This report was prepared by a geology student under the direction of her advisor as a product of the EDMAP Component of the U.S. Geological Survey National Cooperative Geologic Mapping Program, Contract Number 06HQPA0004.
INTRODUCTION

The Snowline 7.5’ quadrangle in southwest Montana represents a geographic area in Beaverhead County north of the Continental Divide in the Beaverhead Mountains and south of the Red Rock River (Fig. 1). Cretaceous-Tertiary stratigraphy and Quaternary sedimentary deposits in this quadrangle record several episodes of tectonism. The effects of Late Cretaceous interaction of a broken-foreland uplift of the Laramide Orogeny and the fold and thrust belt of the Cordillera Sevier Orogeny are recognized in the Frontier Formation and the Beaverhead Group conglomerate members (Haley, 1985). Two tertiary extensional regimes are represented in this quadrangle. Volcanic units of tuff, rhyolite, and basalt represent Miocene-Pliocene eruptive events with flow northeast through extensional paleovalleys from the Heise volcanic field in the modern Snake River Plain (Pierce and Morgan, 1992). Quaternary alluvial deposits reflect northern Basin and Range Province extensional tectonic activity associated with the southeastern-most limit of the Red Rock Fault (Harkins and others, 2005).

Mapping conducted in the field at the 1:24,000 scale utilized topographic and orthophoto quadrangles as base maps. Color 2001 aerial photographs supplemented the maps and were especially useful elucidating Quaternary geology. Previously published maps by Wilson (1970), Ryder and Scholten (1973), Perry and others (1988), Dyman and others (1995), and Lonn and others (2000) covering all or part of this quadrangle were used for reference. Digital cartography was completed using ArcGIS software and a cross section was constructed using 2DMove software.

GEOLOGIC SETTING

The southern edge of the southwest Montana reentrant of the Cordillera Sevier fold and thrust belt is manifest as the thin-skinned Tendoy thrust, the easternmost feature with surficial expression. The Lima anticline is a blind-thrust-cored fold north of the Tendoy thrust apparent in subsurface data (Perry and others, 1988), but not apparent from field measured strike and dips. The Tendoy thrust changes from a southeast-northwest strike west of the Snowline quadrangle to an east-west strike as the thrust loses stratigraphic displacement on a frontal hanging wall ramp and displacement is transferred to the Lima anticline. These geometric changes in the thrust are ascribed to either one or a combination of (1) folding of the thrust around a late northeast trending anticline and (2) truncation of the Blacktail-Snowcrest uplift nose by the thrust (Dyman and others, 1995).

The southwestern limit of effects of the Laramide Blacktail-Snowcrest broken-foreland uplift occurs in the subsurface in the Snowline quadrangle. The sub-Snowcrest Range fault is the master basement involved, moderate to high angle reverse fault on the southeastern flank of the Blacktail-Snowcrest uplift north of the quadrangle. The fault system associated with this uplift extends southwestward beneath the fold and thrust belt west of this quadrangle (Kulik and Perry, 1988).

The Snowline quadrangle lies in a zone of overlap between the thin-skinned Sevier fold and thrust belt, and the thick-skinned Laramide broken-foreland uplift. Structural and stratigraphic relationships suggest approximately coeval deformation from these tectonic regimes with the last stages of Sevier tectonism occurring after the major
Figure 1. Location map for Snowline 7.5’ quadrangle showing relationship to other completed or in-progress quadrangle maps in the area. See MBMG web site (www.mbmg.mtech.edu) for status of maps.
stage of uplift in the Laramide broken-foreland (McDowell, 1997). Determination of relative timing of tectonic activity is based on the intercalation of conglomerate lithosomes shed off each of the orogens (Haley, 1985) and fault transfer zones shared by the regimes (Perry and others, 1989).

Subsequent to Sevier and Laramide Cretaceous-Paleocene tectonism several episodes of extensional tectonics occurred. The arm of the Centennial Tectonic Belt in the Intermountain Seismic Belt is located north of the modern topographic and structural depression of the Snake River Plain. Thermal uplift of the Heise volcanic field developed northeast-trending extensional paleovalleys. Grabens filled with fluvial gravels and silicic and mafic effusive volcanic flows sourced in the Heise field (Pierce and Morgan, 1992).

The diffuse zone marking Quaternary extension connects to the east-dipping Red Rock normal fault in the northwest and the north-dipping Centennial fault in the east. The Snowline quadrangle captures this change in strike from southeast-northwest to east-west. Footwall-tilted alluvial terraces and fault trace proximal debris flow alluvial fans along the graben-bounding normal faults in the central part of the Snowline quadrangle represent minimal modern offset.

**STRUCTURAL/STRATIGRAPHIC RELATIONSHIPS**

The tectonic regimes that passed through the Snowline quadrangle produced the observed structural and stratigraphic relationships. The sediments shed off the active structures record two of the most important aspects of geologic history: timing and location.

