2015

GEOLOGIC MAP OF THE LOWER SEYMOUR LAKE 7.5' QUADRANGLE, SOUTHWESTERN MONTANA

MBMG Open-File Report 664

Mapped by
Colleen G. Elliott

Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey under contract number G14AC00221

MBMG
Montana Bureau of Mines and Geology

Cover image: View towards the southwest from the northern boundary of the Lower Seymour Lake quadrangle.
Photo by Colleen Elliott.

Contents

Figures

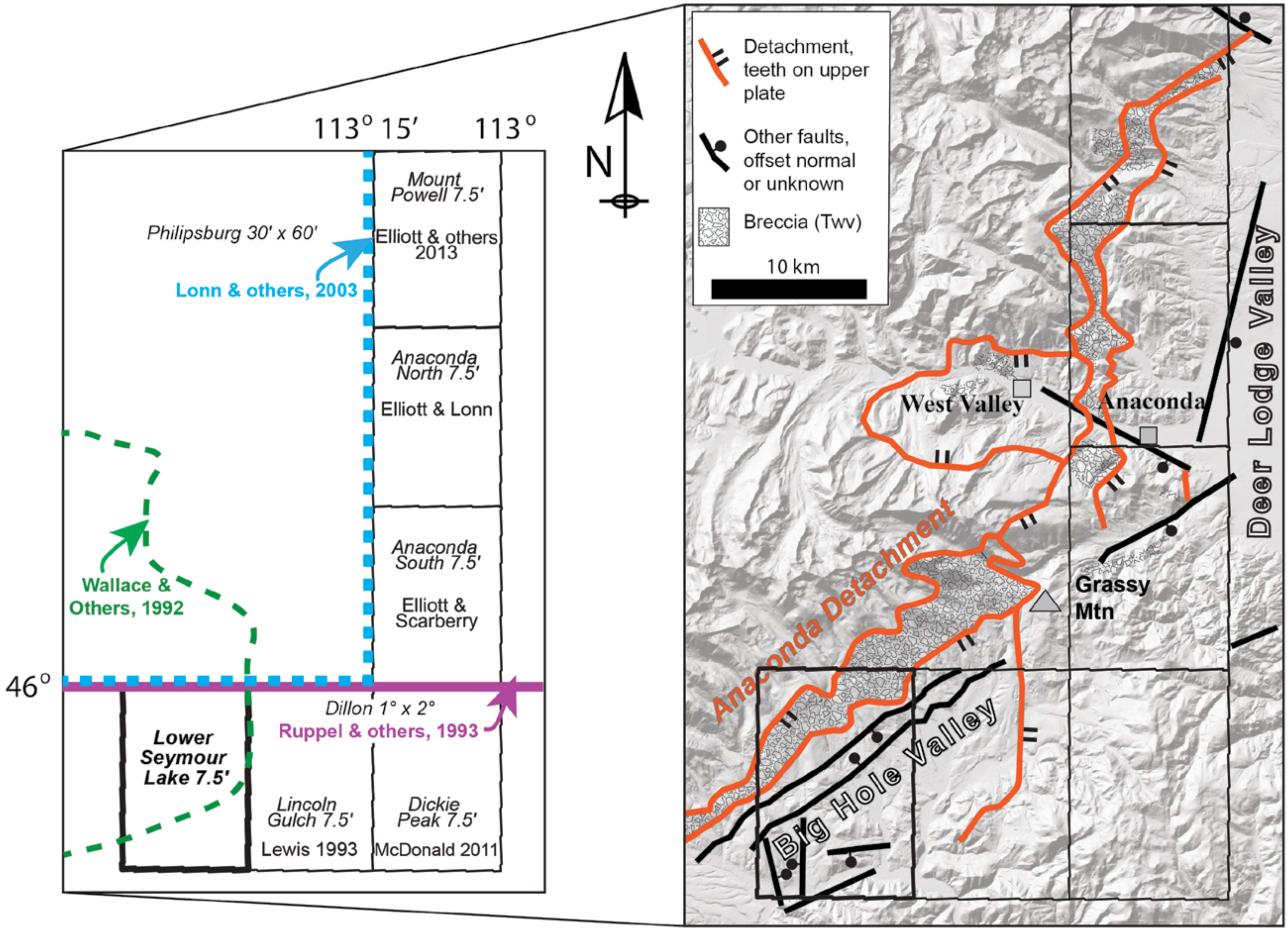

Figure 1. Previous mapping in and around the Lower Seymour Lake 7.5’ quadrangle and locations of features mentioned in text.

