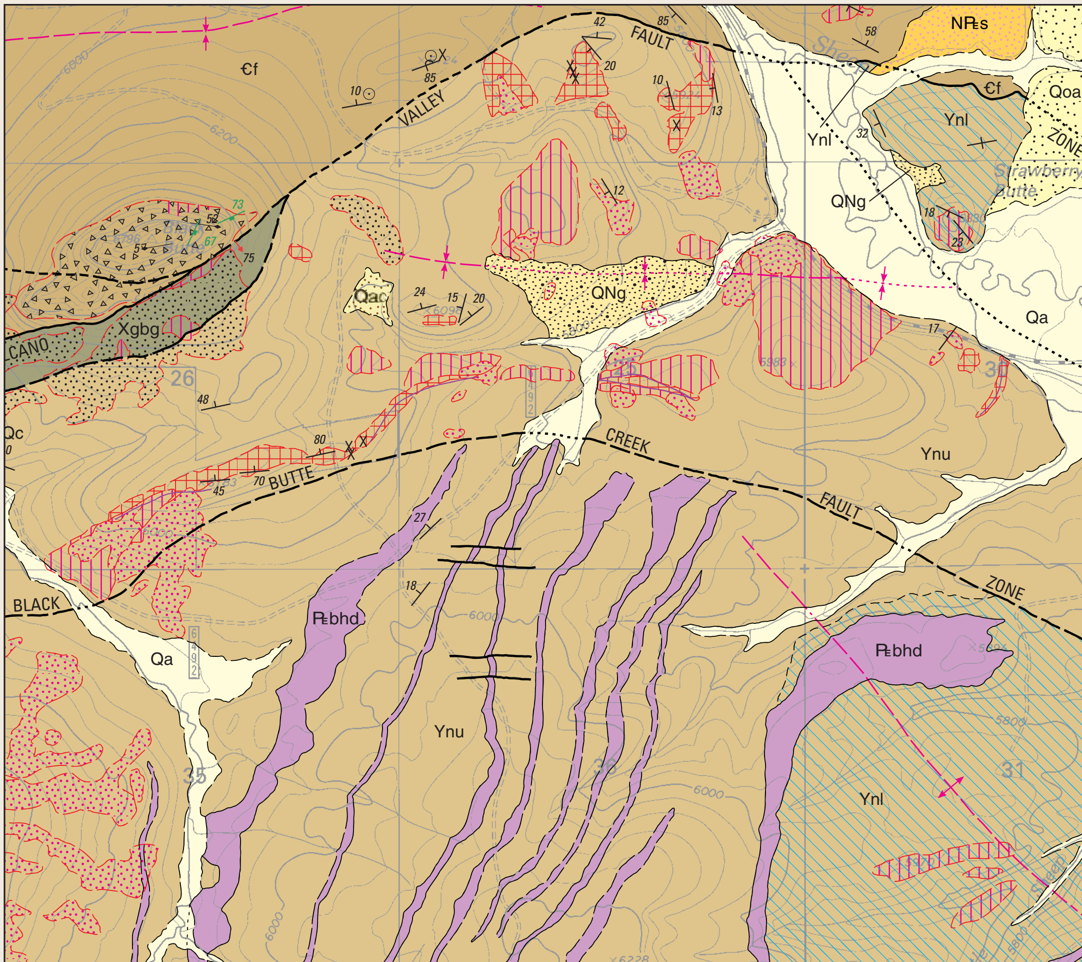
Geologic Map of the Strawberry Butte 7.5′ Quadrangle Meagher County, Montana



Pamphlet to accompany
Scientific Investigations Map 3379

U.S. Department of the Interior
U.S. Geological Survey

Geologic Map of the Strawberry Butte 7.5′ Quadrangle, Meagher County, Montana

By Mitchell W. Reynolds and Theodore R. Brandt

Pamphlet to accompany
Scientific Investigations Map 3379

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Reynolds, M.W., and Brandt, T.R., 2017, Geologic map of the Strawberry Butte 7.5' quadrangle, Meagher County, Montana: U.S. Geological Survey Scientific Investigations Map 3379, pamphlet, 16 p., 2 sheets, scale 1:24,000, https://doi.org/10.3133/sim3379.

ScienceBase link: Reynolds, M.W., and Brandt, T.R., 2017, Data release for the geologic map of the Strawberry Butte 7.5' quadrangle, Meagher County, Montana: U.S. Geological Survey data release, https://doi.org/10.5066/F73J3B61.

ISSN 2329-132X (online)

Contents

Figures

Conversion Factors

U.S. Customary Units to International System

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

International System to U.S. Customary Units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

Geologic Map of the Strawberry Butte 7.5′ Quadrangle, Meagher County, Montana

By Mitchell W. Reynolds and Theodore R. Brandt

Abstract

The 7.5′ Strawberry Butte quadrangle in Meagher County, Montana, near the southwest margin of the Little Belt Mountains, encompasses two sharply different geologic terranes. The northern three-quarters of the quadrangle are underlain mainly by Paleoproterozoic granite gneiss, across which Middle Cambrian sedimentary rocks rest unconformably. An ancestral valley of probable late Eocene age, eroded northwest across the granite gneiss terrane, is filled with Oligocene basalt and overlying Miocene and Oligocene sandstone, siltstone, tuffaceous siltstone, and conglomerate. The southern quarter of the quadrangle is underlain principally by deformed Mesoproterozoic sedimentary rocks of the Newland Formation, which are intruded by Eocene biotite hornblende dacite dikes. In this southern terrane, Tertiary strata are exposed only in a limited area near the southeast margin of the quadrangle. The distinct terranes are juxtaposed along the Volcano Valley fault zone—a zone of recurrent crustal movement beginning possibly in Mesoproterozoic time and certainly established from Neoproterozoic–Early Cambrian to late Tertiary time. Movement along the fault zone has included normal faulting, the southern terrane faulted down relative to the northern terrane, some reverse faulting as the southern terrane later moved up against the northern terrane, and lateral movement during which the southern terrane likely moved west relative to the northern terrane. Near the eastern margin of the quadrangle, the Newland Formation is locally the host of stratabound sulfide mineralization adjacent to the fault zone; west along the fault zone across the remainder of the quadrangle are significant areas and bands of hematite and iron-silicate mineral concentrations related to apparent alteration of iron sulfides. The map defines the distribution of a variety of surficial deposits, including the distribution of hematite-rich colluvium and iron-silicate boulders. The southeast corner of the quadrangle is the site of active exploration and potential development for copper from the sulfide-bearing strata of the Newland Formation.

Geologic Setting

The Strawberry Butte 7.5′ quadrangle lies near the southwest edge of the Little Belt Mountains about 24 kilometers (km) north of White Sulphur Springs, the seat of Meagher County, Montana (fig. 1). As a broad northwest-trending mountain range in west-central Montana, the Little Belt Mountains are bounded on the west by the canyon of the Smith River, merge on the northeast with the Judith River basin, and are bounded on the south by the North Forks of the Smith and the Musselshell Rivers. Sheep Creek and Black Butte Creek are the principal drainages that flow northwest and west across the quadrangle toward the Smith River (fig. 2). The southeast quarter of the quadrangle is of special interest to economic geologists as a result of the identification of apparent stratabound sulfide mineralization in Mesoproterozoic sedimentary rocks (Zieg and others, 2004; 2013). This quadrangle map, a part of the U.S. Geological Survey (USGS) legacy project, was produced during geologic mapping of the White Sulphur Springs 30′ × 60′ quadrangle (Reynolds and Brandt, 2006) before the intense latest subsurface exploration in the area. The map does not reflect the latest described subsurface extent of reported mineralization in a limited area west and south of Strawberry Butte (Zieg and others, 2013). The map depicts in detail the areal setting of the prospective area of mineralization, contributes to an understanding of the complex geologic history of the area, and provides baseline geologic information with which to compare possible changes to the area as a result of mineral exploration and potential development activities.

The geology of the Strawberry Butte quadrangle has two contrasting parts separated by the major Volcano Valley fault (Weed and Pirsson, 1900, p. 305) (see Volcano Valley fault zone in fig. 3). The southern quarter of the quadrangle, south of the fault, is underlain by strata of Mesoproterozoic age which are intruded by sills and dikes of Eocene age, and is mantled along the eastern edge by sedimentary rocks of Oligocene and younger age. By contrast, the northern three-quarters of the quadrangle consists of Paleoproterozoic metamorphic rocks overlain unconformably by the Middle Cambrian Flathead Sandstone that, in turn, is overlain along the southwestern margin of the quadrangle by Middle and Upper Cambrian strata. Oligocene basalt flows and Oligocene and Miocene sedimentary rocks are preserved in ancestral valleys of Sheep Creek and Black Butte Creek eroded across the metamorphic rocks and Middle Cambrian terranes, respectively, in the northern part of the quadrangle. A small erosional remnant of Oligocene basalt rests on Middle Cambrian strata and on a thin remnant of Eocene biotite hornblende monzonite above Allan Park in the northeast corner of the quadrangle (unsurveyed, T. 13 N., R. 7 E. [center, PB40—Protracted Block, see Strawberry Butte basemap]).

