Preliminary Geologic Map of the Eastern Flint Creek Basin West-central Montana

By

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Geologic Summary

Introduction

The Cenozoic Flint Creek basin is a northeast-southwest-oriented basin centered along the Flint Creek Valley south of Drummond, Montana (figure 1). The eastern half was first mapped in detail by Gwinn (1961) and the western half by Maxwell (1965). Both maps emphasized the adjacent bedrock geology of the basin. Rasmussen (1969) remapped the eastern portion of the basin north of the Clark Fork River and primarily focused on Cenozoic stratigraphy. Rasmussen (1973) identified the mid-Miocene unconformity south of the Clark Fork River and established a discrepancy with the earlier mapping of Gwinn (1961). The purpose of the present report was to compile the bedrock geology of Gwinn (1961) with geologic mapping done by Rasmussen (1969) and to remap the Cenozoic units south of the Clark Fork River using a detailed lithostratigraphic approach supported by paleontologic data of Rasmussen (1973) and Christensen (oral comm., 2004). The map area chosen for this study is the eastern half of the basin where units are best exposed (figure 2).

Structural Geology

Folded and faulted rocks of Paleozoic through Cretaceous age constitute the bedrock geology of the eastern Flint Creek basin. These strata were initially deformed by Sevier style deformation during the Late Cretaceous. To the south in the central Flint Creek and Anaconda Ranges, these rocks are intruded by Cretaceous and Tertiary plutons and have been extensively brecciated during Eocene extension of the Anaconda metamorphic core complex (O'Neill and others, 2002; Kalakay, 2003; Lonn and others, 2003). The northern extent of the Anaconda metamorphic core complex detachment zone is enigmatic and has been proposed to terminate into the Lewis and Clark shear zone in the vicinity of the Flint Creek basin (O'Neill and others, 2004). Structural trends across the Clark Fork River Valley in the Flint Creek basin change from north-south to northwest-southeast and have been interpreted to be a consequence of Late Cretaceous left lateral transpressional motion along the Lewis and Clark shear zone (Gwinn, 1960; Lorenz, 1983; Reid, 1984; Baken, 1984; Hyndman and others; 1988; Lonn and McFaddan, 1999; Sears and Clements, 2000; Geraghty and Portner, 2003). A structural depression defined by converging plunges (Clark Fork sag of Gwinn, 1960) is associated with the change in regional strike and was interpreted by Weidman (1965) to be kinematically linked to the lineament. South of the Clark Fork River, overturned folds and associated eastward-dipping axial planes have minor offset along high-angle reverse faults. The reverse faults were likely reactivated as normal faults during Tertiary time. Gravity and seismic data suggest up to 1900 feet of displacement on a set of horst-graben normal faults buried in the center of the basin and less than 300 feet of displacement along the Dunkleberg and Coberly Gulch faults mapped at the surface (Stalker and Sherriff, 2004). Normal faults exposed at the surface offset strata as young as middle

