

Cross Section A-A' 2500 m -2000 m-1500 m-No vertical exaggeration Surficial units not shown 4000 5000 6000 7000 8000 9000 10,000 SCALE: 1:24,000

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG) and the Idaho Geological Survey (IGS) selected the Polaris 7.5' quadrangle in the southern Pioneer Mountains of southwestern Montana for a 1:24,000-scale collaborative mapping project as part of a larger project designed to understand the structural and stratigraphic relationships between two dissimilar Mesoproterozoic sedimentary rock packages. To the north, in the Anaconda Range (fig. 1), are exposures of known Belt Supergroup rocks (Ruppel and others, 1993; Lonn and McDonald, 2004), whereas to the southwest in the Lemhi Range and Salmon River Mountains of Idaho are the reference sections of the Lemhi Group, Swauger Formation, and Yellowjacket Formation (Ross, 1934; Ruppel, 1975). In the intervening Beaverhead and Pioneer Mountains, previous workers have proposed very different stratigraphic and structural interpretations (MacKenzie, 1949; Coppinger, 1974; Tucker, 1975; Hansen, 1983; Pearson and Zen, 1985; Ruppel and others, 1993; Winston and others, 1999; Evans and Green, 2003; Tysdal and others, 2005; O'Neill and others, 2007; Burmester and others, 2011a). These previous geologic maps disagree on the stratigraphy and on the presence and type of tectonic structures in the area, making regional correlation of the Mesoproterozoic sedimentary packages—the Belt Supergroup and the Lemhi Group/Yellowjacket Formation—very controversial (Winston and others, 1999; Evans and Green, 2003; Ruppel and others, 1993). Since 2007, the MBMG/IGS team has mapped eight other 7.5' quadrangles in the region (Lonn and others, 2008, 2009a, 2011; Lewis and others, 2009a, 2009b, 2011; Burmester and others, 2011b; Lonn and Lewis, 2011) in an ongoing attempt to resolve some of the long-standing controversies.

PREVIOUS WORK

Data collected in 2011 were supplemented with attitudes and contacts from Pearson and Zen's (1985) 1:48,000-scale map that included the northern part of the Polaris quadrangle. The entire quadrangle was also included on small-scale maps by Zimbelman (1984; scale 1:100,000) and Ruppel and others (1993; scale 1:250,000).

GEOLOGIC SUMMARY

The eastern margin of the southern arm of the 1.40 Ga Belt–Lemhi Basin is thought to lie near the Polaris quadrangle (fig. 1), and was probably controlled by synsedimentary growth faults. In the northern Pioneer Mountains, this eastern shore is marked by the Proterozoic Black Lion Formation conglomerate, interpreted as a coarse marginal facies that interfingers westward, towards the basin, with thick quartzite deposits (McDonald and others, in review) similar to those of the Polaris quadrangle.

This eastern margin of the Mesoproterozoic basin was reactivated during the Cretaceous when the Grasshopper thrust system brought a thick slab of Proterozoic sedimentary rocks, the Grasshopper allochthon, eastward (Ruppel and others, 1993). On the Polaris quadrangle, two major thrusts within this imbricate system carried the Proterozoic strata eastward (see cross section A–A'). The lower thrust, the Kelly thrust (Myers, 1952), crops out east of the quadrangle, and its hanging wall carries a Proterozoic-to-Devonian stratigraphic section. The lower Paleozoic section is severely deformed by a fault system at a low angle to bedding that omits various Cambrian units. One of these fault omissions is visible along Scudder Creek in E½, sec. 16, T. 6 S., R. 12 W. (fig. 2) where 80 Ma (Snee, 1982) gabbro (unit Kgb) contains cleavage parallel to the fault plane, implying a minimum age of 80 Ma for the fault. Therefore, this fault system is postulated to have formed during emplacement of the regional-scale Grasshopper allochthon (fig. 1). The bedding-parallel fault system is very similar to one in the northern Pioneer Mountains that also tectonically thins the lower Paleozoic section (McDonald and others, in review).