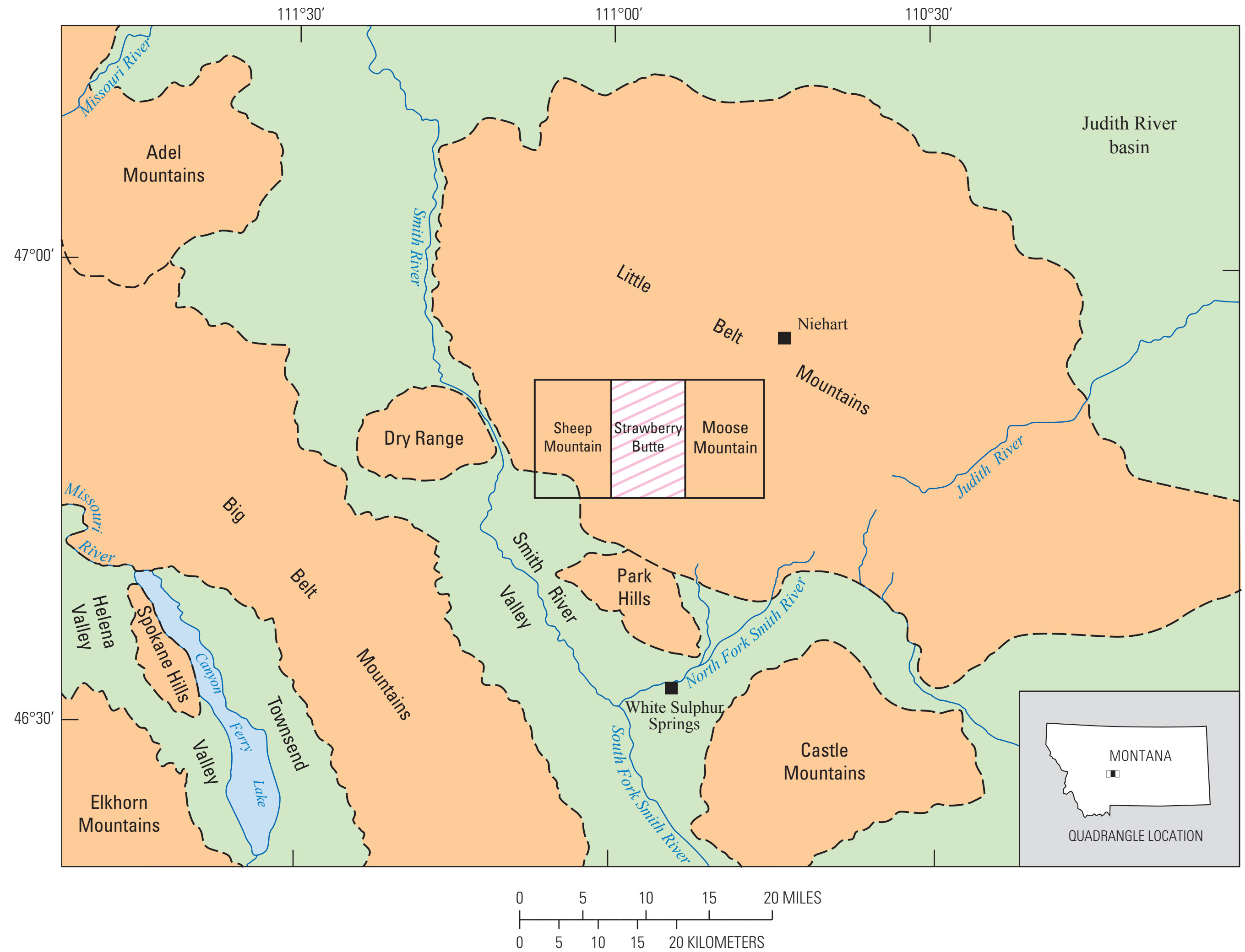


Figure 1. Generalized physiography of west-central Montana showing location of the Strawberry Butte and adjacent 7.5′ quadrangles referred to in the text and annotated with names of selected topographic and cultural features; orange shading indicates highlands and green indicates lowlands.

Stratigraphy

The stratigraphic succession across the northern three-quarters of the quadrangle is simple: Granite gneiss (Xgg) that includes small areas of biotite gneiss and local inclusions of metadiorite (amphibolite) (Xgbg) forms the basement of the northern area. Vogl and others (2004, p. 20, 30) termed the granite gneiss the Sheep Creek intrusive complex and provided a generalized description of a complex that includes older, more strongly foliated granite gneiss, and a younger weakly to moderately foliated granite gneiss (both apparent sequences termed leucogranite by Vogl and others, 2004, p. 30). Those authors determined a $^{207}Pb/^{206}Pb$ age of 1,817±11 million years ago (Ma) for the Sheep Creek complex and an upper intercept age of 1,851±11 Ma on amphibolite within the less-foliated granite gneiss of the complex (Paleoproterozoic; Vogl and others, 2004, p. 30). The youngest granite gneiss remains undated but is clearly part of the Paleoproterozoic succession. Within the quadrangle the granite gneiss is generally weakly foliated, but in some outcrops is moderately to strongly foliated. Foliation commonly dips steeply north or south and generally strikes eastward. Fractures are common, but tracing faults through the complex is difficult. Thin fault-bounded selvages of biotite gneiss (Xgbg) structurally interleaved with the granite gneiss are present along the south edge of the Volcano Valley fault zone. At the surface the selvages range from 0 to about 200 meters (m) wide and 600 to 3,900 m long.

Across the northern three-quarters of the quadrangle, the Middle Cambrian Flathead Sandstone (Ꞓf) rests unconformably on the Paleoproterozoic metamorphic rocks; Mesoproterozoic metasedimentary rocks (Ynu, Ynl), present south of the Volcano Valley fault zone, are absent beneath the unconformity north of the fault within the quadrangle. Stratigraphically throughout the Flathead Sandstone across

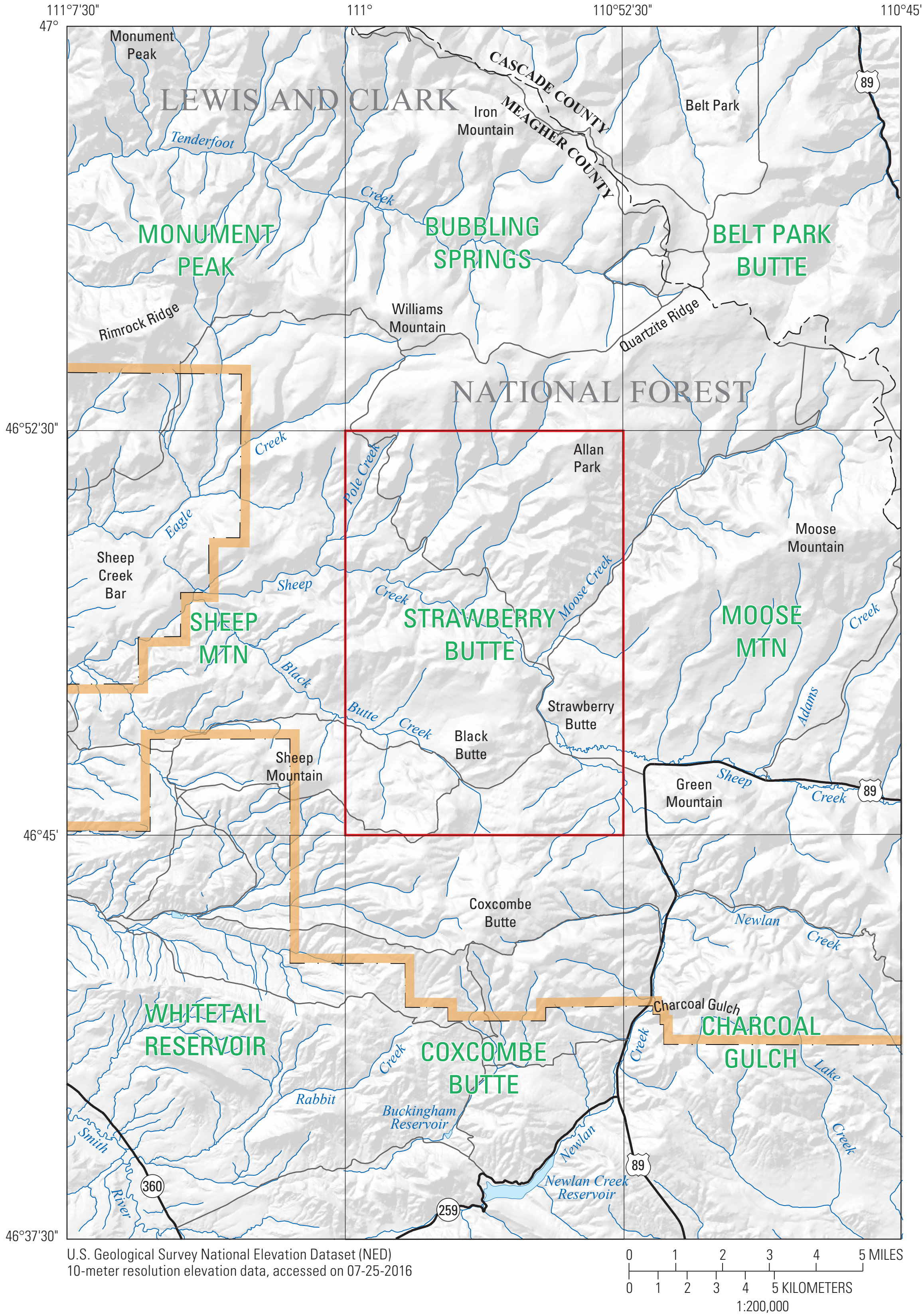


Figure 2. Shaded relief map of the Strawberry Butte 7.5´ quadrangle (red rectangle) and adjacent areas showing features referred to in the text. Selected streams, blue; roads and vehicle trails, black and gray lines respectively; quadrangle names, green; Lewis and Clark National Forest exterior boundary, dashed and orange lines. There are private inholdings within the boundaries of the National Forest shown on this map.

