GEOLOGIC MAPS OF THE TARKIO AND LOZEAU 7.5' QUADRANGLES WESTERN MONTANA

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Introduction

The Tarkio and Lozeau 7 ½' quadrangles in westernmost Montana (figure 1) lie 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 2). Various combinations of Precambrian geography and structure have been proposed to explain the Lewis and Clark Line's location (Hobbs and others, 1965; Harrison and others, 1974; Reynolds, 1979; Leach and others, 1988; Winston, 1986a; Sears, 1988), but the 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 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 Tarkio and Lozeau quadrangles straddle a portion of the Lewis and Clark Line that coincides with a northwesterly jog 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 sinistral transpression (Smith, 1965; Lorenz, 1984; Hyndman and others, 1988; Sears and Clements, 2000), dextral transpression (Wallace and others, 1990), rotation of originally north-trending folds through left-lateral (Burmester and Lewis, 2003) or right-lateral (Hobbs and others, 1965) shear, or northeast-directed compression that did not involve lateral movement (White, 1993; Yin and others, 1998). Subsequent Cenozoic extension and/or right-lateral shear (Hobbs and others, 1965; Reynolds 1979; Harrison and others, 1974; Bennett and Venkalakrishnan, 1982; Sheriff and others, 1984; Winston, 1986a; Doughty and Sheriff, 1992; Yin and others, 1998; 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 may resolve some of the conflict.

The Montana Bureau of Mines and Geology (MBMG) selected the Tarkio and Lozeau quadrangles for detailed (1:24,000 scale) mapping because previous detailed work in the area (Campbell, 1960; Lonn, 1984, 2001; Winston and Lonn, 1988; Lewis, 1998a) conflicted with Harrison and others' (1986) interpretation of the regional geology. MBMG expects this work to lead to completion of the Plains 1:100,000-scale quadrangle in 2007.

