# GEOLOGIC MAP OF THE GREAT FALLS SOUTH 30' X 60' QUADRANGLE

# CENTRAL MONTANA

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SELECTED GEOLOGIC NOTES

**Adel Mountain Volcanics**

- Two main episodes of thrusting occurred in the area. One pre-dated and one post-dated the emplacement of the Adel Mountain Volcanics (Swenson, 1988; Sears, 1988).

- The Adel Mountain Volcanics probably did not originate from a central magma chamber (Hyndman and Alt, 1987; Beall, 1973), but rather from numerous magma vents that manifest themselves as dikes along ridge crests. They are not directly related to the dike swarm that post-dated the emplacement of the volcanics (Swenson, 1988).*

- The Adel Mountain Volcanics mass differentially subsided relative to thickness of the pile (Swenson, 1988. Hyndman and Alt, 1987).*

- Development of most dike swarms and associated laccoliths post-dated subsidence of the volcanic pile and was directly related to development of stress fractures from overburden stresses (Hyndman and Alt, 1987).*

- The Three Sisters stock of Lyons (1944) may actually be a zone of densely spaced dikes (Beall, 1973), assumed to be the type of ridge crest dikes described above.

- Rocks of the Adel Mountain Volcanics previously termed alkali gabbro (Beall, 1973) and trachybasalt (Lyons, 1944; Beall, 1973; Whiting, 1977) are referred to as shonkinite (Hyndman and Alt, 1987) on the map.

- The Cretaceous age indicated for the Adel Mountain Volcanics is based on $^{40}Ar/^{39}Ar$ dates (Harlan, Mehnert, and Snee, 1991; Sheriff and Gunderson, 1990).

*Interpretations used in cross section A-A'

**Laccolith**

- A large quartz monzonite laccolith, not indicated on any published map to date, was mapped in the southeastern part of the quadrangle as the Monument Peak Intrusion. It was emplaced primarily along the base of the Cambrian Wolsey Shale and secondarily along the base of the Cambrian Park Shale, both of which are locally a hornfels because of contact metamorphism. The Flathead Formation, the lowest Cambrian unit, was not seen anywhere overlying the laccolith, so it is assumed that the Flathead underlies it in association with the basement crystalline rocks. For this reason, the Flathead is shown with the crystalline basement in cross section B-B'.

**Mesozoic section**

- The Kevin Member of the Marias River Formation is apparently not present in a limited area south of Shaw and Square buttes. The map suggests that this may be the result of an unconformity, but faulting (although not mapped) is suspected in this area, and may also explain the apparent offset of the feeder dike leading to Square Butte.

- The Kootenai Formation was mapped as five members, three informal and two formal. The Sunburst Member, which pinches out in an arcuate pattern in the map area and in the eastern adjacent Belt 30'x 60' quadrangle, may be marginal marine, reflecting a brief advance into part of the area of the Moosebar Sea from the north.

- Interbedding of the basal Kootenai channel sandstone with carbonaceous shale of the upper Morrison Formation is apparent in a road cut near the Eden Bridge on the Smith River. This relation makes the interpretation of a significant unconformity between the Morrison and Kootenai formations suspect.

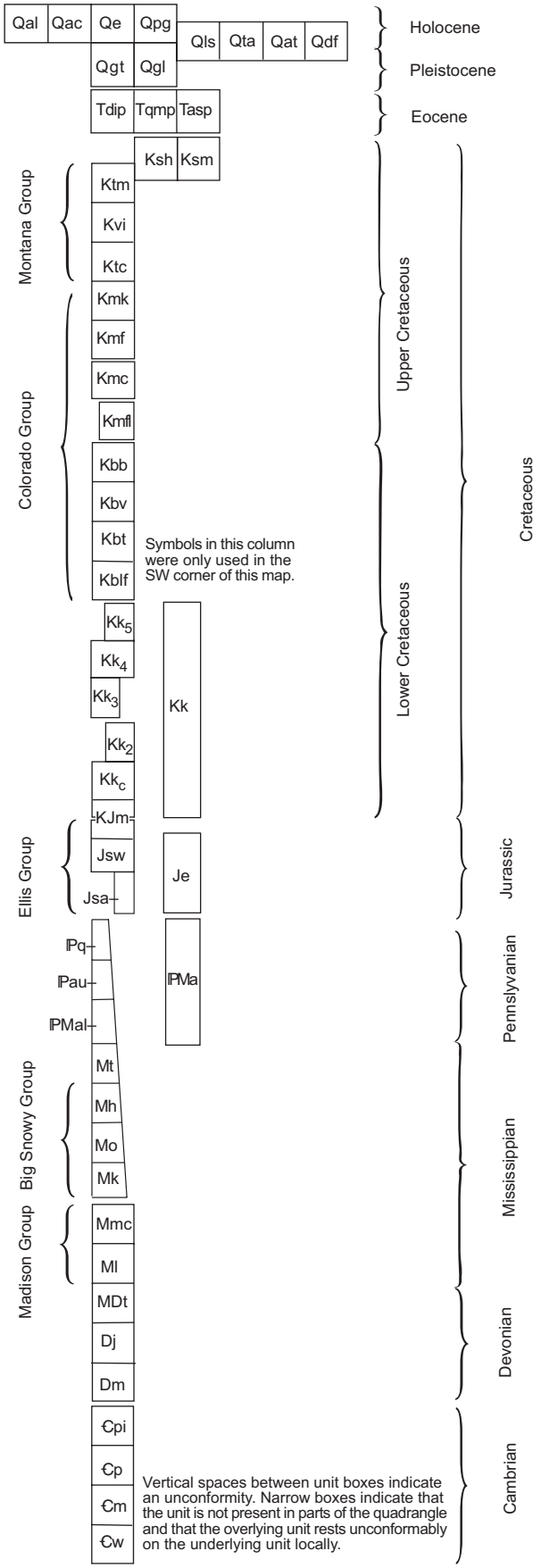
- Carbonaceous shale or subbituminous coal occur in the upper part of the Morrison Formation in the map area. The shale was sampled from a core taken near Stockett, Montana for palynomorph data which yielded Neocomian (Cretaceous) pollen (Don Engelhardt, palynologist for Lloyd Furer, Indiana Geological Survey, 1999). A significant unconformity probably is present within the Morrison Formation below the dark shale zone (Lloyd Furer, personal communication, 1999). This unconformity likely marks the boundary between Jurassic and Cretaceous rocks, rather than the Morrison-Kootenai contact as has been generally accepted.