INTRODUCTION AND BACKGROUND

New mapping of the Lower Seymour Lake 7.5’ quadrangle is a step toward completing the geologic map of the Wisdom 30’ x 60’ quadrangle. It also continues detailed mapping of the hanging wall, or upper plate, of the Anaconda Detachment (fig. 1; Elliott and others, 2013; Elliott and Lonn, in review; Elliott and Scarberry, in review). The main objectives are to piece together the Cenozoic extensional history and stratigraphy of southwest Montana, and to resolve the large-scale structure of today’s valleys and mountain ranges. The Lower Seymour Lake 7.5’ quadrangle mapping follows the Anaconda Detachment into the Big Hole Valley, building on the work cited above.

The footwall, or lower plate, of the Anaconda Detachment has been mapped by Lonn and others (2003), Kalakay and others (2003), O’Neill and others (2004), Grice (2006), and Berger and Elliott (2007). Extension lineations within the footwall are gently inclined towards ca. 100°–110° (Kalakay and others, 2003; O’Neill and others, 2004; Grice, 2006). Isotopic analyses bracket the age of extension between 53 Ma and 27 Ma (Grice, 2006; Foster and others, 2010), a range that encompasses extrusion of the Lowland Creek Volcanics (53–48 Ma, Dudás and others, 2010; Foster and others, 2010; Scarberry and Smith, 2014) and intrusion and mylonitization of granitic plutons in the footwall (41–38 Ma, Foster and others, 2010). Displacement on the Anaconda Detachment may be as much as 28 km (Foster and others, 2010).

Since recognition of the Anaconda Metamorphic Core Complex (O’Neill and others, 2004), there has been little structural analysis of the upper plate. The sole stratigraphic study is O’Neill (2005), which reinterprets the “Anaconda beds” of Csejtey (1962) as syntectonic sediments called the “Anaconda Conglomerate.” New mapping (Elliott and others, 2013), however, shows that the Anaconda Conglomerate, as defined, includes gravels of different ages and different stratigraphic levels, so it is not used here.

PREVIOUS MAPPING

The Dillon 1° x 2° quadrangle (Ruppel and others, 1993, 1:250,000 scale) includes the Lower Seymour Lake 7.5’ quadrangle, and the geologic map of the Anaconda–Pintler wilderness area (Wallace and others, 1992, 1:50,000 scale) covers part of the 7.5’ quadrangle. There are geologic maps for the east-adjacent Lincoln Gulch 7.5’ sheet (Lewis, 1993, 1:24,000 scale) and the north-adjacent Philipsburg 30’ x 60’ quadrangle (Lonn and others, 2003, 1:100,000 scale).

GEOLOGIC SUMMARY

PROTEROZOIC

Mesoproterozoic quartzite, conglomerate, and argillite (Ysw, Ylc) underlie the south half of the Lower Seymour Lake quadrangle, extending north of the Big Hole River into an area previously mapped as Tertiary deposits (Wallace and others, 1992) and Tertiary Bozeman Group (Ruppel and others, 1993). Mesoproterozoic strata in the area mapped as Missoula Group of the Belt Supergroup (Ruppel and others, 1993) are now known to belong to the Lemhi subbasin, which includes the Lemhi Group and overlying strata (Burmester and others, 2013; Lonn and others, in review).

The Lemhi subbasin rocks are shortened into variably plunging, northwest-trending, upright folds in what appears to be the hinge of a regional anticline.

