Montana Bureau of Mines and Geology

GEOLOGIC MAP OF THE MONTANA PART OF THE WALLACE 30' x 60' QUADRANGLE

by

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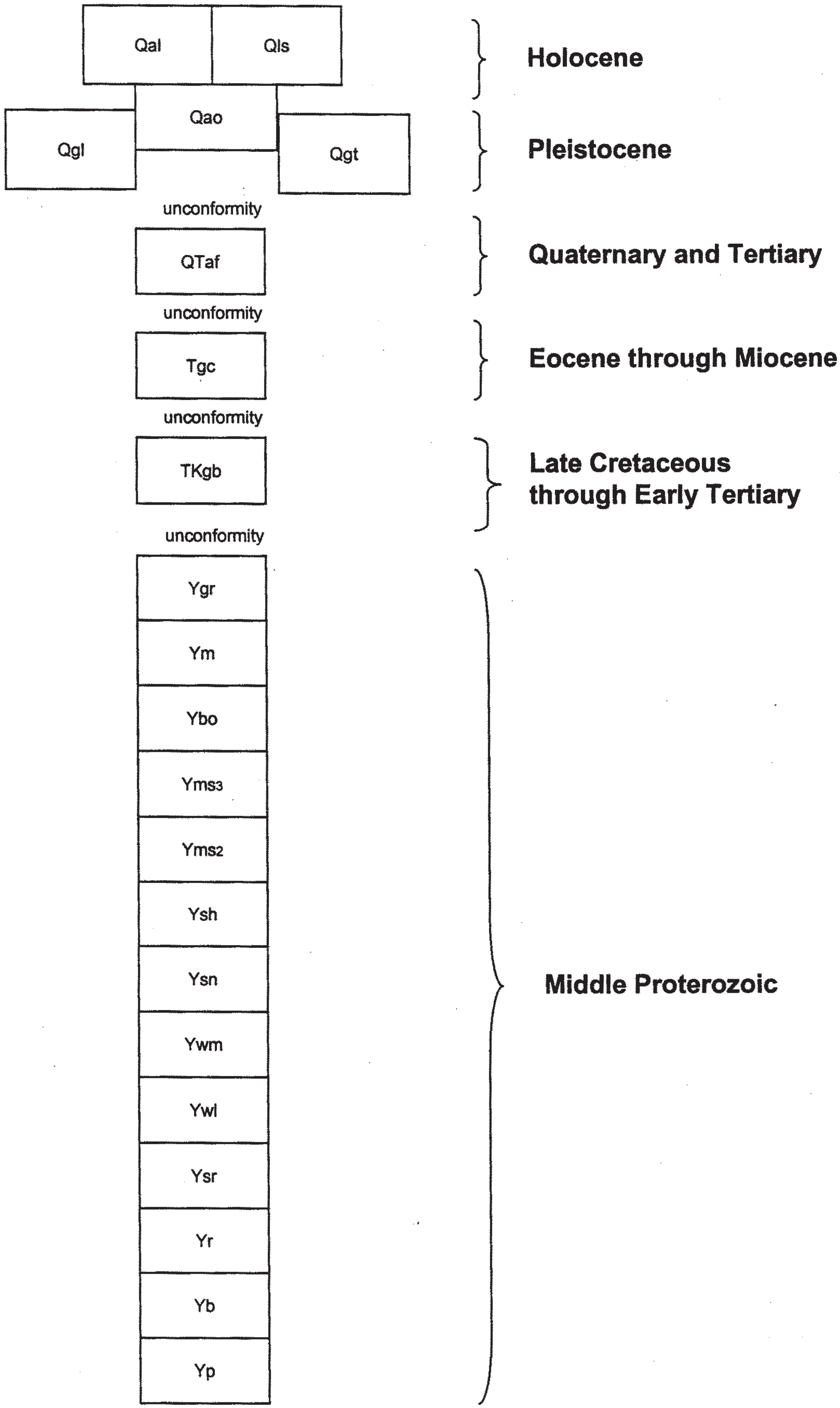


Figure 1. Age correlation of map units.

Introduction

The Wallace 30' x 60' quadrangle contains structures critical to understanding the tectonic history of western Montana, but the area has been largely neglected by mapping geologists. In 1998, the joint U.S. Geological Survey/Montana Bureau of Mines and Geology STATEMAP project funded new mapping of the Montana portion of the Wallace quadrangle. Although Harrison *et al.* (1986) had compiled existing mapping (Calkins and Jones, 1912; Wallace and Hosterman, 1956; Campbell, 1960) and added some original mapping at the 1:250,000 scale, we remapped most of the area in an effort to unravel the structural complexities. Lewis *et al.* (1999) mapped the adjoining Idaho portion of the Wallace quadrangle. Unpublished mapping of some Revett Formation exposures by Appelgate and Lafco (1981) was invaluable in pointing the way towards some key areas. Additionally, structural geology has been well studied in the Coeur d'Alene mining district immediately to the west, and this knowledge has been instrumental in deciphering the geologic history of the Wallace quadrangle.

