2006

Bedrock and Surficial Geologic Map of the Red Rock 7.5' Quadrangle, Beaverhead County, Southwestern Montana

Daryn Reyman-Lock
Sacred Heart University

Christine A. Regalla

David J. Anastasio

Frank J. Pazzaglia

Bedrock and Surficial Geologic Map of the Red Rock 7.5' Quadrangle, Beaverhead County, Southwestern Montana

Mapped and compiled by:

Christine A. Regalla, Daryn K.S. Reyman, David J. Anastasio, and Frank J. Pazzaglia

Earth and Environmental Sciences Department
Lehigh University, Bethlehem, PA

Montana Bureau of Mines and Geology
Open File Report 533

2006

Support has been provided by the EDMAP Program of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey under Contract Number 05HQAG001

Introduction

The Red Rock 7.5 minute quadrangle, located in Beaverhead County, southwestern Montana, spans the Red Rock River Valley, an extensional graben formed between the Tendoy mountain front and the western flank of the Blacktail-Snowcrest uplift (Fig. 1). Notable landmarks within the quadrangle include the Clark Canyon Reservoir (Bureau of Reclamation dam number MT00569) located in the northwest area of the quadrangle and Interstate 15 which runs northwest-southeast through the quadrangle. The highest elevations in the map area are located within the Tendoy Mountains and the Red Rock Hills and are underlain by Paleozoic and Cenozoic bedrock. From these points, broad alluvial fans grade down to the Red Rock River Valley. The quadrangle contains about 3,000 ft of relief.

Mapping of the Red Rock quadrangle was done at a scale of 1:12,000 and was compiled at a scale of 1:24,000. Field work was completed in the summer of 2005 in collaboration with the mapping of the adjacent Briggs Ranch and Kidd quadrangles (Figs. 1 and 2). This strategy allowed for the comparison of structure and stratigraphy across quadrangle boundaries and provided a regional context for the mapping of each quadrangle. This new mapping complements previous mapping of the Monument Hill quadrangle (Newton and others, 2005), Dixon Mountain quadrangle (Harkins and others, 2004b), Caboose Canyon quadrangle (Harkins and others, 2004a), and Dell quadrangle (Aschoff and Schmitt, 2005) and collectively provides new detailed mapping and analysis of a portion of the Red Rock River Valley from Lima to the Clark Canyon Dam (Figs. 1 and 2). This report includes a map and cross section for the Red Rock quadrangle as well as a discussion of the stratigraphy and structure of the map area.

Key Contributions

Mapping of the Red Rock quadrangle supports previous mapping at a scale of 1:25,000 by Scholten and others (1955) and more recent mapping compiled at a scale of 1:100,000 by Lonn and others (2000). It contributes to the understanding of the geology of the area by subdividing previously grouped formations and by refining the extent and location of the Monument Hill fault system at a larger map scale. The Tendoy Group, the Snowcrest Range Group, and the Beaverhead Group have been subdivided into formations and members based upon previously published studies (Sando and others, 1985; Wardlaw and Pecora, 1985; Haley and Perry, 1991; Schmitt and others, 1995). Subdivision of the Tendoy and Snowcrest Range Groups aids in the recognition of imbricate thrusts within the McKenzie thrust sheet. Subdivision of the Beaverhead Group has revealed outcrops of limestone conglomerate and a mixed lens conglomerate in areas that have previously been mapped as quartzite conglomerate (Lonn and others, 2000) and has identified an andesitic to dacitic volcanic unit located stratigraphically between the limestone and quartzite conglomerate members. New mapping of the Red Rock quadrangle has also delineated the presence of both the Sixmile Creek and Renova Formations in the northern half of the quadrangle and has remapped Beaverhead outcrops in the northern segment of the quadrangle as Sixmile Creek Formation, based on the presence of volcanic clasts and interbedded rhyolites and basalts. Lastly, subdivision of Quaternary alluvial fans and detailed mapping of the Monument Hill fault system have provided refinements of the location, extent, total offset, and timing of offset of three fault strands, including a newly identified strand located 1.25 miles (2 km) southeast of the Clark Canyon Dam.

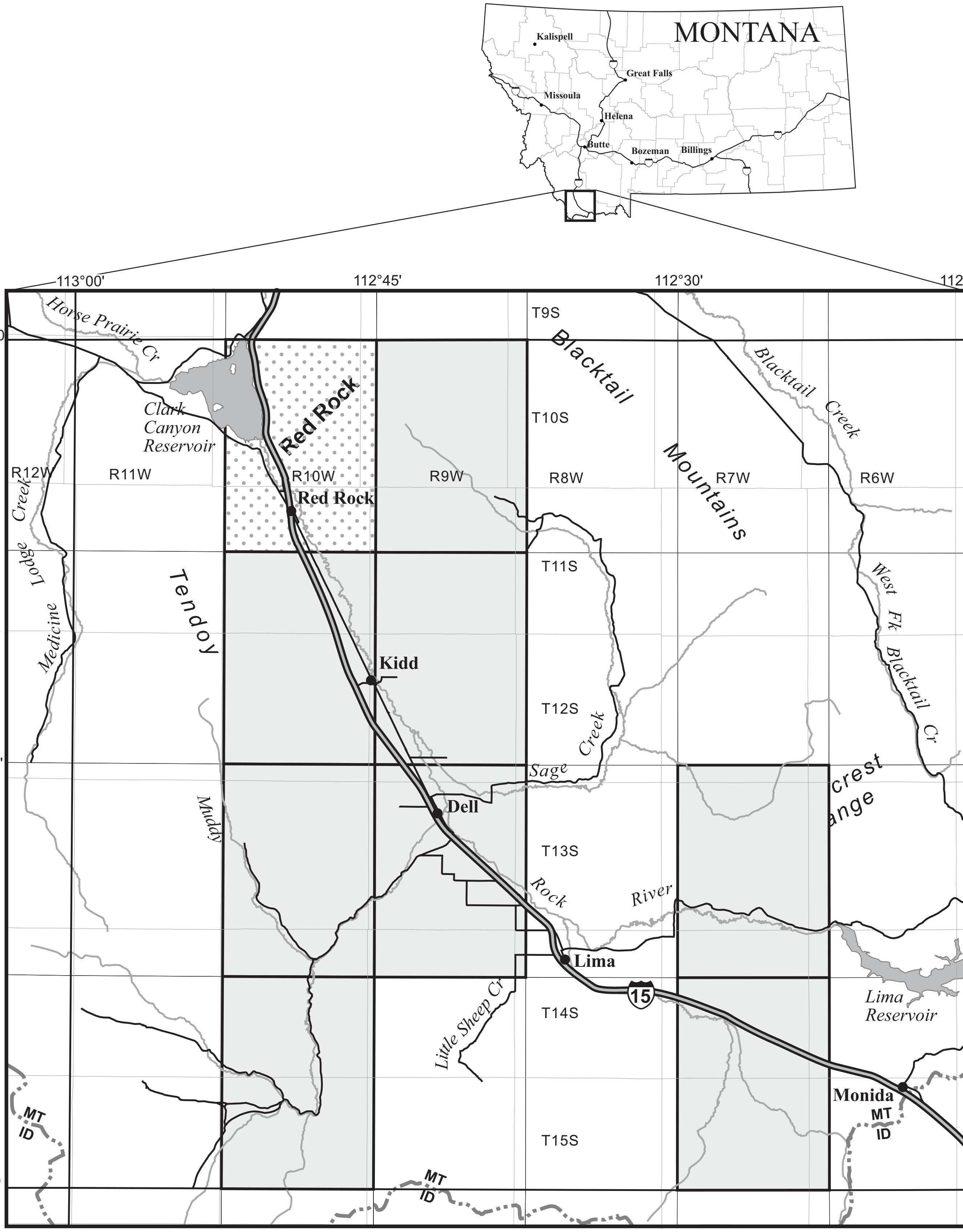


Figure 1. Location map for Red Rock 7.5' quadrangle, showing relationship to other completed or in-progress quadrangle maps in the area. See web site (www.mbmg.mtech.edu) for status of maps.