PALEOZOIC

Paleozoic rocks do not crop out in the Lower Seymour Lake quadrangle; however, Tertiary breccia (Twv) in the northeast corner is composed entirely of Paleozoic clasts. The farthest northeastern exposure of Twv is a tectonic breccia of carbonate-cemented limestone and dolomite (fig. 2a). Farther west, sedimentary breccia contains the same clasts (fig. 2b). The source rock for these breccias is probably Cambrian sedimentary rocks exposed in the Philipsburg 30' x 60' quadrangle to the north (Lonn and others, 2003). Other breccias are composed entirely of Mesoproterozoic quartzites (fig. 2c).

MESOZOIC

The porphyritic tonalite body (Ktop) along the Big Hole River was emplaced roughly parallel to bedding in the Swauger Formation. The intrusion has a contact metamorphic aureole characterized by sheaves of coarse crystalline biotite and muscovite in Swauger Formation quartzite (Ysw). The tonalite (Ktop) is continuous with Cretaceous intrusive bodies south and east of the map area (Lonn and McDonald, 2004), and correlates with tonalites of the Pioneer Batholith (Ruppel and others, 1993).

CENOZOIC

The Paleogene Anaconda Detachment separates the lower plate of the Anaconda Metamorphic Core Complex from unmetamorphosed upper plate rocks and sediments. The detachment cuts obliquely through the northern half of the Lower Seymour Lake quadrangle. This report is the first to recognize that a second detachment within the upper plate parallels the Anaconda Detachment, and that both extend east and north for over 75

Figure 2. West Valley breccia Twv. (a) Tectonically brecciated carbonates. (b, opposite page) Sedimentary breccia of varied carbonate clasts. (c, opposite page) Tectonically brecciated Ysw quartzite. Pencil 15 cm long.


2b


2c

km (fig. 1). In the Lower Seymour Lake quadrangle, the two strands trend between 155° and 165° and dip 17°–20° southeast. Associated lineations in mylonitic biotite–muscovite granite and granodiorite (Tbmg) trend shallowly toward the east–southeast and southeast, generally oblique to the dip direction of the detachment.

The sheared Tbmg in the northwest corner of the quadrangle is part of the early to middle Eocene Hearst Lake plutonic suite (Foster and others, 2010). The suite was simultaneously intruded and mylonitized during extension and uplift of the core complex (Grice, 2006; Foster and others, 2010).

The West Valley breccia (new name) (Twv, figs. 1, 2) is a widespread, syntectonic, sedimentary, and tectonic breccia named after the well-described West Valley "chaos" of O'Neill and others (2004) and O'Neill (2005) (fig. 1). These authors included the West Valley chaos in the Anaconda Conglomerate. In the Lower Seymour Lake quadrangle, the West Valley breccia extends along the Anaconda Detachment throughout its mapped extent (fig. 1). Large exposures in the Mount Powell area shown as brecciated Cenozoic and Paleozoic units by Elliott and others (2013) are actually part of a continuous, mappable sheet of syntectonic West Valley breccia.

A sequence of gravel, silt, tuff, and red clay (figs. 3 a, b) is here named the Grassy Mountain sediments (Tgm) after the sedimentary sequence on Grassy Mountain about 8 km (5 mi) north–northeast of the Lower Seymour Lake quadrangle. These sediments were mapped in adjacent areas as Anaconda Conglomerate (Lonn and others, 2003; Foster and others, 2010). Tgm appears to have the same stratigraphic position as the Renova Formation (lower Miocene to upper Eocene), and the smectitic clay resembles the altered volcanic ashes of the Climbing Arrow Member (Vuke, 2004, 2006).

At Grassy Mountain (fig. 1), white tuff of the Lowland Creek Volcanics ($^{40}Ar/^{39}Ar$ age 53.7 ± 1.4 Ma, Foster and others, 2010) is overlain by red and brown smectitic clay. Gravel, sands, silt, and whitish tuff are intermixed with the clay, and poorly sorted, mixed-clast gravel lag rests on the top. In the Lower Seymour Lake quadrangle, this unit is poorly exposed, but is identifiable where red, gray, and brown soils have a characteristic popcorn texture. Gravel associated with the unit is typically a poorly sorted mixture of angular to well-rounded clasts of rock types found within the Anaconda Metamorphic Core Complex. The Grassy Mountain unit occurs in patches within the upper plate of the Anaconda Metamorphic Core Complex, and is prone to forming large landslides.