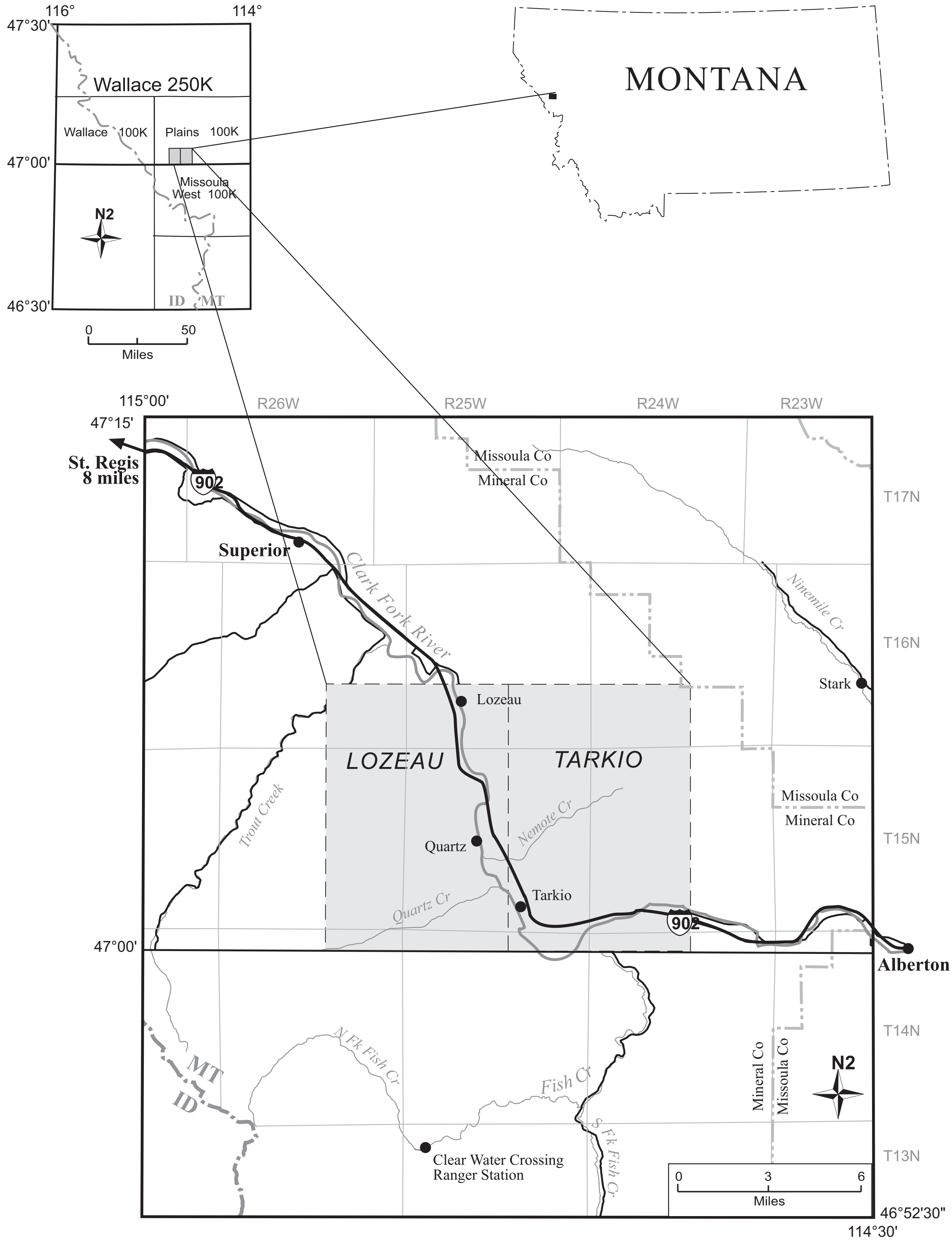


Figure 1. Location map of the Lozeau and Tarkio 7.5' quadrangles.

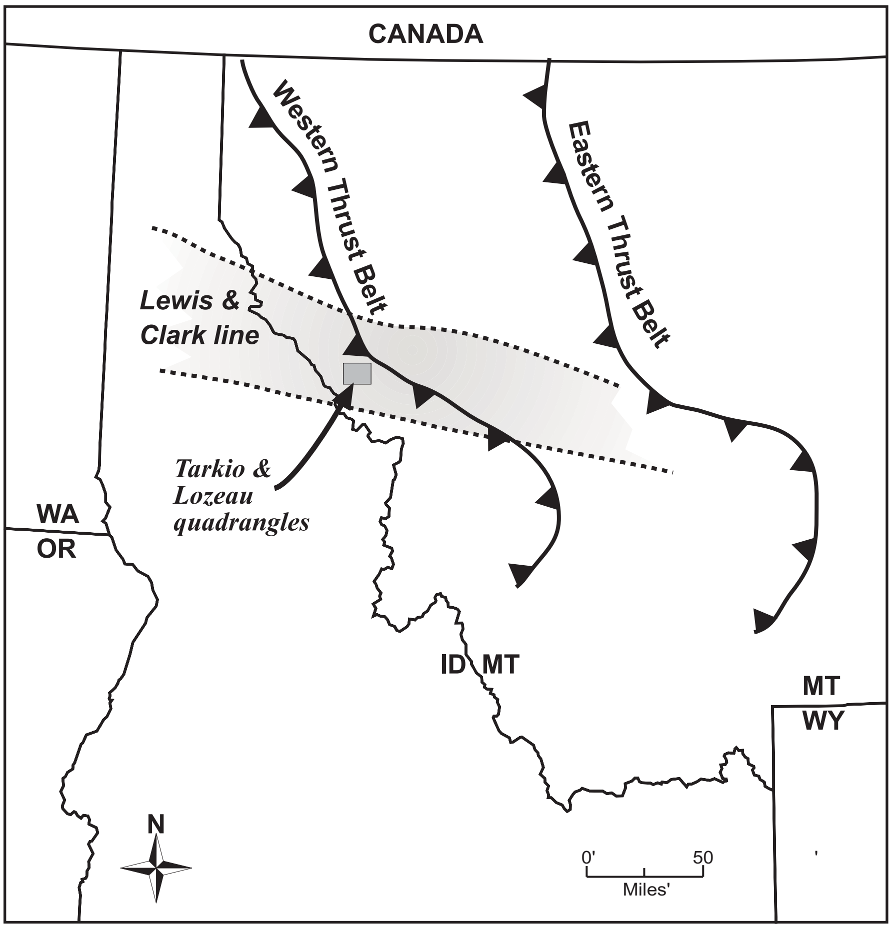


Figure 2. Location of map area with respect to major structural features of western Montana.

Stratigraphy

The Description of Map Units section and the Correlation Chart (p. 8) 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 Tarkio and Lozeau quadrangles include the Belt section from the Middle Wallace Formation through the Pilcher Formation that has a total estimated thickness of 14,400 feet. About 500 feet of the Cambrian section is also exposed.

Unusual lithologies in the Proterozoic Snowslip Formation have produced a great deal of confusion in mapping this region. A 400- to 600-foot-thick quartzite unit at the top of the Snowslip was misidentified as Mount Shields member 2 by Campbell (1960) and Harrison and others (1986) in several localities. And a carbonate-rich zone beneath the Snowslip quartzite appears on Harrison and others' (1986) map as Lower Wallace Formation. These miscorrelations resulted in some complicated structural interpretations. Assignment of these rocks as part of a normal stratigraphic sequence significantly simplifies the structural complexity depicted on those earlier maps.

<u>Quaternary history and deposits</u>

Extensive Quaternary units present on the Tarkio and Lozeau quadrangles 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 to altitudes of about 4,250 feet.

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 beds exhibiting set heights of 6 to greater than 100 feet, and down-river or up-tributary paleocurrents. A 200-foot-tall dune bedform east of Tarkio developed at the mouth of a narrow canyon.