Digital topography of the Red Rock Valley

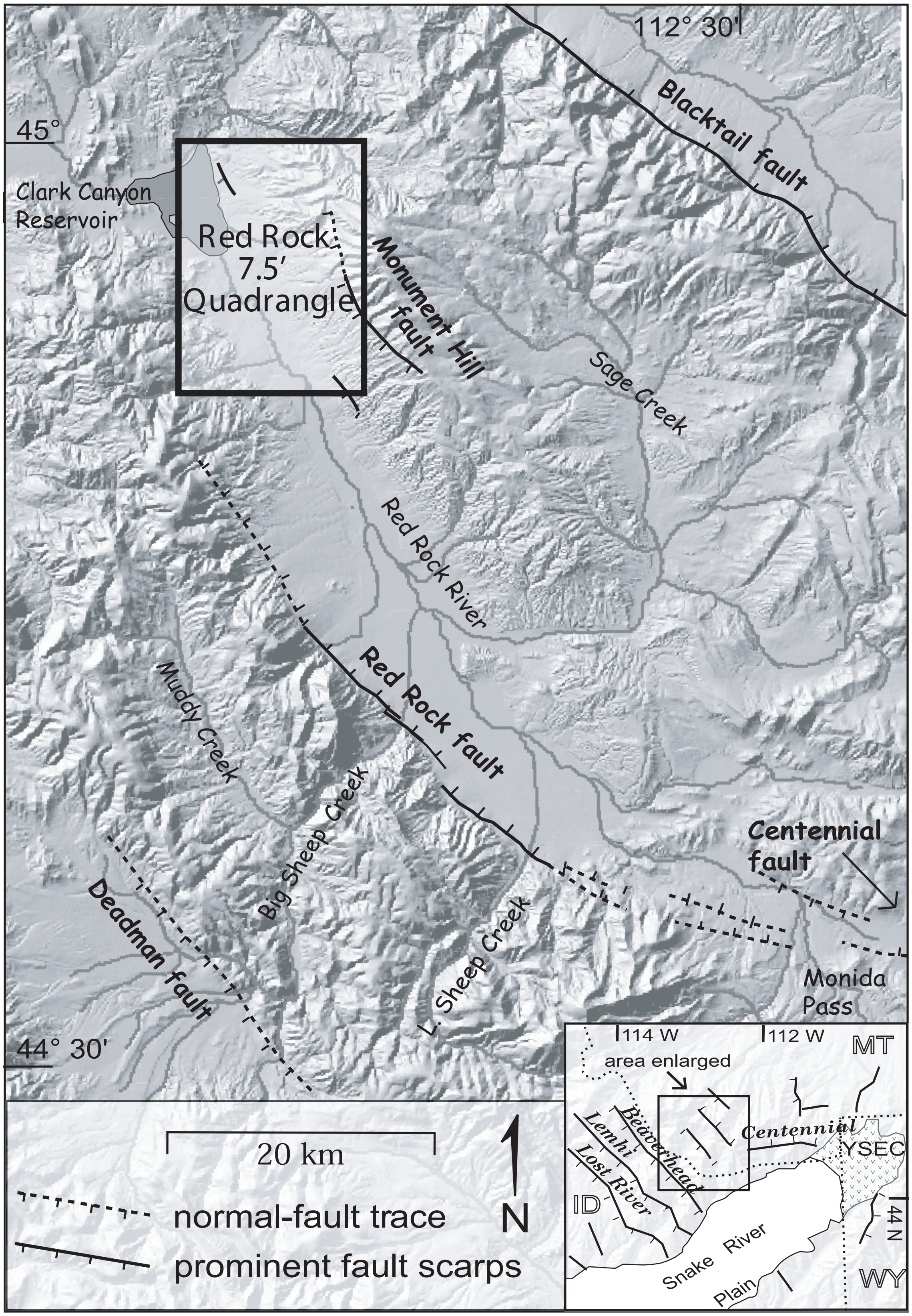


Figure 2. Digital Elevation Model (DEM) of the Red Rock valley showing location of the Red Rock 7.5′ quadrangle. Mapped fault traces and scarps, and notable streams and rivers are labeled for reference. Inset shows regional tectonic setting.

Comparison with Adjacent 7.5' Quadrangles

The Red Rock quadrangle shares its eastern border with the Monument Hill quadrangle (Newton and others, 2005) and its southern border with the Kidd quadrangle (Wilson and Schmitt, in progress) (Fig. 1). Different naming conventions have been used for some units within these adjacent quadrangles due to different styles of outcrop. In the Monument Hill quadrangle, the Qafo (Alluvial fan deposit, older) of Monument Hill correlates to the Qaf4 (Alluvium of oldest alluvial fan deposits) of Red Rock, and the Qafy (Alluvial fan deposit, younger) of Monument Hill corresponds to the Qaf3 and Qaf2 (Alluvium of the third and second youngest alluvial fan and associated alluvial channel deposits) of Red Rock (Table 1). In the Kidd quadrangle, the Qal (Alluvium) correlates to both the Qal (Alluvium) and Qalo (Older alluvium) units in the Red Rock quadrangle. Additionally, while in the Kidd quadrangle the units Mmc (Mission Canyon Formation) and Mmck (McKenzie Canyon Formation) are mapped both as individual units and as the combined Mmm (McKenzie Canyon and Mission Canyon Formations, undivided), within the Red Rock quadrangle, the Mission Canyon and McKenzie Canyon Formations are everywhere mapped as Mmm (Table 1).

<table>
<tr><th>Monument Hill</th><th>Red Rock</th><th colspan="2">Kidd</th></tr>
<tr><td>Qafo</td><td>Qaf4</td><td colspan="2">Qaf4</td></tr>
<tr><td>Qafy</td><td>Qaf3, Qaf2</td><td colspan="2">Qaf3, Qaf2</td></tr>
<tr><td>-------</td><td>Ppp</td><td colspan="2">Pp</td></tr>
<tr><td rowspan="2">-------</td><td rowspan="2">Mmm</td><td rowspan="2">Mmm</td><td>Mmck</td></tr>
<tr><td>Mmc</td></tr>
</table>

Table 1. Stratigraphic correlation of units mapped within the Red Rock 7.5′ quadrangle compared to units mapped within the Monument Hill and Kidd 7.5′ quadrangles.

Stratigraphy

The stratigraphy of the Red Rock quadrangle can be divided into the Paleozoic units of the frontal foreland Sevier thrust sheets and the Mesozoic to Cenozoic synorogenic conglomerates, paleovalley fill deposits, and alluvium of the Red Rock Hills (Figs. 3, 4 and 5). A conformable sequence of Mississippian through Permian carbonates and siliciclastics deposited on the North American passive margin are imbricated in the frontal thrusts of the Sevier thrust belt now exposed in the easternmost Tendoy Mountains in the McKenzie and Tendoy thrust systems. These units include the Tendoy Group (Sando and others, 1985), the Snowcrest Range Group (Wardlaw and Pecora, 1985), the Quadrant Sandstone, and the Phosphoria and Park City Formations, undivided (Cressman and Swanson, 1964). The Paleozoic units are unconformably overlain by the Cretaceous and Tertiary Beaverhead Group, a synorogenic conglomerate deposited in Sevier wedge top and foreland basins (Ryder and Scholten, 1973; Haley, 1986; Haley and Perry, 1991; Schmitt and others, 1995). The Beaverhead Group is unconformably overlain by two generations of Tertiary valley-fill deposits, the Eocene and early Miocene Renova Formation, and the mid-Miocene and late-Pliocene Sixmile Creek Formation (Kuenzi and Fields, 1971; Fields and others, 1985; Sears and Hurlow, 1995; Newton and others, 2005). Quaternary units dominate much of the low elevations in the quadrangle and include multiple generations of river alluvium, alluvial fans, colluvium, and landslide deposits (Harkins and others, 2005; Lonn and others, 2000).