- Morrison coal has been mined from two coal fields in the area: Stockett-Sand Coulee, and Hound Creek. By the late 1940's, all the commercial coal mines in the area were abandoned. Acid mine drainage has been a problem, particularly in the Stockett and Sand Coulee areas.

- The Ellis Group (Sawtooth and Swift Formations, Sawtooth Formation, or Swift Formation) was mapped resting on the following formations in a general direction from the northeastern part of the quadrangle to the south-central part: Mission Canyon, Kibbey, Otter, Heath, Tyler, lower Amsden (lithologically equivalent to Stonehouse Canyon Member of Tyler farther east), upper Amsden (lithologically equivalent to Alaska Bench Formation farther east), and Quadrant.

- The Swift Formation thins to a pebble lag in the southeastern part of the quadrangle.

# GREAT FALLS SOUTH 30’ X 60’ QUADRANGLE
## CORRELATION OF MAP UNITS



## EXPLANATION OF MAP UNITS

Note: Thicknesses are given in feet because original field maps were on 7.5' quadrangles, with contour intervals in feet. To convert feet to meters (the contour interval unit on this map), multiply feet x 0.3048. Color names are from Goddard and others (1980).

Qal ALLUVIUM (Holocene)
Yellowish-brown to gray gravel, sand, silt, and clay beneath flood plains and in valleys of active streams. Deposits are well to poorly stratified and moderately well sorted. Holocene alluvium is generally about 20 ft thick or less, but the Missouri River Holocene alluvium may rest on pre-glacial valley fill as thick as 270 ft (Fox, 1966; Lyons, 1944; Alden, 1932).

Qac ALLUVIUM AND COLLUVIUM, Undivided (Holocene)
Grayish orange to brownish gray, poorly sorted to moderately well sorted, locally derived sediment deposited on slopes. Sediment size ranges from clay and silt to gravel depending on source. Thickness generally less than 20 ft.

Qe EOLIAN DEPOSIT (Holocene)
Light-brown to light-gray, unconsolidated, stratified windblown sand and silt in the Missouri River valley, mouth of the Smith River valley, and adjacent uplands, in stabilized, semi-active, or actively migrating dunes. Thickness generally less than 20 ft.

Qpg PEDIMENT DEPOSIT (Holocene)
Dark-gray and dark-reddish-brown sand and gravel veneer composed almost entirely of clasts derived from the Adel Mountain Volcanics. Thickness 3 inches.

Qls LANDSLIDE DEPOSIT (Holocene and Pleistocene)
Mass-wasted deposit that consists of stable to unstable, unsorted mixtures of clay- to boulder-size sediment. Includes rotated or slumped blocks of bedrock and surficial sediment, earthflow deposits, and mudflow deposits. Color and lithology reflect that of parent rock and transported surficial materials. Thickness general less than 80 ft.

Qta TALUS DEPOSIT (Holocene and Pleistocene)
Locally derived angular rock fragments, generally cobble size or larger that occur in piles or aprons on mountain slopes; color and lithology reflect that of parent rock. Thickness 20 ft or less.

Qat ALLUVIAL TERRACE DEPOSIT (Holocene and Pleistocene)
Light-brown to light-gray, unconsolidated crudely to well-stratified and moderately to well-sorted sand and gravel on alluvial terraces adjacent to and at higher elevation than associated modern streams and rivers. Alternatively, some of these gravel deposits may be beach deposits of one of the Glacial Lake Great Falls episodes (R. Colton, USGS, written communication, May, 2000). Thickness generally less than 20 ft.

Qdf DEBRIS FLOW DEPOSIT (Holocene and Pleistocene)
Brownish-gray, dissected, mass-wasted deposit of poorly sorted, angular and subangular sediment with abundant matrix-supported clasts, many of which are boulder size. Matrix dominantly mud that has been locally eroded leaving a lag of cobbles and boulders. Thickness 10-50 ft.

