PRELIMINARY GEOLOGIC MAP OF THE DEARBORN RIVER 30' X 60' QUADRANGLE, WEST-CENTRAL MONTANA

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Compiled by
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GEOLOGIC MAP OF THE DEARBORN RIVER 30’ x 60’ QUADRANGLE

The Dearborn River quadrangle was prepared as a digital compilation through the STATEMAP Component of the National Cooperative Geologic Mapping Program. The map was compiled from previous U.S. Geological Survey and M.S. thesis maps without additional fieldwork. Limited adjustments were made by the compiler in order to meld maps of various scales. The only available map for the western part of the quadrangle was at 1:250,000 scale, whereas quadrangle maps in the southeastern part of the Dearborn River 30’ x 60’ quadrangle were available at 1:24,000 scale. This variation in scales is reflected in the inconsistent level of map detail and identifies areas that need more detailed mapping.

The purpose of the compilation is to provide a digital map that presents available mapping at 1:100,000 scale, consistent with the goal of the Montana STATEMAP Program to map the entire State at that scale. The preliminary map also provides a basis for assessing the best areas for future, more detailed field mapping.

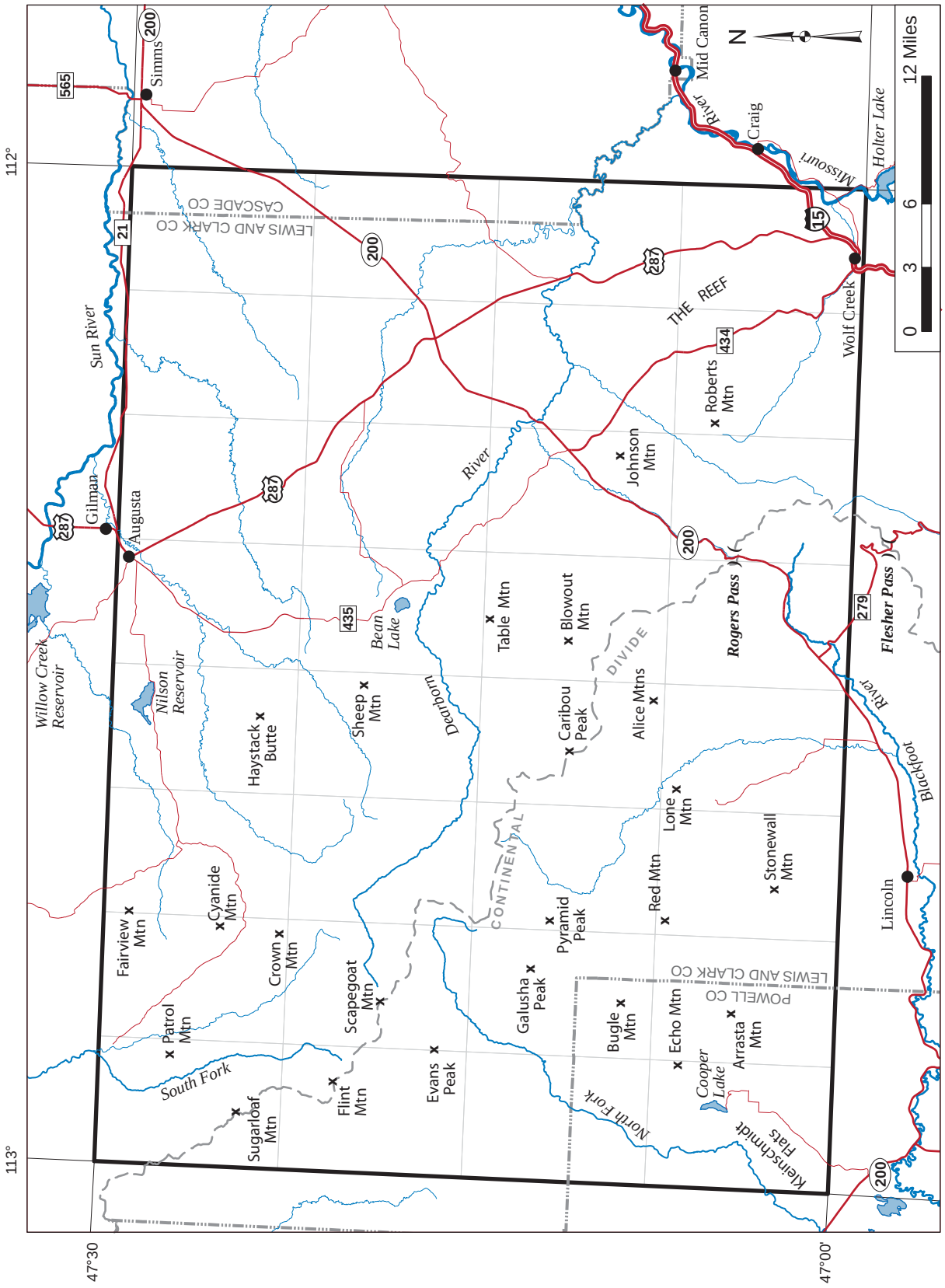
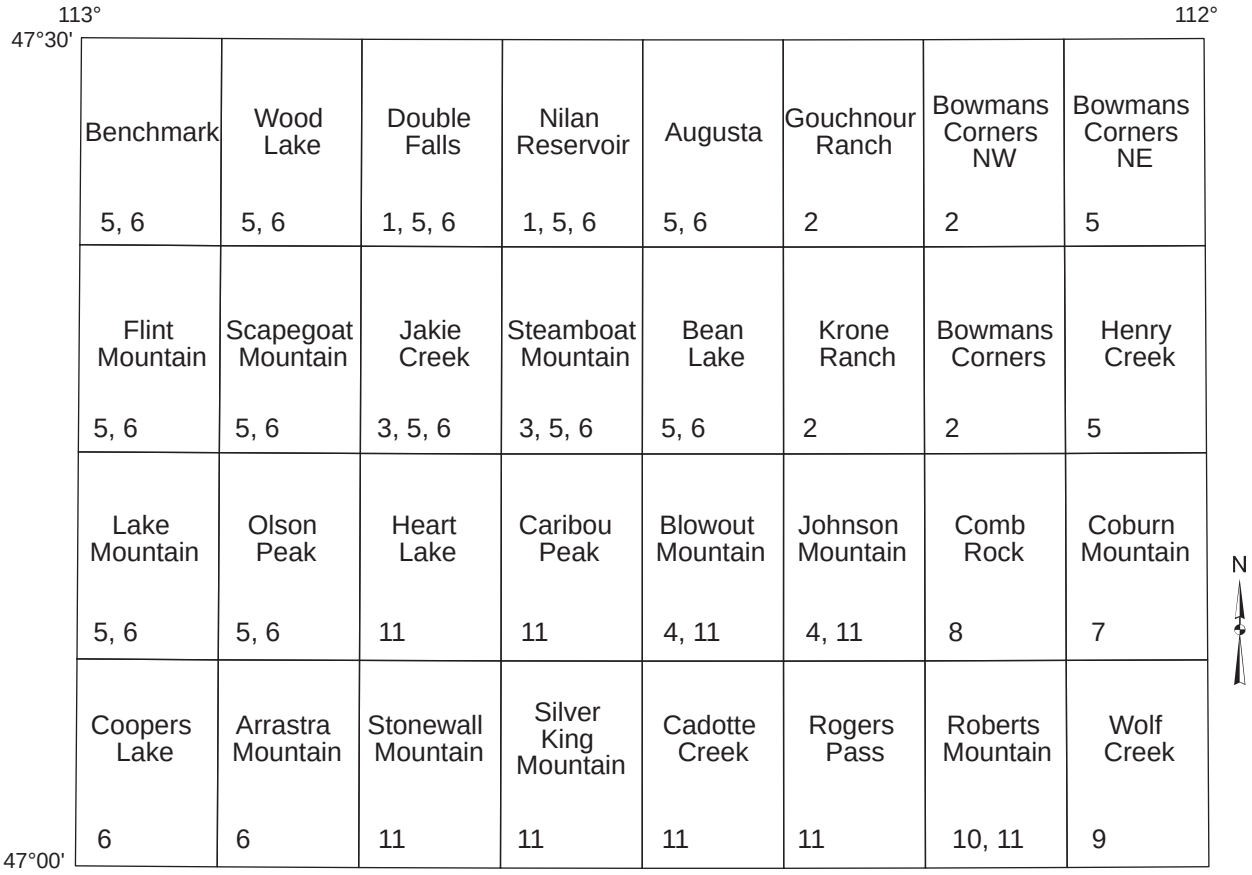


Figure 1. Geographic features in the Dearborn River 30' x 60' quadrangle.