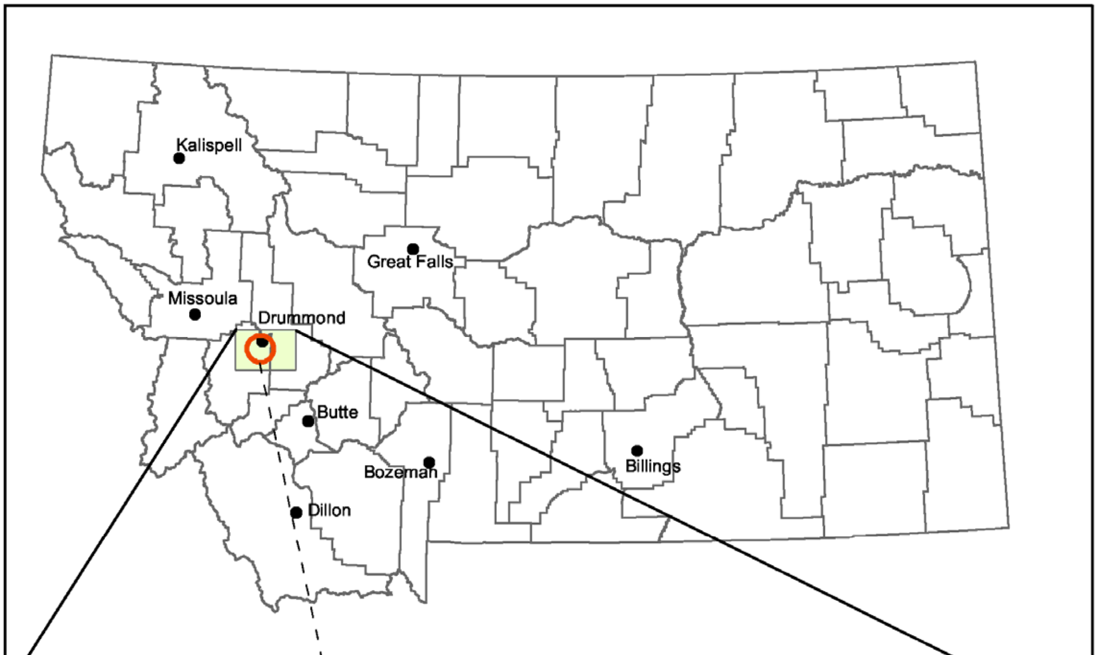


Figure 1: Location map of Flint Creek basin

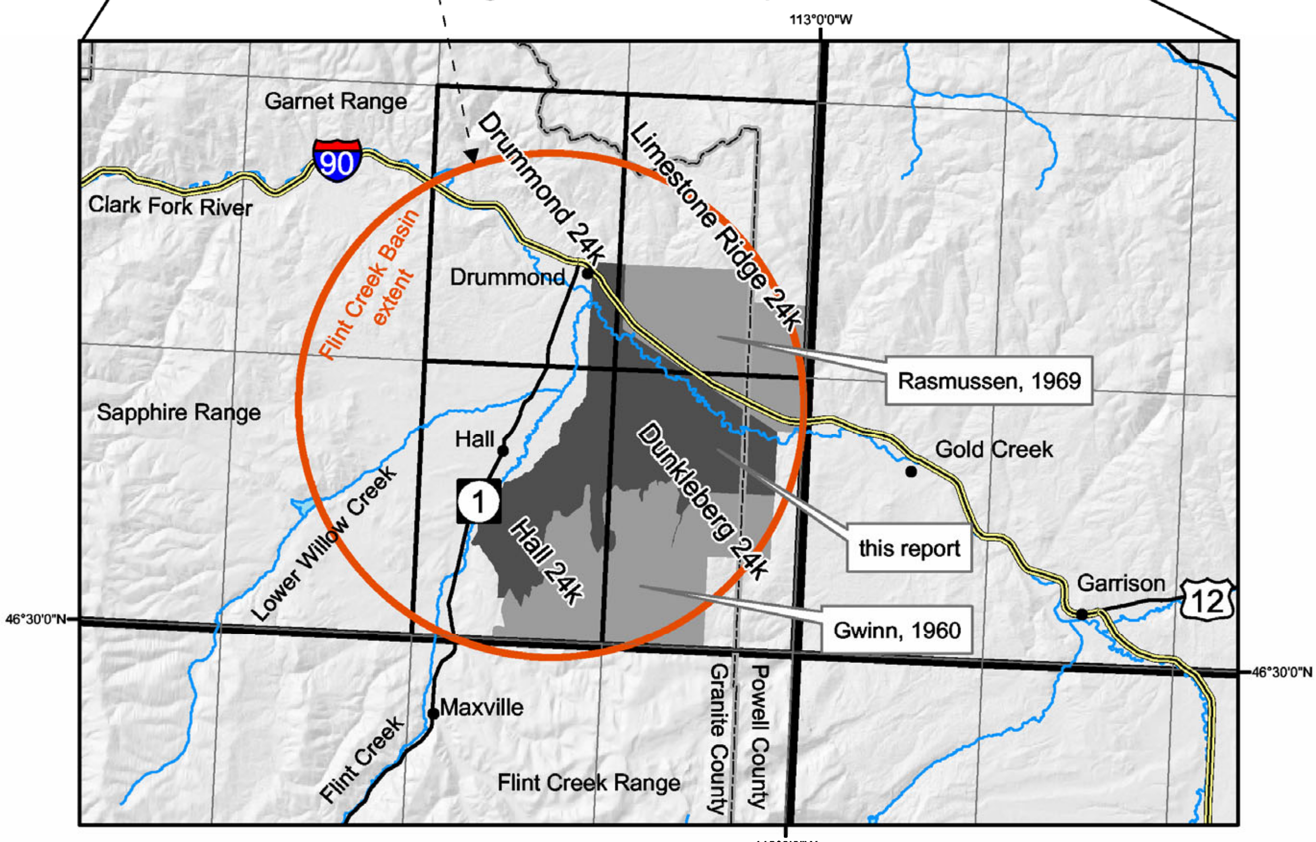


Figure 2: Reference to map area and geologic data sources incorporated into map.

Miocene. Several workers have suggested that right lateral motion along the Lewis and Clark shear zone accompanied extension during Tertiary time (Harrison and others, 1974; Reynolds and Kleinkopf, 1977; Wallace and others, 1990; White, 1993; Yin and others, 1993). In the Flint Creek basin, right lateral offsets overprint fold axes at the head of Barnes Creek and in the Coberly Syncline; they may have been caused by dextral movement along the Lewis and Clark shear zone during Tertiary time.

Stratigraphy

An estimated 20,000 feet of Cretaceous siliciclastic strata are preserved in the vicinity of the field area. These prove to be the thickest accumulation of Cretaceous rocks in Montana. Bedrock geology in the map area consists primarily of folded and thrusted Cretaceous siliciclastics and alkalic sills (figure 3). The youngest Mesozoic rocks in the field area are a swarm of ~76 My alkalic sills that intrude members of the Blackleaf Formation (Sears and others, 2000). Local exposure of a bedrock breccia with overlying red regolith is exposed along the Cretaceous-Tertiary contact.