Where possible, the Tendoy and Snowcrest Range Groups have been subdivided into the formations described in Sando and others (1985) and in Wardlaw and Pecora (1985). The Tendoy Group in the McKenzie thrust system (Fig. 3) locally consists of deeper water carbonates with interbedded fossiliferous and chert-rich horizons. These carbonates are regionally correlated to shallower-water carbonates of the Tendoy Group in other thrust sheets (Sando and others, 1985; McDowell 1992). Within the McKenzie thrust sheet, the Tendoy Group is divided into the Paine Limestone (not exposed in the Red Rock quadrangle), the Middle Canyon Formation, the Mission Canyon Formation, and the McKenzie Canyon Limestone. However, because of the lithologic similarity between the Mission Canyon and McKenzie Canyon Formations, and the inability to definitively recognize the McKenzie Canyon Formation outside of its type section at Bell Canyon (Sando and others, 1985), these two formations have been mapped as a single unit. The Snowcrest Range Group (Fig. 3) consists of subtidal to supratidal carbonates, evaporates, and siliciclastics deposited as a transgressive sequence on the North American margin (Wardlaw and Pecora, 1985). The group is subdivided within the Red Rock quadrangle into the Kibbey Sandstone, the Lombard Limestone, and the Conover Ranch Formation. Outside of the Tendoy Mountains, to the northeast of the Red Rock quadrangle, the Conover Ranch is late Mississippian and early Pennsylvanian in age (Wardlaw and Pecora, 1985). However, within the Red Rock quadrangle, only late Mississippian fossils have been found in the Conover Ranch Formation, making its age here only late Mississippian (Sando and others, 1985).

Stratigraphic Column of Paleozoic Units Mapped within the Red Rock 7.5' Quadrangle

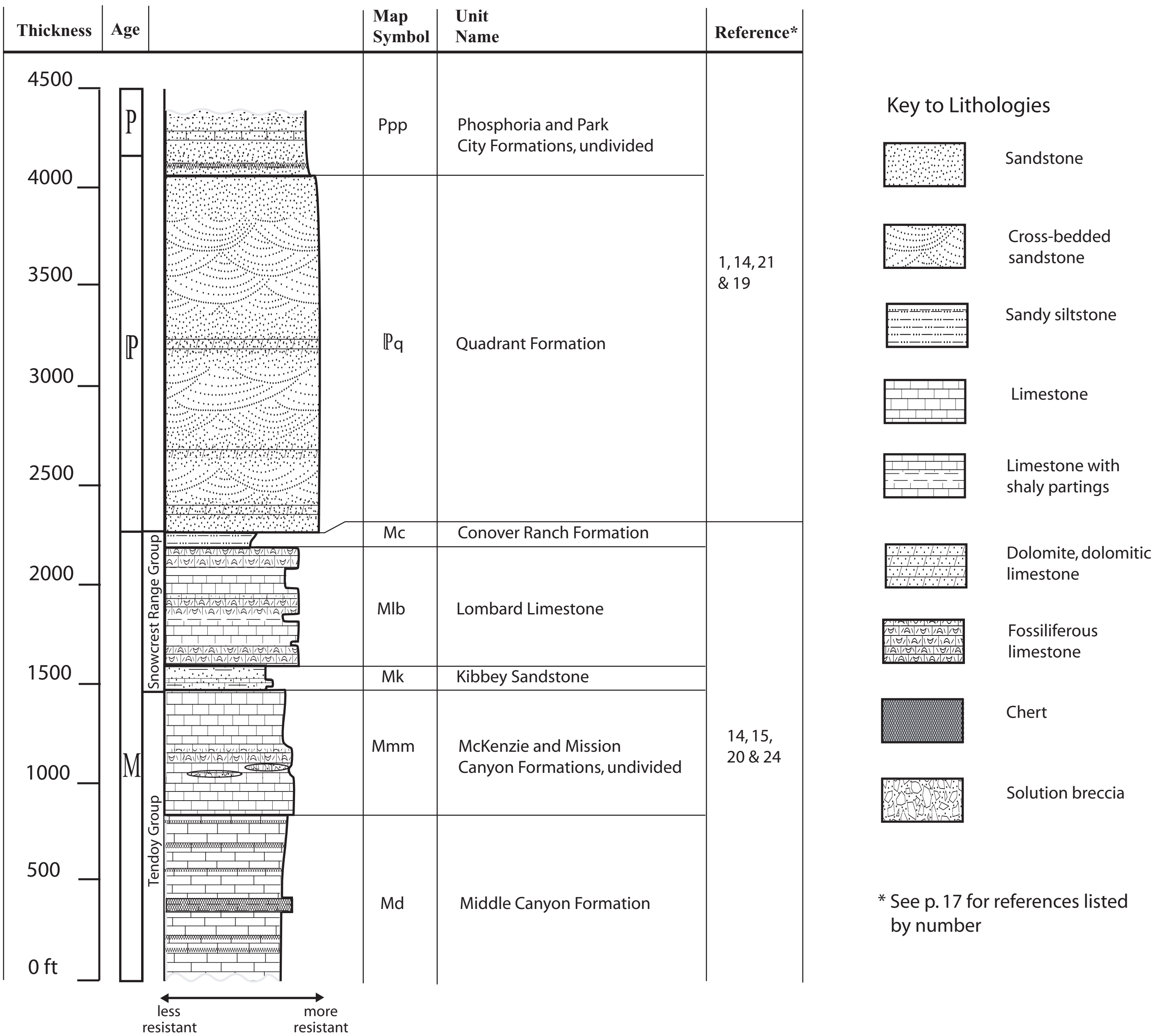


Figure 3. Stratigraphic column of Paleozoic units mapped within the Red Rock quadrangle. Unit thicknesses represent maximum exposed thicknesses within the quadrangle.

Stratigraphic Column of Cretaceous and Tertiary Units Mapped within the Red Rock 7.5' Quadrangle