The Devonian Jefferson Formation, at the top of the incomplete Paleozoic section, is structurally overlain by west-dipping thrusts (cross section A–A'). In the southwestern part of the map area, imbricate thrusts carry Proterozoic and Cambrian strata over Devonian strata, and in the northwest, a thrust carries an older, stratigraphically lower Proterozic unit (Yqff) over the Devonian rocks.

Deformation, probably driven by extensional tectonics, must have continued through the Tertiary and into the Quaternary, forming the basins that accumulated the Tertiary deposits (Tcg and Tcl), tilting these deposits to dips as much as 35° on the south-adjacent Mill Point 7.5' quadrangle (Lonn, unpublished mapping, 2011), and forming the north to north-northwest high-angle normal? faults that cut the Cretaceous thrust faults. A fault scarp that cuts unit QTdf along the east side of the Grasshopper Valley (fig. 3) suggests that some of the north-striking faults are still active.

DESCRIPTION OF MAP UNITS

Grain-size classification of unconsolidated and consolidated sediment is based on the Wentworth scale (Lane, 1947). Bedding thicknesses and lamination type are after Winston (1986) and McKee and Weir (1953). Distances and bed thicknesses are given in metric units. Formation thickness and elevation are listed in meters and feet. Multiple lithologies within a rock unit description are listed in order of decreasing abundance.

- Alluvium (Holocene)—Moderately well- to well-sorted, rounded to subrounded, cobble to boulder gravel and sand. Mostly derived from re-worked till and outwash gravel. Includes minor fine-grained deposits of silt and clay deposited on floodplains
- **Talus deposit (Holocene)**—Unconsolidated deposits of angular rock fragments derived from and lying at the base of cliffs or very steep slopes.
- Landslide deposit (Holocene-Pleistocene)—Unsorted mixtures of silt, clay, sand, gravel and boulders. Typically characterized by hummocky topography.
- Qaf Alluvial fan and debris flow fan deposits (Holocene-Pleistocene)—Sub-angular to subrounded, poorly sorted, cobble to boulder gravel, silt, and sand.
- Glacial till (Pleistocene)—Poorly sorted sandy to clayey boulder till. Clasts sub-angular to subrounded. Includes end moraine, recessional moraine, lateral moraine, and subordinate outwash and kame deposits. Thickness up to 100 m (330 ft).
- Alluvial fan and debris flow fan deposits (Pleistocene-Tertiary)—Sub-angular to subrounded, poorly sorted, cobble to boulder gravel, sand, and silt. As much as 60 m (195 ft) above modern streams.
- Silt and clay (Miocene? or Oligocene?)—Light yellowish brown, massive siltstone and claystone containing sparse floating pebbles and boulders. Typically capped by a flat surface of lag deposits containing sub-angular to subrounded cobbles and boulders Very poorly exposed. Thickness at least 540 m (1,750 ft) on the south-adjacent Mill Point 7.5' quadrangle, where it is in stratigraphic contact with underlying Tcg. Probably equivalent to the upper Medicine Lodge beds of Janecke and others (2005).
- Conglomerate (Oligocene or Eocene?)—Red to pink, crudely bedded, poorly sorted, angular to sub-rounded boulders, cobbles, pebbles, and sand. Very poorly exposed, but on the south-adjacent Mill Point 7.5' quadrangle a better-exposed, tilted section occurs. There, it grades upward into well-sorted, well-rounded conglomerate in stratigraphic contact with the overlying Tcl unit. Mapped as Cretaceous to Tertiary Beaverhead conglomerate by Ruppel and others (1993) and reinterpreted as Tertiary Medicine Lodge beds by Janecke and others (2005). Thickness as much as 250 m (800 ft).

downthrown side

Vertical bedding

Strike and dip of inclined beds

Contact: dashed where approximately located

Fault: dotted where concealed, bar and ball on

Reverse or thrust fault: teeth on upthrown block

Strike and dip of bedding where stratigraphic tops were confirmed using primary sedimentary structures