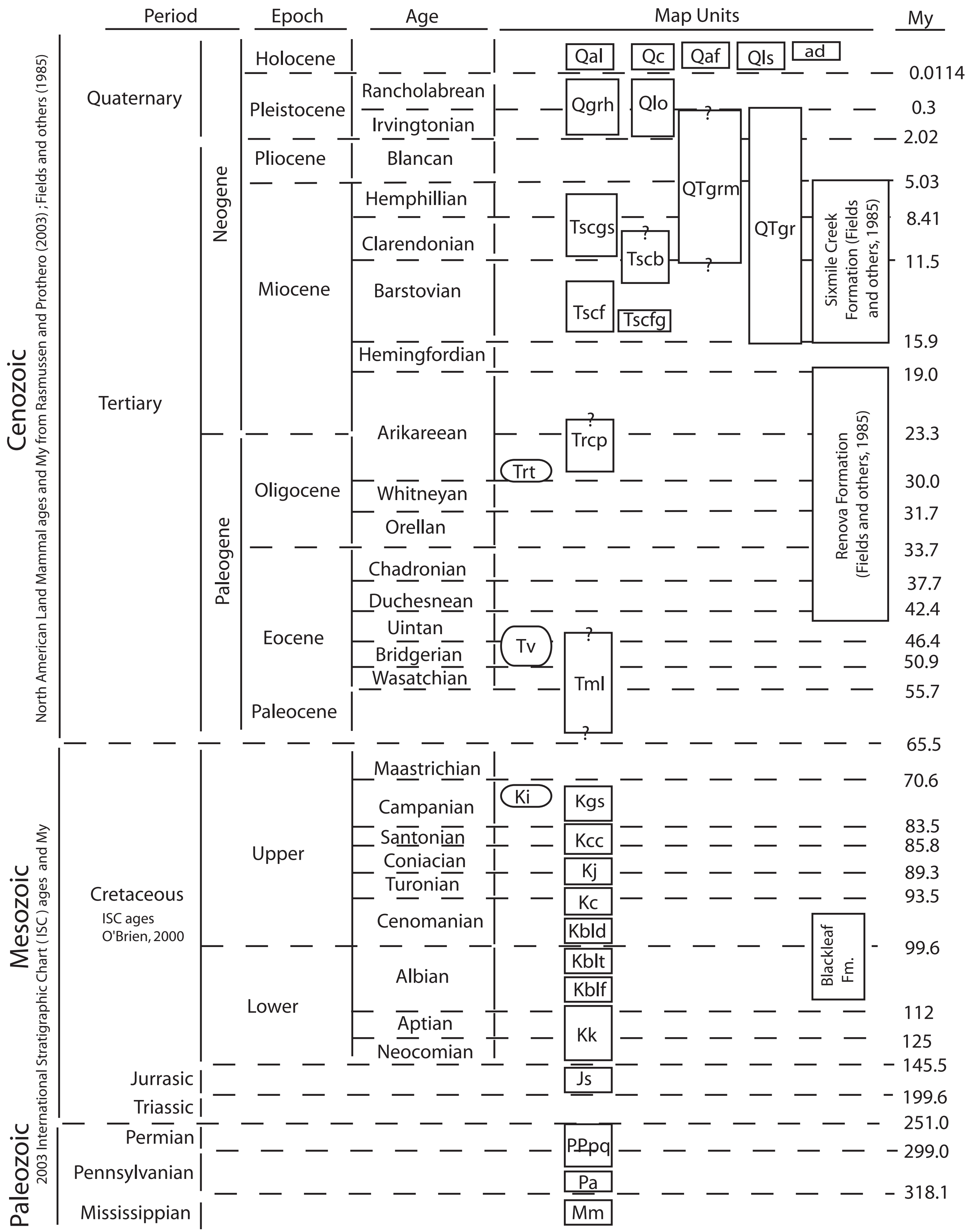
Stalker and Sherriff (2004) estimated the thickest accumulation of Tertiary rocks in the center of the Flint Creek basin to be approximately 4,000 feet. Eocene volcanic rocks are widespread in the west and north parts of the basin but nearly absent on the east side of the basin. These volcanics were dated at 44-49 Ma and are the oldest Tertiary rocks filling the basin (Williams and others, 1976; Carter, 1982). They are nonconformably overlain by tuffaceous rocks of the middle Oligocene to early Miocene Renova Formation. In the study area, the Renova Formation has been referred to as the Cabbage Patch beds by previous workers (eg. Konizeski, 1958; Rasmussen, 1969; Rasmussen, 1977; Fields and others, 1985; Rasmussen and Prothero, 2003) and has yielded Arikareean (see figure 3 for North American Land Mammal Age) vertebrate fossils. A very competent rhyolitic welded tuff occurs locally at the base of the Cabbage Patch beds and yielded a 29.5 Ma zircon fission track date (Rasmussen, 1977). Where exposed in the study area, the uppermost Cabbage Patch beds contain smectitic clays with barite nodules, iron mottling, and scattered pedogenic slickensides, suggesting extensive subarial exposure during that time. A locally well-exposed, 6-foot-thick boulder conglomerate overlies the Arikareean Cabbage Patch beds with a very pronounced basal erosion surface (Tscfg). Biostratigraphy above and below the erosion surface suggests a correlation with the regional late-early Miocene unconformity (Rasmussen, 1973). Up to 157 feet of massive mudstone, carbonate nodules, and very fine-grained sandstone of the Flint Creek beds rests above the conglomerate and has yielded Barstovian vertebrate fossils (Rasmussen, 1969; Craig Christensen, written communication, 2004). The Flint Creek beds, as well as unconformably overlying poorly consolidated gravel and sand of the Barnes Creek beds and an unnamed boulder-sized gravel unit, can be correlated with conglomerates of the middle to upper Miocene Sixmile Creek Formation of southwestern Montana (Fields and others, 1985).

Hanneman and Wideman (1991) discussed problems with the currently used Tertiary lithostratigraphy in western Montana and the difficulties in identifying pre- and post-Hemingfordian strata. The occurrence of dominantly fine-grained Barstovian age strata (Flint Creek beds) overlying fine-grained Arikareean age strata (Cabbage Patch beds) in the Flint Creek basin supports those observations made by Hanneman and

Wideman (1991). The intervening conglomerate identified by this mapping project was used as a key stratigraphic marker bed, but is most likely a locally occurring unit and may or may not be present in other basins.

Overlying the youngest Tertiary strata are unnamed gravels, loess, and mud that only occur on high terraces. Rasmussen (1974) identified Pleistocene vertebrate remains in these deposits east of the town of Hall, Montana. This unit mantled much of the underlying Tertiary strata but was only mapped in the absence of Tertiary exposure and where it was exposed as a thick accumulation.

Figure 3: East Flint Creek Basin Stratigraphic Correlation



Map Descriptions

See Figure 3 for North American Land Mammal Ages

Quaternary

ad **Anthropogenic Deposits** (modern)
Placer mine tailings, retention pond mud, and coarse, angular, exotic boulders deposited by human activity. Thickness 0-50 ft.