Qgt GLACIAL TILL (Pleistocene)
Unstratified, compact, heterogeneous mixture of brownish-gray or reddish-brown clay, silt, and sand with scattered pebbles, cobbles, and boulders. Deposited at the southernmost limit of continental glaciation in this area. Dominantly clay loam, silty clay loam, and loam. Typically 2-10% pebbles, cobbles, and boulders, by volume. Glacial erratics are dominantly limestone, dolostone, orthoquartzite, and igneous and metamorphic rocks from the Canadian Shield. Not mapped where thin and patchy. Deposits include Wisconsin and Illinoian till and may include pre-Illinoian till (D. Fullerton, USGS, by R. Colton, USGS, written communication, May, 2000).

Qgl GLACIAL LAKE AND REWORKED GLACIAL LAKE DEPOSIT (Pleistocene)
Grayish-orange to pale-orange silt interbedded with layers of very fine grained sand and clay. Deposits are horizontally bedded and laminated. Unit also contains grayish-orange to pale-orange silt and very fine grained sand in alluvial, colluvial, and eolian deposits reworked from glacial lake deposits. Includes alluvium of underfit streams in the northeastern part of the map area in the abandoned pre-glacial channel of the Missouri River and its tributaries (Gibson Flats-Johnson Flats area). Thickness generally less than 20 ft, but may be substantially thicker in local areas.

Tdip DIORITE PORPHYRY (Eocene)
Light gray-weathered rock of Black Butte and Temple Gulch intrusions, with numerous large, light-gray phenocrysts of plagioclase (Pulju, 1964). Exposed thickness 1300 ft.

Tqmp QUARTZ MONZONITE PORPHYRY (Eocene)
Light brown- to light gray-weathered intrusive rock that contains numerous large, round phenocrysts, of smoky quartz and white plagioclase. Exposed thickness 1400 ft.

Tqsp QUARTZ SYENITE PORPHYRY (Eocene)
Light brown- to light gray-weathered intrusive rock of Tiger Butte than contains potassium feldspar, quartz, plagioclase, and biotite phenocrysts in a fine-grained groundmass; mainly consisting of potassium feldspar and quartz. Sphene, apatite, and pyrite are accessory minerals. Miarolitic cavities several millimeters across are common (Berg, 1991). Exposed thickness 1500 ft.

Ksh SHONKINITE (Upper Cretaceous)
Dark gray-weathered alkalic intrusive rock of the laccoliths and dikes associated with the Adel Mountain Volcanics (Hyndman and Alt, 1987). Thickness in laccoliths up to 500 ft.

Kam ADEL MOUNTAIN VOLCANICS (Upper Cretaceous)
Dark-gray, dark-grayish red, brownish-gray, and dark-grayish-green skonkinite (Hyndman and Alt, 1987) intrusive rocks and flows, porphyritic with augite,phenocrysts (Soward, 1975b); medium-light- to medium-dark-gray, olive-gray, greenish-gray, pale-yellowish brown, and grayish orange-pink latite intrusive rock (Soward, 1975b) and flows (Schmidt, 1977); red, purplish-gray, gray, and brownish-gray, poorly sorted and indistinctly bedded volcanic conglomerate composed of rounded and subrounded clasts of trachybasalt (skonkinite), trachyandesite, latite, and quartz latite ranging from pebble size to as much as 2 ft across (Schmidt, 1977); pale-red, red, purplish-red, brown, and gray volcanic breccia, composed of blocks and lapilli of trachybasalt (shonkinite), trachyandesite, and latite embedded in a fine-grained to microcrystalline tuff matrix (Soward, 1975); and very light gray to medium-gray monzonite intrusive rock of the

Antelope Mountain pluton, porphyritic with small plagioclase, sanidine, and augite phenocrysts, (Soward, 1975b).

Montana Group

Ktm Interbedded dark-grayish-green-, grayish-green-, brownish-gray-, and grayish-purple-weathered mudstone, and gray-weathered, cross-bedded, medium- to coarse-grained sandstone with conglomeratic lenses of quartz or volcanic rock pebbles. Contains some bentonitic claystone and tuff in middle part, and thin beds of dark-gray carbonaceous shale or black lignite in the lower part. Thickness of formation 790-1950 ft.

Kvi VIRGELLE FORMATION (Upper Cretaceous)
Light gray-, yellowish gray-, pale olive-, and very light gray-weathered, poorly to moderately well indurated, very fine- to medium-grained, massive or thinly bedded and cross-bedded sandstone; contains large, dark brownish-gray-weathered calcareous sandstone concretions; dark reddish-brown-weathered magnetite-rich sandstone, as much as 4 ft thick at the top of the formation at most exposures. Thickness of formation 114-145 ft.

Ktc TELEGRAPH CREEK FORMATION (Upper Cretaceous)
Yellowish-gray, light-olive gray, and light-gray, very fine- to medium-grained calcareous sandstone interbedded with yellowish-gray-weathered silty mudstone and light to dark gray-weathered fissile shale. Limestone concretions 1 or 2 ft wide near the base. Thickness of formation 300-330 ft.