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 drainage of the last lake(s) was more restricted than during the earlier drainages. Networks of dry paleovalleys are incised into glaciolacustrine silt, as can be seen on Quartz Flat in the east-central part of the Lozeau quadrangle. These paleovalleys are interpreted to have been established and abandoned as the last stand of the lake receded. 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 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 empty onto broad valleys.

Structure

The structural geology of the Tarkio and Lozeau quadrangles is characterized by upright, open folds cut by several types and generations of faults figure 3. The folds strike northwesterly and are doubly plunging; however, on a regional scale they plunge gently southeast (Lonn, 1984; Sears and Clements, 2000). Northwest-striking cleavage developed in argillites appears to be axial planar to these folds (Campbell, 1960; Lonn, 1984). The 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). Two major thrust/reverse faults, the Tarkio and Rivulet thrusts, are present in the Tarkio and Lozeau quadrangles. Both have sinuous traces but strike generally northwestward, and both display older-over-younger, southwest-side-up relationships. Behind (southwest of) and closely paralleling both thrusts are southwest-dipping normal faults that merge along strike and probably at depth with the thrusts, producing wedges or lozenges of older rocks surrounded by younger rocks. These unusual and complex fault zones are interpreted as thrusts that have been reactivated by extension (Lewis, 1998a, b; Lonn, 2001).

Another major northwest-striking fault, the Lothrop fault in the northeast corner of the Tarkio quadrangle, may also be a thrust fault that slid back. Although this southwest-dipping fault exhibits normal fault relationships here, it appears to pass southeastward into the Lothrop thrust system near Alberton (Hall, 1968; Wells, 1974; Lonn, 1984; Lewis, 1998a) that consists of a thrust backed by a normal fault (Lonn, 2001) similar to the Tarkio and Rivulet thrusts. Also, although data are preliminary, the Lothrop fault apparently becomes the Osburn fault to the northwest near Superior, Montana, as mapped by Campbell (1960).

The Boyd Mountain fault strikes NW-SE across both the Tarkio and Lozeau quadrangles, and is a major, steeply dipping, northwest-striking fault that post-dates the thrust systems. It shows down-to-the-southwest offset along its entire length. Lonn and McFaddan (1999) interpreted it as a southwest-dipping listric normal fault.

Finally, several east- to northeast-striking high-angle faults with relatively minor displacements offset all the previously described northwest-trending faults. The most prominent of these strikes up Quartz Creek and has been intruded by a quartz-diorite dike that may be associated with gold mineralization present there.

The northwesterly orientation of compressional features within the more west-trending Lewis and Clark Line certainly supports a sinistral transpressive setting along the line during the Cretaceous. The existence of left-lateral tear(?) faults along the Tarkio thrust in the northwest corner of the Lozeau quadrangle and near St. Regis (Lonn and McFaddan, 1999) also lends credence to this theory. The Cenozoic strain history is less