Qal **Alluvium (Holocene)**
Unconsolidated to semi-consolidated stream and floodplain deposits exposed primarily along modern stream channels. Mostly coarse gravel and sand with local overbank brown mud deposits. Gravel is rounded and poorly sorted. Locally contains a 1-ft-thick bed of volcanic ash. Less than 30 ft thick.

Qaf **Alluvial fan (Holocene)**
Unconsolidated gravel and mud deposits at mouth of ephemeral drainages and along the edge of the Flint Creek and Clark Fork River floodplains. Well-developed fan-shaped geomorphology. Unit composed of locally derived, poorly sorted, angular clasts. Less than 15 ft thick.

Qc **Colluvium (Holocene)**
Unconsolidated, very angular gravel, silt, and mud deposited at base of slopes. Gravel is moderately to well sorted and primarily granule to cobble sized. Less than 10 ft thick.

Qls **Landslide deposits (Holocene)**
Semi-consolidated sediment composed of locally derived source material. Identified by lobate and hummocky geomorphology. Tends to occur on steep slopes composed of Trcp and Tscf map units overlain by boulder-sized gravel. Less than 850 ft in diameter.

--Unconformity--

Qgrh **Gravel deposit of Hoover Creek (Pleistocene)**
Poorly consolidated, well-rounded but poorly sorted, pebble- to boulder-conglomerate with framework support. Discontinuous sand lenses are very fine to medium grained, micaceous and angular. Abundant volcanic clasts. Local deposit along northern margin of modern Clark Fork River. Age from Rasmussen, (1969). Less than 20 ft thick.

Qlo **Loess (Pleistocene)**

Loess, mud, and local deposits of unconsolidated angular gravel. Color medium-brown to buff-tan. Occurs locally on terrace surfaces. Gravel becomes finer-grained farther away from the Flint Creek Range. This unit probably was deposited contemporaneously with Glacial Lake Missoula sediments. Age from Rasmussen (1974). Less than 40 ft thick.

Quaternary and Tertiary

QTgrm **Gravel and mud (Pleistocene-Miocene?)**

Unconsolidated boulders, cobbles, and pebbles in brown mud matrix support. Gravel ranges from very angular to rounded. Largest boulders characterized by compression marks and high sphericity. Probably deposited by debris-flow processes along edge of basin. Less than 120 ft thick.

QTgr **Gravel undivided (Pleistocene-Miocene?)**

Unconsolidated boulder- to pebble-sized gravel with poorly to well-rounded clasts in a sandy-mud matrix. Also includes undivided mud and silt deposits. Less than 240 ft thick.

Tertiary

Sixmile Creek Formation

Tscgs **Gravel and sand of Sixmile Creek Formation (Miocene; Hemphillian-Clarendonian?)**

Semi-consolidated, framework-supported boulders and cobbles with coarse, angular sand matrix. Lacks bedding. Boulders well-rounded and imbricated to the N-NE at the mouth of Douglas Creek. Boulders up to 3 ft in diameter and predominantly composed of tan quartzite. Unit commonly occurs on high terraces and along valley slopes. Locally contains brownish-red clay with caliche nodules. As much as 400 ft thick in the southern Flint Creek Valley.

Tscb **Barnes Creek beds, informal, of Sixmile Creek Formation (late Miocene, Clarendonian-late Barstovian)**

Conglomerate facies (not mapped) typically has pebble to small cobble sized clasts with well-developed framework support. Pebbles are locally imbricated, well sorted, moderately well rounded and spherical. Intercalated sandstone lenses contain abundant tabular foresets and are commonly a greenish-pinkish hue. Sand matrix is angular, fine to very coarse grained and locally cemented with $CaCO_3$. Mudstone facies (not mapped) is commonly composed of variegated reddish-orange silty clay and poorly lithified. Contains scattered vertebrate bone fragments. Less then 240 ft thick.

--Unconformity--

Tscf **Flint Creek beds, informal, of Sixmile Creek Formation (middle-late Miocene; early Barstovian)**

Calcrete facies consists of abundant irregular to tubular-shaped carbonate nodules within massive siltstone and mudstone. Local well-indurated tabular sheets of calcrete composed of floating angular granules. Unit often forms prominent outcrops. Mudstone is yellow-tan or buff colored throughout with large curve-shaped fractures (pedogenic slickensides) and no stratification. Minor volcanic detritus commonly altered to smectite clay. Conglomerate and sandstone facies typically have lenticular geometries and internal scour surfaces. Clasts are granule to pebble sized, very angular and lack imbrication. Sandstone units are fine to coarse grained and characterized by local mottling and preservation of root traces. Thin- to medium-bedded siltstone facies are more common in higher stratigraphic levels. Approximately 200 ft thick.

Tscfg **Gravel bed, informal, at base of Flint Creek beds (early-middle Miocene; early Barstovian)**

Boulder- to pebble-sized conglomerate. Clasts are sub-rounded to very rounded, moderately sorted, framework supported, imbricated and locally $CaCO_3$ cemented. Sand matrix is medium to very coarse grained, poorly sorted and locally forms lensoidal beds. Unit as a whole has a sharp erosive base and a crude fining upward profile. Unit occurs immediately above the regionally extensive late-early Miocene (Hemingfordian) unconformity. Thickness of 6 feet where locally exposed.