MAP SYMBOLS

http://www.mbmg.mtech.edu

IGNEOUS ROCKS

- **Basalt (Oligocene?)**—Rusty brown weathering, dark gray aphanitic, vesicular and amygdaloidal basalt. Janecke and others (2005) reported Ar⁴⁰/Ar³⁹ ages of 27–28 Ma for similar flows to the south and southeast.
- Volcanic rocks, undivided (Tertiary or Cretaceous)—Gray hornblende porphyry and white to red lithic tuff containing round quartz grains. Poorly exposed in the southeastern corner of the quadrangle.
- **Granodiorite** (Cretaceous)—Light gray, massive, medium-grained, hornblende-biotite granodiorite. Locally contains large K-spar phenocrysts up to 2 cm long (Pearson and Zen, 1985; Zimbelman, 1984). Equivalent to the Uphill Creek granodiorite of Pearson and Zen (1985), the predominant rock type of the Pioneer Batholith. Best age estimate of the unit is an Ar⁴⁰/Ar³⁹ date of 75 Ma (Snee, 1982).
- Hornblende gabbro (Cretaceous)—Medium to dark gray, medium- to coarse-grained, hypidiomorphic granular hornblende gabbro containing an average 40-45% plagioclase, 45–55% hornblende after augite, 3–5% augite cores in hornblende, and 0–5% biotite (Zimbelman, 1984; Pearson and Zen, 1985). An Ar⁴⁰/Ar³⁹ age on hornblende provides a minimum age of 79.9 Ma (Snee, 1982). Thought to be an early border phase of the Pioneer Batholith (Snee, 1982; Zimbelman, 1984).

PALEOZOIC STRATA

A poorly exposed and incomplete Middle Cambrian to Devonian section is present in the Polaris quadrangle. The lower Paleozoic section is incomplete because a fault system that occurs at a low angle to bedding has omitted various parts of the section. See the Geologic Summary section for more detail. Thicknesses represent maximum observed thicknesses in the Polaris quadrangle.

- Jefferson Formation (Devonian)—Dark gray, yellow, and white, sucrosic dolomite and limestone. Often bleached and recrystallized to white marble. Dark gray dolomite distinguishes this unit from the Hasmark Formation (unit €h). Strongly deformed in the Polaris quadrangle, with numerous intraformational faults, abundant tectonic breccia, and tight folds. Deformation makes thickness estimates problematic, but probably more than 300 m (1,000 ft) thick.
- **Red Lion Formation (Cambrian)**—Multi-colored and lithologically variable unit that includes red dolomite with thin maroon anastomosing shaly layers, shaly conglomerate containing limestone and mud-chip intraclasts, reddish calcareous silty shale, and calcareous and non-calcareous sandstone and quartzite. Thickness approximately 40 m (130 ft).
- Hasmark Formation (Cambrian)—Light gray to white thinly laminated to massive dolomite with minor magnesium limestone intervals. Weathers very light gray with a smooth, laminated surface. Thickness as much as 100 m (325 ft).
- Silver Hill Formation (Cambrian)—Lithologically varied unit. Very poorly exposed, but contains brown to greenish brown shale, distinctive red to maroon argillite and siltite, dark gray limestone with wavy yellow-brown silty seams that impart a "black and gold" color to rock, calcareous sandstone, white feldspar-poor quartzite, and quartz-pebble conglomerate. Thickness as much as 105 m (340 ft).
- Flathead Formation (Cambrian)—Pink to salmon, medium-grained, moderately well-sorted, thick-bedded, feldspar-poor quartzite. Difficult to distinguish from unit ZYgc in the field, but is better sorted, lacks mud chips and feldspar, and has a more massive appearance. Laminations are faint, with flat laminations more common than cross laminations. Eight slabbed and stained samples contained 97–100% quartz, 0% K-spar, 0–2% plagioclase, and up to 3% red chert? grains. Compositionally similar quartzite near Argenta on the east-adjacent Ermont 7.5' quadrangle was interpreted as Flathead by Pearson (1996), but as Neihart Formation of the lower Belt Supergroup by Sears and others (2010) on the basis of detrital zircon ages. Thickness as much as