Colorado Group

Kmk KEVIN MEMBER OF MARIAS RIVER SHALE (Upper Cretaceous, Coniacian and Santonian)
Dark-gray-weathered, partly calcareous shale that contains thin beds of yellowish gray-weathered, very fine grained sandstone and siltstone near the top that are gradational with the overlying Telegraph Creek Formation, numerous thin bentonite beds, and septarian limestone concretions at several horizons. Thickness of member 0-600 ft.

Kmf FERDIG MEMBER OF MARIAS RIVER SHALE (Upper Cretaceous, Turonian)
Dark-gray-weathered, noncalcareous, fissile shale that contains a pale yellowish-brown-weathered, lenticular-bedded siltstone and fine-grained sandstone unit near top of member with abundant trace fossils, including small burrows and trails, and arthropod and ammonite tracks. Distinctive reddish orange ferruginous dolostone concretions weather into small chips that are strewn over the shale surfaces. Thickness of member 160-200 ft.

Kmc CONE MEMBER OF MARIAS RIVER SHALE (Upper Cretaceous, Cenomanian)
Upper: Dark gray-weathered, petroliferous silty limestone with blue fish scales, *Inoceramid,* and oyster fragments. Lower: One or two bentonite beds, and gray-weathered septarian concretions. May locally include Floweree Member where the Floweree is very thin. Thickness of member about 65 ft.

Kmfl FLOWEREE MEMBER,OF MARIAS RIVER SHALE (Upper Cretaceous, Cenomanian)
Dark bluish gray-weathered, noncalcareous shale that contains several thin beds of grayish orange-weathered siltstone, fine-grained sandstone, and light-yellowish-gray, low-swelling, thin bentonite beds. Thickness ranges from 0–60 ft.

Kbb BOOTLEGGER MEMBER OF BLACKLEAF FORMATION (Upper Cretaceous, Albian and Cenomanian)
Dark-gray-weathered shale interbedded with light-gray-weathered sandstone beds that may contain fish scales and sporadic thin layers of black or black-coated chert granules or pebbles, and very well cemented pebble-conglomerate beds. Several pale-green- or yellowish-green-weathered bentonite beds occur within the shales. Thickness about 150 ft.

Kbv VAUGHN MEMBER OF BLACKLEAF FORMATION (Lower Cretaceous, Albian)
Upper: Greenish- to light-greenish gray-weathered bentonitic and tuffaceous siltstone; tuffaceous to bentonitic silty mudstone irregularly colored a distinctive reddish-orange by an abundance of the zeolite clinoptilolite; thin sporadic beds of dark-gray carbonaceous shale; and thin, gray sandstone beds. Middle: Light-gray-, green-, and pink-weathered bentonitic shale with light-greenish gray tuffaceous well cemented siltstone lenses. Lower: Yellowish-gray-weathered tuffaceous to argillaceous friable, cross-bedded sandstone, locally with reddish to greenish tint, that contains reddish brown-weathered, relatively well cemented lenses. Thickness about 100 ft.

Kbt TAFT HILL MEMBER OF BLACKLEAF FORMATION (Lower Cretaceous, Albian)
Dark-gray-weathered shale that contains numerous thin bentonite beds and limestone or ironstone concretions, interbedded with greenish gray-weathered medium- to coarse-grained glauconitic sandstone. A six-inch bed of black chert pebbles in a matrix of coarse-grained sand is present in sec. 18, T. 20 N., R. 2 E. (Fox, 1966). Thickness about 240 ft.

Kblf FLOOD MEMBER OF BLACKLEAF FORMATION (Lower Cretaceous, Albian)
Upper: Light-brownish-gray-weathered, medium-grained resistant sandstone with argillaceous or siliceous cement. Middle: Dark-gray-weathered shale interbedded with thin beds of light-brownish-gray-weathered siltstone and fine- to medium-grained sandstone. Lower: Light-brownish-gray-weathered coarse-grained cross-bedded sandstone that contains numerous large (1–10 ft in diameter) ferruginous, calcareous concretions in lower part. Thickness about 200 ft.

Kk KOOTENAI FORMATION, Undivided (Lower Cretaceous)(undivided in southwestern part of map only)
Upper: Grayish-green, medium- to coarse-grained, thick-bedded sandstone, grayish-brown-weathered gastropod- and pelecypod-bearing limestone near top. Middle: Gray to purplish-gray, fine- to medium-grained, thin- to thick-bedded sandstone; red, purple, and purplish-red siltstone and mudstone; thin beds of gray nodular limestone and massive, brown-weathered gastropod-bearing limestone. Lower: Light-gray, tan- to orange-weathered, thick-bedded and locally cross-bedded quartzitic sandstone. Thickness about 700 ft (Schmidt, 1977).

$Kk_5$ FIFTH MEMBER OF KOOTENAI FORMATION (informal)(Lower Cretaceous, Albian)
Red-weathered mudstone that contains lenses of sandstone and limestone. Uppermost part of member massive, color-banded, greenish-gray-, grayish-red purple-, moderate red-, and very dark-red-weathered mudstone with lenses of fine- to medium-grained, trough cross-bedded, greenish-gray-weathered sandstone. Thickness 100–162 ft.