Compilation sources and index of 7.5' quadrangles



1. Dolberg, D.M., 1986
2. Henry, H.M., 2007
3. Holcombe, T.L., 1963
4. Lange, S.S., 1963
5. Mudge, M.R., and Earhart, R.L., 1983
6. Mudge, M.R., Earhart, R.L., Whipple, J.W., and Harrison, J.E., 1982
7. Schmidt, R.G., 1972a
8. Schmidt, R.G., 1972b
9. Schmidt, R.G., 1972c
10. Schmidt, R.G., and Strong, C.P., 1972
11. Whipple, J.W., Mudge, M.R., and Earhart, R.L., 1987

Figure 2. Compilation sources and index of 7.5' quadrangles.

GEOLOGIC MAP OF THE DEARBORN RIVER 30’ x 60’ QUADRANGLE
EXPLANATION

Descriptions were compiled from map sources (figure 2).

Qal ALLUVIUM (HOLOCENE)—Unconsolidated stream-laid gravel, sand, silt, and clay; poorly to moderately well sorted, unconsolidated; includes some slope wash and colluvium. Thickness as much as 10 m (33 ft).

Qac ALLUVIUM AND COLLUVIUM, undivided (HOLOCENE)—Sheetwash alluvium and fine-grained colluvium on gentle slopes. Thickness generally less than 15 m (50 ft).

Qls LANDSLIDE DEPOSIT (HOLOCENE AND PLEISTOCENE)—Mostly rock debris, locally with coarse, angular rock fragments in silt or clay matrix. Forms hummocky topography. Produced by rockfall- and rockslide-avalanches, slumps, and earthflows. Thickness possibly as much as 300 m (985 ft).

Qlst LANDSLIDE AND TALUS DEPOSITS, undivided (HOLOCENE AND PLEISTOCENE)—Jumbled, dislocated rock debris of local origin produced by slump, earthflow, rock creep, and rock fall on steep to moderate slopes; unsorted and unconsolidated. Thickness as much as 30 m (100 ft).

Qat ALLUVIAL TERRACE DEPOSIT (HOLOCENE AND PLEISTOCENE)—Poorly sorted, unconsolidated coarse stream gravel on remnants of four bench surfaces along South Fork of Dearborn River, Rock Creek, and Wolf Creek. Thickness as much as 3 m (10 ft).

Qgt GLACIAL TILL (HOLOCENE AND PLEISTOCENE)—Unsorted, heterogeneous mixture of rock fragments in silty clay matrix. Forms hummocky topography. May include local glacial outwash deposits. Thickness as much as 100 m (330 ft).

Qgo GLACIAL OUTWASH DEPOSIT (PLEISTOCENE)—Gravel with abundant boulders along the Rocky Mountain Front with poorly to moderately size-sorted clasts, dominantly limestone.

Qgl GLACIAL LAKE DEPOSIT (PLEISTOCENE)—Light gray to dark gray and gray brown thin- to thick-bedded, silty clay, clay, and some sand; deposited in glacial lakes. Thickness as much as 30 m (100 ft).

Qgof GLACIAL OUTWASH FAN DEPOSIT (PLEISTOCENE)—Kleinschmidt Flat fan in the southwestern corner of the map area. Unconsolidated, poorly size-sorted outwash gravel derived from the Ovando Glacier (Witkind and Weber, 1982). Fan appears to have been truncated along a northeast-trending Quaternary fault. Based on well logs, deposit is hundreds of feet thick (Roberts and Waren, 1999).

QTgr GRAVEL (PLEISTOCENE AND PLIOCENE?)—Coarse stream-deposited gravel on remnants of at least four bench surfaces as much as 250 m (820 ft) above modern stream alluvium. Thickness as much as 10 m (33 ft).

QTtu TUFA (PLEISTOCENE OR PLIOCENE?)—White, cream, and brown tufa and travertine composed of coarsely crystalline calcium carbonate; commonly banded. Occurs along normal fault near Rogers Pass.

Ta ANDESITE (EOCENE)—Dark gray, porphyritic andesite, latite, and trachyte in dikes, sills, and irregular-shaped bodies related to the Adel Mountain Volcanics. Contains variably altered euhedral to subhedral phenocrysts of potassium feldspar as much as 5 mm (0.2 in) across, and smaller phenocrysts of plagioclase, biotite, and hornblende set in an aphanitic groundmass. Phenocrysts constitute about 60 percent of the rock. Alteration products are sericite, chlorite, sparse epidote, and hematitic stain along fractures.

Tba BASALT (EOCENE)—Dark gray to gray brown, finely porphyritic flows with numerous calcite- and zeolite-filled cavities. Locally weathers into spheroidal boulders and overlies Tertiary lake bed deposits. Present only in southern part of map area.

Tda DACITE (EOCENE)—Gray to light gray volcanic neck or plug and sills. Aphanitic groundmass of greenish gray feldspar with phenocrysts of light gray feldspar, hornblende, and biotite. Present only at Haystack Butte.

Tmo MONZONITE (EOCENE)—Light gray hornblende monzonite composed of andesine, sanidine, biotite, augite, and abundant euhedral hornblende. Occurs mostly as dikes and as an irregular sill(?) in Cretaceous rocks east and along the Steinbach thrust fault. Dated 47.5 $\pm$ 1.5 Ma (Whipple and others, 1987).

Tmop MONZONITE PORPHYRY (EOCENE)—Brownish gray, coarsely porphyritic monzonite that contains white phenocrysts of oligoclase as much as 2 cm (0.8 in) long and plagioclase as much as 1 cm (0.4 in) long in a fine-grained groundmass of oligoclase, potassium feldspar, hornblende, magnetite, biotite, and quartz. Forms main body of Mike Horse Stock reported as early Eocene by Miller and others (1973). Also occurs as numerous small dikes within Mike Horse stock and as sills and dikes along the Steinback thrust. Breccia pipes associated with Tmop of Mike Horse Stock not shown on map.

Ttrb TRACHYBASALT (EOCENE)—Dark gray, brown-weathered, coarsely porphyritic with abundant large phenocrysts of augite in an aphanitic groundmass. Composed of labradorite, sanidine, augite, olivine, and magnetite. In dikes and small intrusive bodies.

Trb RHYOLITE BRECCIA (EOCENE)— Gray, buff, and pale pink rhyolite flow breccia that contains clasts of maroon and grayish green siltite, volcanic rocks as large as 1 cm, and embayed quartz phenocrysts as much as 2 mm across. Located in the valley east of Stonewall Mountain along the southern map border.