Stratigraphy

Figure 1 and the Description of Map Units provide a detailed description of the stratigraphy in this quadrangle. Most of the area is underlain by metasedimentary rocks of the Middle Proterozoic Belt Supergroup. The Wallace quadrangle includes the Belt section from the upper Pritchard Formation up through the Garnet Range Formation, probably representing a 10,700-meter thickness of Belt section. However, intraformational folds and faults have tectonically thickened many units, and thickness estimates should be viewed with suspicion. Note that even on the cross sections there is considerable variation in formation thicknesses.

Thin, mafic dikes and sills have intruded the Belt rocks. Paleozoic and Mesozoic rocks that were presumably deposited in the area have all been eroded. Unconsolidated Tertiary through Quaternary sedimentary deposits cover the bedrock in some areas.

Structure

The Wallace quadrangle lies at the intersection of two major tectonic features, Montana's western thrust belt and the Lewis and Clark line (figure 2). In the area, a complex episode of Cretaceous compression was followed by Cenozoic extensional and dextral movement.

<u>Compressive Tectonism</u>

Compressional fabrics dominate the structural geology of the map area. Cretaceous compression produced asymmetric to overturned, northeast-verging folds, a prominent cleavage, and sinuous and anastomosing fault systems. The compressional history may be quite complex. Folds have west-northwest-striking axial planes within the Lewis and Clark line, and north-striking axial planes both north and south of the line. Transection cleavage (Reid *et al.*, 1991) has developed subparallel to these axial planes and changes strike with them. Cleavage is most intensely developed in a 8-10 km-wide zone on the north side of the Osburn-Boyd Mountain