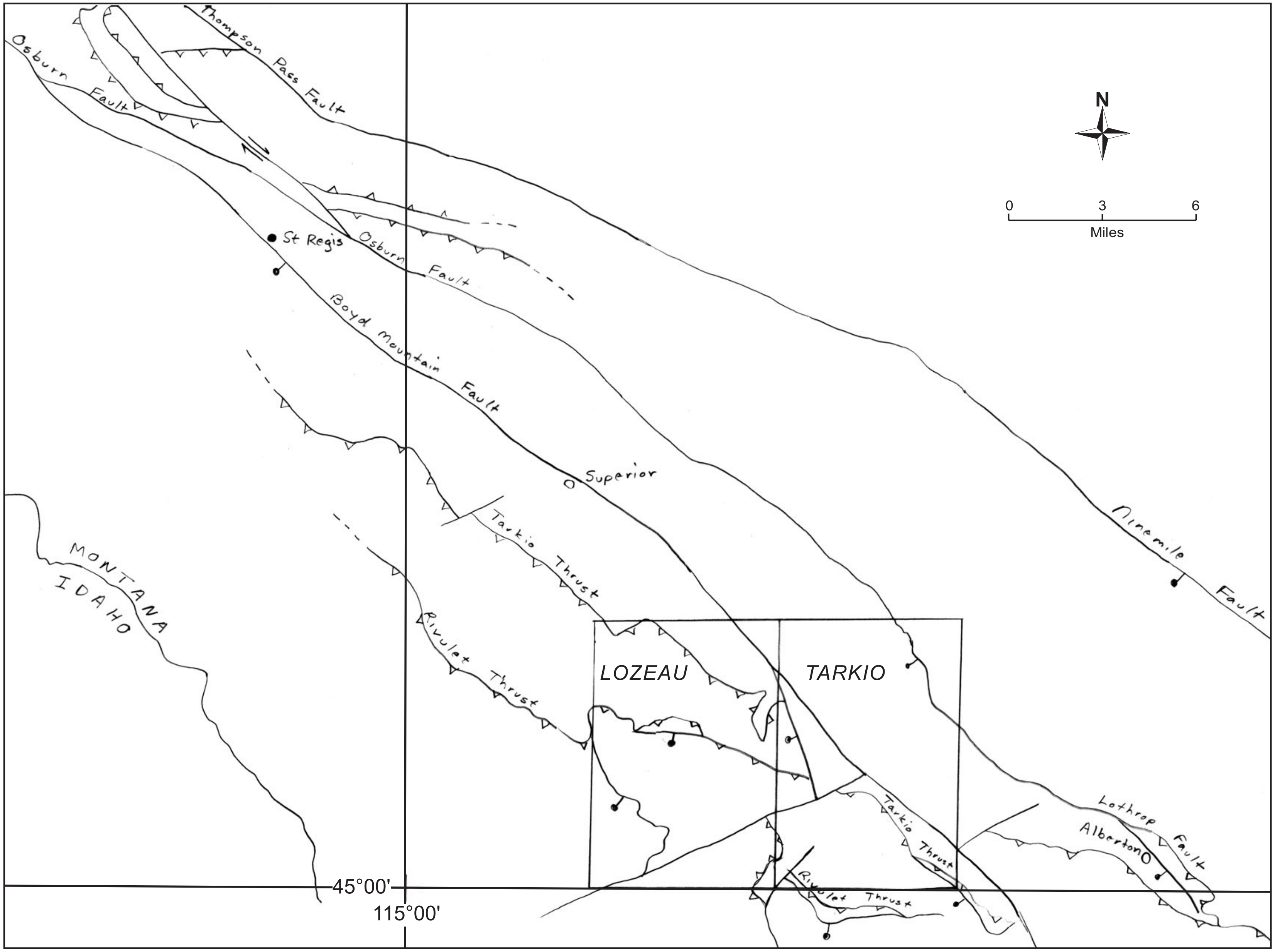
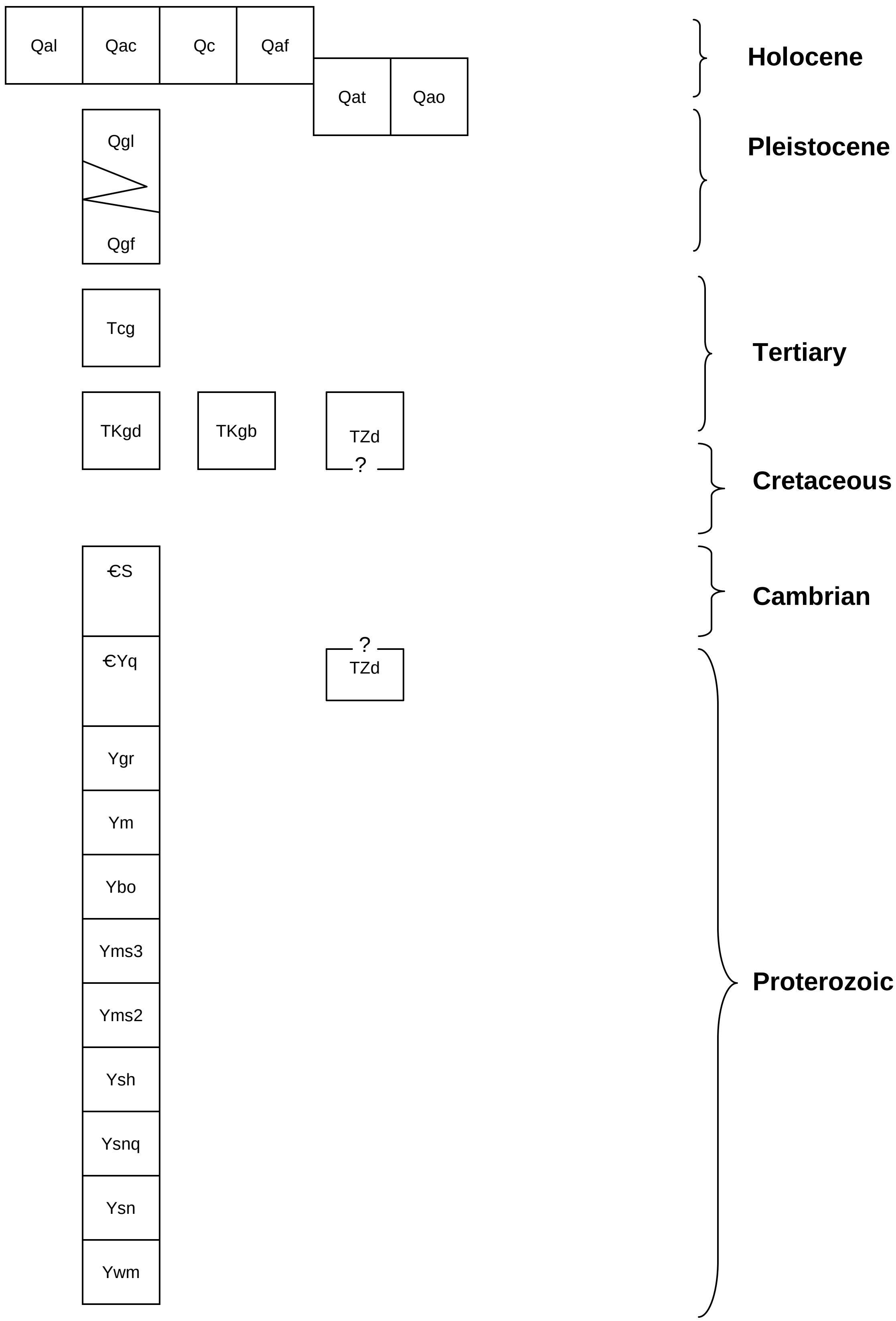