**Cordilleran Sevier Orogeny**

The Cordilleran Sevier Orogeny produced the Tendoy Thrust and the Late Cretaceous Frontier Formation shed of the fold and thrust belt. The thrust loses stratigraphic displacement from the Lima Peaks 7.5’ quadrangle in the west (McDowell, 1997) into the Snowline quadrangle in the east. On the western edge of the Snowline quadrangle, Cretaceous Blackleaf Formation occurs as allochthonous, partially overturned strata in the hanging wall of the Tendoy thrust. The thrust dies out to the east, and juxtaposes older Frontier Formation on younger Frontier. Along the southern edge of the quadrangle, in the Tendoy thrust hanging wall, the Cretaceous-Tertiary quartzite conglomerate of the Beaverhead group lies conformably on the Frontier Formation and reflects a change in deposition with sediment size increasing and composition becoming more quartzose (Dyman and others, 1995).

**Broken Foreland Laramide Orogeny**

The Sub-Snowcrest Range fault of the broken-foreland Laramide Orogeny is reflected in the northern portion of the Snowline quadrangle by deposits of the synorogenic Antone Peak Formation of the Beaverhead Group. Sediment provenance is ascribed to the Paleozoic section in the proximal uplift to the north, the source for limestone, lithic and chert clasts (Wilson, 1970, Ryder and Scholten, 1973). Deposition of the Lima Member conglomerate and undifferentiated sandstone lithosomes occurred
from Coniacian to middle Campanian time (Nichols and others, 1985). The sandstone and conglomerate lithosomes gradationally interfinger in the northern part of the Snowline quadrangle. Grain size decreases and textural maturity increases distal to the uplift, representing genetic equivalency of the conglomerate and sandstone. Southwest of the quadrangle, the Antone Peak Formation is cut by the Tendoy Thrust, implying that uplift of the Blacktail-Snowcrest Range preceded uplift on the Tendoy Thrust.

**Tertiary-Recent Extension**

Evidence of extension in the Snowline 7.5’ quadrangle is focused in the central valley of the quadrangle, generally along the same fault system for multiple tectonic episodes, but the effects of normal faulting are distributed over most of the quadrangle. The first episode was associated with the uplift of the Heise volcanic field, and subsequent inundation of the paleovalleys with rhyolite, tuff, and basalt originating south of the Snowline quadrangle in the modern topographic and structural depression of the Snake River Plain (Pierce and Morgan, 1992). Caldera collapse resulted in rhyolitic ignimbrite eruptions followed by fracturing of the cooled subcaldera plutons, which led to basaltic effusive volcanism (Kuntz and others, 1992). The volcanic units in the Snowline quadrangle have variable lateral continuity and thickness, and both underlie and cap sedimentary deposits of similar ages at Diamond Butte and Timber Hill. They are nowhere juxtaposed, and relative timing is impossible to discern from field observations.

Quaternary movement has occurred on two normal faults bounding the Lima Anticline to the north and south in the central portion of the quadrangle. The effects of a current extensional regime are recognized primarily in depositional environment spatial variability and surface geomorphology. Alluvial fans are associated with the uplift on the northern normal fault. Progressively rotated and uplifted alluvial terrace deposits south of Junction Creek show uplift and rotation along the southern normal fault. The degree of dissection, elevation, surface tilt, and carbonate rind development on clasts exposed in soil pits in the terrace deposits (Qat5 to Qat1) indicate younger deposits are located towards the normal faults near the central valley floor.

**CONCLUSIONS**

Mapping at the 1:24,000 scale captures new detail of structural and stratigraphic relationships as well as previously undescribed Tertiary and Quaternary deposits. Tectonostratigraphic interpretations explicate geologic structural evolution in the Snowline quadrangle. Cretaceous to early Tertiary stratigraphy reflects the Laramide and Cordilleran Sevier compressional orogenies. Tertiary fluvial gravels underlying Diamond Butte and assorted volcanic units are evidence of extensional paleovalleys from the Heise volcanic field. Quaternary alluvial deposits reflect modern dissection of topography associated with the northern Basin and Range Province.

Behaviors of successive tectonic regimes are strongly affected by pre-existing anisotropies such as structural geometry and lithology. Reactivation along faults and weak layers is complicated in the Snowline quadrangle due to the spatial changes in structural grain from southeast-northwest to east-west, as well as temporal changes in compression and extension directions.
ADJACENT QUADS

Every effort was made to maintain consistency across quadrangle borders. Mapping in the field was conducted in concert with the Henry Gulch Quadrangle mapping (Majerowicz and others, 2007). Collaboration was useful for consistent descriptions and interpretations across borders. Stratigraphic nomenclature, however, was adjusted from previous publications and adjacent quadrangles to reflect detail observed at the 1:24,000 scale of the Beaverhead Group lithosomes and Quaternary deposits.