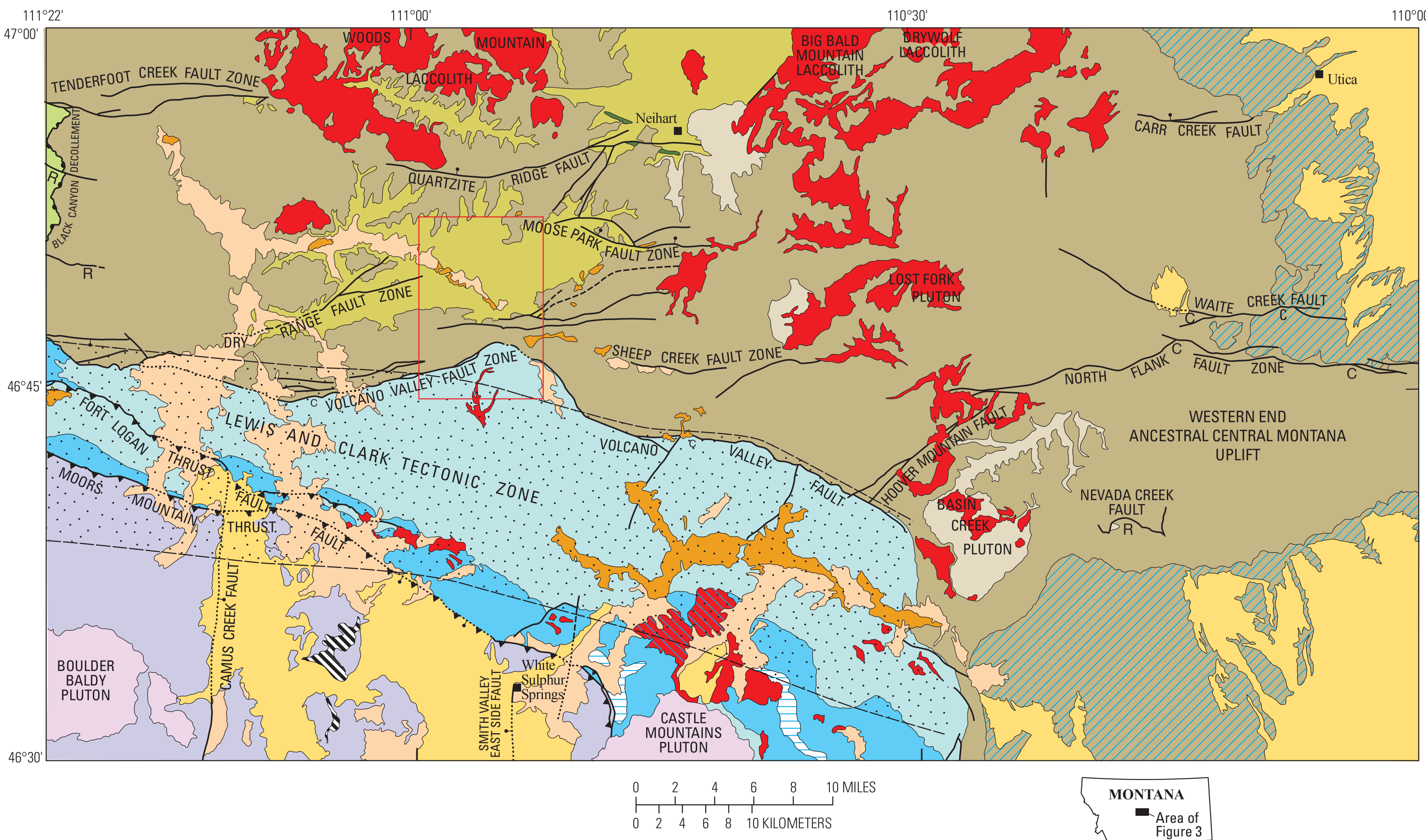


Figure 3. Tectonic map of west-central Montana showing principal faults, major tectonic elements, intrusive and extrusive igneous rock bodies, Tertiary strata and major areas of Quaternary sediments. Thrust sheets and igneous units listed in descending succession of inferred increasing age within tectonic elements (for example, autochthons and parautochthons). Red rectangular outline shows the location of the Strawberry Butte 7.5′ quadrangle (modified from Reynolds and Brandt, 2005, fig. 2, sheet 1).

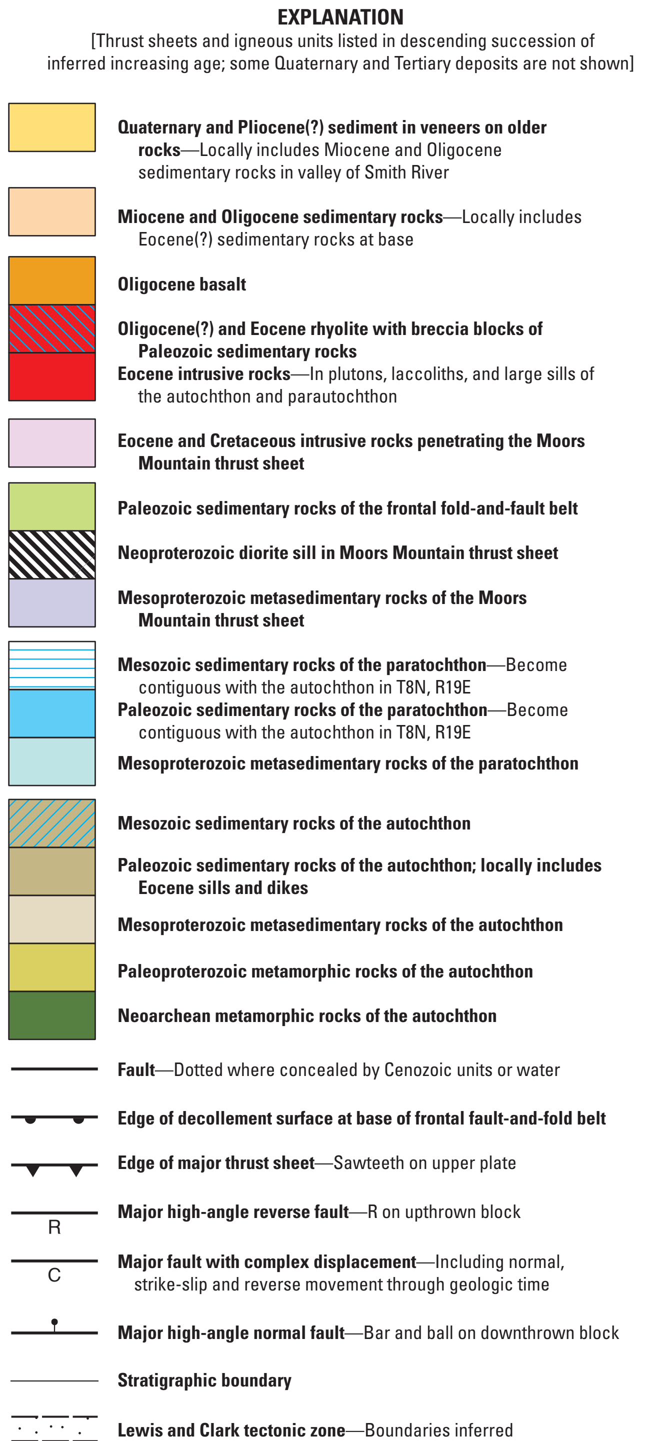


Figure 3. Tectonic map of west-central Montana showing principal faults, major tectonic elements, intrusive and extrusive igneous rock bodies, Tertiary strata and major areas of Quaternary sediments. Thrust sheets and igneous units listed in descending succession of inferred increasing age within tectonic elements (for example, autochthons and parautochthons). Red rectangular outline shows the location of the Strawberry Butte 7.5´ quadrangle (modified from Reynolds and Brandt, 2005, figure 2, sheet 1). —Continued

the quadrangle are granules and pebbles of feldspar, quartz, and pegmatitic quartz, derived from the granite gneiss (Xgg), and common clasts of the Mesoproterozoic Neihart Quartzite (fig. 4*A*). Other clasts that range in size from pebbles to small boulders are present in paleochannels scattered at all stratigraphic levels within the Flathead (fig. 4*B*). These clasts were derived from Paleoproterozoic metamorphic rocks and from Mesoproterozoic strata including the Neihart Quartzite, and Newland, Greyson, and Spokane Formations belonging to the Belt Supergroup. The erosionally-truncated edges of these Belt rocks are present beneath the Flathead Sandstone about 12 to 25 km north-northeast and northeast of the Strawberry Butte quadrangle (Keefer, 1972; Reynolds and Brandt, 2006). Metasedimentary clasts derived from the Belt Supergroup are generally subrounded to rounded, and clasts derived from the Neihart Quartzite and Paleoproterozoic metamorphic rocks are angular to subrounded, locally rounded (fig. 4*B*). Relief on the unconformity at the base of the Flathead is locally as much as about 11 m. Rare in the lower part of the Flathead, but common to very abundant in the upper part are trace fossils including *Thallasinoides*, *Scolithus*, *Arenicolites*, *Chondrites*, and other annelid(?) burrows.

Middle Cambrian strata of the Wolsey Formation, (Ꞓw), Meagher Limestone (Ꞓm), and lower part of the Park Shale (Ꞓp) rest conformably on the Flathead Sandstone north of the Volcano Valley fault zone west of Black Butte Creek and at the eastern edge of the quadrangle north of Sheep and Newlan Creeks. An erosional remnant of the Wolsey Formation, resting on Flathead Sandstone, is preserved on the ridge above Allan Park in the northeast corner of the quadrangle. Structural relief between this high outcrop of the Wolsey and outcrops of the formation adjacent to the Volcano Valley fault zone is about 560 m.

