GEOLOGIC MAP OF THE STARK SOUTH 7.5' QUADRANGLE, CENTRAL-WESTERN MONTANA

by

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Introduction

Montana Bureau of Mines and Geology (MBMG) staff selected the Stark South 7.5' quadrangle in central-western Montana (figure 1) for detailed (1:24,000-scale) mapping because prominent northwest-striking structures on mapped adjacent quadrangles (Lonn and Smith, 2005; Lewis, 1998; Wells, 1974) to the northwest and southeast appeared to be unrelated to each other (figure 2). Those to the northwest appeared to be extensional features, while those to the southeast appeared to be compressive in origin. This study was undertaken to determine the relationships between these two contrasting structural styles. MBMG expects this work to contribute to completion of the Plains 1:100,000-scale quadrangle in 2007.

The Stark South quadrangle lies along the enigmatic Lewis and Clark Line (Billingsley and Locke, 1941), a poorly understood west-northwest-striking zone of faults and folds that transects the more northerly structural grain of western Montana (figure 3). Although Precambrian structure has been proposed to explain the Lewis and Clark Line's existence (Hobbs and others, 1965; Harrison and others, 1974; Reynolds, 1979; Leach and others, 1988; Winston, 1986a; Sears, 1988), the recognized structures that define the zone are all Cretaceous or younger. Although Billingsley and Locke's (1941) original definition of the line was based on a topography [geography] controlled by Cenozoic strike-slip and normal faults, older compressive features including overturned folds, reverse faults, and metamorphic foliation within the zone also trend northwest to west-northwest.

The Stark South quadrangle straddles a portion of the Lewis and Clark Line that coincides with a northwesterly jog (figure 3) in the Late Cretaceous-Paleocene western fold and thrust belt of western Montana (Winston, 1986a, 2000; Sears, 1988). This northwesterly alignment of compressive structures may represent (1) sinistral transpression (Smith, 1965; Lorenz, 1984; Hyndman and others, 1988; Sears and Clements, 2000), (2) dextral transpression (Wallace and others, 1990), (3) rotation of originally north-trending folds through left-lateral (Burmester and Lewis, 2003) or right-lateral (Hobbs and others, 1965) shear, or (4) northeast-directed compression that did not involve lateral movement (White, 1993; Yin and others, 1993). Subsequent Cenozoic extension and/or right-lateral shear (Hobbs and others, 1965; Reynolds, 1979; Harrison and others, 1974; Bennett and Venkatakrishnan, 1982; Sheriff and others, 1984; Winston, 1986a; Doughty and Sheriff, 1992; Yin and others, 1993; Lonn and McFaddan, 1999) superimposed high-angle normal and/or dextral faults that roughly parallel and obscure the compressional features.

Clearly, the Lewis and Clark Line is a complex and controversial feature whose boundaries cannot even be agreed upon. As Winston (2000) suggests, much of the confusion may stem from workers combining diverse structures of different origins into one feature. In addition, geologic mapping along much of the Lewis and Clark Line is available only at the 1:250,000 scale; more detailed mapping is resolving some of the conflict.