Ttu TUFF (EOCENE)—Gray, lavender, and pale pink rhyodacite tuff, lapilli tuff, and ash-flow tuff. Contains subhedral to euhedral crystals of quartz and sanidine, and lithic clasts of Belt rocks as much as 5 mm (2 in) across. Contains limonite casts after cubic pyrite and locally limonite stain. Thickness as much as 450 m (1,475 ft).

Ts SEDIMENT OR SEDIMENTARY ROCK (TERTIARY)—Gray, brownish gray, greenish gray and brown conglomerate, sandstone, siltstone, claystone, and marlstone; locally tuffaceous and carbonaceous. Contains coaly plant debris and fossil leaf impressions, insects, and fish; locally contains interbedded light to dark brown shale, oil shale, and rare coal and limestone. Conglomerate contains rounded clasts of Belt Supergroup rocks as much as 13 cm (5 in) across. Small remnants exposed in valleys along southern border of quadrangle.

TKtra TRACHYANDESITE (PALEOCENE OR UPPER CRETACEOUS)—Dark grayish brown, aphanitic groundmass of feldspar with phenocrysts of plagioclase, potassium feldspar, pyroxene, and quartz in sills in northwestern part of quadrangle.

TKr RHYOLITE (PALEOCENE OR UPPER CRETACEOUS)—Light gray to white, finely porphyritic, with abundant 2–3 mm phenocrysts of quartz and oligoclase. Present in sills and dikes only in southeast corner of map area.

TKwc WILLOW CREEK FORMATION (PALEOCENE AND UPPER CRETACEOUS)—Light to dark red, purplish red, brown, gray, and greenish gray mudstone, siltstone, and sandstone; some dark brown and dark red, very coarse-grained beds of volcanic sandstone are locally conglomeratic with small rounded pebbles of andesite, latite, and welded rhyolitic tuff; top not exposed. Probably equivalent to the lower part of the Willow Creek Formation of Late Cretaceous and Paleocene age in southern Alberta, Canada. Thickness from 0 to as much as 155 m (0–500 ft).

Kam ADEL MOUNTAIN VOLCANICS (UPPER CRETACEOUS)—Volcanic and volcanic-sedimentary rocks. Trachyandesite and trachybasalt flows, volcanic conglomerate, breccias, and lacustrine deposits of volcanic sandstone, siltstone, and mudstone.

Klk LAKE DEPOSIT (UPPER CRETACEOUS)—Gray, brown, and yellowish brown volcanic sandstone, siltstone, and mudstone in thin beds; thin beds of pale green to yellowish brown ash fall tuff locally near base; plant fragments abundant; small-scale penecontemporaneous folds in mudstone. Associated with Adel Mountain Volcanics. Thickness 0–150 m (0–500 ft).

Kvc VOLCANIC CONGLOMERATE (UPPER CRETACEOUS)—Red and purplish red, poorly sorted, and indistinctly bedded. Composed of rounded and subrounded clasts of trachybasalt, trachyandesite, latite, and quartz latite ranging from pebble size to as much as 0.6 m (2 ft) across; a few thin interbeds of red and purplish gray volcanic sandstone, siltstone, and mudstone; maximum exposed thickness about 365 m (1,200 ft). Associated with Adel Mountain Volcanics.

Kla Latite (UPPER CRETACEOUS) —Gray, grayish purple, massive, and porphyritic with abundant phenocrysts of labradorite in an aphanitic groundmass. Sill in southeastern corner of map.

Kqm QUARTZ MONZONITE PORPHYRY (UPPER CRETACEOUS)—Light gray and light grayish orange, coarsely porphyritic with orange to white phenocrysts of oligoclase as much as 1 cm (0.4 in) long in a fine-grained groundmass of oligoclase, sanidine, biotite, hornblende, quartz, magnetite, and apatite. Thick sills in eastern part of map.

Krhp RHYODACITE PORPHYRY (UPPER CRETACEOUS)—Greenish gray, porphyritic, with phenocrysts of oligoclase and hornblende in a groundmass of quartz, potassium feldspar, oligoclase, hornblende, magnetite, and apatite. Occurs in sills.

Ktr TRACHYTE (UPPER CRETACEOUS)—Brownish gray to reddish purple, massive and finely porphyritic with small phenocrysts of andesine and augite in an aphanitic groundmass. Composed of andesine, sanidine, augite, biotite, and magnetite. Forms thick sills and small dikes.

Ksm ST. MARY RIVER FORMATION (UPPER CRETACEOUS)— Grayish green, olive gray, and light gray calcareous mudstone, siltstone, and sandstone; a few red and purplish gray beds; some dark greenish gray, coarse- to very coarse-grained beds of volcanic sandstone in lower part; small limy concretionary nodules, derived from beds of calcareous mudstone, abundant on outcrop in middle and upper parts; *Crassostrea glabra* sparsely distributed in sandstone and siltstone beds 35–40 m (120–140 ft) above base and underlain by carbonaceous shale bed as much as 1 m (3 ft) thick. Some reptile bone fragments and pelecypods near base. Unit includes lower part of Willow Creek Formation in southeastern part of quadrangle. Thickness of St. Mary River Formation as much as 430 m (1,400 ft).

Kh HORSETHIEF FORMATION (UPPER CRETACEOUS)—Upper part of formation: Mostly gray to gray brown, fine- to medium-grained, crossbedded sandstone. Upper 6–12 m (20–40 ft) commonly contains lentils of titaniferous magnetite sandstone. Southeast of Augusta, contains volcanic-rich sandstone and conglomerates (Viele and Harris, 1965) that are absent in the southeast part of the quadrangle where their position is marked by an *Ostrea glabra* bed (Viele, 1960). Locally the sandstone contains pelecypods. Upper part is as much as 50 m (165 ft) thick.

Lower part of formation (Bearpaw–Horsethief transition unit of Cobban, 1955): Dark gray mudstone interbedded with light- to medium-gray mudstone and fine- to medium-grained sandstone that is thin-bedded in the lower part, becoming thicker bedded in the upper part. Thickness of lower part of formation as much as 60 m (195 ft). Thickness of formation 0–110 m (0–360 ft).

Ktm TWO MEDICINE FORMATION (UPPER CRETACEOUS)—Gray green and gray mudstone with minor sandstone in upper and middle parts with gray green, olive drab, and gray sandstone and mudstone in lower part. Upper and middle parts locally contain reddish gray, red brown, and purple mudstone interbeds. The sandstones are fine- to coarse-grained and locally conglomeratic. Carbonaceous shale and locally a coalbed are present in the lower part. Petrified wood common about 30 m (100 ft) above base; vertebrate bones common in upper 150 m (490 ft). Pelecypods locally present at various horizons. Thickness about 670 m (3,000 ft).

Ktmv TWO MEDICINE FORMATION, VOLCANIC FACIES (UPPER CRETACEOUS)—Alternating clastic volcanic rocks and volcanic flows and tuffs. Green, grayish green, gray, dark greenish gray, dark brown, grayish purple, brownish gray, and maroon clastic volcanic conglomerate, sandstone, siltstone, and mudstone; locally crossbedded and locally with rounded pebbles of andesite, latite, and welded rhyolitic tuff. Green, grayish green, tan, red, and grayish red, rubbly pumiceous tuff and red, purple, and brown densely welded rhyolitic and dacitic tuff.

Brownish gray and reddish purple trachyte flow. Gray, grayish purple, and brown-weathered latite flows. Thickness 500–1,430 m (1,660–4,700 ft).

Kvt VIRGELLE AND TELEGRAPH CREEK FORMATIONS, UNDIVIDED (UPPER CRETACEOUS)

Kvi VIRGELLE SANDSTONE (UPPER CRETACEOUS)—Moderately thick-bedded, light gray, fine-grained sandstone. Some beds are locally iron-impregnated and crossbedded. At the top, a titaniferous magnetite sandstone bed, as much as 6 m (20 ft) thick, forms a prominent rimrock in many places. Rare pelecypods; wood fragments locally in upper part. Thickness 40–60 m (130–195 ft).