South of the Volcano Valley fault zone, the Strawberry Butte quadrangle is underlain by metasedimentary rocks of the Mesoproterozoic Newland Formation. In general, Newland Formation strata are folded and dip gently south from the Volcano Valley fault zone, but are folded to dip generally north into the fault from near Strawberry Butte (SW¼ sec. 19 and NW¼ sec. 30, T. 12 N., R. 6 E.) on the east to the southwest edge of the quadrangle. As mapped, the upper part of the formation (Ynu) consists of interbedded limestone, cherty limestone, and dolomitic argillite and argillite. Limestone intervals that range from 2 to 12 m thick are generally thin bedded and display internal flat to wavy laminae and local disrupted laminae. Several beds of arkosic arenite, 0.2–1 m thick, are present in the lower part of this limestone-bearing succession. The lower half of the upper part grades downward into dominantly dolomitic argillite, argillite, minor silty argillite, minor siltite, and scattered very thin interbeds of silty limestone and limestone. These rock types locally include very thin intervals of strongly contorted and broken beds of calcareous and dolomitic silty argillite and silty limestone. Strata of the lower half are typically intruded by Eocene biotite hornblende dacite sills (₽ebhd) in secs. 25, 26, 35 and 36, T. 12 N., R. 6 E., and secs. 1 and 2, T. 11 N., R. 6 E. The upper part of the formation grades downward through about 150 m into the lower part of the formation.

Figure 4. Rock fragments, pebbles, cobbles, and small boulders interbedded with medium- to coarse-grained sandstone of the Middle Cambrian Flathead Sandstone. *A*, Angular to subrounded clasts of Mesoproterozoic Neihart Quartzite and Paleoproterozoic vein quartz, granite gneiss, some orthoclase feldspar, and rare clasts of biotite gneiss in the Flathead Sandstone, NW¼ SW¼ NE¼ sec. 15, T. 12 N., R. 6 E. Pencil for scale is 14 centimeters (cm) long. *B*, Pebbles, cobbles and small boulders of Mesoproterozoic Neihart Quartzite, Spokane Formation and rare Greyson Formation together with fragments of vein quartz, orthoclase feldspar and granite gneiss derived from the Sheep Creek granite gneiss widely exposed across the northern part of the quadrangle. SW¼ SW¼ SW¼ sec. 15, T. 12 N., R. 6 E. Pocket knife for scale is 9 cm long.

The lower part of the Newland Formation (Ynl) consists of laminated to very thin bedded dark gray to black dolomitic argillite and silty argillite with scattered very thin pale-brown weathering interbeds of dark gray limestone, generally 1–4 centimeters (cm) thick. This lower part of the formation includes very thin to thin beds of contorted and broken argillite and dolomitic silty argillite. Several thin intervals of silty, argillitic dolostone are present in the Little Sheep Creek area. The lowest part of the formation is exposed at Strawberry Butte in secs. 19 and 30, T. 12 N., R.7 E., where it contains common disseminated sulfide minerals, and in the core of a broad anticline in the southeast corner of the quadrangle.

South, southwest, and west of the quadrangle a succession of Belt Supergroup rocks belonging to the Greyson and Spokane Formations conformably overlies the Newland Formation (Reynolds and Brandt, 2005, 2006). In turn, this succession of Belt Supergroup rocks is overlain unconformably by the Middle Cambrian Flathead Sandstone. The contrast of rocks below the Flathead north of the Volcano Valley fault zone and south of the fault zone documents faulting that is up on the north side of the fault zone and down on the south side, sometime during the time interval of Neoproterozoic through Early Cambrian (sections *A–A′*, *B–B′*, and *C–C′*). That contrast, with as much as 2,600 m of Mesoproterozoic rock, mostly very fine-grained strata on the south block, abruptly truncated against the Volcano Valley fault but absent by erosion across most of the upthrown north block, documents that the Mesoproterozoic Belt basin must have extended north well beyond the fault and likely north of the area of the Little Belt Mountains. The present north margin of Belt rocks is a structural boundary. Thus, the northern and eastern extent of the Belt Supergroup in the area is not a sedimentologic embayment, but rather is a structural salient bounded on the north by a major fault zone.

Xenoliths in Eocene dikes intruding the Newland Formation in the central southern part of the Strawberry Butte area provide evidence of the substrate below the Newland south of the Volcano Valley fault zone. Xenoliths include fragments of the lower part of the Newland, the Neihart, and Paleoproterozoic quartz-biotite gneiss, biotite schist, and quartz-feldspar fragments derived from the granite gneiss. Clearly, before the Middle Cambrian Flathead Sandstone was deposited across the entire area, the Mesoproterozoic Neihart Quartzite, possibly the Chamberlain Formation, and Paleoproterozoic metamorphic rocks were present beneath the Newland on the south side of the Volcano Valley fault zone; however, all but the metamorphic rocks had been removed by erosion from the upthrown block on the north side of the fault zone. Debris from erosion of the area north of the fault zone was carried southward and incorporated in the Flathead Sandstone widely across south-central Montana. Strata of Late Cambrian through Cretaceous age, present in areas adjacent to the south, northwest, and east (Reynolds and Brandt, 2005, 2007), are absent in the Strawberry Butte quadrangle.

Tertiary igneous rocks are present in three forms in the quadrangle. The oldest igneous rock, biotite hornblende dacite (₱bhd) of Eocene age, described below, constitutes thin sills and dikes exposed across the southern margin of the quadrangle. An erosional remnant of younger medium to coarsely crystalline biotite hornblende monzonite (₱bhm) crops out in the northeast corner of the map area (unsurveyed, T. 13 N., R. 5 E. [center, sec. PB40]). That rock is likely a remnant of a coarse-grained sill that extends south from the Woods Mountain laccolith north-northwest of the quadrangle ([Reynolds and Brandt, 2005] which has an age of 53.07±0.28 Ma [L.W. Snee and D.P. Miggins, USGS, written commun., 2002]). The youngest igneous rocks are Oligocene trachybasalt (₱b) exposed in the valley of Sheep Creek across the center of the quadrangle.

Biotite hornblende dacite sills and dikes (₱bhd) intrude beds of the lower part of the upper Newland Formation in the southern part of the quadrangle, their northern extent limited by the Black Butte Creek fault. The thin dacite sheets are intruded nearly parallel to bedding in the Newland Formation but locally cross laminae and beds of the Newland at low angles. The sills and dikes extend generally north from an apparent intrusive center on the north flank of Coxcombe Butte (fig. 2), about 1.3 miles south (secs. 2 and 11, T. 11 N., R. 6 E.) of the south edge of the Strawberry Butte quadrangle. At their northern end, the sills and dikes seem to be rotated structurally east adjacent to, and terminate against, the Black Butte Creek fault. Only one sill, too thin to map, was observed in the upper Newland north of the Black Butte Creek fault. Sills range from about 4 to 12 m thick, and have metamorphosed beds of the Newland Formation into which they are intruded a distance of about 5 to 20 cm adjacent to the sills.

The biotite hornblende dacite intrusive rocks are fine to medium crystalline, generally holocrystalline, and locally porphyritic. Phenocrysts include plagioclase 2.5–4 millimeters (mm) across and locally common zoned crystals 5–7 mm across, rarely as large as 2 cm long and 0.8 cm wide. Locally, hornblende crystals and clots of crystals are as large as 6–8 mm long and 2–4 mm wide, with rare clots as much as 1.7 cm across. Biotite crystals are euhedral to subhedral, 1–3 mm across. Quartz crystals commonly display resorbed margins and comprise 3–5 percent of the rock. The biotite hornblende sills locally contain tabular fragments of quartz-biotite schist as large as 2 cm by 3 cm, rare fragments of granite gneiss as large as 1.5–2 cm across, and at several localities, quartzite fragments 0.6–1 cm across, likely derived from Neihart Quartzite below, and feldspar phenocrysts as large as 8 mm across, derived from granite gneiss basement below. Sills within and immediately south of the map area have $^{40}Ar/^{39}Ar$ isotopic ages ranging from 57.04±0.21 to 54.61±0.27 Ma (L.N. Snee and D.P. Miggins, USGS, written commun., 2009).

Andesitic basalt flows of Oligocene age (₽b, 32.04±0.10 to 31.71±0.24 Ma [L.N. Snee and D.P. Miggins, USGS, written commun., 2001]) are banked against Paleoproterozoic granite gneiss and associated crystalline rocks in an ancestral valley of Sheep Creek from the junction of Moose Creek and Sheep Creek (sec. 13, T. 12 N., R.6 E) northwest to Pole Creek at the west edge of the quadrangle (fig. 2); south-center sec. 32, T. 13 N, R. 6 E.). Oligocene sedimentary rocks overlie the basalt unconformably so that along part of the trace of basalt outcrops, the sedimentary rocks rest unconformably on the Paleoproterozoic metamorphic rocks. However, in NW¼ sec. 3 and SE¼ NE¼ sec. 4, T. 12 N., R. 6 E., basalt rests on part of the Oligocene sedimentary sequence and is depositionally overlapped by the younger part of the sedimentary sequence. The basalt is microcrystalline with scattered phenocrysts of olivine and rare pyroxene. Locally the basalt is highly vesicular with white quartz and calcite filling some vesicles. Commonly only single flows are evident, although as many as 3 flows, each with a basal flow breccia, constitute the sequence between Squaw and Pole Creeks (NW¼ sec. 3 and SE¼ NE¼ sec. 4, T. 12 N., R. 6 E.) and on Sheep Creek north of its junction with Moose Creek (SE¼ sec. 12 and NE¼ NW¼ sec. 13, T. 12 N., R. 6 E.). The exposed thickness of the basalt ranges from a wedge edge to about 75 m. The basalt accumulated in a northwest-trending valley eroded by ancestral Sheep Creek; that valley extended beyond the Strawberry Butte quadrangle across the area now drained by Jack Creek and upper Eagle Creek in quadrangles adjacent on the west (Reynolds and Brandt, 2005). From the junction of Moose and Sheep Creeks to Pole Creek, the base of the lowest basalt flows declines in elevation northwest about 90 m toward Smith River. We interpret that the ancestral valley was eroded likely during late Eocene time inasmuch as the Little Belt Mountains were the locus of laccolithic and tabular intrusions intruded at depth during early and early–middle Eocene (for example, Woods Mountain laccolith about 7–12 km north and northwest of the valley [fig.2]; 53.07±0.28 Ma [L.N. Snee and D.P. Miggins, USGS, written commun., 2004; Reynolds and Brandt, 2005]), but those intrusive rocks are now exposed at the surface as much as 245 m above early Oligocene basalt at the bottom of the ancestral valley. The absence of an evident single source for the basalt, such as a volcanic cone or dome, suggests that fractures or a fault, subsequently covered by the basalt, were the likely orifices for flows along Sheep Creek and between Squaw and Pole Creeks (section *A–A′*). An isolated outlier of basalt caps the ridge above Allan Park (unsurveyed, T. 13 N., R. 7 E. [center, PB40]) at an elevation of 2,297–2,320 m (7,510–7,615 ft), about 620 m above outcrops along Sheep Creek.