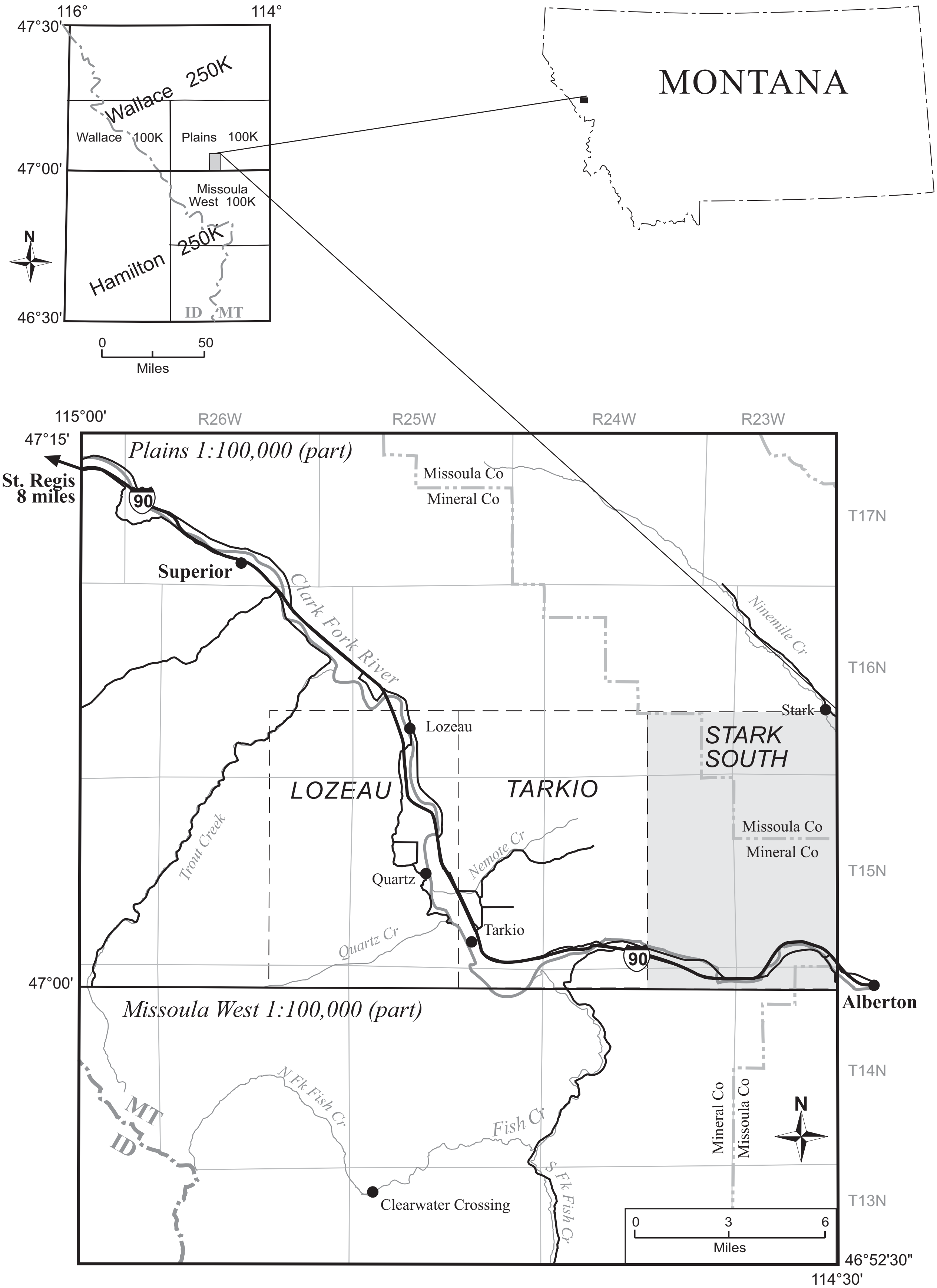


Figure 1. Location map of the Stark South 7.5' quadrangle within the Plains 30' x 60' quadrangle. Adjacent Tarkio and Lozeau 7.5' quadrangles (Lonn & Smith, 2005) are also shown.

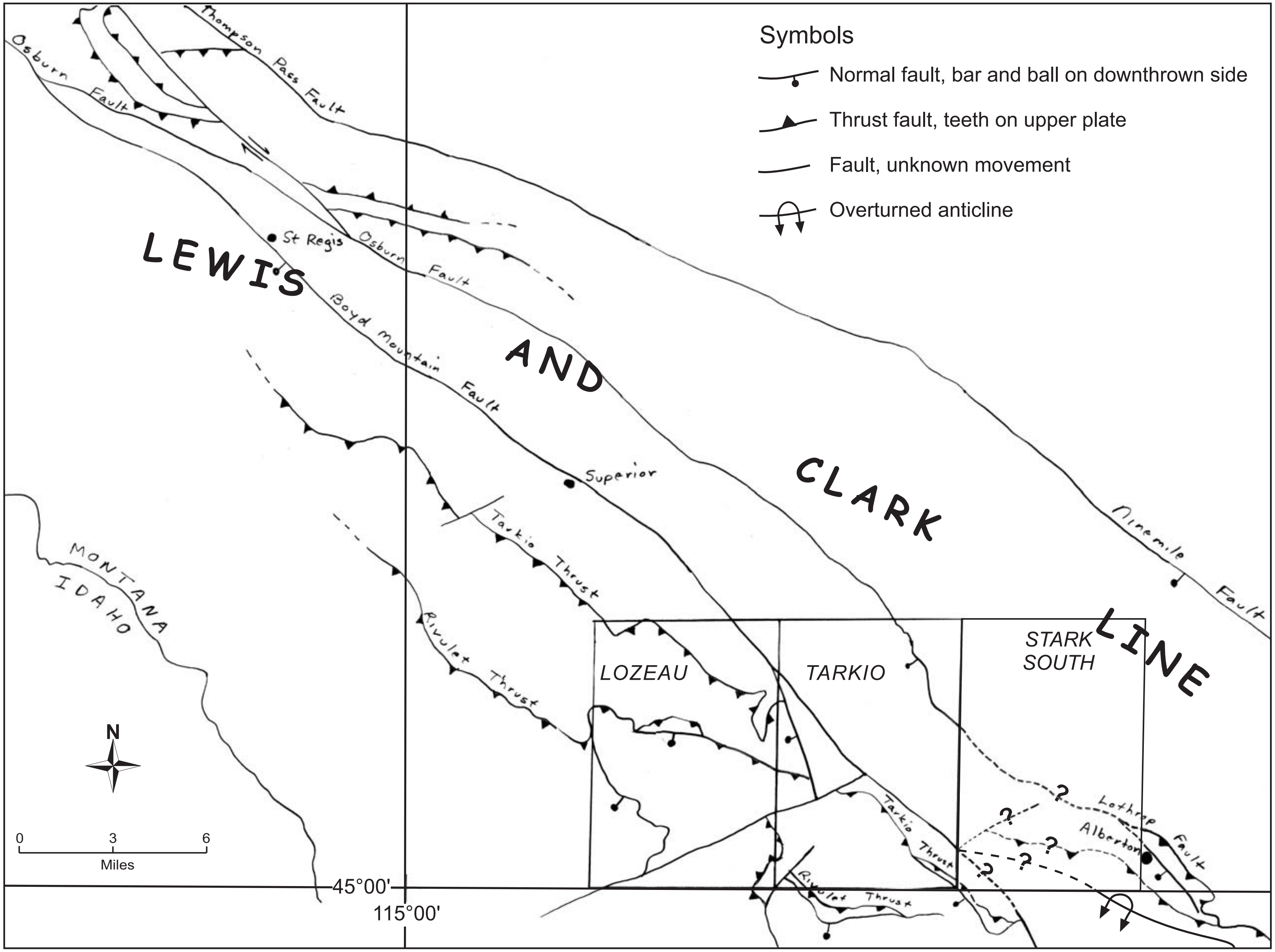


Figure 2. Regional structures tentatively projected through the Stark South quadrangle prior to mappping, postulating an on-strike relationship between extensional structures to the northwest and compressional features to the southeast. Compiled from Campbell, 1960; Harrison & others, 1986; Winston & Lonn, 1988; Lonn & McFadden, 1999; and Lonn, 2001, Lonn and Smith, 2005.