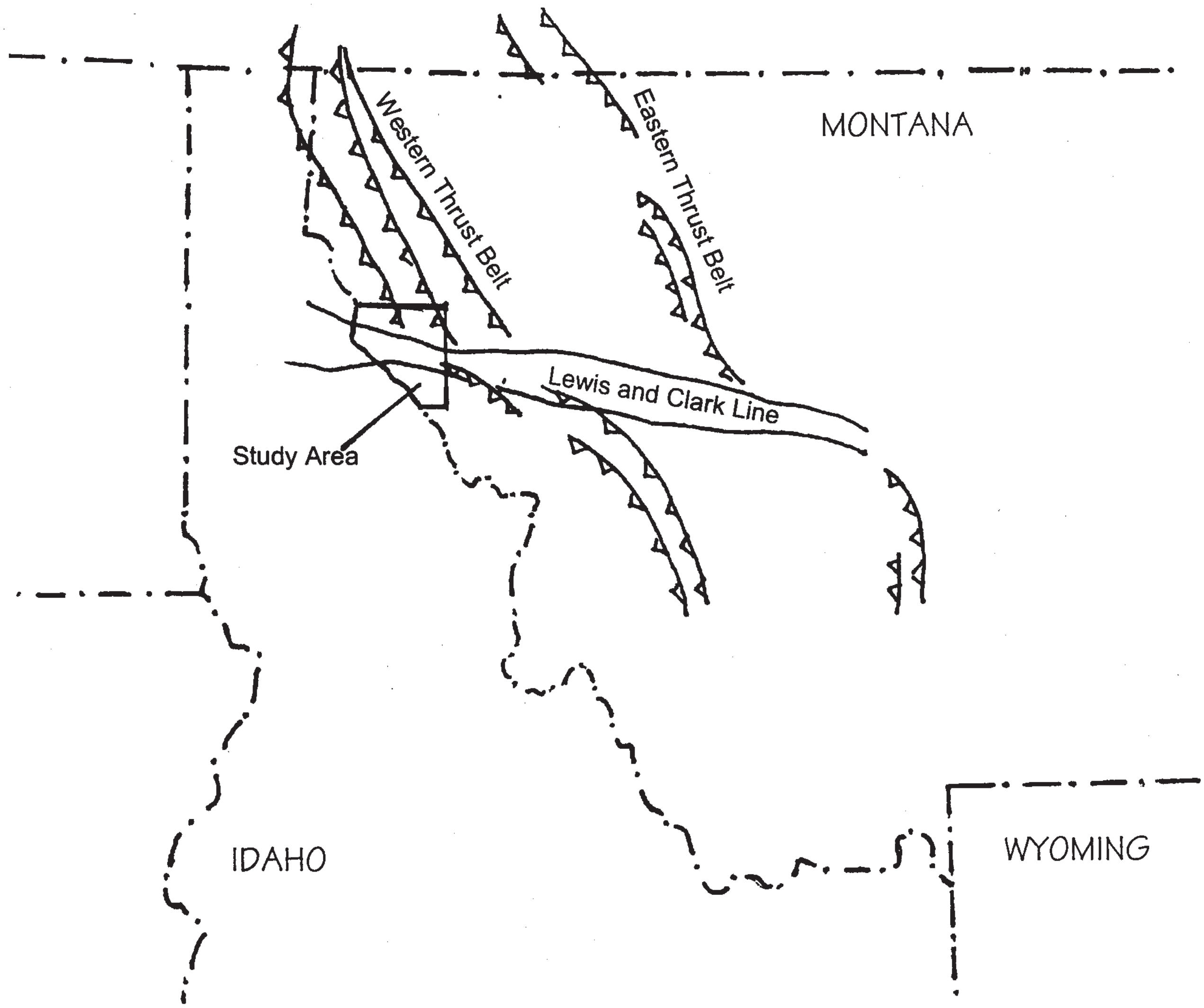


Figure 2. Study area in relation to major structrual features of western Montana.

fault. In the steep, anastomosing, mostly southwest- to west-dipping fault systems, reverse and normal faults are closely associated and commonly merge. Both types of faults likely formed simultaneously during the compressional regime. Reid *et al.* (1995) attributed similar fault systems in the nearby Coeur d'Alene mining district to compressional stress acting in a somewhat ductile environment through constriction fracture flow. They likened these fault systems to a series of steep, south-dipping, oval rods, some of which moved relatively up and others relatively down, with overall reverse displacement exhibited. In the Wallace quadrangle, faults of this type are difficult to discern because they show little stratigraphic offset and are nearly parallel to bedding and have only minor gouge zones so topographic expression is subtle. Undoubtedly, many more of these faults exist than are shown on the map. These faults often die out or are lost when their traces enter the carbonate-rich Wallace Formation. There, shortening was more likely to be accommodated by tight folds.

Our fundamental view, which will need more field corroboration, is that folds, faults, and cleavage were formed through one compressional event and that they acquired their various orientations as thrust plates encountered a basement buttress or changes in stratigraphy across the Lewis and Clark line (Harrison *et al.*, 1974; Sears, 1983; Winston, 1986; White, 1993). However, White (1993) documented superposed north- and west-northwest-trending fold systems in the Coeur d'Alene mining district, and postulated three unrelated tectonic events to form the compressional features. The first event formed the tight west-northwest-trending folds within and south of the Lewis and Clark Line, the second overprinted the north-trending folds that are obvious from map patterns north of the Lewis and Clark line, and the third formed the cleavage and related fault systems, which, moreover, are associated with Coeur d'Alene mineralization. Whether there were three tectonic events or one single event, the important point is that compressive tectonics were responsible for both the west-northwest and north folds, the cleavage, and the sinuous fault systems. These features in large part define the Lewis and Clark line.

Dry Creek Fault

The Dry Creek Fault provides an interesting example of changes in compressive structural style. Detailed mapping has shown the fault to consist of two reverse fault segments that are offset and linked by a steep lateral ramp or a tear fault (figure 3). On the northern segment, the reverse fault breaks from the forelimb of an overturned anticline. Shortening is accommodated by both tight folds and the reverse fault, and the fault dies into the folds to the north. On the southern segment, stratigraphic displacement across the fault is greater and faulting takes up most of the shortening. Folds are broad and open. A high angle fault that we interpret as a tear fault joins the two segments.

Backthrusts and the Camel's Hump Structure

Compression also formed some north-dipping reverse faults, interpreted as backthrusts, and southwest-verging asymmetric to overturned folds. One of these backthrusts comprises part of the Camel's Hump structure (plate 2, cross section BB'). This unusual structure consists of two parallel, upwardly convergent reverse faults and associated folds of opposing vergence. Because it is remarkably regular and persistent over a strike length of 35 km, it can be used to