On the border of the Snowline and Henry Gulch quadrangles, the deposits are interpreted as the unconsolidated Alluvium of oldest terrace (Qat5) on the Snowline quadrangle rather than the Sixmile Creek formation (Tsc) of the Henry Gulch interpretation, due to lack of indurated rock outcrops and the presence of outsize and variable composition clasts. The Snowline quadrangle Conglomerate and Sandstone lithosomes, Lima Member, Antone Peak Formation, Beaverhead Group (Kalc and Kals) are called the Beaverhead Group, Antone Peak Formation, Conglomerate and Sandstone Members (Kabhc and Kabhs) in the Henry Gulch quadrangle.
DESCRIPTION OF MAP UNITS FOR THE SNOWLINE 7.5' QUADRANGLE

QUATERNARY UNITS:

Qal  Modern alluvium (Holocene): Generally unconsolidated, poorly sorted gravel, sand and mud found in or near active, modern river floodplains, channels and tributaries. Variable thicknesses.

Qat1  Alluvium of youngest terrace (Holocene): Unconsolidated alluvium forming tabular, elevated embankments up to approximately forty feet above the present elevation of the river floodplain with low slope angles directed northeast to northwest.

Qat2  Alluvium of second youngest terrace (Holocene): Unconsolidated alluvium forming tabular, elevated embankments above Qat1 with north-northeast directed slopes of a greater angle than those of Qat1.

Qat3  Alluvium of third youngest terrace (Holocene): Unconsolidated alluvium forming tabular, elevated embankments with NE directed slopes of the steepest angle.

Qat4  Alluvium of fourth youngest terrace (Holocene): Unconsolidated alluvium forming tabular, elevated embankments with SE directed slopes. Underlain by Blackleaf or Frontier Formation.

Qat5  Alluvium of oldest terrace (Holocene): Unconsolidated gravel of pebble to boulder size forming perched surfaces, of variable slopes and elevations. Underlain by Beaverhead Group or Frontier Formation.

Qc  Colluvial deposit (Holocene): Unconsolidated, poorly sorted, locally derived, boulders, sand, and mud. Apron landforms most commonly develop as slope wash, talus and rock fall adjacent to steep, unstable slopes.

Qaf  Alluvial fan deposit (Holocene): Unconsolidated, poorly to moderately sorted, reworked boulders, sand and mud. Fan-shaped landforms deposited in debris flow alluvial environments along active valley margins.

TERTIARY UNITS:

Tr  Rhyolite (Pliocene and/or Miocene): Pink-red volcanic rhyolite from Heise volcanic center. Isolated island surrounded by Quaternary deposits in the north-central portion of the map (section 27). Unknown name and date.

Tt  Tuff (Pliocene and/or Miocene): White volcanic tuff from Heise volcanic center. Underlies Frontier Formation forming hills in northeast portion of map (sections 6 and 7). Unknown name and date.

Tba  Basalt (Pliocene and/or Miocene): Black to dark-brown, aphanitic, variably vesicular basalt. Columnar jointed layers filled paleovalleys and overlie fluvial gravel deposits forming topographically distinct buttes and mesas. Unknown name and date.

Tgr  Gravel (Lower Pliocene to Miocene): Chiefly unconsolidated, locally cemented, rounded to sub-rounded, quartzite boulder gravel. Thin veneers underlie basalts. (Lonn and others, 2000).

TERTIARY AND CRETACEOUS UNITS:

TKbq  Quartzite conglomerate, informal member, Beaverhead Group (Tertiary and Upper Cretaceous): Moderately to well sorted, cobble to boulder conglomerate
with ancillary lenses of moderately to well sorted sandstone (Ryder, 1968; Haley, 1985; Lonn and others, 2000). Clasts are predominantly rounded pink quartzite and light-green argillite. Conglomerates are generally poorly exposed and typically form small outcrop patches within densely forested slopes and swales.

**CRETACEOUS UNITS:**
Beaverhead Group, Antone Peak Formation:

*Kalc*  *Conglomerate lithosome, Lima Member, Antone Peak Formation, Beaverhead Group (Tertiary and Upper Cretaceous):* Limestone and chert dominated, pebble to cobble conglomerate derived from Paleozoic section of the Blacktail-Snowcrest uplift (Lonn and others, 2000). Clasts are occasionally imbricated, poorly sorted, and subangular to rounded. Interbedded with sandstone, conglomerate is medium bedded with little stratification.

*Kals*  *Sandstone lithosome, Lima Member, Antone Peak Formation, Beaverhead Group (Tertiary and Upper Cretaceous):* Calcareous salt and pepper sandstone with limestone fragments grading into clean, calcareous quartz sandstone. Replaces Snowline and Monida sandstones of Ryder and Scholten (1973).