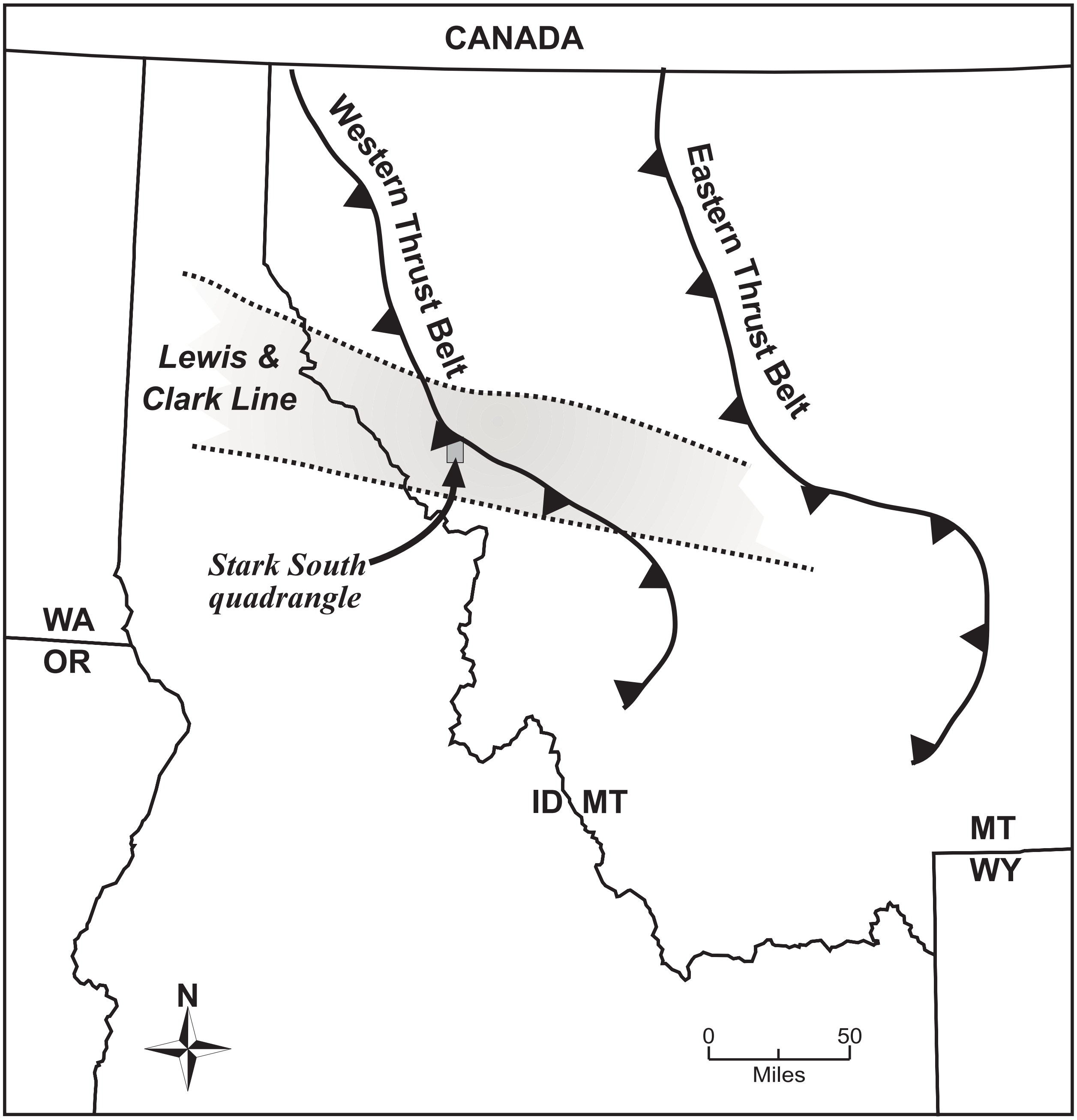


Figure 3. Location of map area with respect to major structural features of western Montana.

Stratigraphy

The Correlation Chart (page 8) and the Description of Map Units provide a detailed description of stratigraphy in the map area. Most of the area is underlain by low-grade metasedimentary rocks of the Middle Proterozoic Belt Supergroup. The Stark South quadrangle includes the Belt section from the Middle Wallace Formation through the Pilcher Formation, having a total estimated thickness of 12,600 feet. About 700 feet of the Cambrian section is also exposed.

Extensive Quaternary units are also present on the Stark South quadrangle and were mostly deposited during Pleistocene glaciation. Most deposits are related to sedimentation in and drainage of Glacial Lake Missoula. Glacial Lake Missoula inundated the Clark Fork River valley up to altitudes of about 4,250 feet above sea level.