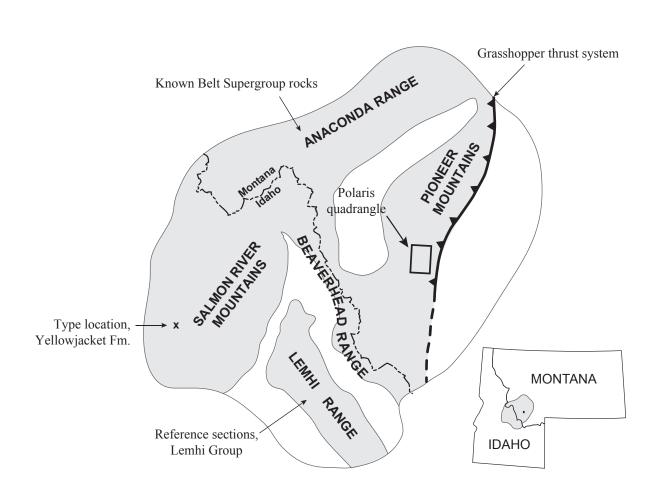


Figure 1. Location of Polaris 7.5' quadrange with respect to known Belt Supergroup rocks and the reference and type sections of the Lemhi Group and Yellowjacket Formation. Shaded areas represent mountain ranges containing Mesoproterozoic sedimentary rocks.

CORRELATION DIAGRAM

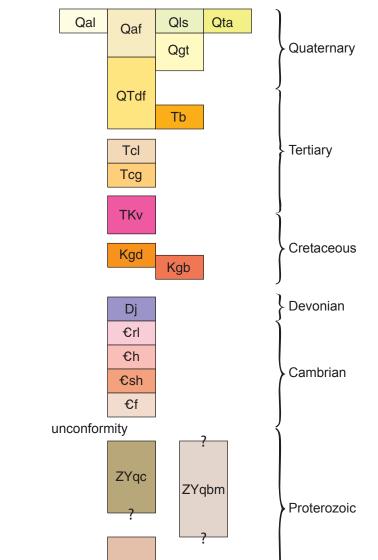


Figure 4. Northward view of west-dipping Proterozoic ZYqc capped by ledge of Cambrian Flathead Fm.

MESOPROTEROZOIC STRATA

Low metamorphic grade metasedimentary rocks of Proterozoic age underlie much of the Polaris quadrangle and have been assigned by previous workers to the Belt Supergroup (Zimbelman, 1984; Pearson and Zen, 1985; Ruppel and others, 1993). But in the nearby Peterson Lake 7.5' quadrangle, Lonn and Lewis (2011) assigned similar quartzite units to Proterozoic formations of the Lemhi Range, Idaho (Ruppel, 1975; Lonn and others, 2009b). Because no terrane-bounding structures have been mapped between the Polaris and Peterson Lake quadrangles, Proterozoic strata in the Polaris quadrangle may correlate with Lemhi Range strata rather than Belt Supergroup strata. The quartzite of the Polaris quadrangle was divided into three fault-bounded units based on grain size and composition, and assigned only descriptive names, pending further study.

- ZYqc Coarse-grained quartzite (Mesoproterozoic and/or Neoproterozoic)—White, pink, red, and purple, poorly sorted, medium- to coarse-grained, trough and planar cross-bedded quartzite. Beds 5 cm to 1 m thick. Contains 5–10% red and black chert? grains that are visible in hand sample. Although feldspar is not obvious in hand sample, 15 slabbed and stained samples contained 10–15% K-spar and 5–10% plagioclase; all samples had K-spar in excess of plagioclase. Contains sparse granules and small floating pebbles. Red mud rip-up clasts are abundant near the top of the unit. Upper contact is a poorly exposed disconformity with the Flathead Formation (fig. 4); lower contact not exposed. Tentatively correlated with the Swauger Formation of the Lemhi Range, Idaho (Ruppel, 1975). Thickness at least 770 m (2,500 ft).
- ZYqbm Coarse-grained quartzite of Black Mountain (Mesoproterozoic and/or Neoproterozoic)—White to light gray, poorly sorted, medium- to coarse-grained, thick-bedded quartzite. Contact metamorphism has obscured most of the bedding characteristics, but some trough cross-beds are visible. Lacks the abundant red and black chert? grains and K-spar of unit ZYqc; five slabbed and stained samples contained 0–5% K-spar, 0–10% plagioclase, and as much as 10% metamorphic sericite. Equivalent to Pearson and Zen's (1985) quartzite of Black Mountain, mapped in stratigraphic contact with the Flathead Formation on the east-adjacent Ermont 7.5' quadrangle, suggesting that it is the same or equivalent to unit ZYqc described above. The low feldspar content suggests affinity with the Swauger Formation that caps the Lemhi Group in the Lemhi Range (Ruppel, 1975). Neither upper nor lower contacts are exposed in the Polaris 7.5' quadrangle, but a minimum stratigraphic thickness of 985 m (3,200 ft) is exposed on Baldy Mountain.
- Yqff Fine-grained feldspathic quartzite (Mesoproterozoic)—Gray, well sorted, fine- to very fine grained, feldspathic quartzite. Contact metamorphism has obscured bedding characteristics, but beds appear to be decimeter-scale and contain abundant flat laminations. Thin (0.5 cm) dark gray argillite beds are common, but desiccation cracks and mud rip-up clasts are not present. Four slabbed and stained samples contained 50–65% quartz, 0% detrital K-spar, and 35–50% plagioclase, sericite, secondary interstitial K-spar, biotite, and porphyroblasts of muscovite and andalusite. Top and bottom not exposed, but at least 770 m (2,500 ft) thick. This quartizte bears a strong resemblance to the Gunsight Formation of the Lemhi Group (Ruppel, 1975) and also to strata above the Swauger Formation in the Lemhi Range (Ruppel, 1975; Lonn and others, 2009b).