Ktc TELEGRAPH CREEK FORMATION (UPPER CRETACEOUS)—Transitional unit between the underlying Marias River Shale and the overlying Virgelle Sandstone. Consists mainly of beds of gray mudstone and fine-grained sandstone. The sandstone beds are thinly bedded in the lower part, becoming thicker bedded in the upper part. Pelecypods and ammonites common. Thickness about 90 m (295 ft).

Kmr MARIAS RIVER FORMATION (UPPER CRETACEOUS)—Dominantly dark gray mudstone that is divided into four members: Kevin, Ferdig, Cone, and Floweree (Cobban and others, 1976). Total thickness 365–395 m (1,200–1,300 ft).

Kmk KEVIN MEMBER—Dark gray mudstone with some very thin sandstone beds, numerous bentonite beds, and many light gray calcareous concretions. Pelecypods and ammonites common. Thickness 245–305 m (800–1,000 ft).

Kmrl LOWER MARIAS RIVER FORMATION

FERDIG MEMBER—Gray, noncalcareous siltstone and shale with many thin, iron-stained sandstone lenses, concretions of yellow-weathering limestone, red-weathering ferruginous dolostone, and some very thin bentonite beds. Contains abundant organic trails and burrows, and rare pelecypods and ammonites (Mudge, 1972a). Thickness 50–105 m (165–345 ft).

CONE MEMBER—Dark gray and dark brownish gray shale with abundant, very thin, medium gray, calcareous siltstone and crystalline limestone beds in upper part, and dark gray, noncalcareous shale in lower part. Contains several bentonite beds throughout. Pelecypods and ammonites common, especially in the upper part. Thickness 18–30 m (60–100 ft).

FLOWEREE MEMBER—Dark gray, noncalcareous fissile to thin-bedded shale with medium gray siltstone in lower part that locally contains lenses of chert-pebble conglomerate. Rare pelecypods and ammonites. Thickness about 10 m (33 ft).

Kbl BLACKLEAF FORMATION (UPPER AND LOWER CRETACEOUS)—Mostly sandstone and mudstone with subordinate fissile shale. Formation divided into three members: Vaughn, Taft Hill, and Flood in map area. Total thickness about 200 m (655 ft).

Kbv VAUGHN MEMBER—Nonmarine, light gray, gray green and green tuffaceous and bentonitic mudstone and sandstone. Dark gray carbonaceous mudstone locally in upper part in the southeastern part of the map area. The sandstone units are fine- to coarse-grained, locally crossbedded, and in places contain pebble and cobble conglomerate channel-fill

deposits as much as 6 m (20 ft) thick (Mudge and Sheppard, 1968). Contains wood and leaf fragments. Thickness about 90 m (295 ft).

Kbt TAFT HILL MEMBER—Marine, gray, thinly bedded, fine-grained sandstone interbedded with dark gray mudstone; sandstone locally crossbedded and ripple marked. Locally contains numerous pelecypods. Thickness about 58 m (190 ft).

Kblf FLOOD MEMBER—Two gray, marine sandstone units separated by as much as 150 m (490 ft) of dark gray, fissile shale. The sandstones are very fine grained, thin- to moderately thick-bedded, and locally crossbedded and ripple marked. Organic burrows and trails common. Thickness about 45 m (150 ft).

Kk KOOTENAI FORMATION (LOWER CRETACEOUS)—Nonmarine, gray green and dark reddish brown mudstone interbedded with lenticular thin to thick sandstone units. Numerous heavily iron-stained, spheroidal nodules of dark grayish red, sandy limestone are in the mudstone and local magnetite grains. Pebble and cobble conglomerate, as much as 15 m (50 ft) thick, fill narrow channels locally at the base of some sandstone units. In most places a distinctive hard, dense, brown coquinoid limestone that contains abundant pelecypods and some vertebrate fragments is at or near the top. Thickness 198–245 m (650–800 ft).

KJme MOUNT PABLO AND MORRISON FORMATIONS, AND ELLIS GROUP (LOWER CRETACEOUS, AND UPPER AND MIDDLE JURASSIC)

MOUNT PABLO FORMATION—Nonmarine; ranges from a dominantly sandstone sequence with interbedded bright reddish brown mudstone to a dominantly reddish brown mudstone sequence with some sandstone. Dense, dark gray to light gray limestone beds as much as 9 m (30 ft) thick are present in the upper part of the formation. In many places, coarse sandstone and thin beds of conglomerate occur as channel-fill deposits. The sandstones are medium to very coarse grained, crossbedded, and contain wood fragments. Exposures widespread in eastern mountains but locally absent in the adjacent foothills. Rests unconformably on Morrison Formation. Thickness 0–60 m (0–195 ft).

Jm MORRISON FORMATION (UPPER JURASSIC)—Grayish green, olive green, and olive gray nonmarine, tuffaceous claystone to siltstone with pink, maroon, purple, and yellowish gray mudstones in the upper part. A thin, dark gray carbonaceous shale present near top. Locally, fine-grained clayey sandstone and abundant polished quartzite pebbles and limestone nodules are present. Cherty siderite lenses and nodules are locally common about 35 m (115 ft) above the base of the formation and locally in the middle part. Gastropods, pelecypods, plant fragments, ostracods, and vertebrate bones are sparse in the middle and lower parts of the formation. Thickness 60–82 m (195–270 ft).

Je ELLIS GROUP (MIDDLE AND UPPER JURASSIC)

SWIFT FORMATION (UPPER AND MIDDLE JURASSIC)—Marine, thickly bedded gray to gray brown fine-grained sandstone in the upper part and dark gray to olive drab mudstone with many thin beds of sandstone in the lower part. The upper beds are locally ripple marked and contain minute cross lamination and wood fragments. A thin glauconitic sandstone with waterworn belemnites present at the base of the formation. Formation rests unconformably on the Rierdon Formation everywhere except in the southeast corner of the map, where it rests on the Sawtooth Formation. Thickness about 35 m (115 ft).

RIERDON FORMATION (MIDDLE JURASSIC)—Consists mostly of gray, calcareous marine mudstone with thin interbedded argillaceous limestone. Barite nodules common in the upper and middle parts. Pelecypods and ammonites common throughout. Widely distributed except in the southeast corner of the map area. Thickness 33–60 m (110–195 ft).

SAWTOOTH FORMATION (MIDDLE JURASSIC)

Upper member: Gray brown to yellowish brown, calcareous, thin-bedded siltstone that contains pelecypods and ammonites. Thickness about 8 m (25 ft).

Middle member: Dark gray, silty to clayey fissile shale with local thin beds of fine-grained sandstone and conglomerate. Locally rests unconformably on Mississippian rocks. Thickness 5–77 m (15–250 ft).

Lower member: Thin-bedded, fine-grained, gray to yellowish brown sandstone with a basal conglomerate of Mississippian rock fragments. Dark gray, silty, thinly laminated shale locally interbedded in the sandstone. Pelecypods locally abundant. Thickness as much as 15 m (50 ft).

Mm MADISON GROUP (MISSISSIPPIAN)

CASTLE REEF DOLOMITE (UPPER AND LOWER MISSISSIPPIAN)

Sun River Member: Light gray thin to thick beds of medium to finely crystalline dolomite and locally some interbedded calcitic dolomite. Many beds contain thick lenses of encrinites and scattered brachiopods and corals. Thickness 0–37 m (0–450 ft).