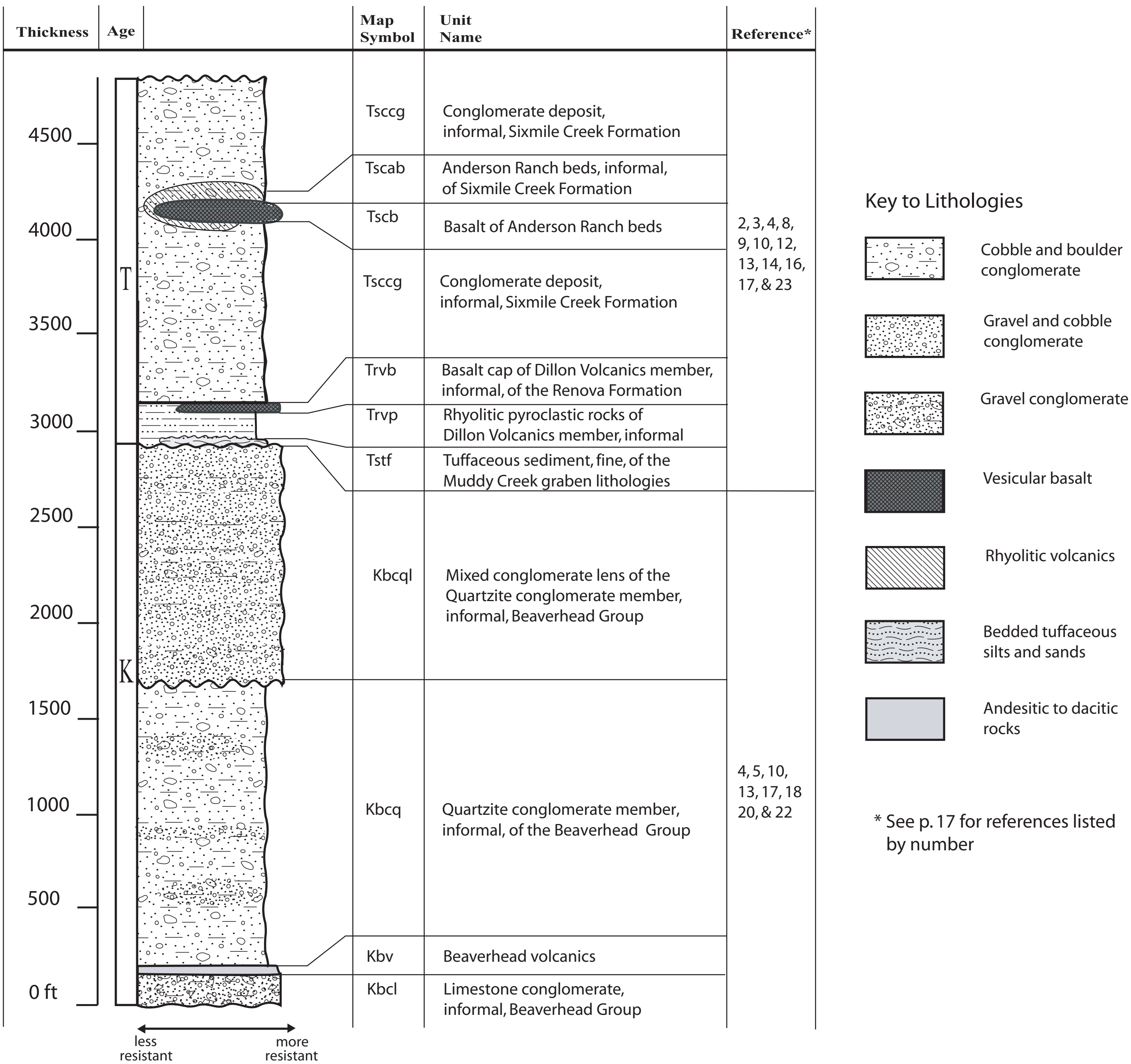
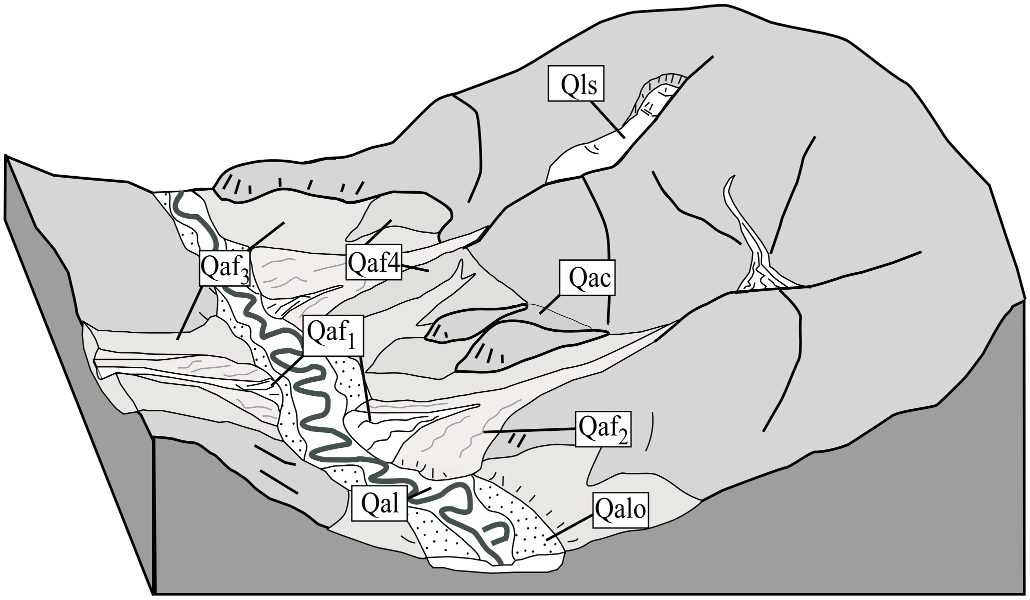


Figure 4. Stratigraphic column of Cretaceous through Teritary units mapped within the Red Rock quadrangle. Unit thicknesses represent maximum exposed thicknesses within the quadrangle.

Quaternary Stratigraphic Units Mapped within the Red Rock 7.5' Quadrangle



Symbol	Unit name	Age estimate	Reference*
Qal	Alluvium	Late Holocene-Modern	7 & 14
Qalo	Older alluvium	Pleistocene	
Qaf$_1$	Youngest alluvial fan and associated terrace deposits	Holocene-Modern	7
Qaf$_2$	Second youngest alluvial fan and associated terrace deposits	Latest Pleistocene	
Qaf$_3$	Alluvium of third youngest alluvial fan and associated terrace deposits	Late Pleistocene	
Qaf$_4$	Alluvium of oldest alluvial fan and associated terrace deposits	Middle Pleistocene (?)	
Qls	Landslide	variable Quaternary	7 & 14
Qac	Alluvium and colluvium	variable Quaternary	

* See p. 17 for references listed by number

Figure 5. Schematic diagram of Quaternary stratigraphic relationships within the Red Rock quadrangle.

In the Red Rock 7.5' quadrangle, the Beaverhead Group (Haley and Perry, 1991, Schmitt and others, 1995) (Fig. 4) is divided into three informal members - a lower limestone conglomerate (Kbcl), an upper quartzite conglomerate (Kbcq), and a middle volcanic unit (Kbv). The Red Rock Hills are dominated by the quartzite conglomerate member, a poorly sorted conglomerate dominated by rounded quartzite cobbles and boulders. The limestone conglomerate member consists of locally derived clasts of Mississippian carbonates and is distinguished from the quartzite conglomerate member by the lack of quartzite clasts.

The Renova Formation is dominated by fine-grained siliciclastics and volcaniclastics with only minor components of conglomerate (Kuenzi and Fields, 1971) and is capped by the Dillon basalt cap (Lonn and others, 2000) (Fig. 4). The Sixmile Creek Formation is dominated by mixed quartzite, limestone, and volcanic-clast conglomerates (Kuenzi and Fields, 1971) with interbedded basaltic lenses and rhyolitic volcanics of the Anderson Ranch Formation (Kreps and others, 1992; Newton and others, 2005). These two units are distinguished in the map area based on the relative abundance of conglomeratic versus volcanic components. In this report, the Anderson Ranch lithologies (Tsca) are considered to be beds within an informal conglomerate member (Tsccg) of the Sixmile Creek Formation (Fig. 4).

Quaternary deposits include modern and older river alluvium, alluvium and colluvium, landslide deposits, and four newly identified generations of alluvial fans. The subdivision of Quaternary alluvial fans is based on stratigraphic position, amount of soil carbonate development, surface morphology, degree of bar and swale modification, degree of incision by modern channels, vegetation patterns, and correlation with alluvial fans of known ages on the western side of the Red Rock Valley (Harkins and others, 2005).

Structure

The structures of the Red Rock quadrangle include the Sevier foreland thrusts of the McKenzie thrust system that are overprinted by Tertiary to Quaternary extensional structures. The McKenzie thrust sheet crops out below the Tendoy thrust sheet south of the quadrangle boundary and overlies structures associated with the Armstead thrust sheet near the northwestern quadrangle boundary. The McKenzie sheet extends about three to four miles farther east than the Tendoy sheet and exposes deeper-water equivalents of the Tendoy Group (Sando and others, 1985; Perry and others, 1989; McDowell, 1992). The McKenzie thrust system in the Red Rock quadrangle is an intensely imbricated thrust sheet with a decollement in the Logan Gulch member of the Devonian Three Forks Formation. The trailing edge of the thrust sheet consists of blind and emergent imbricates with a detachment in the Mississippian Kibbey Sandstone (Perry and others, 1989; McDowell, 1992). An exposure of Lombard Limestone on the east side of the Red Rock River indicates that the McKenzie thrust sheet extends across the Red Rock Valley under a cover of alluvium. Within the map area, disharmonic folds are observed in the Lombard Limestone in association with blind thrusts and in the Middle Canyon Formation near its contact with the underlying Middle Canyon Formation.

The Monument Hill fault system is a Tertiary and Quaternary extensional system located in the Red Rock Hills and consists of three recognized fault strands that are either fully or partially exposed in the Red Rock quadrangle (Fig. 2). The main strand lies at an average elevation of 7,300 ft (2,225 m) in the Red Rock Hills, is approximately 7 miles (11 km) long, and is recognizable in the field and from aerial photos by the presence of faceted spurs, aligned springs, and scarps in alluvium (Scholten and others, 1955). Two smaller strands lie at lower elevations within alluvial fans on the east side of the Red Rock Valley, are 0.5-1.25 miles (1-2 km) long, and are recognizable by aligned springs and scarps in alluvium. All three strands offset the two oldest generations of alluvial fans but do not offset the two youngest generations of fans, indicating a late Pleistocene rupture. Length-scaling relationships that define linear relationships between strike-length of a fault and total displacement suggest an estimated offset of about 1,300 ft (400 m) for the main strand of the Monument Hill fault system.