Silt-dominated, laminated, glacial lake deposits along the valley floors may represent one or more lake stands. Bouldery alluvium beneath laminated silt deposits in the area contain imbricated boulder-sized clasts and planar cross-stratified gravel with set heights of 6 to greater than 100 feet, and down-river or up-tributary paleocurrents.

The giant bedforms, large-scale cross-stratification in bouldery deposits, and scabland erosion surfaces show that high-energy draining of Glacial Lake Missoula transported and deposited much of the gravelly alluvium in the area. Low-energy lake deposits of laminated silt that overlie the high-energy alluvium indicate that the lake was reestablished after earlier catastrophic drainage(s). Significant erosion and gravel transport during draining of the last lake(s) was more restricted within the stream valleys than during the earlier draining events. Scabland erosion related to this draining is restricted to the inner valley of the Clark Fork River.

Holocene erosion and sedimentation were restricted mostly to near-stream channels. The floodplain widened and strath terraces formed locally along the Clark Fork in small areas where the river is not incised into Belt Supergroup bedrock. Minor deposition of alluvial fan sediments occurred where steep drainages end on broad valleys.

Structure Within the Quadrangle

The Stark South quadrangle can be divided into two structural domains separated by the northwest-striking Lothrop fault system (figure 2). Southwest of this fault zone, fold axes strike northwesterly and plunge gently southeast on a regional scale (Lonn, 1984; Sears and Clements, 2000). These folds are interpreted to have developed during southwest-northeast-oriented compression, and are kinematically linked to the thrust and reverse faults that cut them (Lonn, 1984, 2001; Sears and Clements, 2000; Lonn and Smith, 2005). Two major thrust/reverse faults, the Lothrop and Reservoir Creek faults are present in the southern domain. Both strike northwestward, and both display older-overyounger, southwest-side-up relationships. Field relationships along the Reservoir Creek fault suggest that the rocks were first folded in response to Cretaceous compression, and then broke in a forelimb thrust (see cross section A-A'). The Lothrop fault is backed by a parallel, southwest-side-down normal fault that merges with the reverse fault along strike. Where the normal fault does not directly coincide with the reverse fault, it produces a fault-bounded wedge of older rocks surrounded by younger rocks. This geometry is common along thrusts to the south and west of the Stark South quadrangle (Lonn and Smith, 2005; Lewis, 1998) and the unusual and complex fault zones are here interpreted as thrusts that have been reactivated by extension, following Lewis (1998), Lonn (2001), and Lonn and Smith (2005).

North of the Lothrop fault zone are upright, open folds with north-striking axes. The Stark Mountain fault is a west-directed reverse fault that broke from a fold limb. White (1993) provided evidence that a north-trending fold and fault event post-dated the northwest-trending compressive features in the Coeur d'Alene district at the west end of the Lewis and Clark Line. A north-northeast striking fault (en echelon to the Stark Mountain fault?) does cut the northwest-striking compressive features south of the Lothrop fault in the Stark South quadrangle, but no evidence for later north-trending folds was seen in the southern structural domain of the quadrangle.

Although covered by Quaternary deposits, the steep, northwest-striking, down-to-the-southwest Boyd Mountain fault cuts across the southwest corner of the map area. It clearly post-dates the compressive features (Lonn and Smith, 2005).

Regional Structural Relationships

The Lothrop fault, although it displays reverse movement in the Stark South quadrangle (see map), has been traced northwestward into the Tarkio quadrangle (figure 4) where it shows a normal sense of movement (Lonn and Smith, 2005). Further northwest, near Saint Regis, it merges with or becomes the Osburn fault system (unpublished mapping, Lonn, 2004-2006) that also displays apparent normal movement (Lonn and McFaddan, 1999). These relationships, together with the portion of the Lothrop fault that is backed by a normal fault as described above, strongly suggest that the Osburn-Lothrop fault system originally developed as a reverse fault in a compressive regime, and was later reactivated by extensional tectonism.

The Reservoir Creek thrust appears to die into a fold in the west-adjacent Tarkio quadrangle (figure4), and the Stark Mountain fault does the same on both its north and south ends within the map area. This structural style indicates that the thrust and reverse faults are kinematically linked to the folds.