$Kk_4$ FOURTH MEMBER OF KOOTENAI FORMATION (informal) (Lower Cretaceous, Albian)
Dusky-red- to pale-reddish-brown-weathered, and locally light-brownish gray-weathered, fine- to medium-grained, platy, thin- to medium-bedded sandstone interbedded with very dark-reddish-brown-weathered mudstone. Thickness 65–98 ft.

$Kk_3$ SUNBURST MEMBER OF KOOTENAI FORMATION (Lower Cretaceous, Albian)
Light-yellowish-brown-weathered, well sorted, well cemented, resistant quartz sandstone with interspersed limonite specks. Scour base with rip-up clasts and chert pebbles cuts into second member and into Cutback Sandstone Member in a local area near Centerville. As much as 20% interstitial dark chert at base, but dark chert almost completely lacking higher in the section. Top of member typically bioturbated with many trace fossils preserved. Member thins to pods and lenses of quartzose sandstone in very dark reddish brown-weathered mudstone near western limit of exposure near mouth of Hound Creek. Thickness 1–100 ft.

$Kk_2$ SECOND MEMBER OF KOOTENAI FORMATION (informal) (Lower Cretaceous, Neocomian)
Poorly resistant red mudstone that overlies the Cutbank Member with a sharp contact. Mudstone contains dense gray micrite and argillaceous, light-brownish gray micrite concretions that laterally become lenticular, irregular beds, and sporadic thin, lenticular chert-rich quartz-arenite beds and fine-grained sandstone to chert-granule conglomerate that contains granule- to pebble-size intraformational micrite clasts. A facies change in the member in the Sand Coulee area is from dominantly red mudstone to interbedded sandstone and gray, green, or red mudstone. In the Sand Coulee-Centerville-Number Seven area, and in Ming Coulee, the member contains fine-grained planar-bedded light-gray sandstone with red or purple mottling or Liesegang banding near the base, and light-gray sandstone beds with medium to coarse angular black and reddish orange chert and light-gray quartz grains supported in a matrix of fine-grained sand or clay, interbedded with light-gray shale that also contains matrix-supported angular chert and quartz grains. Locally contains intraformational rip-up clast conglomerate in beds up to 25 ft thick, with clasts up to cobble size. At Goon and Walker Coulees, unit contains interbedded lithologies of quartz sandstone with black chert grains, red mudstone with limestone concretions, quartz sandstone without black chert, and greenish-gray shale. In most of the facies change area, member contains a light-gray, fine-grained quartz sandstone bed from 1–2 ft thick with angular matrix-supported medium- or coarse-grained chert and sandstone grains. In a local area near Centerville, the Sunburst Member rests directly on the Cutbank Member. Thickness of second member 0–100 ft.

$Kk_c$ CUTBANK MEMBER OF KOOTENAI FORMATION (Lower Cretaceous, Neocomian)
Dominantly resistant, festoon cross-bedded, moderately well-sorted quartz sandstone with 20-50% black, dark- and light-gray chert. Coarse-grained sandstone, chert-granule conglomerate, or chert-pebble conglomerate crops out in local zones at the base. Near Stockett a coarser conglomerate is present locally with rounded cobbles of chert and subrounded to subangular small boulders of sandstone. Grain size becomes finer upward with upper part of member generally fine- to medium-grained. Thickness 1 inch–100 ft.

KJm MORRISON FORMATION (Lower Cretaceous, Neocomian; Upper Jurassic, Oxfordian and Kimmeridgian.)
Light-greenish gray- or locally light-red-weathered mudstone with interbedded lenses of medium-gray micrite, and fine- to medium-grained, calcaneous, thin-bedded, yellowish-brown-weathered sandstone that resembles the underlying Swift Formation. Subbituminous coal bed up to 12 feet thick of dark-gray carbonaceous shale at or near top of formation. Gradational contact with underlying Swift Formation, and overlying Kootenai Formation, but contains a significant unconformity below the dark shale and coal of the Upper Morrison (Lloyd Furer, Indiana Geoloical Survey, personal communication, 1999). Thickness 86–166 ft.

Je ELLIS GROUP, Undivided (Upper and Middle Jurassic, Oxfordian and Bathonian) (undivided in southwestern part of map only).
Upper (Swift Formation): Brownish-gray, fine-grained, thin- to thick-bedded, resistant sandstone that contains thin partings of dark-gray micaceous shale and abundant brown to black driftwood impressions. Middle (Swift Formation): Dark-gray, finely micaceous shale that contains thin lenses of very fine-grained sandstone; abundant worm-borrow casts and rare pelecypod shells; thin conglomerate with rounded pebbles of tan quartzite, dark-gray chert, and gray limestone locally at base. Lower (Sawtooth Formation): Purplish-gray, massive, sandy, clastic fossiliferous limestone; yellowish brown sandy limestone, gray to dark-gray, tan-weathered, chunky to fissile, calcareous shale; gray, tan-weathered, calcereous, quartzitic sandstone; light-gray, sandy thinly banded algal limestone locally at base. Lower unit locally removed by pre-Swift erosion. Thickness 10–260 ft. (Schmidt, 1977).