Figure 3. Major faults of the Tarkio/Lozeau region. Compiled from Campbell, 1960; Harrison & others, 1986; Winston & Lonn, 1988; Lonn & McFaddan, 1999; and Lonn, 2001.

clear; Tertiary(?) normal faults strike northwest, northeast, or east, and their orientations may have been influenced by pre-existing fabrics. Near Saint Regis, 10 miles northwest of the study area, Lonn and McFaddan (1999) documented northwest-striking right-lateral faults that postdate the compressive features, but in the Tarkio and Lozeau quadrangles, slip direction on later faults is unknown.



Correlation of map units, Tarkio and Lozeau 7.5’ quadrangles

Description of Map Units

Descriptions of Proterozoic units use the terminology of Winston (1986b) for describing bed types, bed thicknesses, 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.

Qac — ALLUVIUM AND COLLUVIUM (HOLOCENE)
Moderately to well-sorted gravel and sand with subangular to subrounded gravel clasts. Channel, sheetflood, and colluvial slope landforms suggest recent deposition. Typically mapped in forested, poorly exposed, small drainages.

Qc — COLLUVIUM (HOLOCENE)
Poorly to moderately sorted gravel and sand with silty sand matrix; clasts are mostly angular and subangular.

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.

Qao — OLDER ALLUVIUM (PLEISTOCENE)
Gravel and sand in dissected landforms.

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. Commonly incised by low, rolling dry valleys like those on Quartz Flat within the Lozeau quadrangle.

Qgf — GLACIAL FLOOD DEPOSITS (PLEISTOCENE)
Stratified granule through boulder gravel, minor sands, and local 5 to 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. Very large-scale relict bedforms include a dune in T15N, R25W, sec 26 & 35. 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. Underlies benches along the southwest side of Boyd Mountain fault in the northwestern part of the Tarkio quadrangle. Found at elevations up to 4500 feet.

TKgd — GRANODIORITE AND QUARTZ DIORITE (TERTIARY TO CRETACEOUS)
Dikes and sills of dark-colored, altered, equigranular, fine- to medium-grained quartz diorite to granodiorite. A Tertiary to Late Cretaceous age is inferred from their occurrence along Tertiary to Cretaceous fault zones.

TKgb — GABBRO AND DIORITE (TERTIARY TO CRETACEOUS)
Dikes and sills of dark-colored, altered, equigranular, fine- to medium-grained gabbro, diabase, and diorite. A Tertiary to Late Cretaceous age is inferred from their occurrence along Tertiary to Late Cretaceous fault zones.

TZd — GABBRO AND DIORITE (LATE PROTEROZOIC OR TERTIARY TO CRETACEOUS)
Dark-colored gabbro and diorite sills and dikes of uncertain age. Although Harrison and others (1986) assigned a late Precambrian age to all mafic igneous rocks in the region based on K-Ar isochronology (Obradovich and Peterman, 1968) of a sill near Alberton, Montana, east of the study area, similar rocks commonly occur along Tertiary to Cretaceous faults, suggesting that some may be as young as early Tertiary.

€s — SEDIMENTARY ROCKS, UNDIVIDED (UPPER AND MIDDLE CAMBRIAN)
Includes the carbonate-rich formations above the Middle Cambrian Flathead Formation, divided into Red Lion, Hasmark, and Silver Hill Formations by Wells (1974) in the Alberton quadrangle 6 miles east of the study area. The Silver Hill 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. The Hasmark consists of 400 feet of gray, massive to mottled dolomite. The lower Red Lion consists of black shale and pink dolomite lenses. (Campbell, 1960; Wells, 1974).

€Yq — 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 sandstone is medium- to coarse-grained, white to red, massive to cross-bedded, vitreous quartzite. Thickness of this unit is 50-250 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. Mostly even couple and couplet sediment types, and distinguished by rusty yellow weathered surfaces and abundant detrital mica. Approximately 900 feet thick in the map area.