Lower member: Thick-bedded, finely to coarsely crystalline, light to medium gray dolomite, calcitic dolomite, dolomitic limestone, and limestone. The coarsely crystalline beds are encrinites. Lower member contains brachiopods and corals, locally abundant in the lower part. Thickness 114–145 m (375–475 ft). The Sun River Member and lower member both thin eastward, mainly as a result of pre-Jurassic erosion.

ALLAN MOUNTAIN LIMESTONE (LOWER MISSISSIPPIAN)

Upper member: Fine-grained thin to thick beds of limestone, magnesian limestone, and dolomitic limestone. Nodules and lentils of gray to gray brown chert are common (Mudge, 1972a). Large and varied fauna, mostly brachiopods and corals, and locally, lenses and beds of encrinites. Thickness 60–90 m (195–295 ft).

Middle member: Dark gray, fine-grained, thin to medium beds of limestone with some dolomitic limestone. Characteristically contains nodules and irregular-shaped to even-bedded lenses of dark gray chert of which some have fibrous appearance (Mudge, 1972a). Contains sparse brachiopods and corals (Mudge and others, 1962). Thickness about 45 m (150 ft) thick.

Lower member: Mostly dark gray, very thin-bedded, argillaceous dolomitic limestone with many calcareous shale partings. Contains dense, gray, moderately thick limestone interbedded with dark gray mudstone. The mudstone has abundant brachiopods and corals. Thickness 60–89 m (195–290 ft).

Thickness of Allan Mountain Limestone 163–200 m (535–656 ft).

MDtm THREE FORKS, JEFFERSON, AND MAYWOOD FORMATIONS, undivided

THREE FORKS FORMATION (LOWER MISSISSIPPIAN AND UPPER DEVONIAN)

Upper member: Black shale bed equivalent to the Sappington Member of the Three Forks Formation. In most places it overlies thinly bedded, gray brown to yellowish gray

limestone. The limestone commonly overlies an evaporite solution breccia. Fossils abundant in the dark gray shale and limestone beds.

Lower member: Pale yellowish brown to yellowish gray evaporite solution breccias that consist of angular fragments of dolomite and dolomitic limestone.

Formation thickness 15–180 m (50–590 ft).

JEFFERSON FORMATION (UPPER DEVONIAN)

Birdbear Member: Mostly pale yellowish brown to brownish gray, finely crystalline dolomite beds that pinch and swell. Brachiopods are commonly present. Thickness 45– 72 m (145–235 m).

Lower member: Dolomite or limestone. Consists of distinctive gray brown beds of dolomite or limestone, mostly less than 0.5 m (1.6 ft) thick, that characteristically have a fetid odor on the broken surface. Many beds have a sucrosic texture. The lower part commonly contains one or more thin beds of evaporite-solution breccias. Dark gray chert lenses common in the lower part. Corals, brachiopods, and stromatoporoids common throughout, and *Amphipora* biostromes widespread in the upper part.

Formation thickness 128–198 m (420–650 ft); thickens eastward.

MAYWOOD FORMATION (UPPER AND MIDDLE DEVONIAN)

Upper member: Crystalline limestone and dolomitic limestone that contains brachiopods and corals.

Lower member: Mostly greenish gray dolomitic mudstone that in western outcrops is interbedded with maroon mudstone. Contains thin beds of crystalline yellowish gray to olive gray dolomite and dolomitic limestone. A widespread dolomite with some breccias present in the middle part of the member. Charophytes and conodonts are locally present in one of the dolomite beds.

Formation thickness about 8–63 m (25–200 ft); thickens westward.

Cambrian formations, northwestern part of map area

Cs CAMBRIAN ROCKS, UNDIVIDED (UPPER AND MIDDLE CAMBRIAN)

Cdgd DEVILS GLEN THROUGH DAMNATION FORMATIONS, UNDIVIDED (UPPER AND MIDDLE CAMBRIAN)

Cdg DEVILS GLEN DOLOMITE (UPPER CAMBRIAN)—Pale brown to light gray, fine-grained, hard, very thick-bedded dolomite that weathers chalk white. Thickness 100–170 m (330–560 ft).

Css SWITCHBACK AND STEAMBOAT FORMATIONS, UNDIVIDED (UPPER AND MIDDLE CAMBRIAN)

SWITCHBACK SHALE (UPPER AND MIDDLE CAMBRIAN)—Dark green to gray, soft, fissile shale interbedded with several horizons of pale brown to brownish gray, fine-grained, thick- to thin-bedded limestone that contains flakes and nodules of pink, reddish brown, and orange brown clay. Shale somewhat darker and softer than Gordon Shale in lower part of the Cambrian section. Thickness 25–40 m (80–130 ft).

STEAMBOAT LIMESTONE (MIDDLE CAMBRIAN)—Three pale brown to brownish gray, fine-grained, hard, thick- to very thin-bedded limestone units with varying amounts of reddish brown to tan clay flakes and laminae giving a mottled appearance to exposed bedding

surfaces. Type locality is in canyon of North Fork of Dearborn River in SW¼ sec 6, T. 17 N., R. 7 W. Thickness 90 m (300 ft).

Cpaf PAGODA THROUGH FLATHEAD FORMATIONS

Cpa PAGODA LIMESTONE (MIDDLE CAMBRIAN)
Upper member: Pale brown to brownish gray, fine-grained, hard, very thick- to thin-bedded, locally oolitic limestone that contains abundant tan clay flakes and nodules. Distinguished from other Cambrian limestone units by the oolitic zones. Thickness 75 m (250 ft).
Lower member: Green shale. Thickness 15 m (50 ft).

Cdd DEARBORN AND DAMNATION FORMATIONS, UNDIVIDED (MIDDLE CAMBRIAN)
DEARBORN LIMESTONE (MIDDLE CAMBRIAN)
Upper member: Pale brown to brownish gray, fine-grained, very thick- to thin-bedded limestone with flakes and nodules of tan clay. Very similar to Damnation Limestone.
Lower member: Green, fissile shale very similar to the Gordon Shale.
Formation thickness: 75–115 m (250–375 ft).

DAMNATION LIMESTONE (MIDDLE CAMBRIAN)—Pale brown to brownish gray; weathered to mottled medium gray and tan; fine-grained, hard, very thick- to very thin-bedded limestone. Distinctive undulatory bedding and flakes, nodules, and thin intercalations of tan clay throughout. Resistant, although not as prominent or as thick as some of the overlying Cambrian limestone units. Thickness 30–55 m (100–180 ft).

Cgf GORDON AND FLATHEAD FORMATIONS, UNDIVIDED (MIDDLE CAMBRIAN)

Cg GORDON SHALE (MIDDLE CAMBRIAN)—Dark green to greenish gray, very thin-bedded to laminated, fissile, micaceous, poorly resistant siltstone, silty shale, and shale, with thin gray limestone stringers distributed irregularly throughout. Thickness 60–70 m (200–225 ft).

Cf FLATHEAD FORMATION (MIDDLE CAMBRIAN)—Very pale orange to moderate pink, yellowish brown-weathered, thin- to thick-bedded, crossbedded, noncalcareous, poorly sorted, poorly indurated fine- to coarse-grained quartzose sandstone with scattered rounded quartz pebbles. Beds characteristically speckled by disseminated hematite. Local interbeds of gray, purple, or maroon mudstone. Thickness 13 to 38 m (40–125 ft).

Cambrian formations, southeastern part of map area

Cm MEAGHER FORMATION (MIDDLE CAMBRIAN)—Gray, fine-grained, thinly bedded, fragmental limestone that weathers light gray and light bluish gray; in places irregularly ribboned and mottled with yellowish orange and yellowish brown dolomite; occurs as large and small detached blocks along Eldorado thrust and as a discontinuous band beneath Wolf Creek thrust ; top not exposed; maximum exposed thickness 150 m (490 ft).

