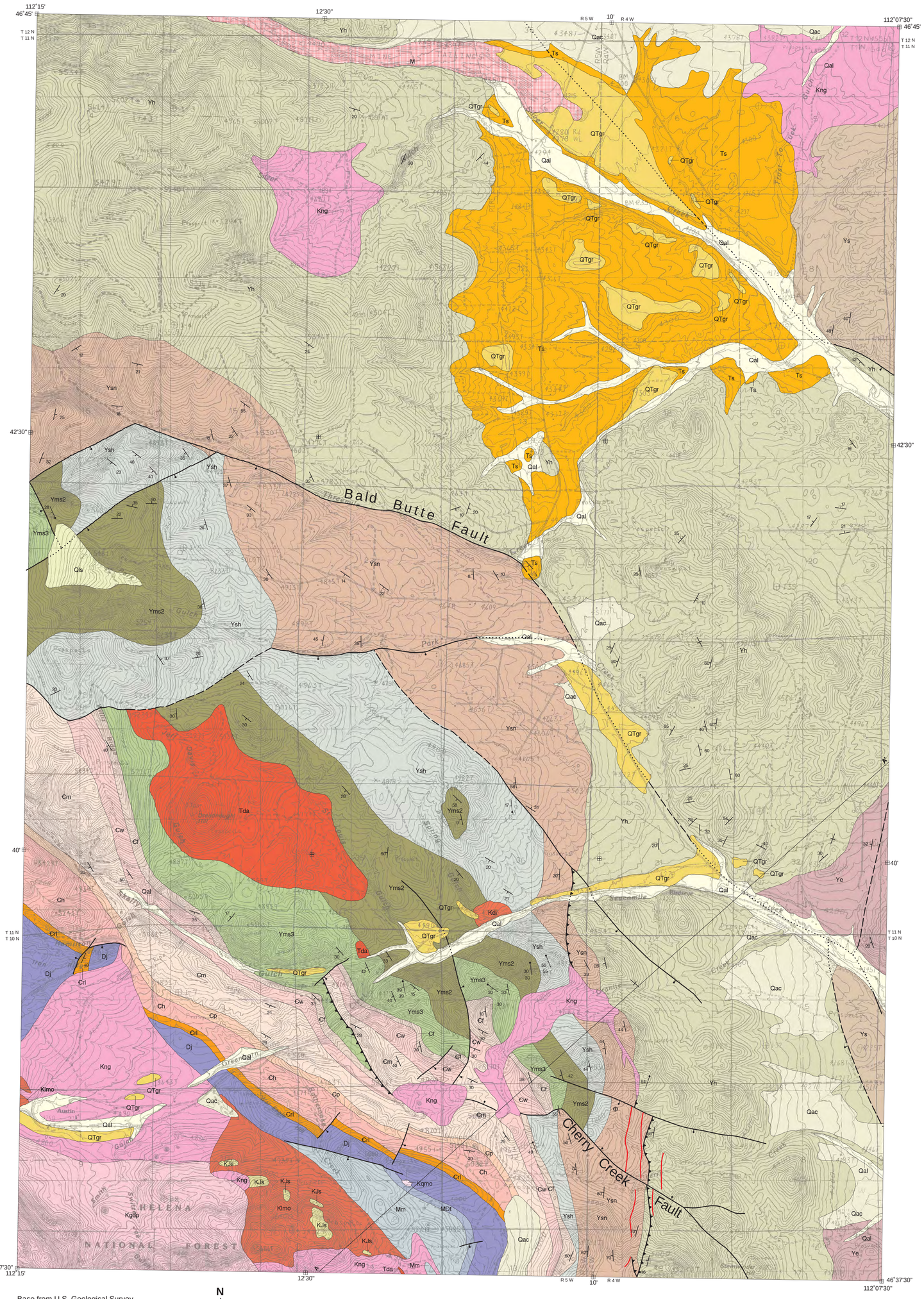
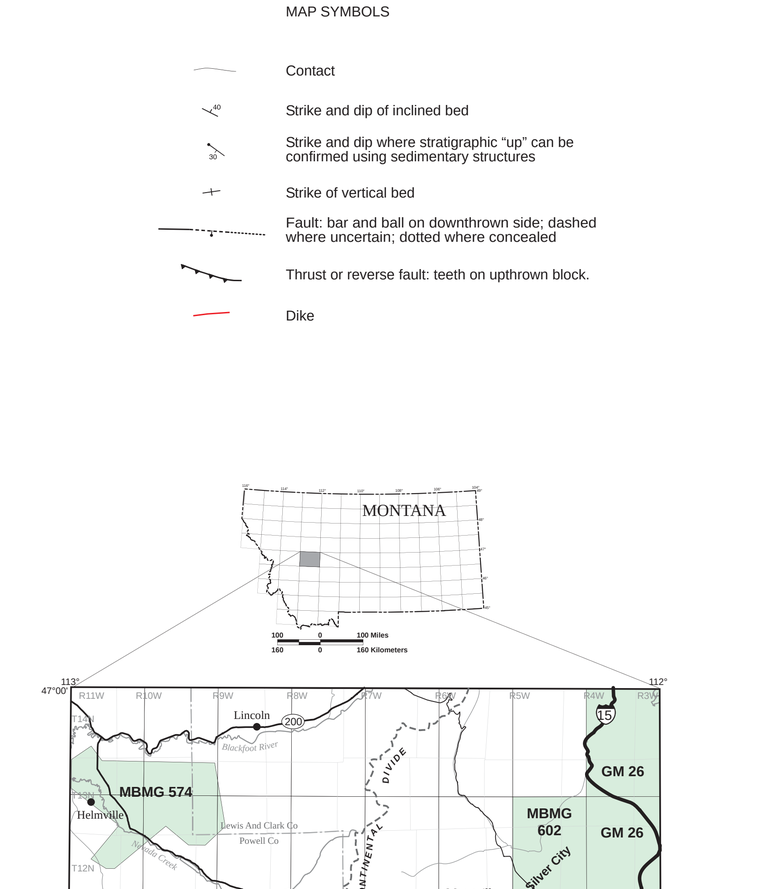