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 chips. Dominated by mudcracked even couplet and mudcracked lenticular couplet sediment types. About 1500 feet thick in the map area; Wells (1974) and Hall (1968) estimated it to be 4000 feet thick about 10 miles east of the map area.

Ybo BONNER FORMATION (MIDDLE PROTEROZOIC)
Pink, medium- to coarse-grained feldspathic, cross-bedded quartzite. Contains some granule-sized grains, and locally includes micaceous, maroon-colored argillite interbeds. Samples slabbed and stained for potassium feldspar show potassic feldspar content greater than plagioclase in contrast to the Mount Shields member 2. Mostly comprised of the cross bedded sandstone sediment type. Thickness 1400 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. Thickness 2600 feet.

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. Difficult to distinguish from the quartzite facies of the Snowslip Formation (Ysnq). 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. Up to 3800 feet is present.

Ysh SHEPARD FORMATION (MIDDLE PROTEROZOIC)
Dolomitc 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 800-1000 feet.

Ysnq SNOWSLIP FORMATION, QUARTZITE FACIES (MIDDLE PROTEROZOIC)
Gray to pink, fine-grained, flat-laminated quartzite. Contains some tan weathering dolomitic blebs and beds. Difficult to distinguish from the Mount Shields Formation member 2, and has been misidentified as such on many previous maps in the region (Hall, 1968; Campbell, 1960; Harrison and others, 1986). Thickness 400 to 600 feet.

Ysn SNOWSLIP FORMATION, GREEN AND BLACK FACIES, UNDIVIDED (MIDDLE PROTEROZOIC)
The upper part is dolomitic and non-dolomitic dark-green siltite and light-green argillite in cracked and uncracked even couplets and microlaminae. Also includes some lenticular couplets of white quartzite and green siltite. The lower half is comprised mainly of dark-green siltite and purple to dark-gray argillite in undulating, uncracked couplets. The carbonate-rich upper part is difficult to distinguish from the Shepard Formation, and has also been confused with the lower member of the Wallace Formation (Harrison and others, 1986). The lower part of the Snowslip resembles the correlative upper member of the Wallace Formation of northwestern Montana and northern Idaho (Harrison and others, 1986, 1992). Thickness about 3000 feet.

Ywm WALLACE FORMATION, MIDDLE MEMBER, INFORMAL (MIDDLE PROTEROZOIC)
Upper part is the dinstinctive “black and tan” lithology comprised of tan weathering dolomitic 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. The lower part exposed in the map area is white, fine-grained quartzite that grades upward to tan, dolomitic siltite and argillite in uncracked undulating and even couplets. This lithology also contains the sedimentary breccia common to the Wallace Formation that is comprised of angular white quartzite clasts in a matrix of punky, orange-weathering silty dolomite. The breccia weathers into spires and hoodoos. Molar tooth structure and non-polygonal crinkle cracks are common throughout the section. Severe internal deformation makes thickness estimates problematic, but it appears that more than 5000 feet is present.

MAP SYMBOLS


Contact: dashed where approximately located; dotted where concealed

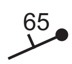

Reverse or thrust fault: teeth on upthrown block; dotted where concealed


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


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

Strike and dip of bedding

Strike and dip of overturned bedding



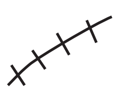
Strike and dip of bedding where sedimentary structures were used to confirm statigraphic tops