Sedimentary and volcaniclastic rocks of Oligocene and Miocene age (N₽s) are present in the drainage of Sheep Creek in the southeastern part of the quadrangle (secs., 19, 20, and 29, T. 12 N., R. 7 E.), and from Moose Creek (secs. 12 and 13, T. 12 N., R. 6 E.) northwest beyond Pole Creek (diagonally across the northern part of T. 12 N., R. 6 E., into the southeast part of T. 13 N., R. 6 E.). These rocks rest unconformably on, and locally interfinger with, the Oligocene basalt (₽b). The rocks include tuffaceous siltstone, commonly very pale orange to grayish orange pink, silty and sandy claystone, pebble conglomerate, and silty sandstone. Commonly near the base of the unit are lenses and beds of dark brown basaltic ash that weather to dark brown soil; higher in the sequence are discontinuous exposures of a vitric pumice tuff interval that we have traced discontinuously from near the Smith River, about 13 km to the west into the Strawberry Butte quadrangle. Clasts in the conglomerate beds range from sand-size to boulders as large as 2 m across with the boulders concentrated mainly at or near the base of the unit. Clasts are subrounded to rounded and consist of Flathead Sandstone, Paleoproterozoic granite gneiss and feldspar grains derived from the gneiss, Upper Cambrian and abundant Devonian and Mississippian carbonate rocks, and rare Mesoproterozoic calcareous argillite and siltite fragments. Clasts derived from the Eocene intrusive rocks in nearby areas are present but rare. Notably absent among clasts of all sizes are fragments of gossan, including ferruginous silica, which are now scattered across surface areas on and adjacent to altered Newland Formation strata exposed by erosion within and south of the Volcano Valley fault zone. Near the upper part of the unit are scattered to common fragments and pebbles of basalt, similar to the unit that underlies the sedimentary succession. Lenses of claystone and silty claystone might be shallow lake deposits, and we conjecture that most of the sandy and clayey siltstone beds are likely of windblown origin. Generally the beds are poorly exposed but can be excavated at shallow depths and are locally exposed both along U.S. Forest Service road 119 and in gullies eroded across the unit.

In addition to thin deposits of alluvium in active stream channels and several young gravel deposits on terraces above the active creeks, two groups of upper Tertiary(?) or Quaternary deposits were mapped in detail. The first group consists of scattered to common cobbles and boulders of Paleozoic sedimentary rocks distributed in patches and linear clusters across bedrock surfaces. In several areas such as on the flanks of Black Butte Creek (secs. 20, 21, 27, 28, 29, T. 12 N., R. 6 E.) the boulders are so abundant that the deposits nearly resemble outcrops of the principal Paleozoic bedrock unit from which the boulders were derived. In particular, clasts of Devonian Jefferson Formation as large as 6 × 3 × 2 m (above ground surface) constitute the principal component of the boulder deposits. The mantle of boulders contains fewer and smaller clasts of Mississippian Mission Canyon and Lodgepole Limestones, and Cambrian Pilgrim Limestone, and sparse, but locally common Cambrian Flathead Sandstone. Most clasts are 0.6–1 m across. The concentration of the boulders on the middle reaches of Black Butte Creek and Copper Creek suggest that those drainages were common tracks for floods or debris flows that transported the boulders west and north from outcrops of those units in the Green Mountain area about 9–12 km east-northeast of the deposits (fig. 2). Common angular fragments of Cambrian Flathead have been shed on hillsides radially south, west, and north from outcrops of the formation on Black Butte.

Deposits of iron gossan, iron-stained bedrock, and colluvial fragments of the gossan constitute the second mapped group of Tertiary(?) and Quaternary age deposits. Bedded iron gossan that dips north is present nearly continuously from the NE¼ sec. 34, T. 12 N., R. 6 E., east-northeast across sec. 26, to the center of sec. 27, T. 12 N., R. 6 E., between the Black Butte Creek fault on the south and limestone beds of the Newland Formation on the south side of the Volcano Valley fault. No major cross faults seem to disrupt the continuity of either the limestone beds or the bedded gossan. At Iron Butte, E½ sec. 34, T. 12 N., R. 6 E., bedded iron gossan dips west at about 12º–20º, shallow enough to have been mined and transported in the past to near Three Forks, Montana to serve as flux in production of cement (fig. 5). Similar but more local gossan beds are present in the southern third of sec. 24, T. 12 N., R. 6 E. adjacent to the Volcano Valley fault and discontinuously east of Little Sheep Creek in SE¼ sec. 31 and SW¼ sec. 32, T. 12 N., R. 7 E. Mapped separately adjacent to these areas are dolomitic argillite beds stained moderate red and grayish red by iron oxides derived from the gossans. These stained beds might locally be indicative of iron-bearing sulfides at depth in their vicinity, such as in the N¼, sec. 33, T. 12 N., R. 6 E., and in secs. 31 and 32, T. 12 N., R. 7 E., as well as in sec. 25 T. 12 N, R. 6 E., and sec. 30, T. 12 N., R. 7 E. Areas across which bedrock is mantled with colluvial boulders and fragments of iron gossan are shown on the map as potentially useful indicators of upslope sites of iron gossan or iron sulfide beds.

Structure

Contrasting geologic structures in the Strawberry Butte quadrangle result from the juxtaposition across the Volcano Valley fault zone of complex geologic structure within the Lewis and Clark tectonic zone on the south and structures of the continental autochthon north of the fault zone (fig. 3). The zone is a fundamental break in the earth's crust in west-central Montana. The Volcano Valley fault zone arcs from west to north to southeast across the southern part of the Strawberry Butte quadrangle. Structural relations along and across the fault zone are complex with regard to rock types involved, geometry of the faults, and ages of movement along the zone. The northernmost principal fault bounding the fault zone generally separates Mesoproterozoic sedimentary rocks (Newland Formation of the Belt Supergroup) on the south from Paleoproterozoic granite gneiss and biotite gneiss overlain unconformably by Paleozoic rocks on the north side of the fault zone. The dip of the principal fault varies along its strike: along its western trace in the quadrangle, the principal fault varies from nearly vertical to approximately 75º–80º south and southeast. Along a short trace of the fault north of Strawberry Butte (SW¼ sec. 19, T. 12 N., R. 7 E.,) the apparent dip of the fault reverses so that the fault dips north and displaces the Cambrian Flathead Sandstone over the lower part of the Newland Formation at the surface and at shallow depths. The dip of that segment of the fault likely reverses with depth to again dip steeply south and southwest. We suggest that, at the maximum curvature of the fault zone (sec. 24

Figure 5. Fractured hematite-stained strata in the upper part of the Newland Formation have been excavated on the west flank of Iron Butte and in the past shipped to Three Forks, Montana, for use as flux in the production of cement. Lenses and thin irregular beds of gossan are interbedded in the altered rocks of the Newland Formation here and along the trace of the Volcano Valley fault zone.

T. 12 N., R. 6 E., and sec. 19, T. 12 N., R 7 E.), the zone intersects at depth in the crust with the major east-west fault zone that extends yet farther east along Sheep Creek (Sheep Creek fault zone) and beyond as high-angle fault zones (North Flank and Waite Creek fault zones bounding the north flank of the eastern part of the Little Belt Mountains [fig. 3; Reynolds and Brandt, 2007]). The southeast striking segment of the Volcano Valley fault zone continues farther southeast and east as an oblique-slip fault, where it separates parautochthonous Mesoproterozoic rocks of the Helena structural salient from younger rocks of the autochthon on the north-northeast (fig. 3).

Narrow wedges of Paleoproterozoic granite gneiss and biotite gneiss are present within the fault zone along the south side of the principal fault and are separated by another major fault bounding the south margin of the zone from continuously exposed Mesoproterozoic sedimentary rocks on the south. The lengths of the wedges vary from west to east from about 3.9 km (wedge extends west into the adjacent Sheep Mountain quadrangle) to 0.62 km to 2.1 km; they pinch and swell in width from about 300 m to 25 m to 200 m from west to east along strike. Rocks along the fault margins of the wedges are sheared and locally mylonized, but rocks within the wedges generally maintain their coarser gneissic texture. The strike wedges along the trace of the fault zone suggest a component of east-northeast horizontal shear together with vertical shear during deformation along the zone in order to generate the narrow wedges of the Paleoproterozoic rocks. The net oblique movement likely translated into dominantly reverse movement in the southeast quarter of the quadrangle.

In the Sheep Mountain quadrangle, immediately adjacent on the west to the Strawberry Butte quadrangle, very thin tectonic wedges, here termed selvages, of Neihart Quartzite are faulted between the Paleoproterozoic gneissic rocks along the Volcano Valley fault zone and the Mesoproterozoic strata south of the fault zone (Reynolds and Brandt, 2005). Those quartzite selvages provide evidence of major vertical movement along the zone, inasmuch as the Neihart Quartzite generally lies as much as 1,050 m stratigraphically beneath strata of the Newland Formation exposed there at the surface.