Cw WOLSEY SHALE (MIDDLE CAMBRIAN)—Greenish gray, sandy, micaceous shale with thin lenses of fine-grained, greenish gray sandstone; nonfossiliferous. Thickness as much as 50 m (165 ft); tectonically thinned.

Cf FLATHEAD FORMATION (MIDDLE CAMBRIAN)—Pale gray to pale pink and purple, banded thin- to thick-bedded and crossbedded, medium-grained quartzite; locally finely conglomeratic with pebbles of quartz as much as a half inch across; nonfossiliferous. Thickness as much as 40 m (130 ft).

Zd DIORITE (NEOPROTEROZOIC)—Dark gray to greenish black, medium-grained, equigranular, diorite composed of andesine-labradorite, augite, biotite, magnetite, and sparse apatite and quartz. Weathers a characteristic rusty brown color. In sills and dikes. Sills bounded by thick zones of hornfels. Age of sills reported as 750 ±25 Ma (Mudge and others, 1968). Thickness as much as 460 m (1,500 ft; Earhart and others, 1977), but commonly 60–150 m (200–500 ft).

Yma META-ANDESITE AND METADIORITE (MESOPROTEROZOIC)—Dark, blackish green to greenish gray, metamorphosed andesite and diorite, commonly porphyritic. Typically has a few small crystals of partially kaolinized andesine in a groundmass of chlorite, hornblende, labradorite, calcite, and magnetite. Forms sills and dikes less than 3 m (10 ft) thick.

Ygr GARNET RANGE FORMATION (MESOPROTEROZOIC)—Pale olive to medium gray and moderate brown, poorly sorted, micaceous, thin even beds of very fine to fine-grained sandstone and siltstone, locally speckled by hematite, crossbedded and ripple marked. Variable thickness because of pre-Middle Cambrian erosion. Thickness 0–490 m (0–1600 ft).

Ym MCNAMARA FORMATION (MESOPROTEROZOIC)

Upper member: Upper part dominantly reddish brown quartzite and lower part dominantly grayish green siltite. Quartzite interbedded with siltite and minor argillite. Most of member is thin-bedded, fine-grained, micaceous, minutely crossbedded, and locally ripple marked.

Lower member: Upper part contains thin beds of glauconitic sandstone, some barite nodules, and vuggy reddish chalcedony, particularly in the eastern part of the quadrangle. In general lower member contains thin beds of argillite, fine- to medium-grained quartzite and locally some reddish-gray siltite. Ripple marks, minute crossbedding, and load casts are common.

Formation thickness variable in part because of pre-Middle Cambrian erosion. Ranges from 0 to 625 m (0 to 2,000 ft).

Ybo BONNER QUARTZITE (MESOPROTEROZOIC)—Mostly pink, pale red, and pinkish gray, fine- to medium-grained, poorly sorted quartzite beds that range from 31 cm (1 ft) to 76 cm (2 ft) thick. The quartzite is mostly feldspathic and locally includes fragments of red argillite. Many beds are crossbedded and ripple marked. Thickness 213–580 m (700–1,900 ft).

Yms MOUNT SHIELDS FORMATION (MESOPROTEROZOIC)—Mostly bright reddish brown, thinly laminated, micaceous siltite, argillite, and thin- to thick-bedded quartzite. Sedimentary features include minute cross laminations, ripple marks, mud-crack fillings, and mud chips. A grayish green siltite unit with local interbedded dark gray, fissile shale widespread in the upper part of the formation. Salt crystal casts widespread in the upper part of the formation beneath the grayish green unit. The quartzite beds are mostly fine- to medium-grained and more common in the middle and lower parts of the formation. A thick [155–305 m (510–1,000 ft)] quartzite is present in the upper to middle part of the formation. It contains poorly

sorted, fine- to coarse-grained, pinkish gray to reddish brown quartzite beds less than 1 m (3 ft) thick that are separated by thin beds of reddish brown siltite and argillite. Color, grain size, and sedimentary features of the quartzite beds are similar to those in the Bonner Quartzite. Lower part of formation commonly contains thin beds of glauconitic quartzite. In the central and northern parts of the area, the formation is more argillitic and contains beds of stromatolitic and oolitic limestone. Thickness ranges from 555 to 1,860 m (1,800 to 6,000 ft).

Ysh SHEPARD FORMATION (MESOPROTEROZOIC)—Greenish gray to grayish yellow, micaceous siltite and some silty limestone and argillite. Beds of maroon siltite and argillite widespread in the middle part and locally in the upper part. Thin glauconitic quartzite lentils widespread in the upper part of the formation. Ripple marks, minute cross lamination, load casts, and mud cracks also common. An edgewise conglomerate present near the base of the formation in the eastern part of the map area with stromatolitic limestone at that horizon to the west. Thickness 249–715 m (815–2,345 ft).

Ysn SNOWSLIP FORMATION (MESOPROTEROZOIC)—Pale red to reddish brown beds of argillite and siltite interbedded with greenish gray beds of argillite and siltite with some thin beds of very fine to fine-grained quartzite. Thin beds of stromatolitic and oolitic limestone and flat pebble conglomerate locally occur at various horizons. Crossbedding, minute laminae, ripple marks, and mud cracks common; raindrop impressions and mud-chip conglomerates less common. Thin beds of poorly sorted, fine- to coarse-grained quartzite and gritstone common near the lower contact. Thickness 215–1,100 m (700–3,600 ft).

Yh HELENA FORMATION (MESOPROTEROZOIC)

Upper member: Beds of limestone interbedded with dolomite, siltite, and argillite. Beds of stromatolites, oolites, and edgewise conglomerates widespread.

Middle member (most of formation): Light to medium gray, thin- to thick-bedded silty limestone, dolomite, and calcitic dolomite that weathers to a yellowish gray to grayish orange. Commonly, vertical ribbons, horizontal mats, lenses, and pods form molar-tooth structures enhanced by differential weathering. Stromatolites, oolites, and edgewise conglomerates locally present at various horizons. Sedimentary structures include asymmetrical ripple marks, scour-and-fill and fluid-escape structures, and abundant syneresis cracks.

Lower member: Mostly calcareous or dolomitic siltite with some beds of dolomite and quartzite. Base of formation in Hoadley Plate marked by a bed of white, greenish white or gray, thinly bedded, medium-grained, calcareous quartzite as much as 10 cm thick that commonly contains minor amounts of galena and sphalerite.

Formation thickness 205 to 1,662 m (675–5,450 ft).

Yes EMPIRE AND SPOKANE FORMATIONS, UNDIVIDED (MESOPROTEROZOIC)

Ye EMPIRE FORMATION (MESOPROTEROZOIC)—Dominantly greenish gray argillite and siltite with interbeds of quartzite, dolomite, and locally stromatolitic and oolitic carbonate rock. The quartzites are poorly sorted, ranging from very fine to medium-grained, and locally carbonate-cemented. The amount of carbonate appears to increase upward. Red to purple beds of dominantly argillite occur in the lower part of the formation. Thickness varies from <1–610 m (<3–2,000 ft).

Ys SPOKANE FORMATION (MESOPROTEROZOIC)—Dominantly pale purplish red and grayish red siltite and argillite interbedded with lithologically similar greenish gray beds. Southeastern outcrops contain light gray, very fine to medium-grained, thin beds of quartzite that locally contain minute crossbeds and ripple marks. Thickness as much as 915 m (3,000 ft).

Yg GREYSON FORMATION (MESOPROTEROZOIC)—Light gray to greenish gray, thinly bedded siltite with some quartzite, grading down into dark gray to greenish gray, very thinly laminated argillite and siltite in the lower part. Sedimentary structures include ripple marks, mudcracks, and locally, salt crystal casts. Thickness as much as 762 m (2,500 ft).