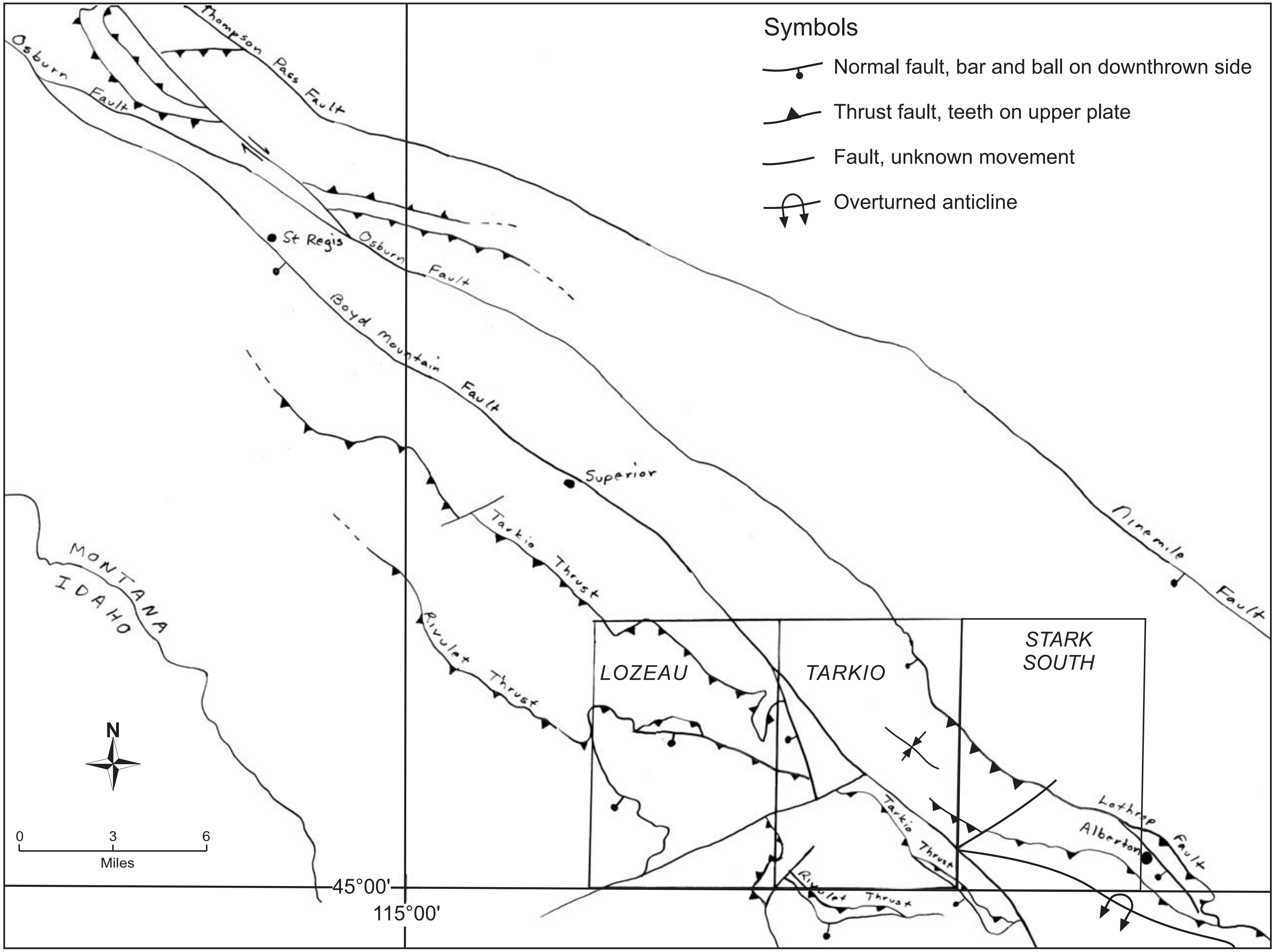
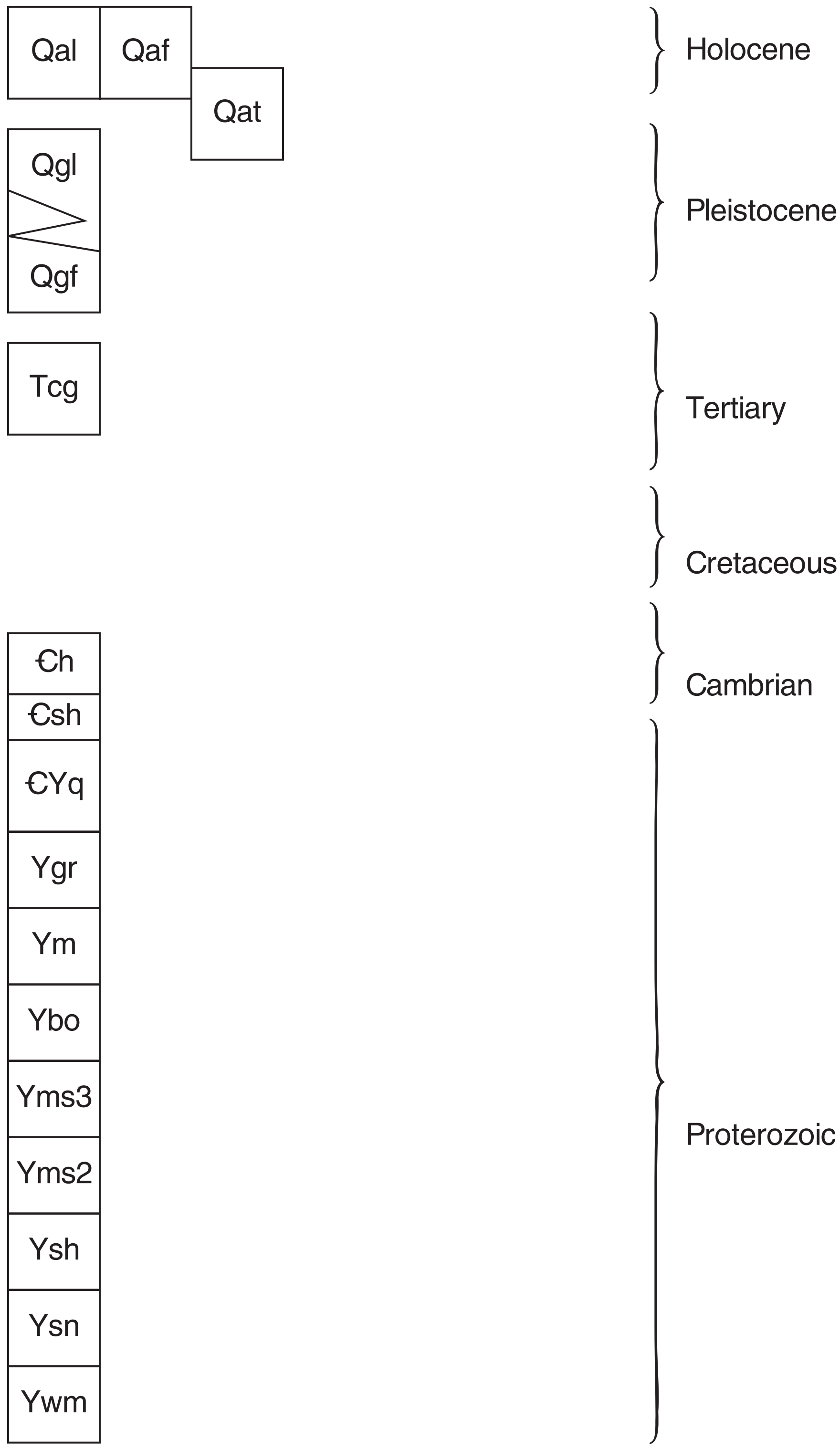