Acknowledgments

Funding for the fieldwork was provided by DOI-USGS-EDMAP grant 05HQAG0015. The authors would like to acknowledge Karen Porter at the Montana Bureau of Mines and Geology for her help with the acquisition of the grant and with the production of the geologic map and report and the Dillon office of the Bureau of Land Management for providing aerial photography and access to public lands. We would also like to thank Danny and Kristen Johnson at the Red Rock Ranch for their continued hospitality and willingness to grant access to private lands, Arlene Greenslade at the Lima Post Office for yet another year of support for Lehigh field studies, Jim Schmitt at Montana State University and Christopher Haley at Virginia Wesleyan University for sharing their time, knowledge and expertise in the field, and Luke Wilson, Michael Newton, Timothy Turk, and Mark Messina for the sharing of resources and for providing company and assistance in the field.

Age	Scholten and others (1955)	Sando and others (1985); Wardlaw and Pecora (1985)	Lonn and others (2000)	This study *
Q	Alluvium; Landslides		Alluvium; Alluvial fan deposit; Landslide Deposit	Qal; Qls; Qac; Qaf1; Qaf2
Q	Terrace gravels and alluvial fans		Older alluvium; Older alluvial fan deposit; Landslide Deposit	Qao; Qls; Qac; Qaf3; Qaf4
T	Clark Canyon basaltic lava flows		Sixmile Creek Formation	Tsccg; Tsca; Tscab
T			Basalt cap, Dillon Volcanics member	Trvb
T	Cook Ranch Formation		Rhyolitic pycroclastic rocks, Dillon Volcanics member	Trvp
T			— — — — — —	Tstf
K	Beaverhead Formation		Quartzite conglom-erate, Beaverhead Group	Kbcql; Kbcq
K				Kbv
K				Kbcl
P	— — — — — —		Phosphoria and Park City Formations, undivided	Ppp
₽	Phosphoria Formation; Quadrant Sandstone	Quadrant Sandstone	Quadrant Sandstone	₽q
M	Amsden Formation	Snowcrest Range Group: Conover Ranch Formation	Snowcrest Range Group (Conover Ranch, Lombard, and Kibbey Formations, undivided)	Mc
M	Big Snowy Group	Snowcrest Range Group: Lombard Limestone		Mlb
M		Snowcrest Range Group: Kibbey Sandstone		Mk
M	Madison Group: Mission Canyon Formation; Lodgepole Formation	Tendoy Group: McKenzie Canyon Limestone	Tendoy Group (McKenzie Canyon, Kibbey, Mission Canyon, Middle Canyon, and Paine Formations, undivided)	Mmm
M		Tendoy Group: Mission Canyon Limestone		
M		Tendoy Group: Middle Canyon Formation	Mission Canyon Formation	Mmd
M		Tendoy Group: Paine Limestone	Lodgepole Formation	— — — — — —

* See Figures 3 and 4 for unit names.

Table 2. Stratigraphic correlation of units mapped within the Red Rock quadrangle.

Description of Map Units
Red Rock 7.5' Quadrangle Beaverhead County, Southwestern Montana

<u>Quaternary</u>

Qal *Alluvium* - unconsolidated, well to poorly sorted fluvial deposits of silt, sand, and gravel in active stream channels and modern floodplain.

Qao *Older alluvium* - unconsolidated, well to poorly sorted fluvial deposits of silt, sand, and gravel in older floodplain deposits.

Qls *Landslide deposit* - unconsolidated deposit of poorly sorted, angular, locally derived debris; forms hummocky topography.

Qaf_1 *Youngest alluvial fan and alluvial channel deposits* - unconsolidated, poorly to moderately sorted silt to cobbles deposited in active fans and alluvial channels; characterized by unmodified bar and swale morphology and supports only sparse sagebrush; incised into older deposits; probable Holocene age.

Qaf_2 *Second youngest alluvial fan and associated alluvial channel deposit* - unconsolidated, poorly to moderately sorted, silt to cobbles in inactive fans and alluvial channels; characterized by slightly modified bar and swale morphology, stage I+ to II soil carbonate development, and support of abundant grass and sagebrush vegetation; both incises and buries older units; probable latest Pleistocene age.

Qaf_3 *Alluvium of third youngest alluvial fan and associated alluvial channel deposits* - unconsolidated, poorly to moderately sorted silt to cobbles in inactive fans and alluvial channels; characterized by subdued bar and swale morphology, stage II+ to III soil carbonate development, and support of dominantly grass with little sagebrush; incised into oldest alluvial surface, and occupies a position 5-15 ft (2-5 m) above the modern channel; probable late Pleistocene age.

Qaf_4 *Alluvium of oldest alluvial fan deposits* - unconsolidated, poorly to moderately sorted silt to cobbles; characterized by a lack of bar and swale morphology, ~1 ft (30 cm) or more of loess, highly weathered cobbles, and stage III to III+ soil carbonate development, and a dominance of grass over sagebrush; incised by younger alluvial surfaces, and occupies a position 30-40 ft (10-12 m) above the modern channel; probable middle Pleistocene age.

Qac *Alluvial fan and colluvial deposits of unknown age and affinity* - unconsolidated, poorly sorted silt through cobble size deposit which grades into the oldest fan surfaces at high elevations.

Tertiary

Sixmile Creek Formation

Tsccg *Conglomerate member, informal, of the Sixmile Creek Formation* - poorly indurated, poorly to moderately well sorted, clast-supported, pebble to cobble, quartzite conglomerate with rare sandy lenses; lithologies include reworked quartzite and limestone clasts of the Beaverhead Group, and locally derived, sub-angular basaltic and volcanic clasts; interbedded with Anderson Ranch member volcanics; unconformably overlies the Beaverhead Group and Renova Formation; unit is distinguishable from lithologically similar Beaverhead Quartzite conglomerate by the presence of volcanic clasts and by the formation of subdued, rounded topography and orange-red soils; correlated with the Big Hole River and Sweetwater Creek members, informal, of the Sixmile Creek Formation of Fritz and Sears (1993). Maximum exposed thickness 1,700 ft (520 m).

Tsca *Anderson Ranch beds of the conglomerate member, informal, Sixmile Creek Formation* – light-gray to tan, rhyolitic volcanics occurring as lenses within the conglomerate deposits of the Sixmile Creek Formation; unit is distinguished from the older, Renova Formation, volcanics by its stratigraphic position within Sixmile Creek conglomerates. Maximum exposed thickness 200 ft (60 m).

Tscab *Basalt of Anderson Ranch beds of the Sixmile Creek Formation* – chocolate-brown to reddish-black, vesicular basalt; where present, forms a cap on top of conglomerate deposits within the Sixmile Creek Formation; distinguished from the older Dillon Basalt member of the Renova Formation by its stratigraphic position within the Sixmile Creek and by a lack of associated volcaniclastics. Anderson Ranch beds were not observed between the basalt and the underlying conglomerate but may occur. Correlates to the Tscb of Newton and others (2005) and may be a time equivalent of the Timber Hill Basalt of Fritz and Sears (1993). Exposed thickness 80 ft (24 m).

Renova Formation

Trvb *Basalt cap of Dillon Volcanics member, informal, of the Renova Formation* – brown to black, vesicular and amygdaloidal basalts, interbedded basaltic, pebble to cobble agglomerates with hydrothermal veining; distinguished from the younger basalts of the Anderson Ranch member, informal, of the Sixmile Creek Formation by its stratigraphic position below Sixmile Creek Conglomerates, its association with agglomeratic and pyroclastic units, and the presence of hydrothermal mineral precipitation. Maximum exposed thickness 500 ft (152 m).