A major fault zone, here called the Black Butte Creek fault zone, diverges from the Volcano Valley fault zone in the eastern edge of the adjacent Sheep Mountain quadrangle (NW¼ sec. 32, T. 12 N., R. 6 E. [Reynolds and Brandt, 2005]). As the Black Butte Creek fault diverges from the Volcano Valley fault zone, the trace of Black Butte Creek fault also arcs across the Strawberry Butte quadrangle. Limestone units of the upper part of the Newland Formation between the two faults are folded anticlinally at the west end of the enclosed block, but from near Copper Creek to the western edge of NW¼ sec. 25, T. 12 N., R. 6 E., the limestone units and preserved iron-silica gossan units dip north. Those strata between the principal faults in sec. 24 and 25, T. 12 N., R. 6 E., are folded in a west-trending syncline. No evidence of cross faults exists in the north dipping beds between the faults from the NE¼ sec. 34, T. 12 N., R. 6 E. and SE¼ sec. 27, T. 12 N., R. 6 E., as far east as the NW¼ sec. 25, T. 12 N., R. 6 E.

Beds of the Newland Formation and Eocene dikes and sills south of the Black Butte Creek fault strike north at moderate to high angles into the fault. In the southeast corner of the quadrangle, the eastward curvature of the dikes and sills adjacent to the Black Butte Creek fault suggest a component of lateral slip, south side moving west along the fault. Apparent stratigraphic separation on the fault increases from the west edge of the quadrangle where displacement is within anticlinally folded limestone units of the upper part of the Newland Formation to the southeast corner where the upper Newland on the east-northeast side of the fault is juxtaposed against the lowest part of the formation on the southwest side. Dolomitic argillite and siltite beds southwest of the Black Butte fault are folded in a northwest-plunging anticline that terminates against the fault in the SE¼ sec. 25, T. 12 N., R. 6 E. The stratigraphic separation thus suggests a rotational component of oblique slip along the fault, south side west and progressively up eastward.

North of the Volcano Valley fault zone, offset of the unconformity between the base of the Flathead Sandstone and the underlying Paleoproterozoic crystalline rocks demonstrates vertical structural relief of about 300–350 m between outcrops of the base of the Flathead against the fault zone to the base of the Flathead above Allan Park (T. 13 N., R 7. E. [secs. PB40 and 41]; section *C–C′*). General south dips of 5º to 10º from the high outcrops at Allan Park to the gentle synclinal axis in the Flathead in secs. 22, 23, and 24, T. 12 N., R 6 E., define the upward arch of the Paleoproterozoic core of the Little Belt Mountains (sections *A–A′* and *C–C′*). The south limb of the gentle arch declines south across the northern two-thirds of the quadrangle. That limb is broken by east-trending normal faults which displace the south flank of the arch downward nearly 650 m from outcrops up-plunge in the Moose Mountain quadrangle adjacent on the east to the Strawberry Butte quadrangle. We infer that a buried normal fault zone follows the general west-northwest trend of Sheep Creek as far as Pole Creek (sections *A–A′* and *B–B′*). Oligocene strata and Oligocene basalt cover the trace of the inferred fault. If so, those units document the age of faulting and, particularly, the time of erosion of the valley of Sheep Creek as pre-Oligocene, likely middle and late Eocene. Similarly, from the narrows on Sheep Creek near Strawberry Butte east across the adjacent Moose Mountain quadrangle, Oligocene and Miocene strata and Oligocene basalt are present in the lower part of the valley of Sheep Creek (Reynolds and Brandt, 2007). Erosion of the valley predated the Oligocene units, and the linearity of the valley further suggests that the valley might have originated by erosion along a fault zone active during late Eocene time that subsequently served as conduits for the basalt to reach the surface.

Arching along the axis of the western part of the Little Belt Mountains accompanied by normal faulting along the south flank (sections *A–A′*; *C–C′*) seems to have been active as late as Pliocene time. The arching might have resulted in the southward migration and superposition of meanders of Sheep Creek onto the Paleoproterozoic granite gneiss core of the quadrangle. Across the center of the quadrangle normal faults have the structural effect of displacing the Flathead Sandstone downward toward the Volcano Valley fault zone. At the southwest edge of the quadrangle, west-trending normal faults offset middle and upper Cambrian rocks adjacent to the fault zone on the north. These normal faults terminate in deformed shale beds of the Wolsey Formation which are, in turn, truncated by north-northwest trending normal faults that terminate south against the Volcano Valley fault zone and merge north along Copper Creek in secs. 21 and 28, T. 12 N., R. 6 E. We have not found evidence of northeast- or north-trending faults in the quadrangle.

The geologic structure at Black Butte (N½ sec. 26, T. 12 N., R. 6 E.) is anomalous (section *B–B′*). Aprons of colluvial fragments of Flathead Sandstone with rare fragments of Meagher Limestone conceal bedrock beneath the northeast, north, and west flanks of the Butte. Silica-cemented quartz arenite that supports and is exposed on the Butte is highly sheared and brecciated throughout. In much of the exposed area of bedrock, iron has been leached from the sandstone so that its color is very light gray, nearly white. Nevertheless, segments of the sheared rock locally contain granules and pebbles of quartzite and rare burrows(?) similar to the nearby unsheared Flathead Sandstone. Slickensides on rock slices exposed on the Butte are commonly oriented about 260° with dips of 5° southwest and 98° with dips 10° to 50° east, generally parallel to the principal fault of the Volcano Valley fault zone; other slickensides dip 60° to 75° south, down the apparent dip of the fault zone and yet others dip only a few degrees south. The structure is interpreted here as tectonically shingled segments of Flathead Sandstone, interleaved along the Volcano Valley fault zone by recurrent reverse movement during Neoproterozoic to Middle Cambrian time and normal movement along high-angle shears during middle Eocene to possibly late Pliocene time. Shearing and leaching of iron and silica cementation might have resulted from thermal effects of an intrusion at depth, suggested also by the unique radial topographic expression of the Flathead Sandstone only in the area of Black Butte.

Summary

The Strawberry Butte quadrangle provides a discontinuous record of recurrent tectonism in this segment of west-central Montana. North and northeast of the Strawberry Butte quadrangle, Mesoproterozoic sedimentary rocks rest unconformably on the metamorphosed Paleoproterozoic rocks (Keefer, 1972). Also, xenoliths of Paleoproterozoic and late Archean metamorphic rocks in biotite hornblende dacite intruded into the Mesoproterozoic Newland Formation suggest that the Mesoproterozoic Belt succession in the southern part of the quadrangle rests unconformably on older Paleoproterozoic and Archean metamorphic rocks exposed by deformation, uplift, and erosion during late Paleoproterozoic or early Mesoproterozoic time, before deposition of the Belt Supergroup strata. A major episode of uplift, principally on the north side of the Volcano Valley fault zone, occurred between early Neoproterozoic and Middle Cambrian time. That movement is represented by the unconformity between the Middle Cambrian Flathead Sandstone that rests on Paleoproterozoic metamorphic rock north of the fault zone and on Mesoproterozoic sedimentary strata on the south side of the Volcano Valley fault zone. During that time interval, vertical movement on the north side of the fault zone in the quadrangle was likely 1,600–1,750 m with an unknown, but significant component of horizontal movement.

A major intrusive episode is represented by both the biotite hornblende monzonite in the Allan Park area that is an outlier of extensive igneous intrusion northwest of the quadrangle (Woods Mountain laccolith, dated as 53.07±0.38 to 50.83±30 Ma [Reynolds and Brandt, 2005]) and the biotite hornblende dacite dikes south of the Black Butte Creek fault. We infer that horizontal and vertical fault movement on the Black Butte Creek fault occurred during the late early and middle Eocene (52–45 Ma). The valleys of Moose and Sheep creeks, possibly along a middle to late Eocene fault, were eroded prior to extrusion of basalt (32.04–31.71 Ma) in the valleys. We infer that the youngest phase of deformation was gentle arching of the northern two-thirds of the quadrangle likely during Miocene and possibly Pliocene time. Our inference is based on the superposition of Sheep Creek meanders across both Miocene-Oligocene sedimentary rocks and basalt in the northwest part of the quadrangle and across Paleoproterozoic metamorphic rocks in the central western part of the quadrangle.

Acknowledgments

Access to private lands in the Strawberry Butte quadrangle was graciously provided by local ranchers and land owners. The U.S. Forest Service, Lewis and Clark National Forest, through the White Sulphur Springs District Office, facilitated access to the public lands in the quadrangle. David J. Lidke and Scott C. Lundstrom (USGS) through their technical reviews improved the presentation of the map and text. Jeremy Havens drafted figure 1 and, through successive reviews, patiently digitized the geologic sections and correlation of map units diagram. Julie A. Herrick (USGS) reviewed geologic names and terminology used in the report, skillfully enhanced figure 2, and served as a thoughtful and careful editor. Figure 3 was prepared by Springfield and Springfield, Inc., Fort Collins, Colorado.