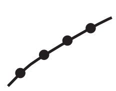

Horizontal bedding


Vertical bedding


Strike and dip of cleavage

Strike and dip of foliation


Dikes and sills composed of granodiorite and quartz diorite


Dike and sills composed of gabbro and diorite

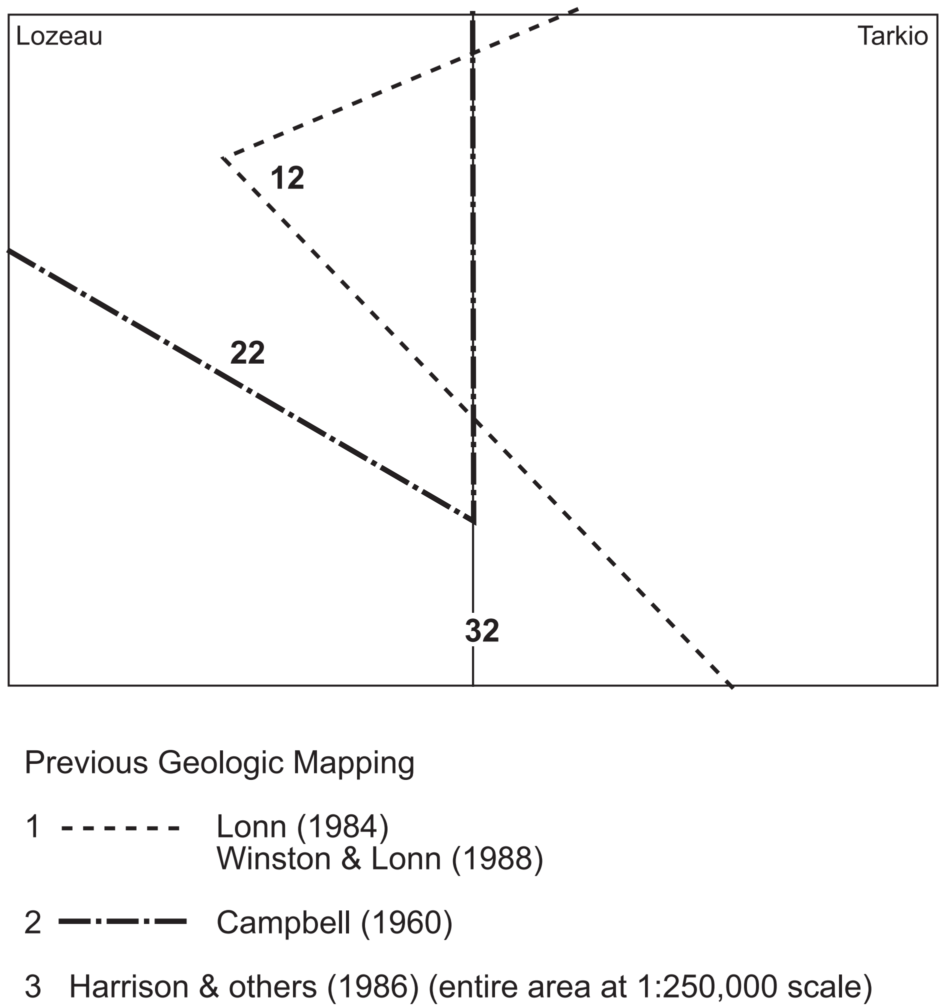


Figure 4. Index of previous mapping in Tarkio and Lozeau 7.5' quadrangles.

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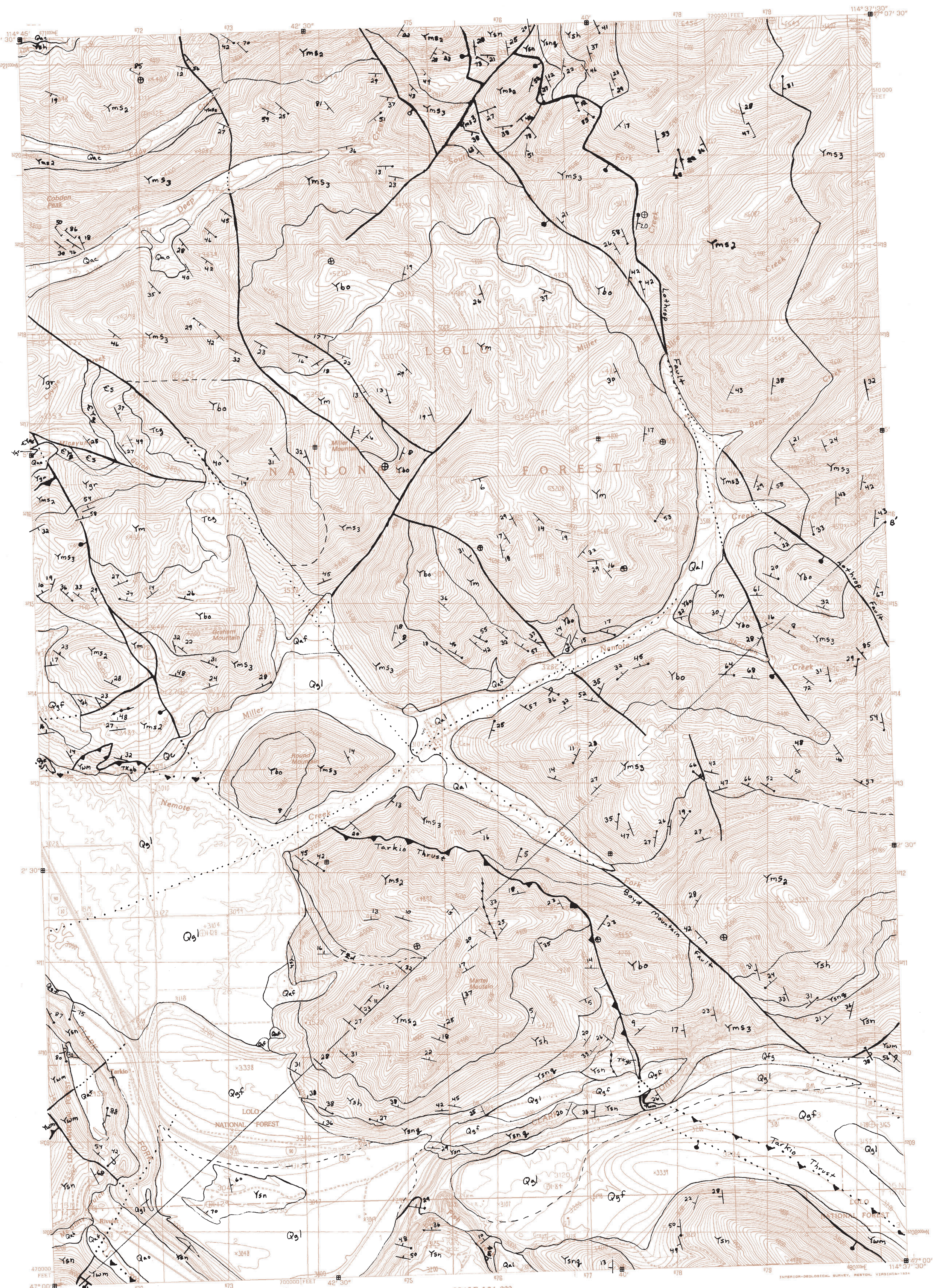