Trvp *Rhyolitic pyroclastic rocks of Dillon Volcanics member, informal, of the Renova Formation* - rhyolitic airfall and pyroclastic flow tuffs, tuffaceous mudstone, and pebble- to cobble-size volcaniclastics associated with the Dillon Basalt cap. Exposed thickness 200 ft (60 m).

Tstf *Tuffaceous sediment, fine, of the Muddy Creek graben lithologies* – thin- to medium-bedded, buff-colored, tuffaceous silts and sands with quartz and biotite phenocrysts; channel forms preserved; likely derived from fluvially reworked sediments of Muddy Creek graben equivalent volcanics; correlated to the Facies A, ash-flow tuffs of the Challis Volcanics Group of Janecke and others (1999). Exposed thickness ~10 ft (~3m).

Cretaceous

Beaverhead Group

Kbcq *Quartzite conglomerate member, informal, Beaverhead Group* – poorly indurated, poorly sorted, rounded quartzite cobble and boulder conglomerate in a sandy matrix; clasts are derived from western sources including the Precambrian Belt Supergroup and Ordovician Kinnikinic Formation; includes minor amounts of limestone and volcanics of unknown source. Quartzite conglomerate of Haley and Perry (1991). Maximum exposed thickness 1,500 ft (450 m).

Kbcql *Mixed conglomerate lens of the Quartzite conglomerate member* - moderately well indurated, moderately well sorted, clast-supported, sand to cobble size, quartzite and limestone conglomerate; interbedded gravel beds and sandy lenses; contained within the Quartzite conglomerate of the Beaverhead Group. Maximum exposed thickness 1,250 ft (380 m).

Kbv *Beaverhead volcanics* - gray to blue-green, andesitic to dacitic rocks of uncertain age; found between the limestone and quartzite conglomerates of the Beaverhead Group; may correlate to a member of the Cold Springs Creek volcanics (Schmitt and others, 1995; Ivy, 1989). Maximum exposed thickness 40 ft (12 m).

Kbcl *Limestone conglomerate, informal, Beaverhead Group* – well indurated, moderately to well sorted, clast-supported, sub-angular to sub-rounded, limestone pebble and gravel conglomerate in a sandy carbonate matrix; clasts derived from various Mississippian carbonate units exposed in thrust sheets to the west; unconformably overlies Mississippian carbonates. Only upper 175 ft (50 m) exposed.

Permian

Ppp *Phosphoria and Park City Formations, undivided* – dark-gray weathering, brown phosphatic and calcareous sandstone and mudstone, with gray to black chert and interbedded limestone. Maximum exposed thickness 330 ft (100m).

Pennsylvanian

Pq *Quadrant Formation* – Buff-colored, thick to massively bedded, cross-bedded calcareous sandstone and dolostone; forms prominent cliffs and talus slopes. Exposed thickness ,800 ft (550m).

Mississippian

Snowcrest Range Group: includes Conover Ranch Formation, Lombard Limestone, and Kibbey Sandstone (Sando and others, 1985)

Mc *Conover Ranch Formation* – fine-grained, moderately well sorted, reddish-brown siltstone, and interbedded micritic limestone; poor outcrop due to extensive weathering; 65-100 ft (20-30 m) thick in map area.

Mlb *Lombard Limestone* – medium-gray, thin- to medium-bedded, fossiliferous limestone interbedded with gray, calcareous siltstone; unit is often disharmonically folded. Maximum thickness 590 ft (180 m).

Mk *Kibbey Sandstone* – medium-grained, golden-brown sandstone and siltstone with rare interbedded micrite; poor outcrop due to extensive weathering; often forms a reddish- to yellowish-brown soil. Maximum thickness 190 ft (58 m).

Tendoy Group: includes McKenzie Canyon Formation, Mission Canyon Formation, Middle Canyon Formation, and Paine Limestone (not exposed in map area) (Sando and others, 1985).

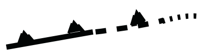
Mmm *McKenzie Canyon and Mission Canyon Formations, undivided* – thick- to medium- or thin-bedded, fossiliferous, medium-grained limestone; occasional thin chert interbeds and less abundant chert nodules; solution breccia of the McKenzie Formation rarely present; unit includes the Mission Canyon and McKenzie Canyon Formations of Sando and others (1985) and begins at the first massive gray limestone bed above the chert-rich Middle Canyon Formation. Maximum thickness 650 ft (200m).

Mmd *Middle Canyon Formation* – dark- to medium-gray limestone with abundant chert conformably overlying the Paine Limestone (not exposed in map area); lower member – medium- to dark-gray limestone with ribbony chert; middle member – dark-gray limestone and abundant tabular dark-gray chert; upper member – medium- to dark-gray limestone with ribbony dark-gray and brown chert and recrystallized calcite. Maximum exposed thickness 820 ft (250 m).

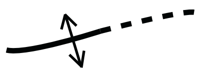
Map Symbols for the Red Rock 7.5' Quadrangle

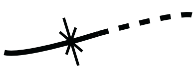

Contact, dashed where inferred

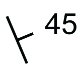

Normal fault, dashed where inferred, dotted where concealed


Thrust fault, dashed where inferred, dotted where concealed


Fault with unknown sense of displacement, dotted where concealed


Anticlinal axial trace, dashed where approximate


Synclinal axial trace, dashed where approximate



Strike and dip of bedding

Key to references for stratigraphic columns

1. Cressman and Swanson, 1964
2. Dunlap, 1982
3. Fritz and Sears, 1993
4. Fields and others, 1985
5. Haley, 1986
6. Haley and Perry, 1991
7. Harkins and others, 2005
8. Harkins and others, 2004b
9. Ivy, 1989
10. Janecke, 1999
11. Janecke and others, 2000
12. Kreps and others, 1992
13. Kuenzi and Fields, 1971
14. Lonn and others, 2000
15. McDowell, 1992
16. McDowell and Fritz, 1995
17. Newton and others, 2000
18. Ryder and Scholten, 1973
19. Scholten and others, 1955
20. Sando and others, 1985
21. Saperstone, 198622.
22. Schmitt and others, 1995
23. Tabrum and others, 1996
24. Wardlaw and Pecora, 1985

References:

Ashchoff, J.L., and Schmitt, J.G., 2005, Geologic map of the Dell 7.5' quadrangle, Cordilleran fold and thrust belt, southwest Montana: Montana Bureau of Mines and Geology Open File Report 520, scale 1:24,000, 32 p.

Cressman, E.L., and Swanson, R.W., 1964, Stratigraphy and Petrology of the Permian rocks of southwestern Montana: U.S. Geological Survey Professional Paper 313-C, 569 p.

Dunlap, D.G., 1982, Tertiary geology of the Muddy Creek Basin, Beaverhead County, Montana: Missoula, MT, The University of Montana, M.S. thesis, 133 p.

Fields, R.W., Rasmussen, D.L., Tabrum, A.R., and Nichols, R., 1985, Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho: a summary, *in* Flores, R.M., and Kaplan, S.S. eds., Cenozoic paleogeography of the west-central United States, Rocky Mountain Paleogeography Symposium 3, Rocky Mountain Section, SEPM, p. 9-36.

Fritz, W.J., and Sears, J.W., 1993, Tectonics of the Yellowstone hotspot wake in southwestern Montana: Geology, v. 21, p. 427-430.

Haley, J. C., 1986, Upper Cretaceous (Beaverhead) synorogenic sediments in the Montana-Idaho thrust belt and adjacent foreland: relationships between sedimentation and tectonism: Baltimore, MD, The Johns Hopkins University, Ph.D. dissertation, 542 p.

Haley, J.C., and Perry, W.J., 1991, The Red Butte Conglomerate – a thrust-belt derived conglomerate of the Beaverhead Group, southwestern Montana: U.S. Geological Survey Bulletin 1945, 19 p.

Harkins, N.W., Newton, M.L., Anastasio, D.J., and Pazzaglia, F.J., 2004a, Bedrock and surficial geologic map of the Caboose Canyon 7.5' quadrangle, Southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 494, scale 1:24,000, 13 p.

Harkins, N.W., Latta, D.K., Anastasio, D.J, and Pazzaglia, F.J., 2004b, Surficial and bedrock geologic map of the Dixon Mountain 7.5' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open-File Report 495, scale 1:24,000, 12 p.