Ellis Group

Jsw SWIFT FORMATION (Upper Jurassic, Oxfordian)
Orangish-brown-weathered, gray or tan, calcareous, glauconitic limonite-specked, coarse- to fine-grained sandstone (becomes finer upward) that contains local fossil hash of pelecypod and oyster shells, and interbeds of gray-weathered shale. Locally contains light-gray-weathered limestone beds within gray-weathered shale. Base of formation in southern part of map area contains black chert pebble conglomerate from one pebble layer thick to 9 ft thick, locally. Formation overlies a significant low-angle angular unconformity. In an approximate north to south direction in the map area the Swift rests unconformably on progressively younger rocks of the Sawtooth, Kibbey, Otter, Heath, Tyler, Amsden, and Quadrant formations. Formation becomes thinner in some areas to south. In the southernmost map area, it is locally represented by little more than a lag deposit of black chert pebbles. Thickness 1 inch–39 ft.

Jsa SAWTOOTH FORMATION (Middle Jurassic, Bathonian)
Upper: Light-brownish gray- to pale-brown-weathered, oölitic, sandy, fossiliferous limestone locally interbedded with calcareous sandstone. Middle: Bioturbated, interbedded light-gray- to light-brownish gray-weathered microcrystalline limestone, oölitic near top; sandy limestone; and calcareous sandstone and siltstone. Lower: Interbedded sandy, oölitic limestone with intraformational conglomerate and very well-sorted calcareous quartz sandstones. Locally, light-gray, poorly resistant, massive, finely crystalline sandy limestone is interbedded with red and green sandstone. Locally brecciated at base and overlies a thin pebble conglomerate. Thickness 0-80 ft.

IPq QUADRANT FORMATION (Pennsylvanian)
Very light gray-weathered friable calcareous sandstone and well cemented resistant quartz sandstone. Only in southernmost part of the map area because of pre-Jurassic erosion elsewhere. Thickness 0–40 ft.

IPMa AMSDEN FORMATION, Undivided (Pennsylvanvian and Mississippian) (undivided in southwestern part of map only)
Red and maroon sandstone, siltstone, and mudstone, and thin beds of gray and purplish-gray limestone that grade upward into ledge-forming beds of pink and gray limestone and quartzitic sandstone; limestone pebble conglomerate, as much as 5 ft thick common at base; formation locally removed by pre-Jurassic erosion. Thickness 0–300 ft. (Schmidt, 1977)

IPau AMSDEN FORMATION, UPPER (Pennsylvanian)
Light gray-weathered, resistant, thin-bedded to massive limestone and lesser dolomite, thinly interbedded with moderate red-weathered mudstone. Only in southernmost part of the map area because of pre-Jurassic erosion elsewhere. Lithologically equivalent to the Alaska Bench Formation of central Montana. Thickness 0–280 ft.

IPMal AMSDEN FORMATION, LOWER (Pennsylvanian and Mississippian)
Red mudstone with a few thin beds of limestone and sandstone. Lithologically equivalent to the Cameron Creek Member of the Tyler Formation in central Montana but with less sandstone. Only in southernmost part of the map area because of pre-Jurassic erosion elsewhere. Thickness 0–120 ft.

Mt TYLER FORMATION (Mississippian)
Dark-gray-weathered carbonaceous shale and silty mudstone, thin coal beds, and sporadic dark gray-weathered limestone beds than alternate with yellowish gray-and light gray-weathered fine- to medium-grained, locally conglomeratic, lenticular, porous, mature quartz sandstone beds. Locally, sandstones are colored with pale-red-purple, pale-red, or moderate-reddish-orange Liesegang banding. Lithologically equivalent to the Stonehouse Canyon Member of the Tyler Formation in central Montana. Not present in northern part of map area because of pre-Jurassic erosion. Thickness 0–160 ft.

<u>Big Snowy Group</u>

Mh HEATH FORMATION (Mississippian)
Dark-gray-weathered, fissile, carbonaceous, locally petroliferous shale that contains dark gray- or light-bluish gray-weathered, platy, micritic limestone beds, and thin coal beds. Not present in northeastern part of map area because of pre-Jurassic erosion. Not present locally beneath the Tyler Formation in the southeastern part of the map area. Thickness 0–300 ft.

Mo OTTER FORMATION (Mississippian)
Moderate yellowish-green-, dark-greenish gray-, dark gray-, and brilliant green-weathered shale and siltstone with light-gray, thin, platy, micrite beds that locally contain black chert, oölites, and stromatolites and other algal structures. Limestone beds are thinly interbedded with moderate red-weathered mudstone locally. Not present in northern part of map area because of pre-Jurassic erosion. Thickness 0–400 ft.

Mk KIBBEY FORMATION (Mississippian)
Dark reddish brown-, moderate red-, and very light brown-weathered poorly resistant mudstone interbedded with pale yellowish-orang-weathered, mature quartz sandstone and siltsotne. Not present in northern part of map area because of pre-Jurassic erosion. Thickness 0–350 ft.

Madison Group

Mmc MISSION CANYON LIMESTONE (Mississippian)
Light-gray- to dark-weathered, resistant, massive to thick-bedded fossilferous limestone that contains black or dark-yellowish orange chert in thin beds or zones up to 3 ft thick, and solution breccia. Thickness 800–1400 ft.