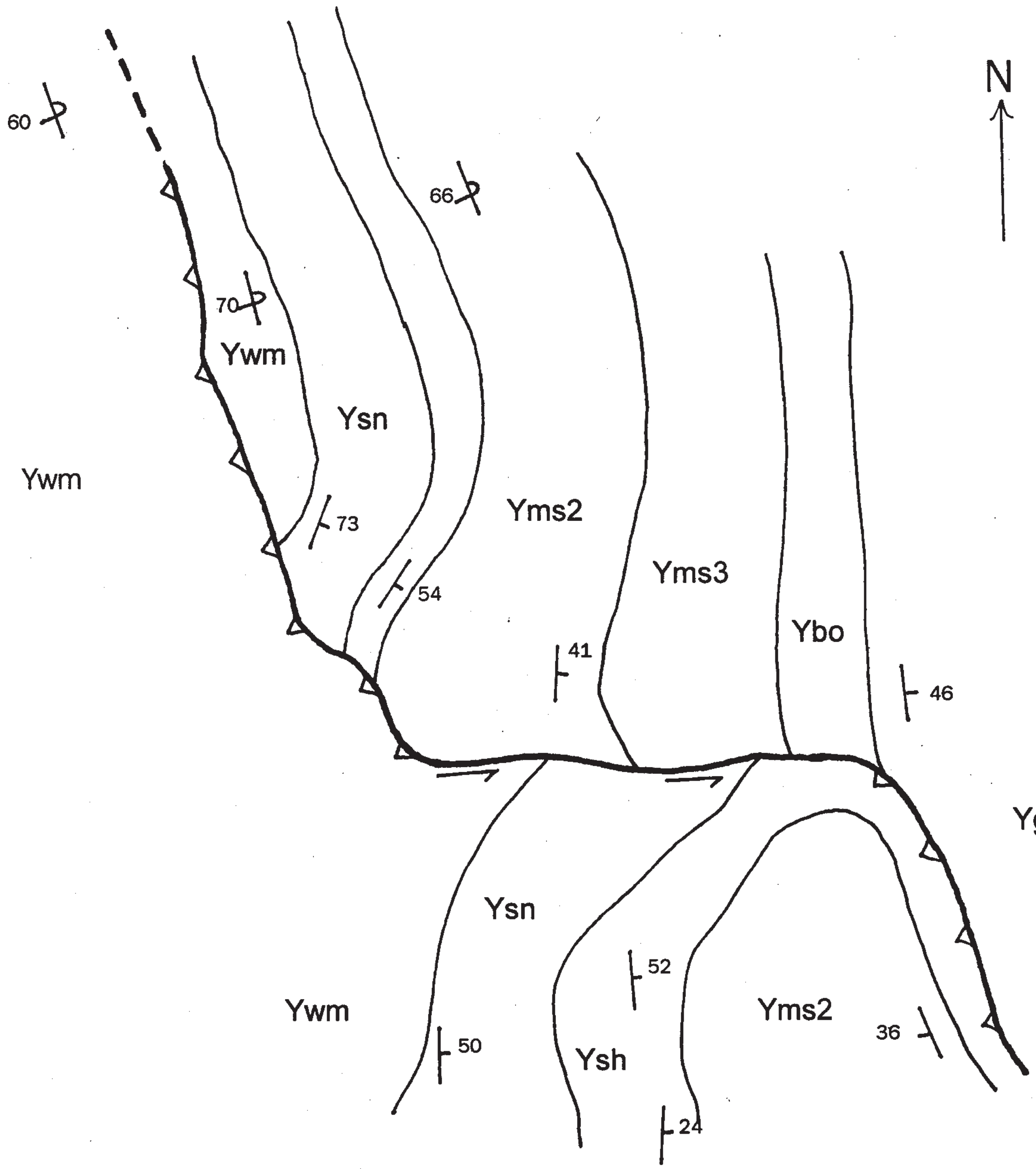


Figure 3. Simplified sketch of the Dry Creek fault showing greater eastward transport of the segment south of the proposed tear fault. This southern segment was named the Campground fault by Campbell (1960).

decipher the post-compressional tectonic history. Perhaps as a result of the north-trending fold event (White, 1993), it was refolded into the northeast-trending synform obvious on the map, called the Flat Rock syncline by Wallace and Hosterman (1956). The refolded Camel's Hump structure was subsequently cut by straight, high-angle faults. Two kilometers of apparent right-lateral offset can be documented along one of these faults. These faults must have formed in the same tectonic regime as the well known Osburn and Boyd Mountain faults.