Figure 4. Relationships between major structures northwest and southeast of the Stark South quadrangle as determined by this study. Compiled from Campbell, 1960; Harrison & others, 1986; Winston & Lonn, 1988; Lonn & McFadden, 1999; and Lonn, 2001.



Correlation of map units on Stark South 7.5' quadrangle.

Description of Map Units

Descriptions use the sediment type terminology of Winston (1986b) for describing bed thickness and sedimentary structures.

Qal ALLUVIUM OF MODERN CHANNELS AND FLOODPLAINS (HOLOCENE)
Well- to moderately sorted gravel, sand, and minor silt along active stream channels and on modern floodplains. Unit includes minor colluvium at the bases of hill slopes. Average thickness 40 feet, but as much as 300 feet in paleochannels along the Clark Fork River.

Qaf ALLUVIAL FAN DEPOSITS (HOLOCENE)
Gravel, sand, and silt in distinctly fan-shaped landforms at the mouths of small drainages.

Qat ALLUVIUM OF STREAM TERRACES (PLEISTOCENE)
Gravel and sand underlying flat benches perched above present river level.

Qgl GLACIAL LAKE DEPOSITS (PLEISTOCENE)
Grayish-brown, light- to dark-yellowish-brown gravelly silt, light-pink silt and sand, very fine-grained sand in cyclic beds, and silty and clayey gravel. Deposit caps many benches. Typically 30-40 feet thick, but locally as much as 130 feet thick.

Qgf GLACIAL FLOOD DEPOSITS (PLEISTOCENE)
Stratified granule through boulder gravel, minor sands, and local 5-20-inch-thick interbeds of laminated silty clay and very fine-grained sand. Gravels may contain silt and very fine-grained sand in pore spaces. Clasts commonly subangular to sub-rounded; clast lithologies mostly Belt Supergroup quartzites and argillites, with lesser amounts of diorite, granitic rocks, and poorly indurated mudstones and siltstones. Cross bedding is typically large-scale, ranging from a few feet to many tens of feet in height; imbricated boulder-sized clasts and planar cross-stratified gravel with set heights of 5-100 feet display paleocurrents oriented down the Clark Fork River and up tributaries to the Clark Fork, suggesting a high-energy, high-volume alluvial environment. Thicknesses typically about 40 feet, but reach more than 300 feet in paleochannels along the Clark Fork River.

Tcg CONGLOMERATE (TERTIARY)
Poorly exposed deposits of well-rounded boulders in a silt and sand matrix. Clasts are mostly quartzite, but also include rare volcanic and granitic rocks that are not locally derived. Present only in the northeast corner of the map area.

Ꞓh HASMARK FORMATION (UPPER CAMBRIAN)
Light-gray to white, massive to mottled dolomite.Thickness 400 feet (Wells, 1974).