Ml LODGEPOLE LIMESTONE (Mississippian)
Light gray-, and dark gray- weathered fossiliferous, thin-bedded limestone interbedded with light-gray shale. Thickness 400–700 ft.

MDt THREE FORKS FORMATION (Mississippian and Devonian)
Light gray- and greenish gray-weathered, poorly resistant shale that contains reddish-gray-weathered, thin-bedded siltstone beds and brownish-gray-weathered dolomite beds. Thickness about 65 ft.

Dj JEFFERSON FORMATION (Devonian)

Upper (Birdbear Member): Light-gray-weathered resistant dolomite with saccharoidal texture. Middle: Medium- to dark-gray-weathered, coarsely crystalline dolomite with petroliferous odor. Lower: Light-gray-weathered limestone that contains black chert, corals, and algal structures. Thickness 250–400 ft.

Dm MAYWOOD FORMATION (Devonian)
Yellowish-brown-, and reddish-brown-weathered, thin-bedded, poorly resistant siltstone interbedded with medium gray-weathered shale. Thickness about 80 ft.

Cpi PILGRIM LIMESTONE (Cambrian)
Light gray- to medium gray-weathered limestone that characteristically contains intraformational flat-pebble limestone conglomerate; and thin beds of dark gray-weathered shale. Thickness 50–100 ft.

Cp PARK SHALE (Cambrian)
Light gray- to greenish gray-weathered micaceous shale that contains irregular thin beds of light-gray limestone in upper part. Dark-gray hornfels near intrusions from contact metamorphism. Thickness 150–250 ft.

Cm MEAGHER LIMESTONE (Cambrian)
Medium gray- to light gray-weathered, thin- and irregular-bedded, glauconitic limestone with irregular-shaped yellowish orange, silty claystone mottles. Thickness 75 ft.

Cw WOLSEY SHALE (Cambrian)
Dark gray-, dark greenish gray-, and grayish purple-weathered, glauconitic, micaceous shale. Very dark gray-weathered hornfels near intrusions from contact metamorphism. Thickness 150 ft.

CROSS SECTION EXPLANATION

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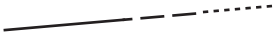
|---|---|
| Tdip | Diorite porphyry |
| Tqmp | Quartz monzonite porphyry |
| Kam | Adel Mountain Volcanics |
| Ktm | Two Medicine Formation |
| Kvt | Virgelle and Telegraph Creek Formations |
| Kmr | Marias River Formation |
| Kbl | Blackleaf Formation |
| Kk | Kootenai Formation |
| KJme | Morrison Formation and Ellis Group |
| PMa | Amsden Formation |
| Mbs | Big Snowy Group |
| Mm | Madison Group |
| MDtjm | Three Forks, Jefferson, and Maywood Formations |
| Cpif | Pilgrim, Park, Meagher, Wolsey, and Flathead Formations (cross section A–A ) |
| Cpiw | Pilgrim, Park, Meagher, and Wolsey Formations (cross section B–B') |
| Ac | Archean crystalline rocks (cross section A–A ) |
| CAfc | Flathead Formation and Archean crystalline rocks (cross section B–B') |

# GEOLOGIC MAP SYMBOLS



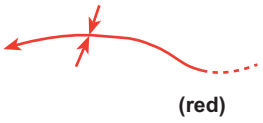
CONTACT-dashed where approximately located, dotted where concealed.


STRIKE AND DIP OF BEDS INCLINED LESS THAN 90 - symbol indicates direction of strike and dip; number indicates amount of dip.

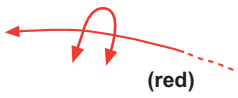

STRIKE AND DIP OF OVERTURNED BEDS-symbol indicates direction of strike and dip; number indicates amount of dip.


DIKE


ANTICLINE AXIAL TRACE-showing plunge direction where known (arrowhead), and dip direction of limbs (paired arrows); dotted where concealed. In the southwestern corner of the map, arrows are omitted on some anticline axial trace symbols for graphic purposes where strike and dip symbols make clear the type of fold.




SYNCLINE AXIAL TRACE-showing plunge direction where known (arrowhead), and dip direction of limbs (paired arrows); dotted where concealed. Where folds are closely spaced at the map scale, anticline axial trace symbol arrows may be shown, but arrows are omitted on adjacent syncline axial trace symbol.




OVERTURNED ANTICLINE AXIAL TRACE-showing plunge direction where known (arrowhead), and dip direction of limbs (paired arrows); dotted where concealed.


OVERTURNED SYNCLINE AXIAL TRACE-showing plunge direction where known (arrowhead), and dip direction of limbs (double paired arrows); dotted where concealed. Paired arrows omitted where overturned synclines are closely adjacent on either side of an overturned anticline in T. 1 5 N., R. 3 E.


MONOCLINE: AXIAL TRACE OF ANTICLINAL FLEXURE-more steeply dipping limb indicated by shorter arrow.


MONOCLINE: AXIAL TRACE OF SYNCLINAL FLEXURE-more steeply dipping limb indicated by shorter arrow.


STRUCTURAL DEPRESSION-arrows point to center.