--Unconformity--

Renova Formation

Trcp **Cabbage Patch beds, informal, of Renova Formation (late-early Miocene through middle Oligocene; Arikareean; upper Renova Formation equivalent)**

Composed of sandstone, massive mudstone, and well-stratified, predominantly fine-grained deposits. Sandstones are very coarse grained to pebbly; grains are poorly rounded to angular, arkosic, and well cemented with silica in stratigraphically lower beds and with calcium carbonate in stratigraphically higher beds. Sandstones commonly occur as fining-upward sequences with abundant tabular trough-cross bedding. Sandstone beds are thick bedded, wedge-shaped, and interstratified with massive mudstone. Massive mudstone is buff colored with scattered spherical $CaCO_3$ nodules. Lack of stratification probably relates to extensive paleosol development. Intervals of well-stratified fine-grained lithologies consist of laterally discontinuous, interstratified, locally tuffaceous sandstone, siltstone, mudstone, marlstone, and lesser amounts of gypsum, lignite, diatomite, and chert. Local tephra units are fine grained. Marlstone intervals are well indurated with abundant shell debris including gastropods, ostracods, and pelecypods. Paleosols are common and characterized by claystone with abundant iron-stained root traces, slickensides, mottling, and $CaCO_3$ nodules. Total unit approximately 2,300 ft thick (Rasmussen and Prothero, 2003).

Trt **Rhyolitic Tuff, welded (late Oligocene)**
Rhyolitic welded tuff with euhedral sanidine and smoky quartz grains. Very competent unit locally interstratified with basal Cabbage Patch units. Rasmussen (1977) reported a 29.2 Ma zircon fission track age date. Approximately 100 ft thick at mouth of Coberly Gulch.

--Unconformity--

Tv **Volcanic rocks (Eocene)**
May include basalt, dacite, andesite, and rhyolite. Primarily mapped as basalt by Rasmussen (1969). Part of Garnet Range volcanic sequence in Bearmouth area (Carter, 1982). Very extensive in the western and northern parts of the Flint Creek basin. K-Ar dates of ~44-49 $\pm$ 2 Ma reported by Williams (1976) and Carter (1982). Thickness 0-600 ft in Garnet Range (Carter, 1982).

Tml **Mudstone, lateritic (Eocene(?)-Paleocene)**
Bright-orange-red mudstone with local gravel lenses. Mud is primarily composed of kaolinite and interlayered smectite/illite clay. Poor exposures found locally along Cretaceous-Tertiary unconformity. Local occurrence of breccia with in uppermost 8 inches of Kbld along unconformity. A reddish staining is prominent in underlying Cretaceous units to a depth of about 25 ft and suggests a pedogenic laterite origin for this unit. Thickness 0-250 ft.

--Unconformity--

Cretaceous

Ki **Intrusive sills, alkalic**

Alkalic igneous sill (shonkinite) that is highly weathered to a medium grus. Commonly found along Blackleaf-Coberly Formation contact and folded along parallel sedimentary rock bedding planes. Age ~65 Ma (Sears and others, 2000).

--Intrusive--

Kgs **Golden Spike Formation (Maastrichtian-Campanian)**

Cobble to pebble conglomerate, matrix-supported, well-rounded and interbedded with sandstone. Clast composition dominated by chert. Sharp erosive basal contact. Locally well-exposed on north slope of Dunkelberg ridge. Regionally 5,000-8,000 ft thick (Gwinn, 1965); 10 ft exposed in field area.

--Unconformity--

Kcc **Carter Creek Formation (Santonian-Coniacian)**

Primarily sandstone, green siltstone, and mudstone. Sandstone beds have trough cross sets, lateral accretion surfaces, and a continental-volcanic sedimentary source (**Waddell, 1992**). Volcanic clasts occur in local interstratified conglomerates. Regionally 4,500-6,000 ft thick (Gwinn, 1965).

Kj **Jens Formation (Coniacian-Turonian)**

Drab colored shales with minor siltstone and fine-grained sandstone with well-developed sandstone. Varicolored red-purple mudstone and siltstone in middle portion of unit. Thickness 1,000-1,500 ft (Gwinn, 1965).

Kc **Coberly Formation (Turonian-Cenomanian)**

Variegated green-brown mudstone and siltstone, local shaley lignite, fine-grained sandstone, and fossiliferous limestone. Limestone beds dark-gray-brown with abundant large gastropods, pelcypods, and oyster coquinas. Approximately 600 ft thick (Gwinn, 1965).

--Unconformity—

Blackleaf Formation

Kbld **Dunkleberg Member (Cenomanian)**

Salt-and-pepper-colored, medium- to coarse-grained sandstone, light-green to dark-greenish-brown, porcellanite and variegated red to purple mudstone in the uppermost portion of unit below the unconformity at the base of Coberly Formation. Six-ft-thick, chert pebble conglomerate occurs toward base and middle of formation. Thickness 1,500-1,700 ft (Gwinn, 1965).

Kblt **Taft Hill Member (Albian)**
Thick- to medium-bedded, brownish-tan, fine- to medium-grained sandstone with abundant trough and planar cross stratification. Contains minor black shale interbeds. Basal contact with underlying black shale of Flood Member gradational. Approximately 900-1,100 ft thick (Gwinn, 1965)

Kblf **Flood Member (Albian)**
Black fissile shale with local interbeds of very fine- to fine-grained sandstone. Two-ft-thick, fine-grained sandstone commonly occurs at base of member. Approximately 700 ft thick (Gwinn, 1965).