Єsh	SILVER HILL FORMATION (UPPER OR MIDDLE CAMBRIAN) Consists of a lower shale member 80-100 feet thick, and an upper limestone member 175 feet thick that contains wavy, irregular stringers of brown silty limestone (Wells, 1974).
ЄYq	QUARTZITE, UNDIVIDED (MIDDLE CAMBRIAN AND MIDDLE PROTEROZOIC) Includes the Cambrian Flathead and Middle Proterozoic Pilcher Formations; the disconformable contact between these formations is difficult to locate in the field. The Pilcher consists of medium- to coarse-grained, vitreous to feldspathic quartzite with distinctive alternating purple and light-gray trough cross-laminae. Flathead Formation sandstone is medium- to coarse-grained, white to red, massive to cross-bedded, vitreous quartzite. Thickness of this unit is 100-250 feet.
Ygr	GARNET RANGE FORMATION (MIDDLE PROTEROZOIC) Rusty-brown to yellow weathering, greenish-gray, micaceous, hummocky cross-stratified, fine-grained quartzite with olive-green to black argillite interbeds. Distinguished by rusty yellow weathered surfaces and abundant detrital mica. Thickness is approximately 4,000 feet thick in the map area, but Wells (1974) reported a thickness of 9,000 feet in the east-adjacent Alberton quadrangle.
Ym	MCNAMARA FORMATION (MIDDLE PROTEROZOIC) Dense, interbedded, green and red siltite and argillite in microlaminae and couplets. Mudcracks and chips are common. Contains diagnostic thin chert beds and chert rip-up clasts. Dominated by mudcracked even couplet and mudcracked lenticular couplet sediment types. About 2,300 feet thick in the map area, although Wells (1974) and Hall (1968) estimated it to be 4,000 feet thick in the east- and south-adjacent quadrangles.
Ybo	BONNER FORMATION (MIDDLE PROTEROZOIC) Pink, medium- to coarse-grained feldspathic, cross-bedded quartzite. Contains some granule-sized grains, and locally includes micaceous, maroon argillite interbeds. Samples slabbed and stained for potassium feldspar show feldspar content greater than plagioclase in contrast to the Mount Shields Member 2. Mostly comprised of the cross-bedded sand sediment type. Thickness 1,800 feet.
Yms3	MOUNT SHIELDS FORMATION, INFORMAL MEMBER 3 (MIDDLE PROTEROZOIC) Red quartzite to argillite couples and couplets with abundant mudcracks, mudchips, and salt casts. Includes green interbeds, and also some red microlaminae. A complete section is not present in the Stark South quadrangle, but Lonn and Smith (2005) estimated a thickness of 2,600 feet in the west-adjacent Tarkio quadrangle.

Yms2 MOUNT SHIELDS FORMATION, MEMBER 2, INFORMAL (MIDDLE PROTEROZOIC)

Pink to gray, flat-laminated to cross-bedded, fine- to medium-grained quartzite. Contains some tan-weathering dolomitic blebs. Cross-bedded intervals are difficult to distinguish from the Bonner Formation; however, in contrast to the Bonner, Mount Shields Member 2 contains sub-equal amounts of plagioclase and potassium feldspar. A complete section is not present in the map area but up to 3,800 feet is present in the west-adjacent Tarkio quadrangle (Lonn and Smith, 2005).

Ysh SHEPARD FORMATION (MIDDLE PROTEROZOIC)

Dolomitic and non-dolomitic, dark-green siltite and light-green argillite in microlaminae and couplets, and lenticular couplets of white quartzite and green siltite. Poorly exposed, but weathers into thin plates. Dolomitic beds have a characteristic orange-brown weathering rind. Ripples and load casts are common, and mudcracks are rare. Difficult to distinguish from carbonate-rich intervals in the Snowslip Formation (Ysn). Thickness approximately 800 feet.

Ysn SNOWSLIP FORMATION (MIDDLE PROTEROZOIC)

The upper 100 feet consist of quartzite to red argillite couples and couplets. The middle 2,400 feet are mostly dark-green siltite and light-green argillite in couplets and microlaminae with abundant dessication cracks and mud rip-ups. Some intervals of quartzite to red argillite cracked couplets are interbedded. The lower 500 feet is comprised of dolomitic and non-dolomitic, dark-green siltite and light-green argillite in cracked and uncracked even couplets and microlaminae that are difficult to distinguish from the Shepard Formation. Thickness about 3,000 feet.

Ywm WALLACE FORMATION, MIDDLE MEMBER, INFORMAL (MIDDLE PROTEROZOIC)

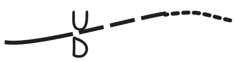
Only the uppermost 500 feet are exposed in the map area. They are characterized by the dinstinctive “black and tan” lithology comprised of tan weathering, dolomitic, hummocky cross-stratified quartzite and siltite capped by black argillite in pinch-and-swell couples and couplets. The quartzite/siltite beds commonly have scoured bases or bases with load casts. Molar tooth structure and non-polygonal crinkle cracks are common throughout the section.

MAP SYMBOLS
Stark South 7.5' quadrangle

Contact: dashed where approximately located

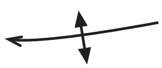
Reverse or thrust fault: teeth on upthrown block; dotted where concealed. Regionally, long segments of these faults can be shown to be reactivated as normal faults by subsequent extension (see figures 2 and 4).

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



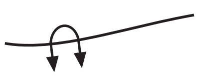
Fault: stratigraphic effect denoted by U & D; dashed where approximately located; dotted where concealed

Fault: unknown sense of movement; dashed where approximately located; dotted where concealed



Anticline: showing trace of axial plane and plunge direction where known

Syncline: showing trace of axial plane and plunge direction where known



Overturned anticline: Showing trace of axial plane and dip direction of bedding

Strike and dip of bedding

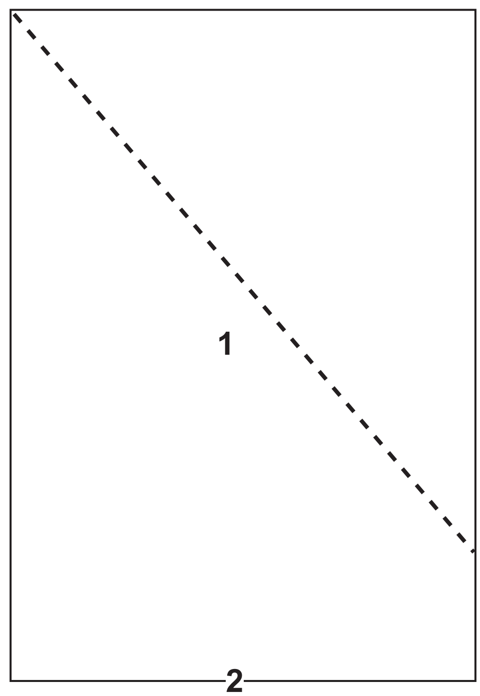
Strike and dip of overturned bedding

Strike and dip of bedding where sedimentary structures were used to confirm stratigraphic tops