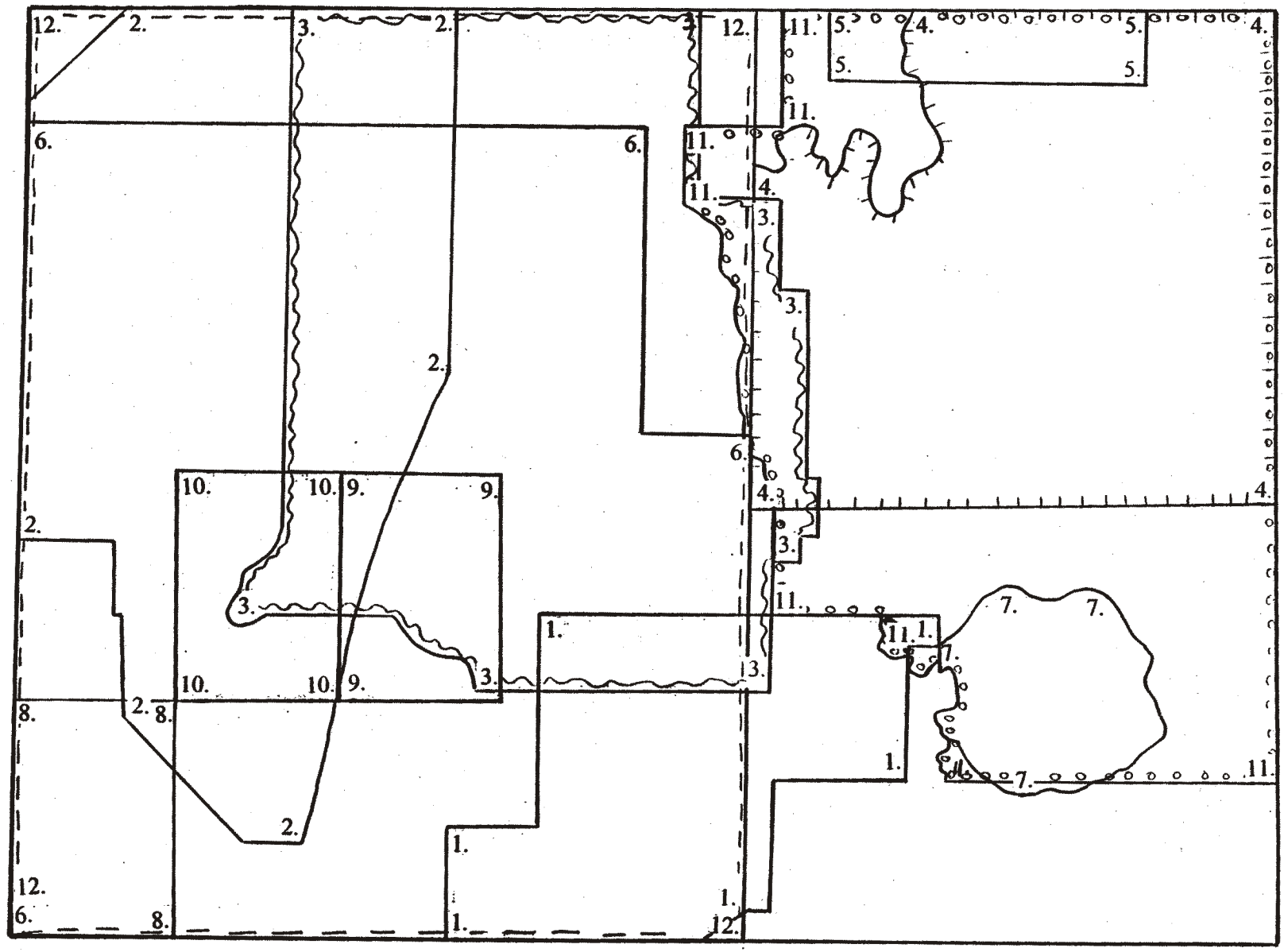
NORMAL FAULT-ball and bar on downthrown side; dashed where inferred, dotted where concealed.

THRUST FAULT-teeth on upthrown side; dashed where inferred, dotted where concealed.

DETACHMENT FAULT-teeth on downthrown side.

**(Mh)**

CONCEALED UNIT-unit indicated in brackets is assumed to underlie surficial deposit



INDEX OF PREVIOUS MAPPING
Great Falls South 30' x 60' Quadrangle

KEY TO INDEX OF PREVIOUS MAPPING
(refer to previous page)

1. Barnett, V. H., 1917, pl. 22 by W. R. Calvert, V.H. Barnett, and J. R. Coats, 1915, 1:125,000 scale

2. Beall, J.J., 1973, pl. 1, 1:253,500.

3. Fox R. D., 1966, pl. 1, 1:90,000 scale.

4. Goers, J. W., 1968, pl. 1, 1:63,000 scale.

5. Lemke, R. W., and Maughan, E.K., 1:24,000 scale.

6. Lyons, J. B., 1942, pl. 1, 1:125,000 scale.

7. Pulju, H. J., 1964, pl. 1, 1:31,680.

8. Schmidt, 1977, 1:24,000 scale.

9. Soward, K. S., 1975a, 1:24,000 scale.

10. Soward, K. S., 1.975b, 1:24,000 scale.

11. Walker, T. F., 1:63,000 scale.

12. Swenson, 1988, pl. 1, 1:200,000 scale.

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