Alluvial gravel (Tal, fig. 4) overlies Tgm sediments across an angular unconformity. The gravel is dominated by large, well-rounded cobbles and closely resembles the Miocene Sixmile Creek Formation elsewhere in southwest Montana (Fritz and Sears, 1993). Tal has not been dated, but it occurs at high elevations (almost 33 m above the Big Hole River in places) and is cut by faults, suggesting that it is Tertiary rather than Quaternary, and late Miocene if correlated with the Sixmile Creek Formation.

Steep normal faults parallel to the trend of the Anaconda Detachment appear syntectonic and therefore probably do not offset either strand at depth. Oblique faults separate blocks of Mesoproterozoic basement rocks within a structural transition zone between the western Pioneer Mountains to the south, and a central graben transecting the Lower Seymour Lake quadrangle from northeast to southwest. Faults in the upper plate of the Anaconda Detachment are typically mutually crosscutting and therefore formed at the same time. Mutually intersecting fault relationships are common in the hanging wall of other detachments (Reches, 1978; Krantz, 1988), and typically separate basins with related but distinct stratigraphic sequences (Oner and Dilek, 2013; Ersoy and others, 2014).

Figure 3. Grassy Mountain unit (Tgm). (a) SE-dipping red clay, gray silt, and cobble gravel on Bear Gulch in Lower Seymour Lake quadrangle. Matrix-supported gravel has angular and rounded clasts. Notebook is 19 cm long. (b) Red clay, gray silt, and cobble gravel on Grassy Mountain (location in fig. 1). Model is 1.7 m tall.

GLACIAL GEOLOGY

Quaternary sediments record two glacial advances. Most of the older till deposits (Qgto) are exposed in the upper drainage of the East Fork of La Marche Creek. The distribution of those sediments suggests that the earlier glacial advance followed the East Fork drainage, but the second advance turned sharply south into the Middle Fork of La Marche Creek, truncated the older glacial valley, and flowed south into the main stem of La Marche Creek.

Figure 4. Alluvial gravel (Tal). Cobbles range from subrounded to well rounded. Most cobbles are quartzite.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Modern stream and floodplain deposits. Thickness as much as 45 m (150 ft).

Qls **Landslide deposits (Holocene–Pleistocene)**—Unstratified, unsorted mixtures of sediment that moved downslope by mass wasting processes. Color, composition, and grain size reflect the parent rock and transported surficial material. Thickness probably less than 30 m (100 ft).

Qlso **Landslide deposits, older than Qls (Holocene–Pleistocene)**—Unstratified, unsorted mixtures of sediment that moved downslope through mass wasting processes. Color, composition, and grain size reflect the parent rock and transported surficial material. Distinguished where reactivated by younger landslides (Qls). Thickness probably less than 30 m (100 ft).

Qaf **Alluvial fan deposits (Holocene–Pleistocene)**—Angular to subrounded, unsorted, cobble to boulder gravel fans. Thickness probably less than 45 m (150 ft).

Qta **Talus (Holocene–Pleistocene)**—Angular and subangular cobble- to boulder-size clasts at the base of steep valley walls or cliffs. Thickness probably less than 30 m (100 ft).

Qgo **Glacial outwash deposit (Pleistocene)**—Moderately to well-sorted, subrounded to well-rounded gravel and sand sheets immediately downslope from glacial till (Qgt deposits). Thickness may be as much as 65 m (220 ft).

Qgoo **Glacial outwash deposit, older (Pleistocene)**—Moderately to well-sorted, subrounded to well-rounded gravel and sand sheets immediately downslope from older glacial till (Qgto) deposits. Deposits are typically incised by younger outwash (Qgo). Thickness may be as much as 65 m (220 ft).

Qgt **Glacial till (Pleistocene)**—Unsorted clay to boulder deposits in lateral, ground, and medial moraines. Characterized by hummocky terrain scattered with large subangular to subrounded granite boulders. Thickness may be as much as 120 m (400 ft).