Kk **Cretaceous Kootenai Formation (Albian-Neocomian)**
Upper and middle parts of the formation consist of medium-gray limestone with abundant gastropods. Limestone is interstratified with red-purple mudstone and local lenticular, medium- to coarse-grained sandstone beds. Thickness 900-1,100 ft (Gwinn, 1965)

--Unconformity--

Jurassic

Js **Sedimentary rocks, undivided, includes Morrison Formation and Ellis Group**
Morrison Formation – Poorly exposed brown-green mudstone and siltstone with interstratified salt-and-pepper sandstone locally.
Ellis Group
Swift Formation– Chert pebble conglomerate and tan, medium- to coarse-grained sandstone.
Rierdon Formation- Tan-gray siltstone, shale, and local argillaceous limestone. Contains scattered invertebrate remains.
Sawtooth Formation- Dark-brown shale.
Total unit thickness approximately 900 ft (Gwinn, 1961)

--Unconformity--

Permian and Pennsylvanian

PlPpq **Phosphoria and Quadrant Formations, undivided**

Phosphoria Formation- Beds of black chert with interbedded dolomite and phosphorite. Poorly exposed except in artificial mine and pit exposures. Thickness 0-50 ft (Gwinn, 1961).

Quadrant Formation- Well-sorted and very mature, thick-bedded quartzite. Very competent ridge-former that weathers reddish-tan. Thickness 200-250 ft (Gwinn, 1961).

Pennsylvanian

Pa **Amsden Formation**

Very poorly exposed red siltstone, mudstone, and dolomite. Forms red soil below Quadrant quartzite. Thickness 300-325 ft (Gwinn, 1961).

--Unconformity--

Mississippian

Mm **Madison Group, undivided**

Thick- to medium- bedded limestone with dolomite in uppermost beds. Contains scattered gray chert nodules. Only uppermost part of unit exposed in map area. Thickness approximately 1,200 ft (Gwinn, 1961).

Map Symbols

Map boundary

Contact: dashed where approximately located; dotted where concealed

Inferred fault

Thrust fault: dashed where approximately located; dotted where concealed; teeth on hanging wall

High-angle reverse fault: dashed where inferred

Normal fault: dashed where approximately located; dotted where concealed; ball and bar on downthrown side

Overturned anticline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known

Anticline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known

Overturned syncline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known

Syncline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known

Horizontal bedding

20 Strike and dip of bedding

20 Strike and dip of overturned bedding

50 Foliation in igneous rocks

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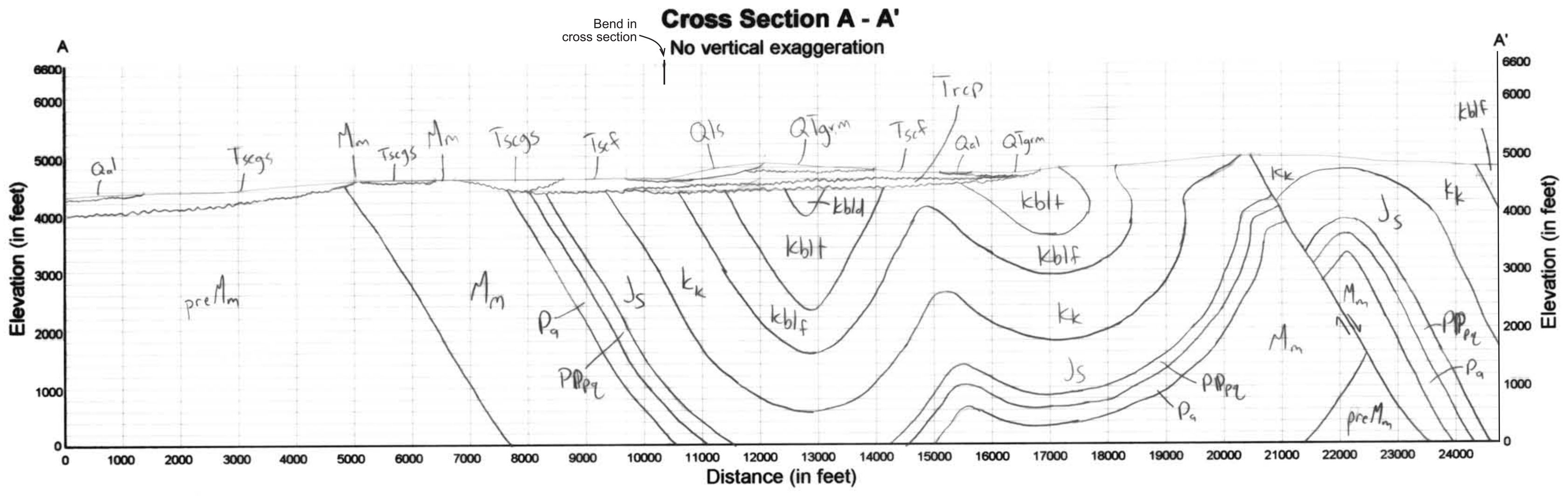
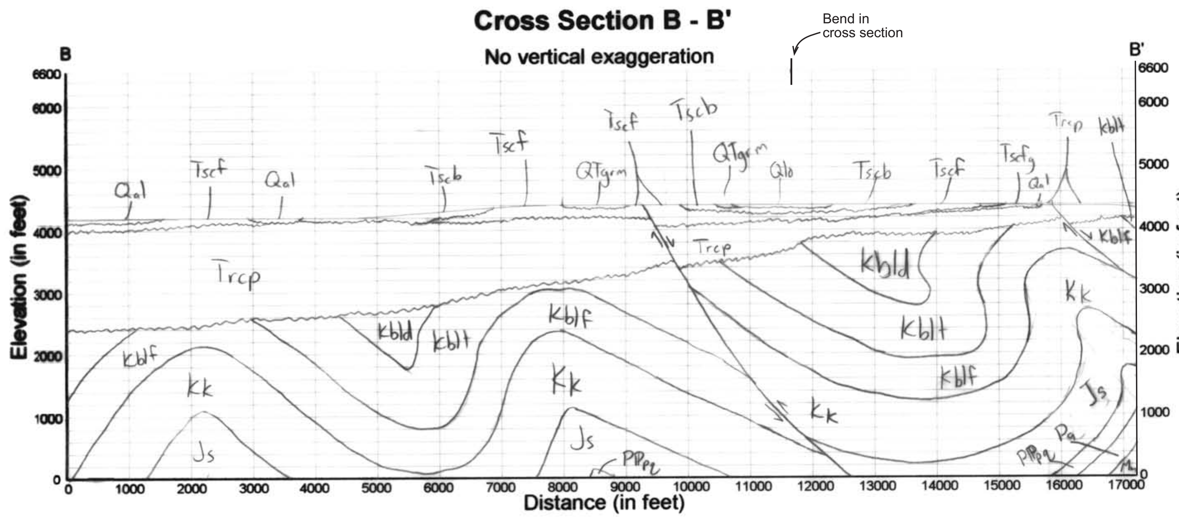
Cross Section A - A'