<u>Extension and Right-Lateral Shear</u>

Both normal and right-lateral faults exist and are difficult to distinguish from one another. In fact, many faults probably have both strike-slip and dip-slip components. The Osburn fault bounds a well defined mountain front with associated fan deposits, and Tertiary deposits are tilted 30-35^{o} into the Boyd Mountain fault. Both of these faults probably have some dip-slip movement component and may be listric. Yin *et al.* (1993) actually found no kinematic indications of strike slip movement on the Osburn, Ninemile, Placer Creek, or Hope faults, and suggested that they are late Cretaceous thrusts reactivated by mid-Tertiary extension. Reid *et al.* (1993) postulated that the Osburn fault represents a late brittle break localized along the southern margin of a zone of intense ductile deformation (the Terror fault zone) that formed during compressive tectonism and that may extend eastward as far as Superior. Undoubtedly, some reverse faults did backslide and now show normal offset.

White (1993) felt that extension occurred before strike-slip faulting. However, strike slip movement may have occurred as part of the extensional event (Sheriff *et al.*, 1984), which began in the Eocene epoch and continued until at least the late Tertiary period. Unlike the compressional fault systems, these late normal and right lateral faults are straight, have wide gouge zones, and are topographically well-expressed. Most faults of this type strike west-northwest and appear to be concentrated along the Lewis and Clark line; like the west-northwest-trending compressional features, they help delineate the line.

<u>Lewis and Clark Line</u>

In the Wallace quadrangle, Cretaceous and Tertiary structures appear to define the Lewis and Clark line. These defining structures--the fold belt, the compressive fault systems, and the high-angle normal and strike-slip faults--all display anomalous, for northwestern Montana, west-northwest trends. These anomalous trends actually express the Lewis and Clark line, but they were formed through a series of unrelated tectonic events. Although there is no evidence for Precambrian movement on any of these features, they must have been caused by changes in Belt stratigraphy or by some feature in the basement that formed during Precambrian time. Thus, evidence in the Wallace quadrangle supports the conclusion that the Lewis and Clark Line is a late Cretaceous and Cenozoic expression of a Precambrian feature as previously suggested (Harrison *et al.*, 1974; Winston, 1986; Sears, 1983; White, 1993).

Description of Map Units

Differentiating Belt Supergroup units in the field is difficult, and describing them so others can recognize them is even more problematic. Neither grain size, nor color, nor mineralogy can be used to distinguish the formations. Argillite, siltite, and quartzite are found in virtually every formation; color is mostly a diagenetic or metamorphic feature, and mineralogy is quite uniform. Winston (1986b, 1998) proposed using Belt sediment types in conjunction with these conventional modifiers to define the Belt formations. Below, we have included the dominant sediment types (after Winston 1986b, 1998) for each unit as well as criteria we feel are diagnostic of the formation.

Qal ALLUVIUM OF MODERN CHANNELS AND FLOODPLAINS (HOLOCENE)
Well rounded, well sorted cobbles, gravel, and sand deposited in active stream channels and floodplains. Provenance appears to include all of west-central Montana.

Qls LANDSLIDE DEPOSITS (HOLOCENE)
Unsorted and unstratified mixtures of angular material that have been moved down slope by gravity. Landslides are uncommon in areas underlain by Belt rocks. The most dramatic example of a landslide in the Wallce quadrangle is the Little Joe Slide (T17N R29W sec 36) that formed catastrophically in 1968.

Qao OLDER ALLUVIUM (PLEISTOCENE?)
Well sorted, well rounded boulders, cobbles, gravel, sand, and silt deposited by streams, then incised by modern streams and now stranded up to15 m above the present watercourses. Includes both terrace deposits along rivers and outwash fan deposits emerging from the mountains.

Qgl GLACIAL LAKE DEPOSITS (PLEISTOCENE)
Light tan to light brown, varved silt and clay deposited in Glacial Lake Missoula. Supports vertical cuts along streams and in road cuts. On topographic maps, forms flat surfaces that are usually dissected into a badlands topography.

Qgt GLACIAL TILL (PLEISTOCENE)
Unsorted, unstratified clay- through boulder-sized material deposited in glacial moraines; only found above 1250 m in elevation. Many small moraines in the mountain valleys are not shown on the map.

QTaf ALLUVIAL FAN DEPOSITS (QUATERNARY AND LATE TERTIARY)
Locally derived, poorly sorted, subangular to subrounded boulders, cobbles, gravel, sand, and silt deposited in fans along the mountain front just south of the Osburn Fault. Surfaces of these dissected fans generally stand 60 m above the present streams.

Tgc FLUVIAL GRAVEL AND CLAY (EOCENE THROUGH MIOCENE ?)
Mostly fluvial channel deposits of well rounded, well sorted boulders, cobbles, pebbles, and sand. Clasts of Bonner Formation, and some of granitic rocks and porphyritic volcanic rocks are from outside the area. Found up to 1500 m in elevation, and interpreted to have been deposited by the ancient Clark Fork River system. South of St. Regis, along the Boyd Mountain Fault, these rocks dip into the fault at 30^{o} and indicate late Tertiary, listric, normal movement on the Boyd Mountain Fault.