REFERENCES CITED AND BIBLIOGRAPHY

Bregman, M.L., 1976, Change in tectonic style along the Montana thrust belt: Geology, v. 4, p. 775–778.

Cobban, W.A., 1955, Cretaceous rocks of northwestern Montana: Billings Geological Society, Guidebook, 6th Annual Field Conference, Sweetgrass Arch—Disturbed Belt Montana, p. 107–119.

Cobban, W.A., Erdmann, C.E., Lemke, R.W., and Maughan, E.K., 1976, Type sections and stratigraphy of the members of the Blackleaf and Marias River Formations (Cretaceous) of the Sweetgrass Arch, Montana: U.S. Geological Survey Professional Paper 974, 66 p.

Cox, B.E., and Berg, R.B., 2005, Two Medicine Volcanics near Augusta, Montana: Discussion and field trip guide, *in* Gibson, R.E., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 103–118.

Deiss, Charles, 1939, Cambrian stratigraphy and trilobites of northwestern Montana: Geological Society of America Special Paper 18, 115 p.

Dolberg, D.M., 1986, A duplex beneath a major overthrust plate in the Montana Disturbed Belt: Surface and subsurface data: Missoula, University of Montana M.S. thesis, 57 p., scale 1:63,360.

Earhart, R.L., Grimes, D.J., Leinz, R.W., and Marks, L.Y., 1977, Mineral resources of the proposed additions to the Scapegoat Wilderness, Powell, and Lewis and Clark Counties, Montana: U.S. Geological Bulletin 1430, 62 p.

Funk, John L., III, 1969, The geology of the Landers Fork of the Blackfoot River area: Rolla, University of Missouri, M.A. thesis, 119 p., scale 1:62,500.

Geraghty, E.M., and Mudge, M.R., 2005, Revisiting the structure and stratigraphy of the Sun River Canyon, Sawtooth Range, Montana: Road log—Augusta to Sun River Canyon, *in* Gibson, R.I., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 71–80.

Geraghty, E.M., and Watkinson, A.J., 2005, Reactivation of bedding-planes within carbonate thrust sheets, Sun River Canyon, Sawtooth Range, northwestern Montana, *in* Gibson, R.I., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 7–27.

Harlan, S.S., Snee, L.W., Reynolds, M.W., Mehnert, H.H., Schmidt, R.G., Sheriff, S.D., and Irving, A.J., 2005, $^{40}Ar/^{39}Ar$ and K-Ar geochronology and tectonic significance of the Upper Cretaceous Adel Mountain Volcanics and spatially associated Tertiary igneous rocks, northwestern Montana: U.S. Geological Survey Professional Paper 1696, 29 p.

Harris, Frank G., 1963, Geology of the Dry Creek area, Lewis and Clark County, Montana: Rolla, University of Missouri, M.S. thesis, 108 p., map scale 1:24,000.

Henry, H.M., 2007, Investigation of a triangle zone structure between Augusta and Bowmans Corners, Lewis and Clark County, Montana: Missoula, University of Montana, M.S. thesis, 102 p., scale 1:24,000.

Hoffman, J., Hower, J., and Aronson, J.L., 1976, Radiometric dating of time of thrusting in the Disturbed belt of Montana: Geology, v. 4, no. 1, p. 16–20.

Holcombe, T.L., 1963, Geology of the Elk Creek area, Lewis and Clark County, Montana: Rolla, University of Missouri, M.S. thesis, 108 p., scale 1:31,680.

Holl, J.E., and Anastasio, D.J., 1992, Deformation of a foreland carbonate thrust system, Sawtooth Range, Montana: Geological Society of America Bulletin, v. 104, p. 944–953.

Johnson, D.M., 1988, Folding and faulting in the footwall of the Diversion Thrust, north-central Montana: Pullman, Washington State University, M.S. thesis, 78 p.

Johnson, D., and Watkinson, J., 2005, A balanced cross-section of the footwall duplex below the Diversion Thrust, Sun River, Central Sawtooth Mountains, Montana, *in* Gibson, R.I., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 83–91.

Jolly, A.D., and Sheriff, S.D., 1992, Paleomagnetic study of thrust-sheet motion along the Rocky Mountain front in Montana: Geological Society of America Bulletin, v. 104, p. 779–785.

Knapp, G.L., 1963, A diorite sill in the Lewis and Clark Range, Montana: Amherst, University of Massachusetts, M.S. thesis, 63 p.

Lageson, D.R., 1987, Structural geology of the Sawtooth Range at Sun River Canyon, Montana Disturbed Belt, Montana: Geological Society of America Centennial Field Guide—Rocky Mountain Section, p. 37–39.

Lageson, D.R., and Stickney, M.C., 2000, Seismotectonics of northwest Montana, USA, *in* Schalla, R.A., and Johnson, E.H., eds., Montana/Alberta thrust belt and adjacent foreland: Montana Geological Society Fiftieth Anniversary Symposium, v. 1, p. 109–126.

Lange, S.S., 1963, The geology of the Lewis and Clark Pass area, Lewis and Clark County, Montana: Rolla, University of Missouri, M.A. thesis, 144 p., scale 1:31,680.

Langfield, P.M., 1967, Geology of the Ford Creek area, Sawtooth Range, Montana: Missoula, University of Montana, M.S. thesis, 120 p.

Lyons, J.B., 1944, Igneous rocks of the northern Big Belt Range, Montana: Geological Society of America Bulletin, v. 55, no. 4, p. 445–472.

Merrill, R.D., 1965, Geology at the southern terminus of the Sawtooth Range, northwestern Montana: Amherst, University of Massachusetts, M.S. thesis, 72 p., scale 1:63,360.

Miller, R.N., Shea, E.P., Goddard, C.C., Jr., Potter, C.W., and Brox, G.B., 1973, Geology of the Heddleston copper-molybdenum deposit, Lewis and Clark County, Montana: Pacific Northwest metals and minerals conference, Coeur D'Alene, Idaho, American Institute of Mining and Metallurgical Engineers, Proceedings, p. 1–33.

Moore, J.R., Watts, M.D., Ball, N.M., and Ratcliff, M.D., 2000, Geology of the Ford Creek area, northern Montana thrust belt, *in* Schalla, R.A., and Johnson, E.H., eds., Montana/Alberta thrust belt and adjacent foreland: Montana Geological Society Fiftieth Anniversary Symposium, v. I, p. 151–168.

Mudge, M.R., 1970, Origin of the disturbed belt in northwestern Montana: Geological Society of America Bulletin, v. 81, p. 311–392.

Mudge, M.R., 1972a, Pre-Quaternary rocks in the Sun River Canyon area, northwestern Montana: U.S. Geological Survey Professional Paper 663-A, 142 p.

Mudge, M.R., 1972b, Structural geology of the Sun River Canyon and adjacent areas, northwestern Montana: U.S. Geological Survey Professional Paper 663-B, 52 p.

Mudge, M.R., 1982, A resume of the structural geology of the northern Disturbed Belt, northwestern Montana, *in* Powers, R.B., Geologic studies of the Cordilleran thrust belt, v. 1: Rocky Mountain Association of Geologists, Denver, Colorado, p. 91–122.

Mudge, M.R., 2005, A summary of the geology of the Sun River Canyon area, northwestern Montana, *in* Gibson, R.E., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 1–6.

Mudge, M.R., and Earhart, R.L., 1983, Bedrock geologic map of part of the Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, Cascade, and Powell Counties, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1375, scale 1:125,000.

Mudge, M.R., and Earhart, R.L., 1980, The Lewis thrust fault and related structures in the Disturbed Belt, northwestern Montana: U.S. Geological Survey Professional Paper 1174, 18 p.