Qgto **Glacial till, older than Qgt (Pleistocene)**—Unsorted clay to boulder deposits in lateral, ground, and medial moraines. Deposit surfaces are more subdued than Qgt, and granite boulders are smaller and more rounded. Thickness may be as much as 120 m (400 ft).

Qc **Colluvium (Quaternary)**—Structureless pebble and cobble lag over Tertiary sediments. Thickness less than 3 m (10 ft).

Tal **Alluvial gravel (Miocene?)**—Boulder and cobble gravel dominated by rounded to very well-rounded quartzite clasts (fig. 4). Gravel closely resembles some members of the Miocene Sixmile Creek Formation and appears to have the same stratigraphic position. Thickness less than 65 m (220 ft).

Tgm **Grassy Mountain unit (early Oligocene?–late Eocene)**—Gravel, sand, silt, and clay; typically red, though gray and tan beds occur, as well as some white tuffaceous beds. Unit is poorly exposed, but is characterized by popcorn-textured smectitic soils that are prone to landslides. Gravel is immature, with subangular to well-rounded pebbles and cobbles of Mesoproterozoic quartzites and argillites, granite mylonite, and vesicular andesite. Can be matrix- or clast-supported. In the north half of sections 14 and 15, T. 2 N., R. 13 W., Tgm gravel rests on Proterozoic quartzite (Ysw) and contains a vesicular andesitic flow (Tv) within poorly exposed gravel, tuff, and clay. Quartzites are typically intensely brecciated where directly overlain by Tgm. Thickness as much as 1,400 m (4,600 ft).

Twv **West Valley breccia (Oligocene–Eocene)**—Sedimentary and tectonic breccias (figs. 2a,b,c) that extend along the Anaconda Detachment from the northwest end of the Deer Lodge Valley into the Big Hole Valley. Named after the West Valley "chaos" described by O'Neill and Lageson (2003) and O'Neill (2005). Thought to be syntectonic with extension of the Anaconda Metamorphic Core Complex, which occurred between 43 and 27 Ma (Foster and others, 2010), therefore ranging from late Oligocene to early Eocene. In the Lower Seymour Lake quadrangle, Twv forms a 400- to 600-m-thick (1,300–2,000 ft) layer between the two detachment strands.

Ylc **Lawson Creek Formation (Mesoproterozoic)**—Feldspathic quartzite and argillite (fig. 5), maroon, gray, and dark pink to red with dark laminae and abundant mud rip-up clasts. Quartzite is fine- to medium-grained and moderately sorted. Feldspar grains can be seen with a hand lens. Maroon argillite forms millimeter-thick layers. Exposed thickness ca. 300 m (1,000 ft). Ylc in the southern Big Hole Valley is estimated to be over 2,000 m (6,500 ft) thick (Lonn and others, in review).

Ysw **Swauger Formation (Mesoproterozoic)**—Feldspathic quartzite and conglomerate that are red, pink, or gray, poorly to moderately sorted, medium- to coarse-grained, and trough and planar crossbedded (figs. 6 a, b). Crossbeds are typically highlighted by black and red laminae. Composed of well-rounded quartz, rounded to angular feldspar grains, and scattered frosted pink granules. Locally contains red and black mud rip-up clasts. Chalky white feldspar grains are obvious in hand samples. Conglomerate composed of angular to rounded quartzite, feldspar, and red and black chert clasts from granule to cobble size. Exposed thickness 3,400 m (11,000 ft). In the southern Big Hole Valley, Ysw is estimated to be as much as 3,000 m (10,000 ft) thick (Lonn and others, in review).

Figure 5. Lawson Creek Formation quartzite and argillite (Ylc). Compass is 17 cm long and pointing north.