*Kf*  *Frontier Formation (Upper Cretaceous):* Interbedded sandstone, siltstone, mudstone, and limestone. Sandstone is light-dark gray with yellow, green and brown variations, very fine, to medium sand clasts, but coarse sand in places, with subrounded or subangular grains of quartz, dark gray chert, feldspar, and biotite. Sandstone is pebbly or conglomeratic in places. Siltstone and mudstone are olive-gray to medium gray or medium-dark gray, partly bentonitic, partly porcellanitic, chippy, and typically concealed. Limestone is medium gray to olive-gray, fine-grained, thinly platy, in thin and irregular beds, nodules and concretions (Dyman and others, 1995; Lonn and others, 2000).

*Kbl*  *Blackleaf Formation (Upper and Lower Cretaceous):* Volcaniclastic mudstone, bentonite, porcellanite, and siltstone (pastel beds) in upper part. Ledge-forming quartz and chert sandstone and minor mudstone in lower part (Dyman and Nichols, 1988).
### MAP UNITS AND SYMBOLS FOR THE SNOWLINE 7.5' QUADRANGLE

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Qal</td>
<td>Modern alluvium (Holocene)</td>
</tr>
<tr>
<td>Qc</td>
<td>Colluvium (Holocene)</td>
</tr>
<tr>
<td>Qaf</td>
<td>Alluvial fan (Holocene)</td>
</tr>
<tr>
<td>Qat1</td>
<td>Alluvium of youngest terrace (Holocene)</td>
</tr>
<tr>
<td>Qat2</td>
<td>Alluvium of second youngest terrace (Holocene)</td>
</tr>
<tr>
<td>Qat3</td>
<td>Alluvium of third youngest terrace (Holocene)</td>
</tr>
<tr>
<td>Qat4</td>
<td>Alluvium of fourth youngest terrace (Holocene-Pleistocene)</td>
</tr>
<tr>
<td>Qat5</td>
<td>Alluvium of oldest terrace (Holocene-Pleistocene)</td>
</tr>
<tr>
<td>Tba</td>
<td>Basalt (Pliocene and/or Miocene)</td>
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<tr>
<td>Tr</td>
<td>Rhyolite (Pliocene and/or Miocene)</td>
</tr>
<tr>
<td>Tt</td>
<td>Tuff (Pliocene and/or Miocene)</td>
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<tr>
<td>Tgr</td>
<td>Gravel (Lower Pliocene to Miocene)</td>
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<tr>
<td>TKbq</td>
<td>Quartzite conglomerate, informal member, Beaverhead Group (Tertiary and Upper Cretaceous)</td>
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<tr>
<td>Kalc</td>
<td>Conglomerate lithosome (Tertiary and Upper Cretaceous), Lima Member, Antone Peak Formation, Beaverhead Group</td>
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<td>Kals</td>
<td>Sandstone lithosome (Tertiary and Upper Cretaceous), Lima Member, Antone Peak Formation, Beaverhead Group</td>
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<td>Kf</td>
<td>Frontier Formation (Upper Cretaceous)</td>
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<td>Kbl</td>
<td>Blackleaf Formation (Upper and Lower Cretaceous)</td>
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</tbody>
</table>

- **Anticline Concealed**  
  - Strike and Dip
- **Normal Fault**  
  - Strike and Vertical Dip
- **Normal Fault Inferred**  
  - Strike and Overturned Dip
- **Thrust Fault**  
  - Strike and Overturned Dip
- **Thrust Fault Inferred**  
  - Strike and Overturned Dip
CORRELATION OF MAP UNITS FOR THE SNOWLINE 7.5' QUADRANGLE

QUATERNARY

TERTIARY

CRETACEOUS

Holocene
Pleistocene
Pliocene
Miocene
Paleocene
Upper
Lower
REFERENCES


Geologic Map of Snowline
7.5' Quadrangle, South-Central Montana

J.S. Abrahamson and J.G. Schmitt
2010

Map Symbols
- Anticline Concealed
- Normal Fault
- Thrust Fault
- Normal Fault Inferred
- Thrust Fault Inferred
- Strike and Dip
- Strike and Vertical Dip
- Strike and Overturned Dip

Map Units
- Qaf
- Qg
- Qd1
- Qd2
- Qd3
- Qd4
- Qd5
- Trr
- T3
- T2
- T1
- TPara
- Kals
- Kex
- Kfl
- Kfl
- Kfl
- Kfl

Cross Section Units and Symbols
- Modern Alluvium
- Alluvium of second youngest terrace
- Alluvium of third youngest terrace
- Conglomerate lithosome, Antone Peak Formation
- Sandstone lithosome, Antone Peak Formation
- Frontier Formation
- Blackleaf Formation
- Thrust Fault
- Normal Fault
- Bedding
- Wall