No vertical exaggeration



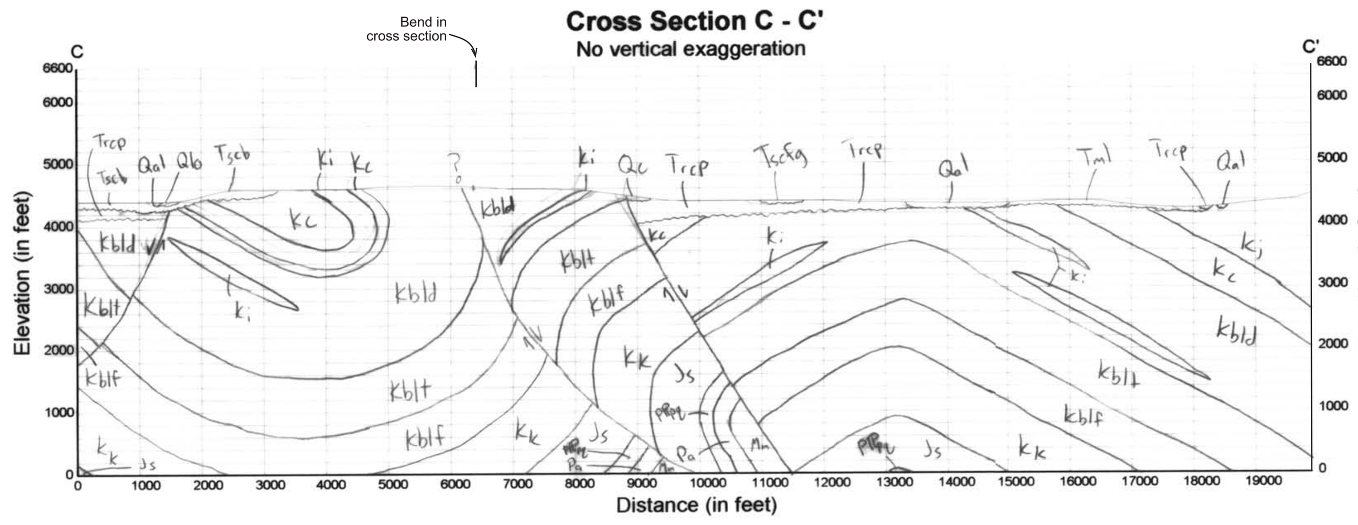
Cross Section B - B'

No vertical exaggeration



Cross Section C - C'

No vertical exaggeration



Datum: mean sea level

Geologic Map Units

Quaternary

Holocene

- ad — Anthropogenic deposits, modern
- Qls — Landslide deposit
- Qc — Colluvium
- Qal — Alluvium
- Qaf — Alluvial fan deposits

Pleistocene

- Qgrh — Gravel of Hoover Creek
- Qlo — Loess, local gravel

Miocene-Pleistocene?

- QTgr — Gravel deposit undivided
- QTgrm — Gravel and mud deposit, undivided

Quaternary and Tertiary

Sixmile Creek Fm.

Middle-Late Miocene

- Tscgs — Gravel and sand of the Sixmile Creek Fm.
- Tscb — Barnes Creek beds, informal, of Sixmile Creek Fm.
- Tscf — Flint Creek beds, informal,of Sixmile Creek Fm.
- Tscfg — Gravel bed, informal,at base of Flint Creek beds

Middle Oligocene-Early Miocene

- Trcp — Cabbage Patch beds, informal of Renova Fm.
- Trt — Rhyolitic Tuff, welded (~29.5 ma)

Eocene

- Tv — Volcanic rocks undivided

Paleocene-Eocene?

- Tml — Mudstone, lateritic

Cretaceous

- Ki — Intrusive sills, alkalic
- Kgs — Golden Spike Formation
- Kcc — Carter Creek Formation
- Kj — Jens Formation
- Kc — Coberly Formation

Blackleaf Formation

- Kbld — Dunkleberg Member of Blackleaf Fm.
- Kblt — Taft Hill Member of Blackleaf Fm.
- Kblf — Flood Member of Blackleaf Fm.
- Kk — Kootenai Formation

Jurrassic

- Js — Sedimentary rocks undivided, includes Morrison Formation and Ellis Group

Permian - Pennsylvanian

- PPpq — Phosphoria (Permian) and Quadrant (Pennsylvanian) Formations Undivided
- Pa — Amsden Formation (Pennsylvanian)