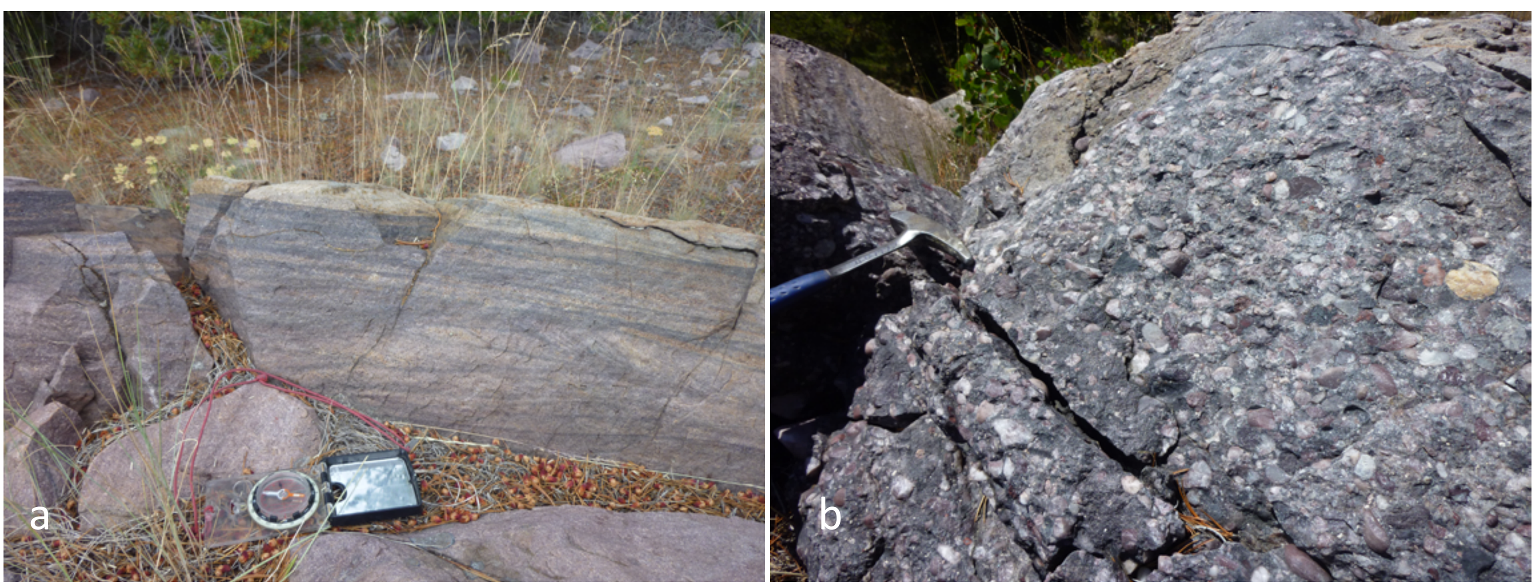

Figure 6. Swauger Formation (Ysw). (a) Crossbedded feldspathic quartzite. Compass is 17 cm long and pointing north. (b) Conglomerate with dark feldspathic quartzite matrix. Clasts are mostly older quartzites.

IGNEOUS UNITS

Tv **Volcanic rocks (Oligocene?–Eocene)**—Variety of volcanic and hypabyssal rocks ranging from rhyolitic crystal tuff to porphyritic andesite. In the north half of sec. 14, T. 2 N., R. 13 W., Tv is a weathered, dark gray, flow-banded vesicular andesite with small orange-weathered feldspar phenocrysts. Tv near the center of sec. 33, T. 2 N., R. 13 W. and in SW¼ SW¼ sec. 20, T. 2 N., R. 13 W. is purple- to orangish-pink rhyolite with glassy quartz eyes and biotite and feldspar phenocrysts. Other exposures are light gray to white, variably welded, quartz–biotite–muscovite–feldspar crystal tuff. With the exception of the porphyritic andesite, all of these lithologies are found in the Eocene Lowland Creek Volcanics (48–53 Ma) (Dudás and others, 2010; Scarberry and Smith, 2014), which are widely exposed east and north of the quadrangle. However, there are a few occurrences of Oligocene volcanic rocks nearby. A zircon age of 29.6 Ma (Oligocene) was obtained for tuff along French Creek just east of the Lower Seymour Lake quadrangle (Roe, 2010). Fritz and others (2007) got a K-Ar date of 21.9 Ma for a basanite flow west of the quadrangle.