Description of Map Units

[Terminology for carbonate rocks from Folk, 1962]

Qa **Alluvium (Holocene)**—Unconsolidated stratified to poorly stratified sand, gravel, silt, and clay, deposited primarily by streams; locally includes some colluvium and some gravel on low terraces in stream valleys. Thickness as much as 18 m

Qac **Alluvium and colluvium, undivided (Holocene)**—Unconsolidated stratified to poorly stratified rock fragments, gravel, sand, and silt deposited by gravity and stream transport down hillsides and rills east of Black Butte in ¼NE ¼SE ¼NE sec. 26, T. 12 N., R 6 E., and along valley walls of Moose Creek in west-center sec. 7, T. 12 N., R. 7 E.; thin local deposits are not shown. Thickness as much as 14 m

Qc **Colluvium (Holocene)**—Unconsolidated generally unstratified rock fragments, gravel, some interstitial silt deposited by gravity on hillsides; mapped locally west-southwest of Black Butte in NE¼ SE¼ sec. 27, T. 12 N., R 6 E.; very thin local deposits are not shown. Thickness as much as 7 m

Ql **Landslide deposits (Holocene and Pleistocene)**—Angular blocks and fragments of basalt (₱b), other rock debris, and soil that have moved down slope on shale substrate in N½ SE¼ sec. PB40 (unsurveyed), T. 13 N., R. 7 E.; generally chaotic and unstratified fragments. Thickness as much as 12 m

Qt **Terrace gravel (Holocene? and Pleistocene)**—Gravel, sand, and some silt, generally unconsolidated, locally stratified and poorly stratified; clasts rounded to subrounded; contains angular colluvial rock fragments derived from adjacent hillside; mantles smooth surface inclined gently north at elevations about 3–8 m above recent stream channel of Copper Creek in sec. 28, T, 12 N., R. 6 E., and mantles a surface inclined gently east at elevations about 6–10 m above Sheep Creek in SE¼ SE¼ sec. 13, T. 12 N., R. 6 E. Thickness as much as 5 m

Qoa **Old alluvium (Holocene? or Pleistocene)**—Stratified to poorly stratified sand, gravel, silt, and clay; unconsolidated to weakly and locally moderately consolidated; deposits generally form abandoned braided alluvial fans where major streams emerged from areas of confining bedrock slopes; also forms rounded natural benches adjacent to, and dissected by, braided modern stream channels. Deposited primarily by sheetflood. Mapped at the east edge of the quadrangle in secs. 19, 20, 29, and 30, T. 6 N., R. 7 E. Thickness 0–10 m, but locally as much as 15 m

QNg **Older gravel (Pleistocene? and Neogene?)**—Gravel, sand, and some silt, unconsolidated to weakly consolidated; stratified; deposited dominantly by streams and as colluvium; clasts rounded to subrounded, subangular and locally angular; pebbles and small cobbles of Phanerozoic, Mesoproterozoic, and Paleoproterozoic rocks in silty or clayey silty matrix. Highest deposits consist of scattered pebbles in thin, patchy unconsolidated matrix on bedrock. Deposits at different elevations are likely of significantly different ages: Highest deposits (about 1,787 m, north-center sec. 25, T. 12 N., R.6 E.) might be as old as Miocene(?), and in NE¼ NW¼ sec. 30, T. 12 N., R. 7 E. might be as old as Pleistocene or Pliocene. Thickness as much as 12 m

N₱s **Sedimentary rocks (Miocene and Oligocene)**—Shown as MiOgS in Reynolds and Brandt (2005, 2007). Pebble to boulder conglomerate, clayey siltstone, sandy tuffaceous siltstone, sandstone, vitric tuff, and local basaltic tuff; siltstone, clayey siltstone, and sandy tuffaceous siltstone; grayish orange pink and very pale orange, locally grayish orange pink, weathers same; vitric tuff very light gray to white, weathers same; basaltic tuff dusky brown and grayish brown, weathers same; pebble and boulder conglomerate grayish orange to pale yellowish brown, weathers same; conglomerate lenses contain subangular to dominantly well rounded granules, pebbles, and cobbles of Paleoproterozoic metamorphic rocks, Mesoproterozoic clasts derived from within and north of the Strawberry Butte quadrangle (Reynolds and Brandt, 2007), Paleozoic sedimentary rocks, rare Eocene intrusive rocks and, in the upper part, Oligocene basalt clasts. Separate conglomerate beds commonly have different sources of dominant clasts, including beds with dominantly resistate clasts including Paleoproterozoic granitic and basic metamorphic rocks, Mesoproterozoic and Middle Cambrian quartzite, metasiltite, siltite and siltstone derived from the north-central Little Belt Mountains, and beds with dominantly carbonate clasts derived from Paleozoic terranes southeast and east of the quadrangle. Subrounded to rounded boulders of Flathead Sandstone, locally as large as 2 m across, are concentrated in the lowest part of the unit above underlying basalt flows (Pɇb), and are more widely scattered higher in the unit. Vitric tuff and tuffaceous siltstone beds contain abundant glass shards, some very fine biotite crystals and scattered sanidine(?) crystals, and contain reworked rounded sand grains derived from older units. Unit NPɇs laps unconformably onto Paleoproterozoic metamorphic rocks, Middle Cambrian rocks in secs. 19 and 20, T. 12 N., R. 7 E. and onto Oligocene basalt (Pɇb). Thickness as much as 85 m

Pɇb **Basalt (Paleogene)**—Shown as Ogb in Reynolds and Brandt (2005, 2007). Trachybasalt, very dark gray to black, locally reddish orange; microcrystalline, generally equicrystalline; scattered phenocrysts of olivine and rare local biotite pegmatite in narrow fractures; locally vesicular. Unit consists of several flows, likely derived from fracture eruptions; local thin flow breccia between successive flows; $^{40}Ar/^{39}Ar$ isotopic ages range from 32.04±0.10 to 31.71±0.24 Ma (L.N. Snee and D.P. Miggins, USGS, written commun., 2001). Unit occupies ancestral valley of Sheep Creek in north-central part of the quadrangle and caps the ridge above Allan Park in NW¼ SE¼ sec. PB40 (unsurveyed), T.13 N., R.7 E. Thickness as much as 32 m

Pɇbhd **Biotite hornblende dacite (Paleogene)**—Shown as Eobhd in Reynolds and Brandt (2005, 2007). Medium gray to medium-light-gray dacite: phenocrysts of biotite and hornblende in finely crystalline to aphanocrystalline groundmass of plagioclase feldspar, minor sanidine, rare quartz, common fine biotite, and some hornblende; some sills have clots of small hornblende crystals as much as 17 mm across; scattered quartz crystals as much as 2 mm across, many with resorbed margins; plagioclase phenocrysts as much as 3–4 mm across; scattered hornblende needles about 7 mm long; rock locally contains xenoliths, as large as 5 cm across, of Paleoproterozoic granite gneiss and biotite quartz gneiss and Mesoproterozoic quartzite; unit present as sills in the southern part of the quadrangle. Unit has $^{40}Ar/^{39}Ar$ age range from 57.04±0.21 to 54.61±0.27 Ma (L.N. Snee and D.P. Miggins, USGS, written commun., 2009)

Pɇbhm **Biotite hornblende monzonite (Paleogene)**—Shown as Eobhm in Reynolds and Brandt, 2005, 2007 Very light gray to medium gray, weathers very light gray, light brownish gray, and locally very pale red; medium to coarsely crystalline, equicrystalline to porphyritic; common to abundant biotite and euhedral crystals of hornblende; alkali and sodic feldspar in nearly equal abundance in matrix and as phenocrysts as large as 8 mm across; scattered quartz crystals; locally contains xenoliths of Paleoproterozoic and Mesoproterozoic bedrock; exposed on ridge above Allan Park in NW¼ SE¼ sec. PB40, (unsurveyed), T. 13 N., R. 7 E.; the unit might be a remnant distal sill related to the Woods Mountain laccolith present northwest of the map area and dated as 53.07± 0.28 Ma (Reynolds and Brandt, 2005)

€p **Park Shale (Upper and Middle Cambrian)**—Silty claystone and claystone, sparse very thin channels filled with pebbly biosparite limestone; light olive gray and light olive, weathers olive gray and grayish green; fissile and platy. Widely scattered discontinuous lenses, 2–4 cm thick, contain comminuted trilobite, pelmatozoan(?) and brachiopod fragments. Only the lowest part of the formation exposed in center sec. 29, T. 12 N., R. 6 E. Exposed thickness about 18 m

€m **Meagher Limestone (Middle Cambrian)**—Limestone, medium gray, medium dark gray, and medium brownish gray, weathers medium light gray with common grayish orange, moderate brown, and pale grayish red silty mottles, particularly in basal 10 m and in top 12 m. Finely crystalline limestone with channels and beds of medium- to coarsely-crystalline biosparite and biopelsparite limestone. Discontinuous wavy laminae and beds 0.2–4 cm thick, with discontinuous silty limestone partings; weathers with knobby, locally reticular texture especially at base and top; forms low rounded benches. Contains locally abundant small trilobite fragments, some pelmatozoan(?) plates, and sparse chitinous brachiopod fragments. Thickness about 15–32 m

Ꞓw **Wolsey Shale (Middle Cambrian)**—Silty mudstone and siltstone, light olive to light grayish green; weathers light olive gray, dusky yellow gray, and grayish red. Very thin beds of pale grayish red silty sandstone interbedded in olive green siltstone in basal 3 m. Limestone laminae and beds, 0.2–3 cm thick, are scattered throughout the siltstone in the upper part of the formation; limestone is light gray to light greenish-gray, weathers pale yellowish brown to grayish orange; trilobite biosparite; some greenish-gray siltstone chips on parting surfaces. Siltstone in lower third contains scattered *Cruziana* and annelid(?) trace fossils. Strata split shaly and platy; limestone splits platy and flaggy. Only the lower part of the formation is exposed in S½ sec. PB40 (unsurveyed) above Allan Park. Apparent thickness varies as a result of local internal deformation: Thickness 38–50 m