TKgb GABBROIC AND DIORITIC DIKES AND SILLS (LATE CRETACEOUS THROUGH EARLY TERTIARY)
Medium- to fine-grained, equigranular hornblende-pyroxene gabbro and diorite. A Late Cretaceous-Early Tertiary age is inferred for dikes and sills from their common occurrence along faults, although Harrison *et al.* (1986) assigned a late Proterozoic age to some.

Ygr GARNET RANGE FORMATION (MIDDLE PROTEROZOIC)
Greenish-gray, micaceous, tabular and lensoidal, hummocky cross-stratified, fine-grained quartzite with argillite interbeds. Some chert chips and beds in the lower part. Entire thickness is not exposed, but thickness is probably about 1000 m (Lewis, 1998).

Ym MCNAMARA FORMATION (MIDDLE PROTEROZOIC)
Dense, bright green and red interbedded siltite and argillite in microlaminae and couplets. Mudcracks and chips are common. Contains diagnostic thin chert beds and chips. The upper part contains some pink to gray cross-bedded quartzite in beds less than 0.5 m thick. Dominated by mudcracked even couplet and mudcracked lenticular couplet sediment types. Whole unit not exposed, but between 600 and 900 m thick.

Ybo BONNER FORMATION (MIDDLE PROTEROZOIC)
Pink, medium-grained, feldspathic, cross-bedded quartzite. Lewis (1998) found 15-25% potassium feldspar but only a trace of plagioclase in the Bonner Formation. Mostly comprised of the cross-bedded sand sediment type. The sole exposure in the Wallace quadrangle is fault bounded, but it is probably 300 m thick.

Yms3 MOUNT SHIELDS FORMATION, MEMBER 3 (MIDDLE PROTEROZOIC)
Red siltite to argillite couplets with abundant mudcracks, mud chips, and salt casts. Mostly mudcracked even couplet and mudcracked lenticular couplet sediment types. About 600 m thick.

Yms2 MOUNT SHIELDS FORMATION, MEMBER 2 (MIDDLE PROTEROZOIC)
Pink to gray, flat-laminated, fine-grained quartzite, with tan weathering dolomitic blebs. Some cross bedding, which can make it difficult to distinguish from the Bonner Formation. However, in contrast to the Bonner, Lewis (1998) found subequal amounts of plagioclase and potassium feldspar in the Mount Shields for a total feldspar content of

25-35%. Characterized by the flat-laminated sand sediment type; about 900 m thick.

Ysh SHEPARD FORMATION (MIDDLE PROTEROZOIC)
Distinguished by dark green siltite and light green argillite in microlaminae and couplets that are dolomitic and have a characteristic orange-brown weathering rind. Poorly exposed but weathers into thin plates. Some 2-5 cm thick white quartzite beds are present in the upper part. Common sediment types are calcareous microlaminae and calcareous uncracked (non-mudcracked) even couplets. Estimated to be 250 m thick.

Ysn SNOWSLIP FORMATION (MIDDLE PROTEROZOIC)
Mostly silver-green siltite and argillite in planar parallel beds 2-5 cm thick that weather into small blocky pieces with a characteristic spotted, rusty-red-on-green appearance. There are some green siltite-argillite laminae, especially near the base. Mudcracks are abundant. Some fine-grained pure quartzite is present in beds less than 0.5 m thick, especially in the lower part. Dominant sediment types are mudcracked even couplet and mudcracked lenticular couplet. Faults must complicate thickness estimates, because apparent thicknesses range from 600 to 900 m in the quadrangle.

Ywm WALLACE FORMATION, MIDDLE MEMBER (MIDDLE PROTEROZOIC)
Tan weathering dolomitic siltite and quartzite is capped by black argillite in pinch and swell couplets and couples to form a distinctive rock. The quartzite and siltite often have scoured or load-casted bases. “Birdsfoot” cracks common in black argillite. Carbonate-rich beds have molar-tooth structures. Sedimentary breccia, consisting mostly of white quartzite clasts in punky, orange weathering silty dolomite, is common, although we believe some sedimentary breccia zones shown by Campbell (1960) are actually tectonic in origin. The breccia weathers into spires and hoodoos. Euhedral scapolite crystals are present near faults. Severe deformation within this unit makes thickness estimates problematic, but it is no more than 2000 m.