Tbmg **Granite, biotite–muscovite (Eocene)**—Fine- to medium-grained two-mica granite, dacite, and granodiorite of the Hearst Lake suite (fig. 7). Generally porphyritic. Mylonitic foliation is present within and adjacent to the Anaconda Detachment Fault. Foster and others (2007) report a U-Pb crystallization age of 53 ± -1 Ma for a related granodiorite. Foster and others (2010) report $^{40}Ar/^{39}Ar$ cooling ages between 39 and 41 Ma for two-mica granite mylonites north of the Lower Seymour Lake quadrangle.

Ktop **Tonalite, porphyritic (Late Cretaceous?)**—Gray, medium-grained tonalite composed of feldspar, quartz, biotite, and hornblende. Locally weakly foliated. Ruppel and others (1993) correlate Ktop with the Late Cretaceous Pioneer Batholith.

Figure 7. Muscovite–biotite granite (Tgmb). In this exposure, the granite is medium grained and micas are weakly aligned. Orange pencil is about 10 cm long.

REFERENCES

Berger, A., and Elliott, C.G., 2007, Detailed structural geology of the central part of the West Valley 7.5' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open-File Report 560, 11 p., 1 sheet, scale 1:24,000.

Burmester, R.F., Lonn, J.D., Lewis, R.S., and McFaddan, M.D., 2013, Toward a grand unified theory for stratigraphy of the Lemhi subbasin of the Belt Supergroup: Northwest Geology, v. 42, p. 1–20.

Csejtey, B., 1962, Geology of the southeast flank of the Flint Creek Range, western Montana: N.J., Princeton University, Ph.D. dissertation, 208 p.

Dudás, F.Ö., Ispolatov, V.O., Harlan, S.S. and Snee, L.W., 2010, $^{40}Ar/^{39}Ar$ geochronology and geochemical reconnaissance of the Eocene Lowland Creek volcanic field, west-central Montana: Journal of Geology, v. 118, p. 295–304.

Elliott, C.G., and Lonn, J.D., in review, Geologic map of the Anaconda North 7.5' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report, scale 1:24,000.

Elliott, C.G., and Scarberry, K.C., in review, Geologic map of the Anaconda South 7.5' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report, scale 1:24,000.

Elliott, C.G., Smith, L.N., and Lonn, J.D., 2013, Geologic map of the Mount Powell 7.5' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 635, 22 p., 1 sheet, scale 1:24,000.

Ersoy, E.Y., Çemen, İ., Helvacı, C., and Billor, Z., 2014, Tectono-stratigraphy of the Neogene basins in Western Turkey: Implications for tectonic evolution of the Aegean Extended Region: Tectonophysics, v. 635, p. 33–58.

Foster, D.A., Doughty, P.T., Kalakay, T.J., Fanning, C.M., Coyner, S., Grice, W.C., and Vogl, J.J., 2007, Kinematics and timing of exhumation of Eocene metamorphic core complexes along the Lewis and Clark fault zone, northern Rocky Mountains, USA, *in* Till, A., Roeske, S., Sample, J., and Foster, D.A., eds., Exhumation along Major Continental Strike-Slip Systems: Geological Society of America Special Paper 434, p. 205–229.

Foster, D.A., Grice, W.C., and Kalakay, T.J., 2010, Extension of the Anaconda Metamorphic Core Complex: $^{40}Ar/^{39}Ar$ thermochronology and implications for Eocene tectonics of the northern Rocky Mountains and the Boulder Batholith: Lithosphere, v. 2, p. 232–246, doi:10.1130/L94.1.

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

Fritz, W.J., Sears, J.W., McDowell, R.J., and Wampler, J.M., 2007, Cenozoic volcanic rocks of southwestern Montana: Northwest Geology, v. 36, p. 91–110.

Grice, W.C., 2006, Exhumation and cooling history of the middle Eocene Anaconda Metamorphic Core Complex, western Montana: Gainesville, Fla., University of Florida, M.S. thesis, 261 p.

Kalakay, T.J., Foster, D.A., and Thomas, R.A., 2003, Geometry, kinematics and timing of extension in the Anaconda extensional terrane, western Montana: Northwest Geology, v. 32, p. 124–133.