Ꞓf **Flathead Sandstone (Middle Cambrian)**—Sandstone, pebbly sandstone, local conglomerate; very thin sandy siltstone beds at top; dominantly pale red, locally yellowish gray, and very pale red; weathers pale reddish brown, pale red, locally yellowish gray, and light brownish gray. Sandy siltstone interbeds at top are dark grayish red and greenish gray. Sandstone: fine to coarse grained, with locally abundant pebbles as large as 3–6 cm across; cobbles and small boulders in scattered channels in lower and middle parts of the formation and locally near the top. Clasts are quartz, quartzite, red and gray chert and siliceous siltite; minor to locally common feldspar; clasts as much as 1 cm across; clasts are generally rounded, but shapes modified by pressure solution and quartz overgrowths; weakly to firmly indurated; glauconite grains scattered in uppermost 4 m and increase in abundance toward the top. Across the south-central part of the quadrangle the formation contains intervals of very coarse-grained sandstone with clasts dominantly of quartzite, derived likely from the Neihart Quartzite and very thin to thin lenticular beds of conglomerate containing clasts as large as 4 cm across in sequences 0.3–4 m thick, which fill channels of low relief. Conglomerate clasts consist of well-rounded cobbles and boulders of Mesoproterozoic Neihart Quartzite, including Neihart granule-quartz-pebble quartzite, silicified siltite and argillite likely derived from the Spokane Formation, common polycrystalline quartz, rounded twinned feldspar crystals, rare pebbles and small cobbles of granite gneiss and biotite gneiss, and light green to medium gray siliceous siltite and argillite derived possibly from the Greyson Formation. Formation displays cross-laminae to very thin cross beds, herringbone cross-bedding in the lower part; thin sets of trough and ripple cross-laminae common in upper part in which split surfaces locally display ripple marks and some desiccation cracks; formation splits flaggy and slabby, locally platy; forms resistant ledges and ridges. Trace fossils, including *Scolithus*, *Thallasinoides*, *Arenicolites*, *Chondrites*, and other annelid(?) burrows, are scattered to locally very abundant in the uppermost 10–15 m, and present, although rare, in the lower part of the formation. Local friable glauconitic sandstone lenses in the top 2 m contain rare chitinous linguloid brachiopods. Formation unconformably overlies Paleoproterozoic metamorphic rocks in the quadrangle north of the Volcano Valley fault zone and rests unconformably on successively younger Mesoproterozoic metasedimentary rocks of the Belt Supergroup south and southwest of the quadrangle (Reynolds and Brandt, 2006). At Black Butte, N½ sec. 26, T. 12 N., R. 6 E., formation is strongly sheared, repeated by small faults, and recrystallized adjacent to the Volcano Valley fault, but remnants of granule and pebble conglomerate beds and rare trace fossils are preserved locally within sheared blocks. Thickness about 78–110 m

Belt Supergroup, part (Mesoproterozoic)

Newland Formation (Mesoproterozoic)

Ynu **Newland Formation, upper part (Mesoproterozoic)**—Calcareous and dolomitic argillite, calcareous siltite, limestone and thin arkosic sandstone intervals in upper part. Argillite and siltite are medium gray and medium dark gray; weather pale grayish orange and grayish orange; very thin even parallel and wavy parallel laminated locally producing a varve-like appearance on weathered surface; local very thin low-angle inclined laminae. Limestone is medium light gray and medium gray, weathers light and medium light gray; aphanocrystalline and very finely crystalline, locally silty; sparry calcite replacement locally forms some curved surfaces and reticulate patterns in limestone; scattered to common coarse calcite fills fractures; beds locally highly contorted and cleaved; limestone intervals 0.5–5 m thick. Arkosic sandstone is grayish orange pink; weathers very pale orange, and light brown; fine to medium grained, local coarse grains to granules; clasts of quartz, microcline feldspar, polycrystalline quartz, and rare laminated limestone; beds structureless to cross-laminated at low angles; local internal slump structures; beds 0.04–0.3 m thick. Lower exposed part of unit splits shaly and platy, and supports rounded slopes; upper part splits shaly and, in limestone intervals, platy to slabby; forms ledges on steep slopes and ridge crests. Thickness 0 to about 2,100 m

Ynl **Newland Formation, lower part (Mesoproterozoic)**—Dolomitic argillite, siltite, argillite, and silty limestone and dolostone; rare very thin laminae of fine to medium-grained arkose. Dolomitic argillite: medium dark gray and dark gray, weathers same to medium light gray, locally with light brown to dark yellowish orange staining on surfaces; siltite: dark gray, to mainly medium dark gray, locally black and blocky, weathers same; silty limestone and silty dolostone medium gray and medium brownish gray, weather light brownish gray, light olive gray, and pale yellowish brown; dolomitic argillite and argillite very thinly laminated to dominantly laminated, with locally common thin intervals of slump-contorted laminae, and local interbeds of silty limestone and dolostone; black siltite in SE¼ SW¼ SW¼ sec. 19, T. 12 N., R. 7 E. contains discontinuous stringers and laminae of chalcopyrite and pyrite, Unit splits mainly shaly and platy; silty limestone and silty dolomite beds split flaggy. Argillite with local siltite increase in abundance downward. Unit forms rounded hills or weathers to swales between Eocene biotite hornblende dacite sills (₱ebhd). Partial exposed thickness about 500 m

Xgg **Granite gneiss (Paleoproterozoic)**—Granite gneiss, pale red, moderate pinkish red, and grayish orange pink, weathers pale red, light brownish orange pink, to light brownish gray; medium- to coarsely-crystalline; weak to locally moderate foliation defined by alignment of biotite and some hornblende in coarsely crystalline quartz, alkali feldspar, minor sodic feldspar, local muscovite, and rare garnet. Unit includes common to locally abundant undifferentiated bodies of biotite gneiss similar to unit Xbg, below, and thin bodies of amphibolite; unit forms steep, rounded slopes and local cliffs. The granite gneiss complex has an approximate age of 1,817 Ma, and an amphibolite in the complex yielded an age of 1,851±11 Ma (Vogl and others, 2004, p. 20, 30)

Xgbg **Granite gneiss and biotite gneiss undivided (Paleoproterozoic)**—medium light gray, light olive gray, to medium gray, weathers same to dark greenish gray; generally medium crystalline, but locally coarsely crystalline; becomes finely crystalline near margins of principal bodies; plagioclase and orthoclase feldspar in nearly equal amounts, abundant hornblende and common biotite; common quartz; Dark-gray and medium-dark-gray biotite gneiss; grades into biotite schist; biotite with intercrystalline sodic feldspar and some hornblende; bodies of biotite gneiss are foliated and lineated throughout and locally strongly foliated and surrounded by granite gneiss; unit is generally more mafic than unit Xgg. Unit occurs in thin elongate wedges bounded by faults within the structural zone that constitutes the Volcano Valley fault in the quadrangle

Xbd **Biotite hornblende diorite (Paleoproterozoic)**—Inclusions of fine- to medium-crystalline metamorphosed hornblende diorite in coarsely, crystalline granite gneiss (Xgg); dark gray; weathers predominantly very dark gray and black; metamorphic intergrowths of hornblende and sodic feldspar; mapped in SE¼ sec. 18, T. 12 N., R. 6 E.

References Cited

Folk, R.L., 1962, Spectral subdivision of limestone types, *in* Ham, W.E., ed., Classification of carbonate rocks—A symposium: American Association of Petroleum Geologists, Memoir 1, p. 62–84.

Keefer, W.R., 1972, Geologic map of the west half of the Neihart 15-minute quadrangle, central Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–726, scale 1:50,000. [Also available at https://pubs.er.usgs.gov/publication/i726]

Reynolds, M.W., and Brandt, T.E., 2005, Geologic map of the Canyon Ferry Dam 30′ × 60′ quadrangle, west-central Montana: U.S. Geological Survey Scientific Investigations Map 2860, scale 1:100,000. [Also available at https://pubs.er.usgs.gov/publication/sim2860]

Reynolds, M.W., and Brandt, T.E., 2007, Preliminary geologic map of the White Sulphur Springs quadrangle, Montana: U.S. Geological Survey Open-File Report 2006–1329, scale 1:100,000. [Also available at https://pubs.er.usgs.gov/publication/ofr20061329]

Vogl, J.V., Foster, D.A., Mueller, P.A., Wooden, J.L., and Mogk, D.W., 2004, Lithology and age of pre-Belt Precambrian basement in the Little Belt Mountains, Montana—Implications for the role of the Great Falls Tectonic Zone in the Paleoproterozoic assembly of North America: Northwest Geology, v. 33, p. 15–34.

Weed, W.H., and Pirsson, L.V., 1900, Geology of the Little Belt Mountains, Montana: U.S. Geological Survey Annual Report 20 (1898–1899), pt. 3, p. 257–595, pls. 58–77. [Also available at https://pubs.usgs.gov/mr/96/]

Zieg, G.A., Feeback, D.L., Vogl, J.J., Foster, D.A., Mueller, P.A., and Mogk, D.W., 2004, A field tour through the Proterozoic rocks of the southern Little Belt Mountains: Northwest Geology, v. 33, p. 100–110.

Zieg, Jerry, Scartozzi, Vince, Chutas, Nathan, Albers, Doyle, Gostomski, Kevin, and Jones, Jennifer, 2013, Black Butte Copper deposits, lower Belt Supergroup, Montana: Northwest Geology, v. 42, p. 131–148.

Publishing support provided by:
Denver Publishing Service Center, Denver, Colorado

For more information concerning this publication, contact:

Center Director, USGS Geosciences and Environmental Change Science Center
Box 25046, Mail Stop 980
Denver, CO 80225
(303) 236-5344

Or visit the Geosciences and Environmental Change Science Center Web site at:
http://gec.cr.usgs.gov/

This publication is available online at:
https://doi.org/10.3133/sim3379

Reynolds and Brandt—**Geologic Map of the Strawberry Butte 7.5' Quadrangle, Meagher County, Montana**—Scientific Investigations Map 3379

ISSN 2329-132X (online)
https://doi.org/10.3133/sim3379