Ywl WALLACE FORMATION, LOWER MEMBER (MIDDLE PROTEROZOIC)
Consists of cycles, from 1 to 10 m thick and usually incomplete, of a basal white quartzite or intraclast unit, overlain by uncracked (non-mudcracked) even and lenticular couplets of green siltite and argillite, and capped by dolomitic beds. However, these cycles are difficult to recognize in the typical small outcrop. The unit is more easily recognized by wavy but parallel, silver-green couplets of darker green siltite and lighter green argillite, by white quartzite, by beds of tan or brown weathering dolomite from 0.5 to 1 m thick, and by weathered-out pods of carbonate in the green siltite. Some mudcracked intervals exist. About 150 m above the base of this unit is an interval of abundant thick black argillite beds and some pinch and swell couplets capped by black argillite like those of the middle member of the Wallace Formation. This is probably the severely deformed interval displayed in the footwall of the Camel’s Hump structure. Carbonate mud and uncracked (non-mudcracked) even couplets are the principal sediment types. The severity of deformation within the lower Wallace makes thickness

unknown, but it is probably about 1250 m.

Ysr SAINT REGIS FORMATION (MIDDLE PROTEROZOIC)
Identified by gray-purple or, more commonly, bright green mucracked silt to clay couplets with abundant mud chips. Dolomitic silt beds in the upper part weather to a siderite-colored brown, darker than the carbonate in the Wallace Formation. Toward the base, gray-purple, flat-laminated quartzite beds 10 to 30 cm thick become common. Down section in the Revett Formation, the thickness of these sands increases to 0.5 to 1 m and mud cracks and chips become uncommon. Comprised mainly of mudcracked even couplet, mudcracked lenticular couplet, and even couple sediment types. Thickness is estimated at 850 m.

Yr REVETT FORMATION (MIDDLE PROTEROZOIC)
There are three informal members, here undivided. The uppermost member is white to purple or lavender, banded medium-grained quartzite in 1-2 m thick beds. Quartzite beds are capped by green argillite, 5-10 cm thick, that is not obvious in outcrop. Very thin mud skins and associated mud chips are common. Quartzite can be either flat-laminated or cross-bedded, but is a distinctive rock commonly containing intersecting purple liesegang bands and purple cross-beds. The middle member consists mostly of gray-green siltite and argillite in indistinct wispy beds 5-20 cm thick. Load, pillow, and fluid escape structures are common. Some mud cracks and chips are present. This member is mostly of the discontinous layer sediment type. The lowermost member is banded quartzite very similar to the upper unit. The contact with the Burke Formation is gradational and somewhat arbitrary, and placed where the quartzite beds thin to less than 1 m. The Revett is 900 to 1250 m thick.

Yb BURKE FORMATION (MIDDLE PROTEROZOIC)
Poorly exposed and relatively unknown. The uppermost part is purple-gray to white, flat-laminated and cross-bedded sercitic quartzite in beds 0.3-1 m thick interbedded with green siltite. Flat-laminated sand and even couples characterize the sediment types. The middle and lowermost parts contain purple, or alternating green and purple, mudcracked siltite-argillite couplets with abundant mud chips. In the siltite, abundant euhedral magnetite grains may be diagnostic. This part is mainly mudcracked even couplet and mudcracked lenticular couplet sediment types. Approximately 900 m thick.

Yp PRITCHARD FORMATION (MIDDLE PROTEROZOIC)
The upper part consists of pyritic, black and gray, evenly laminated argillite and siltite couplets and couples. Lower in the section, flat-laminated, gray, fine-grained, micaceous quartzite predominates. The whole formation weathers a rusty brown from the abundant pyrite and pyrrhotite. Principal sediment types are plane-laminated silt and clay, flat-laminated sand, and even couples. The entire formation, not exposed in the Wallace quadrangle, is probably more than 6000 m thick.

Sources of Previous Geologic Mapping (figure 4)

1) Appelgate, L., and Lafco, E., 1981, Cabinet Mountains reconnaissance program geologic map: unpublished mapping of scattered Revett Formation exposures for ASARCO Northwest Exploration Division, scale 1:48,000.

2) Calkins, F.C., and Jones, E.L., 1912, Economic geology of the region around Mullan, Idaho, and Saltese, Montana: U.S. Geological Survey Bulletin 540, p. 167-211, map scale 1:125,000.

3) Cambell, A.B., 1960, Geology and mineral deposits of the St. Regis-Superior area, Mineral County, Montana: U.S. Geological Survey Bulletin 1082-I, p. A1-A33, map scale 1:62,500.

4) Harrison, J.E., Griggs, A.B., and Wells, J.D., 1986, Geologic and structure maps of the Wallace 1^{o} x 2^{o} quadrangle, Montana and Idaho: Montana Bureau of Mines and Geology Montana Atlas 4-A, scale 1:250,000.