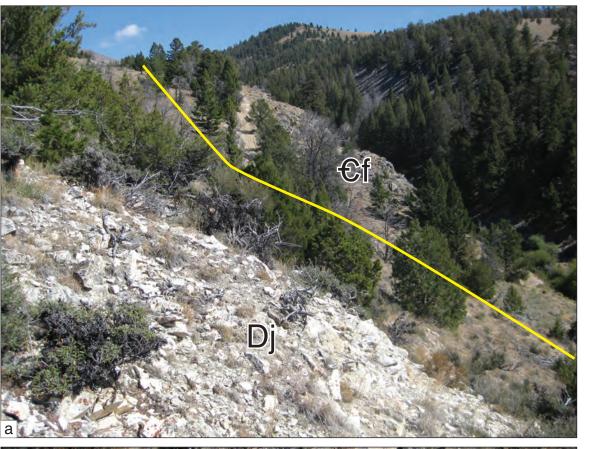
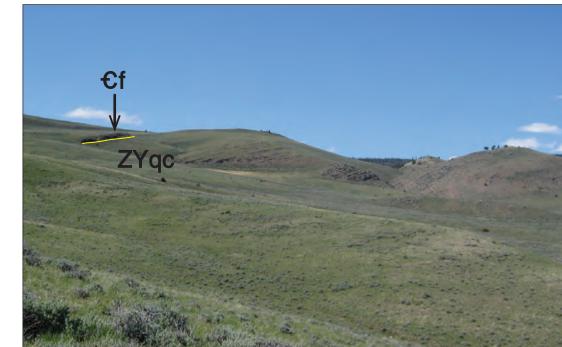




Figure 2, Low-angle fault (below line) along Scudder Creek (SE ¼, sec. 16, T. 6 S., R. 12 W.) omits lower Paleozoic strata: a) Bench is developed along gently dipping fault with Devonian Jefferson Fm. (Dj in oreground) above outcrops of Cambrian Flathead Fm. (£f), b) foliation developed in the Jefferson Fm. parallel to and immediately above the fault plane.

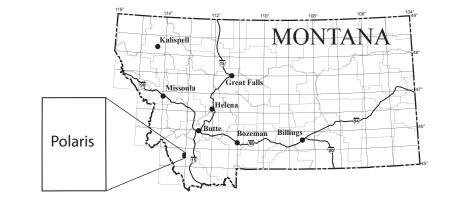
Figure 3. Modern fault scarp (between the arrows) on the east side of the Grasshopper Valley E ½, sec. 29, T. 6 S., R. 12 W., cuts unit QTdf.



(arrow). NW 1/4, sec. 3, and NE 1/4, sec. 4, T. 6 S., R. 12 W.

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MBMG Open-File 621

Geologic Map of the Polaris 7.5' Quadrangle, Beaverhead County Southwest Montana

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2012

Horizontal Datum: 1927 North American Datum

GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.