Krantz, R.W., 1988, Multiple fault sets and three-dimensional strain: theory and application: Journal of Structural Geology, v. 10, p. 225–237.

Lewis, S.E., 1993, Preliminary geologic map of the Lincoln Gulch 7.5' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 272, 10 p., 1 sheet, scale 1:24,000.

Lonn, J.D., and McDonald, C., 2004, Geologic map of the Dickie Hills 7.5' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open-File Report 501, 14 p., 1 sheet, scale 1:24,000.

Lonn, J.D., McDonald, C., Lewis, R.S., Kalakay, T.J., O'Neill, J.M., Berg, R.B., and Hargrave, P., 2003, Geologic map of the Philipsburg 30' x 60' quadrangle, western Montana: Montana Bureau of Mines and Geology Open-File Report 483, 1 sheet, scale 1:100,000.

Lonn, J.D., Elliott, C.G., Lewis R.S., Burmester R.F., McFaddan M.D., Stanford, L.R., Janecke, S.U., and

Othberg, K.L., in review, Geologic map of the Montana part of the Salmon 30′ x 60′ quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report, scale 1:100,000.

O'Neill, J.M., 2005, Syntectonic Anaconda Conglomerate (New Name)—A stratigraphic record of early Tertiary brittle-ductile extension and uplift in southwestern Montana, *in* Stratigraphic studies in southwestern Montana and adjacent Idaho—Lower Tertiary Anaconda Conglomerate and Mesoproterozoic Gunsight Formation: U.S. Geological Survey Professional Paper 1700, Chapter A, p. 1–15.

O'Neill, J.M., and Lageson, D.R., 2003, West to east geologic road log for Paleocene Anaconda Metamorphic Core Complex: Georgetown Lake Dam–Anaconda-Big Hole Valley: Northwest Geology v. 32, p. 29–46.

O'Neill, J.M., Lonn, J.D., Lageson, D.R., and Kunk, M.J., 2004, Early Tertiary Anaconda Metamorphic Core Complex: Canadian Journal of Earth Sciences, v. 41, p. 63–72.

Oner, Z., and Dilek, Y., 2013, Fault kinematics in supradetachment basin formation, Menderes core complex of western Turkey, Tectonophysics v. 608, p. 1394–1412.

Reches, Z.E., 1978, Analysis of faulting in three-dimensional strain fields: Tectonophysics, v. 47, p. 109–129. doi:10.1016/0040-1951(78)90154-3.

Roe, W.P., 2010, Tertiary sediments of the Big Hole Valley and Pioneer Mountains, southwestern Montana: age, provenance, and tectonic implications: Missoula, Mont., University of Montana, M.S. thesis, 117 p.

Ruppel, E.T., O'Neill, J.M., and Lopez, D.A., 1993, Geologic map of the Dillon 1° x 2° quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1803-H, scale 1:250,000.

Scarberry, K.C., and Smith, M.G., 2014, Eocene volcanic stratigraphy and Tertiary fault geometry of the southern Deer Lodge Valley, SW Montana: Geological Society of America, Rocky Mountain Section, Programs with Abstracts.

Vuke, S.M., 2004, Geologic map of the Divide area, southwest Montana, Montana Bureau of Mines and Geology Open-File Report 502, 36 p., 1 sheet, scale 1:50,000.

Vuke, S.M., 2006, Geologic map of the Cenozoic deposits of the lower Jefferson Valley, southwestern Montana, Montana Bureau of Mines and Geology Open-File Report 537, 41 p., 1 sheet, scale 1:50,000.

Wallace, C.A., Lidke, D.J., Elliott, J.E., Desmarais, N.R., Obradovich, J.D., Lopez, D.A., Zarske, S.E., Heise, B.A., Blaskowski, M.J., and Loen, J.S., 1992, Geologic map of the Anaconda–Pintlar wilderness and contiguous roadless area, Granite, Deer Lodge, Beaverhead, and Ravalli counties, western Montana: U.S. Geological Survey Miscellaneous Field Study Map MF-1633-C, scale 1:50,000.