MAP UNITS

M	Modified land	
Qal	Alluvium of modern channels and flood plains	Quaternary
Qac	Alluvium and colluvium, undivided	Quaternary
Qls	Landslide deposit	Quaternary
QTgr	Gravel deposits	Tertiary
Ts	Sediment or sedimentary rocks, undivided	Tertiary
Tda	Dacite	Tertiary
Klmo	Priest Pass leucomonzonite	Cretaceous
Kqmo	Quartz monzonite	Cretaceous
Kdgp	Porphyritic granodiorite	Cretaceous
Kng	Non porphyritic granodiorite	Cretaceous
Kdi	Diorite	Cretaceous
KJs	Sedimentary rocks, undivided	Jurassic
Mm	Madison Group, undivided	Mississippian
MDt	Three Forks Formation	Devonian
Dj	Jefferson Formation	Devonian
Crl	Red Lion Formation	Cambrian
Ch	Hasmark Dolomite	Cambrian
Cp	Park Shale	Cambrian
Cm	Meagher Formation	Cambrian
Cw	Wolsey Shale	Cambrian
Cf	Flathead Formation	Cambrian
Yms3	Mount Shields Formation, third member, informal	Mesoproterozoic
Yms2	Mount Shields Formation , second member, informal	Mesoproterozoic
Ysh	Shepard Formation	Mesoproterozoic
Ysn	Snowslip Formation	Mesoproterozoic
Yh	Helena Formation	Mesoproterozoic
Ye	Empire Formation	Mesoproterozoic
Ys	Spokane Formation	Mesoproterozoic

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

CORRELATION DIAGRAM

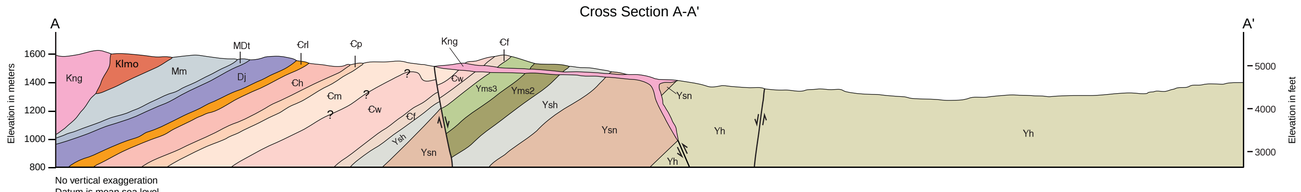


MAP SYMBOLS

- Contact
- 40 — Strike and dip of inclined bed
- 30 — Strike and dip where stratigraphic "up" can be confirmed using sedimentary structures
- Strike of vertical bed
- Fault: bar and ball on downthrown side; dashed where uncertain; dotted where concealed
- Thrust or reverse fault: teeth on upthrown block.
- Dike

Figure 1. Location map of the Austin 7.5' quadrangle. Completed maps (MBMG 403 574, 587, and 602, and EDMAP 1) are available at the Montana Bureau of Mines and Geology Publications Office and online at ***www.mbmg.mtech.edu***. GM 26 is only available in paper format.

Cross Section A-A'



No vertical exaggeration
Datum is mean sea level
Note: For clarity surficial units and QTgr are not shown

Revised	Date
Map & cross section by Jeff Lonn	7/13

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Maps may be obtained from: Publications Office
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