Harkins, N.W., Anastasio, D.J.,and Pazzaglia, F.J, 2005, Tectonic geomorphology of the Red Rock fault, insights into segmentation and landscape evolution of a developing range-front normal fault: Journal of Structural Geology, v. 27, p. 1925-1939.

Ivy, S.D., 1989, Source, evolution, and eruptive history of the Cold Springs Creek Volcanics, Beaverhead County, Montana: Oregon State University, M.S. thesis, 132 p.

Janecke, S., McIntosh, W., and Good, S., 1999, Testing models of rift basins: structure and stratigraphy of an Eocene-Oligocene supradetachment basin, Muddy Creek half graben, southwest Montana: Basin Research, v. 11, p. 143-165.

Janecke, S.U., VanDenburg, C.J., Blankenau, J.J., and M'Gonigle, J.W., 2000, Long-distance longitudinal transport of gravel across the Cordilleran thrust belt of Montana and Idaho: Geology, v. 28, n. 5, p. 439-442.

Kalakay, T.J., 2001, The role of magmatism during crustal shortening in the Sevier retroarc fold-and-thrust belt of southwest Montana: Laramie, WY, University of Wyoming, Ph.D. dissertation, 204 p.

Kreps, J., Fritz, W.J., Sears, J.W., and Wampler, J.M., 1992, The 6 Ma Timber Hill basalt flow: Implications for late Cenozoic drainage systems and the onset of basin-and-range style faulting, southwestern Montana: Geological Society of America Abstracts with Programs, v. 24, no. 6, p. 22.

Kuenzi, W.D., and Fields, R.W., 1971, Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana: Geological Society of America Bulletin, v. 82, p. 3373-3394.

Lonn, J.D., Skipp, B.S., Ruppel, E.T., Janecke, S.U., Perry, W.J., Sears, J.W., Bartholomew, M.J., Stickney, M.C., Fritz, W.J., Hurlow, H.A., and Thomas, R.C., 2000, Geologic map of the Lima 30' x 60' quadrangle, southwest Montana: Montana Bureau of Mines and Geology, Open-File Report 408, scale 1:100,000, 49 p.

McDowell, R.J., 1992, Effects of synsedimentary basement tectonics on fold-thrust belt geometry, southwestern Montana: University of Kentucky Ph.D. dissertation, 328 p.

McDowell, R.J., and Fritz, W.J., 1995, Geochemistry of the Tertiary Dillon Volcanics of southwestern Montana: transition from arc to extensional volcanism: Geological Society of America Abstracts with Programs, Rocky Mountain Section, v. 27, no. 4, p. 46.

Newton, M.L., Regalla, C.A., Anastasio, D.J, and Pazzaglia, F.J., 2005, Bedrock and surficial geologic map of the Monument Hill 7.5' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open File Report MBMG 517, scale 1:24,000, 14 p.

Perry, W. J., Dyman, T.S., and Sando, W.J., 1989, Southwestern Montana recess of Cordilleran thrust belt: Montana Geological Society 1989 field conference guidebook, Montana centennial edition, Geologic resources of Montana, Volume I, French, D.E., and Grabb, R.F., eds., Field Conference - Montana Geological Society, no. 1, p. 261-270.

Ryder, R.T., and Scholten, R., 1973, Synorogenic conglomerates in southwestern Montana: their nature, origin, and tectonic significance: Geological Society of America Bulletin, v. 84, p. 773-796.

Sando, W.J., Sandberg, C.A., and Perry, W.J, 1985, Revision of Mississippian stratigraphy , northern Tendoy Mountains, southwest Montana, *in* Mississippian and Pennsylvanian stratigraphy in southwest Montana and adjacent Idaho, Sando, W.J. ed.: U.S. Geological Survey Bulletin 1656, p. A1-A10.

Saperstone, H.I., 1986, Description of measured sections of the Pennsylvanian Quadrant Sandstone, Beaverhead, Madison, and Park Counties, southwestern Montana: U.S. Geological Survey Open-File Report 86-182, 68 p.

Schmitt, J.G., Haley, J.C., Lageson, D.R., Horton, B.K., and Azevedo, P.A., 1995, Sedimentology and tectonics of the Bannack-McKnight Canyon-Red Butte area, southwest Montana: new perspectives on the Beaverhead Group and Sevier Orogenic Belt: Northwest Geology, v. 24, p. 245-313.

Scholten, R.K., Keenmon, K.A., and Kupsch, W.O., 1955, Geology of the Lima region, southwestern Montana and adjacent Idaho: Geological Society of America Bulletin, v. 66, no. 4, p. 345-404.

Sears, J.W., and Hurlow, H.A., 1995, Late Cenozoic disruption of Miocene grabens on the shoulder of the Yellowstone Hotspot track in southwest Montana; field guide from Lima to Alder, Montana, Field guide to geologic excursions in southwest Montana: Northwest Geology, n. 24, p 201-219.

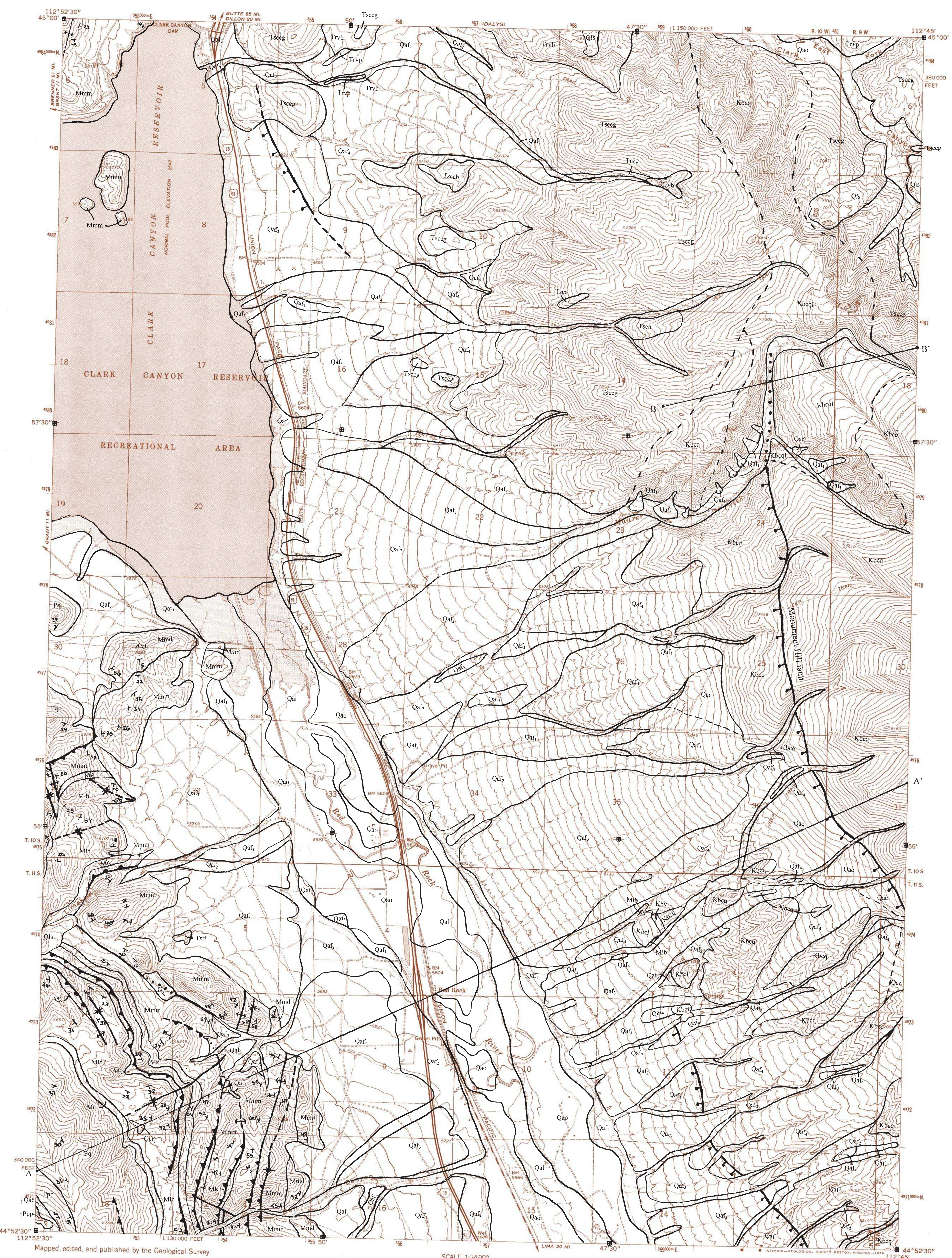
Stickney, M.C., and Lageson, D.R., 2002, Seismotectonics of the 20 August 1999 Red Rock Valley, Montana: Earthquake: Bulletin of the Seismological Society of America, v. 92, no. 6, p. 2449-2464.