Horizontal bedding

Vertical bedding

Strike and dip of cleavage



Previous Geologic Mapping

1 - - - - - - Lonn (1984)
Winston & Lonn (1988)

2 Harrison & others (1986)
(entire area at 1:250,000 scale)

Figure 5. Index of previous mapping in Stark South 7.5' quadrangle.

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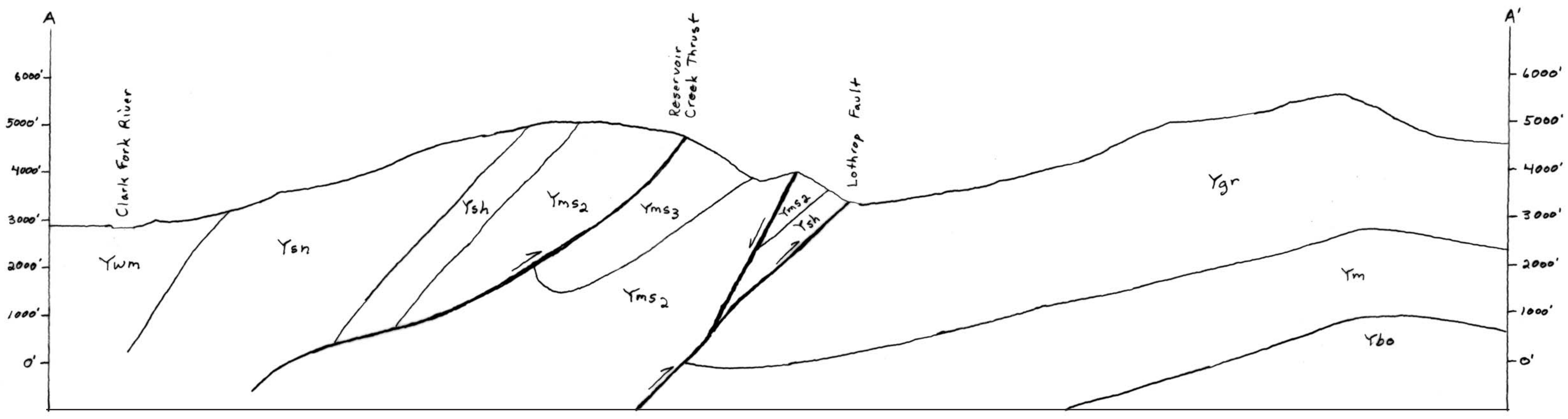
Description of Map Units

Qal	Alluvium of Modern Channels and Floodplains (Holocene)
Qaf	Alluvial Fan Deposits (Holocene)
Qat	Alluvium of Stream Terraces (Pleistocene)
Qgl	Glacial Lake Deposits (Pleistocene)
Qgf	Glacial Flood Deposits (Pleistocene)
Tcg	Conglomerate (Tertiary)
Ꞓh	Hasmark Formation (Upper Cambrian)
Ꞓsh	Silver Hill Formation (Upper or Middle Cambrian)
ꞒYq	Quartzite, Undivided (Middle Cambrian and Middle Proterozoic)
Ygr	Garnet Range Formation (Middle Proterozoic)
Ym	Mcnamara Formation (Middle Proterozoic)
Ybo	Bonner Formation (Middle Proterozoic)
Yms3	Mount Shields Formation, Informal Member 3 (Middle Proterozoic)
Yms2	Mount Shields Formation, Member 2, Informal (Middle Proterozoic)
Ysh	Shepard Formation (Middle Proterozoic)
Ysn	Snowslip Formation (Middle Proterozoic)
Ywm	Wallace Formation, Middle Member, Informal (Middle Proterozoic)

For a more detailed description of the map units and symbols, please refer to the text accompanying this map.



no vertical exaggeration
surficial units not shown

MBMG Open File 351

Geologic Map of Stark South 7.5' Quadrangle Western Montana

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Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S.Geological Survey under Contract Number ____________.

GIS production: Ken Sandau and Paul Thale, MBMG.
Map layout: Susan Smith, MBMG.

Base map produced by the United States Geological Survey
Control by USGS, NOS, NOAA, USFS
Compiled from aerial photographs taken 1977
Field checked 1980; Map edited 1983
Projection – Lambert Conformal Conic
Grid – 1000 meter: Universal Transverse Mercator Zone 11
10,000 foot: State grid ticks: Montana, Central Zone
UTM grid declination – 1°47' East
1983 Magnetic North Declination – 18° 30' East
Vertical Datum – National Geodetic Vertical Datum of 1929
Horizontal Datum – 1927 North American Datum

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Maps may be obtained from: Publications Office
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Butte, Montana 59701-8997
Phone: (406) 496-4167
Fax: (406) 496-4451
http://www.mbmg.mtech.edu