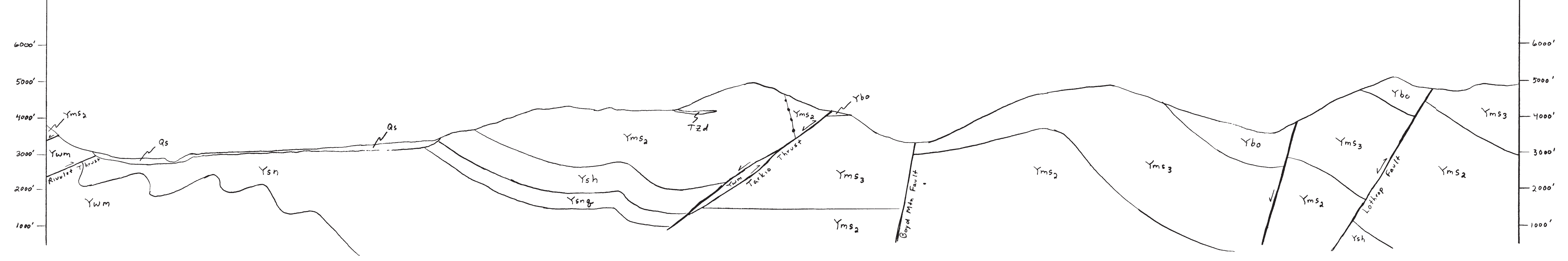

no vertical exaggeration
Qs = surficial deposits, undivided

MBMG Open File 516, Plate 2

Geologic Map of Tarkio 7.5' Quadrangle Western Montana

Jeffrey D. Lonn and Larry N. Smith

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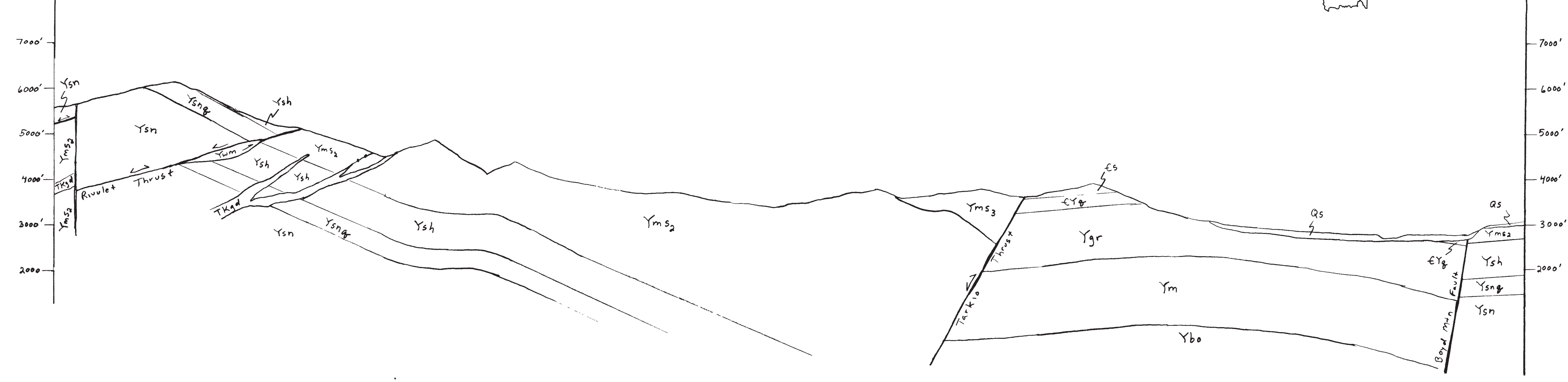

no vertical exaggeration
Qs = surficial units, undivided

MBMG Open File 516, Plate 1

Geologic Map of Lozeau 7.5' Quadrangle Western Montana

Jeffrey D. Lonn and Larry N. Smith

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