Tabrum, A.R., Prothero, D.P., and Garcia, D., 1996, Magnetostratigraphy and biostratigraphy of the Eocene-Oligocene transition, southwestern Montana, *in* The Terrestrial Eocene-Oligocene Transition in North America, Prothero, D.R., and Emry, R.J. eds., Cambridge University Press, p. 278-311.

Wardlaw, B.R., and Pecora, W.C., 1985, New Mississippian-Pennsylvanian stratigraphic units in southwest Montana and adjacent Idaho, *in* Mississippian and Pennsylvanian stratigraphy in southwest Montana and adjacent Idaho, Sando, W.J., ed.: U.S. Geological Survey Bulletin 1656, p. B1-B9.

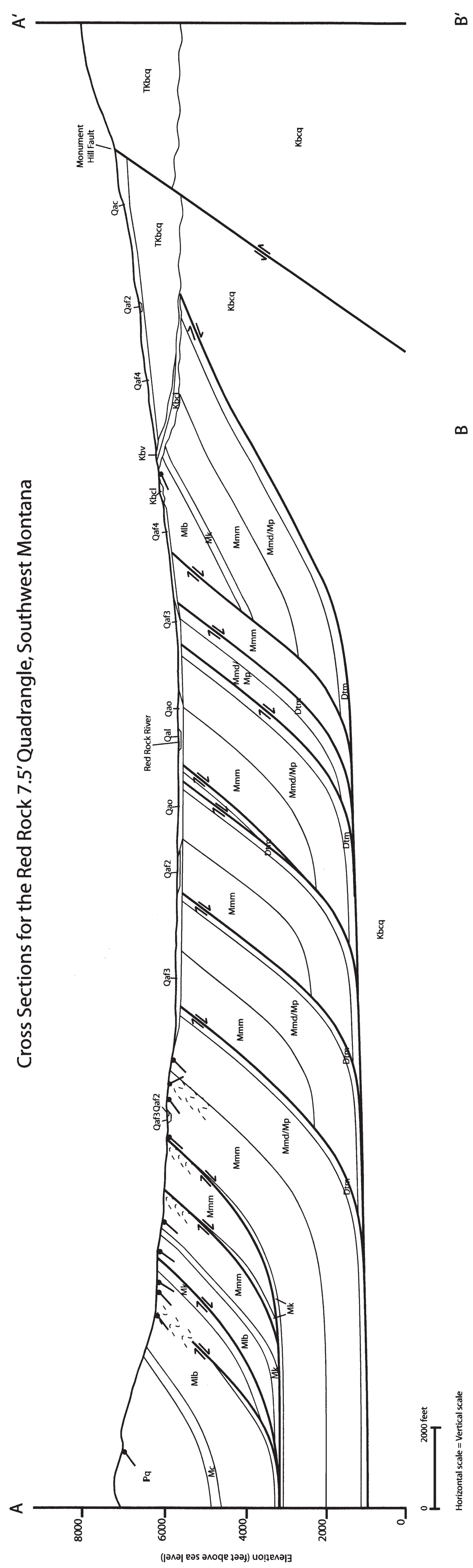
Wilson, L.F., and Schmitt, J.G., in progress, Bedrock and surficial map of the Kidd 7.5’ quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open-File Report, scale 1:24,000

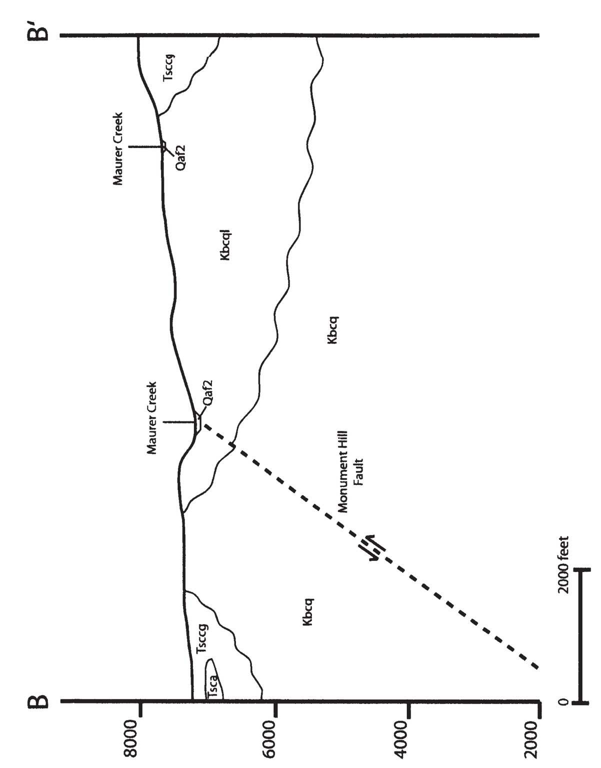
MONTANA BUREAU OF MINES AND GEOLOGY
A Department of Montana Tech of The University of Montana



Base from U.S. Geological Survey
Red Rock 7.5' topographic quadrangle
Map date: 1965; Photorevised 1979
Projection: Polyconic
UTM zone 12; 1927 NAD

Cross Sections for the Red Rock 7.5' Quadrangle, Southwest Montana





Key to Symbols:

Qal	Alluvium	Kbcq	Quartzite conglomerate, Beaverhead Group
Qao	Older Alluvium	Kbv	Beaverhead volcanics
Qaf1	Youngest alluvial fan and fan channel deposits	Kbcl	Limestone conglomerate, Beaverhead Group
Qaf2	Second youngest alluvial fan and fan channel deposits	Kbc	Beaverhead Group, undivided
Qaf3	Alluvium of third youngest alluvial fan and channel deposits	Pq	Quadrant Formation
Qaf4	Alluvium of oldest fan and associated terrace deposits	Mc	Conover Ranch Formation
Qac	Alluvial fan and colluvial deposits	Mlb	Lombard Limestone
Tsccg	Conglomerate deposit, Sixmile Creek Formation	Mk	Kibbey Sandstone
Tsca	Anderson Ranch member, Sixmile Creek Formation	Mmm	McKenzie and Mission Canyon Formations
Kbcql	Mixed conglomerate lens, Quartzite Conglomerate, Beaverhead Group	Mmd	Middle Canyon Formation
Mp	Paine Limestone		Small-scale folds
Dtm	Three Forks—Maywood Formations, und.		Bedding dip orientation
	Fault with reverse displacement		Fault with normal displacement
	Fault, dashed where inferred		

MBMG Open File 533

Bedrock and Surficial Geologic Map of the Red Rock 7.5' Quadrangle, Beaverhead County, Southwest Montana

mapped and compiled by

Christine A. Regalla, Daryn K.S. Reyman,
David J. Anastasio, and Frank J. Pazzaglia

Earth and Environmental Sciences Department
Lehigh University, Bethlehem, PA

2006

Partial support has been provided by the EDMAP component of the National Cooperative Geologic Mapping Program of the U.S.Geological Survey under Contract Number 05HQAG001.
GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.

Map Symbols

Contact, dashed where inferred

Normal fault, dashed where inferred, dotted where concealed

Thrust fault, dashed where inferred, dotted where concealed

Fault with unknown sense of displacement, dotted where concealed

Anticlinal axial trace, dashed where approximate

Synclinal axial trace, dashed where approximate

45 Strike and dip of bedding

N

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