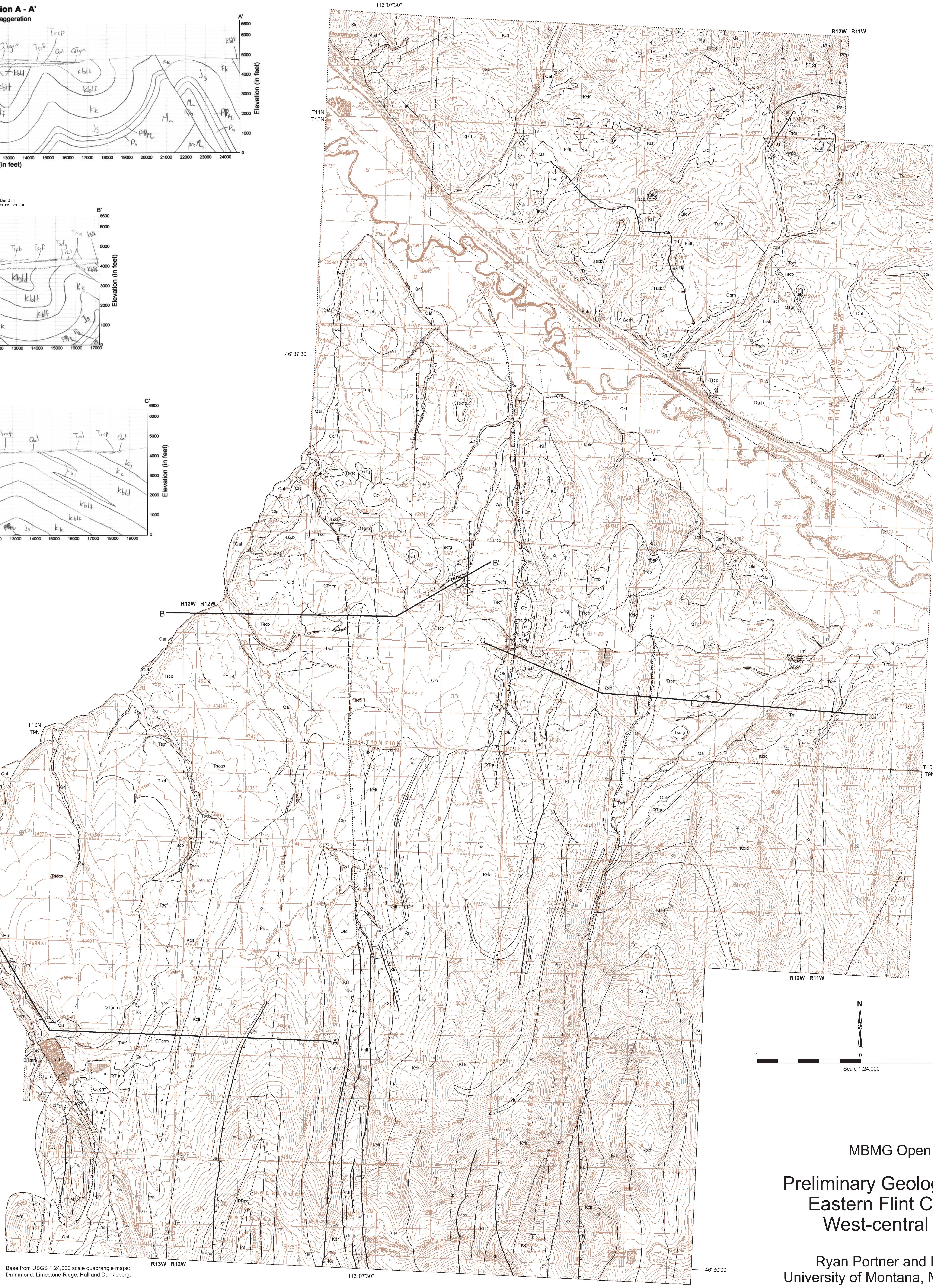
Mississippian

- Mm — Madison Group undivided

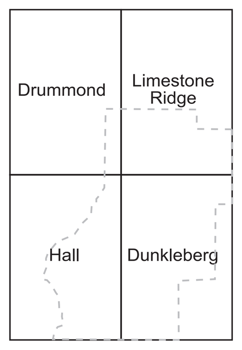
Map Symbols

- Map boundary
- Contact: dashed where approximately located; dotted where concealed
- Inferred fault: question marks where queried
- Thrust fault: dashed where approximately located; dotted where concealed; teeth on hangingwall
- High-angle reverse fault: dashed where inferred
- Normal fault: dashed where approximately located; dotted where concealed; ball and bar on downthrown side
- Overturned anticline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known
- Anticline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known
- Overturned syncline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known
- Syncline: showing trace of axial plane; dotted where concealed; plunge direction indicated where known
- Horizontal bedding
- 20 Strike and dip of bedding
- 20 Strike and dip of overturned bedding
- 50 Foliation in igneous rocks

Maps may be obtained from: Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4167
Fax: (406) 496-4451
http://www.mbmg.mtech.edu



Base from USGS 1:24,000 scale quadrangle maps: Drummond, Limestone Ridge, Hall and Dunkleberg.



Base maps from U.S. Geological Survey

Drummond 7.5' topographic quadrangle
Map date: 1989
Projection: Lambert Conformal Conic
UTM zone 11; 1927 NAD

Limestone Ridge 7.5' topographic quadrangle
Map date: 1989
Projection: Lambert Conformal Conic
UTM zone 11; 1927 NAD

Hall 7.5' topographic quadrangle
Map date: 1996
Projection: Lambert Conformal Conic
UTM zone 11; 1927 NAD

Dunkleberg 7.5' topographic quadrangle
Map date: 1996
Projection: Lambert Conformal Conic
UTM zone 11; 1927 NAD

N

1 0 1 mile

Scale 1:24,000

MBMG Open File 521

Preliminary Geologic Map of the Eastern Flint Creek Basin West-central Montana

Ryan Portner and Marc Hendrix
University of Montana, Missoula, Montana

2005

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