Mudge, M.R., Earhart, R.L., and Rice D.D., 1979, Preliminary bedrock geologic map of part of the northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, and Powell Counties, Montana: U.S. Geological Survey Open-File Report 79-943, 8 p., scale 1:125,000.

Mudge, M.R., Earhart, R.L., and Rice, D.D., 1977, Preliminary bedrock geologic map of part of the northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, and Powell Counties, Montana: U.S. Geological Survey Open-File Report 77-25, 26 p., scale 1:125,000.

Mudge, M.R., Earhart, R.L., Watts, K.C., Tuchek, E.T., and Rice, W.L., 1974, Mineral resources of the Scapegoat Wilderness, Powell and Lewis and Clark Counties, Montana: U.S. Geological Survey Bulletin 1835-B, 82 p.

Mudge, M.R., Erickson, R. L., and Kleinkopf, M.D., 1967, Reconnaissance geologic, geochemical, and geophysical studies of the southeastern part of Lewis and Clark Range, Montana: U.S. Geological Survey Open-File Report 67-163, 8 p., Figures 2 and 7, scale 1:125,000.

Mudge, M.R., Erickson, R.L., and Kleinkopf, M.D., 1968, Reconnaissance geology, geophysics, and geochemistry of the southern part of the Lewis and Clark Range, Montana: U.S. Geological Survey Bulletin 1252-E, 35 p.

Mudge, M.R., and Rice, D.D., 1982, Lower Cretaceous Mount Pablo Formation, northwestern Montana: U.S. Geological Survey Bulletin 1502-D, 19 p.

Mudge, M.R., and Sheppard, R.A., 1968, Provenance of igneous rocks in Cretaceous conglomerates in northwestern Montana: U.S. Geological Survey Professional Paper 600-D, p. D137–D146.

Mudge, M.R., Sando, W.J., and Dutro, J.T., Jr., 1962, Mississippian rocks of Sun River Canyon area, Sawtooth Range, Montana: Bulletin of the American Association of Petroleum Geologists, v. 46, no. 11, p. 2003–2019.

Mudge, M.R., Earhart, R.L., Whipple, J.W., and Harrison, J.E., 1982, Geologic and structure map of the Choteau 1° x 2° quadrangle, western Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1300, scale 1:250,000.

Nichols, K.M., 19894 Stratigraphy of the upper part of the Madison Group, Sawtooth Range, northwestern Montana, *in* McBane, J.D., and Garrison, P.B., eds., Northwest Montana and adjacent Canada: Montana Geological Society 1984 Field Conference and Symposium Guidebook, p. 127–140.

Reinecke, K.M., 1989, Effect of Scapegoat-Bannatyne Trend on structural development of Montana Disturbed belt, *in* French, D.E., and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society 1989 Field Conference Guidebook, v. 1, p. 289–260.

Reinecke, K.M., 1984, Structural geology of the Smith-Weasel Creeks area, Lewis and Clark County, Montana: Kansas State University, M.S. thesis, 97 p.

Roberts, M., and Waren, K., 1999, North Fork Blackfoot River hydrologic analysis—Preliminary Report: Montana Department of Natural Resources and Conservation.

Schalla, R.A., 2000, A re-evaluation of the hydrocarbon potential of the southern Montana Disturbed belt, *in* Schalla, R.A., and Johnson, E.H., eds., Montana/Alberta thrust belt and adjacent foreland: Montana Geological Society Fiftieth Anniversary Symposium, v. II, p. 27.

Sears, J.W., 2000, Rotational kinematics of the Rocky Mountain thrust belt of northern Montana, *in* Schalla, R.A., and Johnson, E.H., eds., Montana/Alberta thrust belt and adjacent foreland: Montana Geological Society Fiftieth Anniversary symposium, v. 1, p. 143–150.

Sears, J.W., 2001, Emplacement and denudation history of the Lewis-Eldorado-Hoadley thrust slab in the northern Montana Cordillera, USA: Implications for steady-state orogenic processes: American Journal of Science, v. 301, no. 4–5, p. 359–373.

Sears, J.W., Braden, J., Edwards, J., Geraghty, E., Janiszewski, F., McInenly, M., MacLean, J., Riley, K., and Salmon, E., 2005, Rocky Mountain foothills triangle zone, Sun River, northwest Montana, *in* Gibson, R.I., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 45–50.

Sears, J.W., Hansen, W.B., Ambrose, R.B., Burtis, E.W., Hennes, A.M., Hofmann, M.H., Laatsch, N.A., and Pallister, B.J., 2002, Montana's triangle zone: Geological Society of America Abstracts with Programs, v. 34, no. 4, p. 49.

Schmidt, R.G., 1972a, Geologic map of the Coburn Mountain quadrangle, Lewis and Clark and Cascade Counties, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-975, scale 1:24,000.

Schmidt, R.G., 1972b, Geologic map of the Comb Rock quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-976, scale 1:24,000.

Schmidt, R.G., 1972c, Geologic map of the Wolf Creek quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-974, scale 1:24,000.

Schmidt, R.G., and Strong, C.P., 1972, Geologic map of the Roberts Mountain quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-977, scale 1:24,000.

Theodosis, S.D., 1955, Cambrian system in northwestern Montana: Billings Geological Society 6th Annual Field Conference, p. 64–69.

Viele, G.W., 1960, The geology of the Flat Creek area, Lewis and Clark County, Montana: Salt Lake City, University of Utah, Ph.D. dissertation, 213 p., scale 1:31,250.

Viele, G.W., and Harris, F.G., III, 1965, Montana Group stratigraphy, Lewis and Clark County, Montana: Bulletin of the American Association of Petroleum Geologists, v. 49, no. 4, p. 379–417.

Watkinson, A.J., 1993, A footwall system of faults associated with a foreland thrust in Montana: Journal of Structural Geology, v. 15, no. 3–5, p. 335–342.

Weberg, E.D., 1986, Structural geology of the Cretaceous rocks in Sun River Canyon, Teton County and Lewis and Clark County, northwest Montana: Pullman, Washington State University, M.S. thesis, 102 p.

Whipple, J.W., 1979, Preliminary geologic map of the Rogers Pass area, Lewis and Clark County, Montana: U.S. Geological Survey Open-File Report 79-719, scale 1:48,000.

Whipple, J.W., and Bregman, M.L., 1981, Geologic map of the Rogers Pass quadrangle, Lewis and Clark County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1309, scale 1:24,000.

Whipple, J.W., Mudge, M.R., and Earhart, R.L., 1987, Geologic map of the Rogers Pass area, Lewis and Clark County, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1642, scale 1:48,000.

White, B.G., 2005, Mechanics of the overthrust belt from Augusta to Glacier National Park: Sequential thrusting of progressively older strata and vital role of transcurrent displacements during thrusting, *in* Gibson, R.I., and Thomas, R.C., eds., Sun River Canyon and Choteau, Montana: Tobacco Root Geological Society 30th Annual Field Conference, Northwest Geology, v. 34, p. 39–40.

Witkind, I.J., 1977, Preliminary map showing surficial deposits in the south half of the Coopers Lake quadrangle, Powell County, Montana: U.S. Geological Survey Open-File Report OF-77-0466.

Witkind, I.J., and Weber, W.M., 1982, Reconnaissance geologic map of the Big Fork-Avon Environmental Study Area, Flathead, Lake, Lewis and Clark, Missoula, and Powell Counties, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1380, scale 1:125,000.

Woodward, L.A., Tectonic framework of Disturbed belt of west-central Montana: American Association of Petroleum Geologists, v. 65, no. 2, p. 291–302.