5) Lewis, R.S., Burmester, R.F., and McFaddan, M.D., 1999, Geologic map of the Wallace quadrangle, Idaho: Idaho Geological Survey, in review, scale 1:100,000.

6) Wallace, R.E., and Hosterman, J.W., 1956, Reconnaissance geology of western Mineral County, Montana: U.S. Geological Survey Bulletin 1027, p. 575-612, scale 1:62,500.

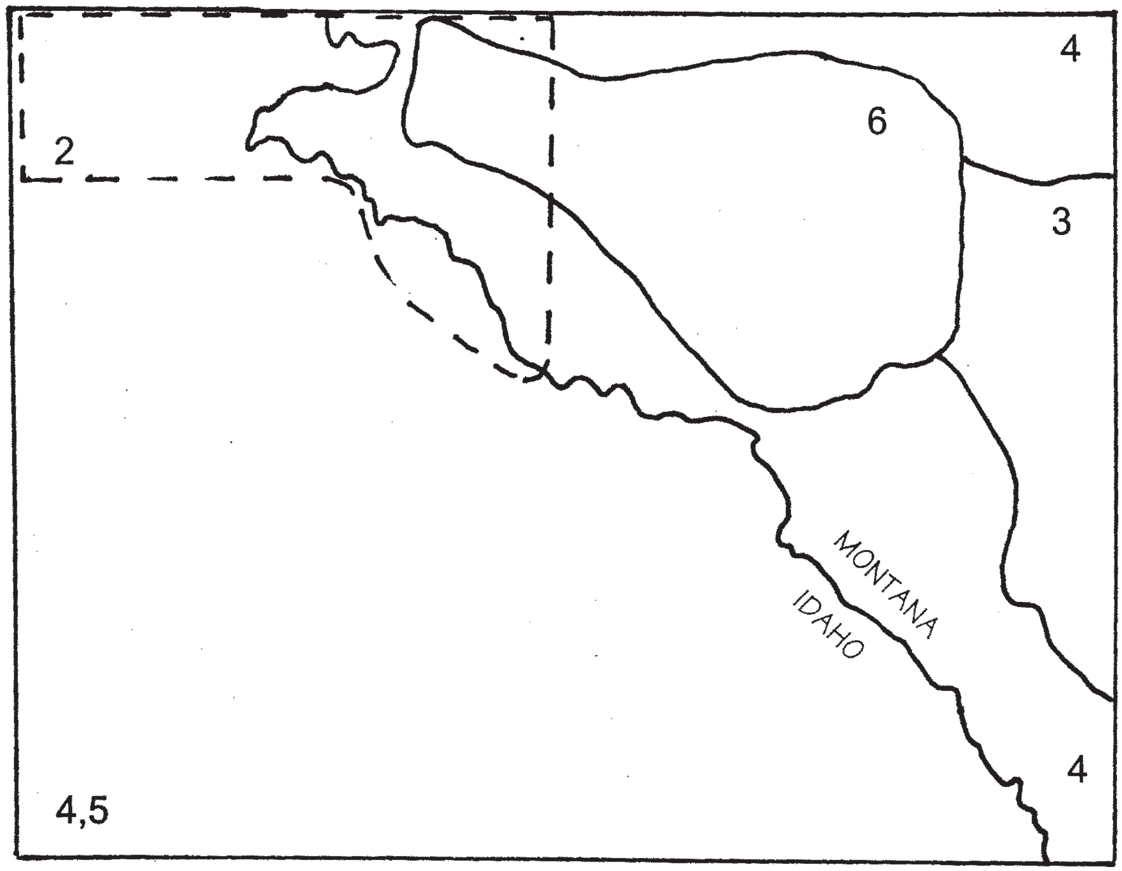
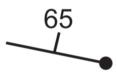


Figure 4. Sources of previous geologic mapping the the Wallace 30´ x 60´ quadrangle.

Map Symbols

Strike and dip of bedding



Strike and dip of bedding where stratigraphic tops can be determined using primary sedimentary structures

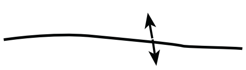
Contact; dashed where approximate; short dashes where concealed

Fault with unknown sense of movement; dashed where approximate; dotted where concealed

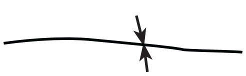
Normal fault; ball and bar on downthrown side; dashed where approximate; dotted where concealed

Reverse fault; teeth on upthrown side; dashed where approximate; dotted where concealed

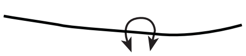
Strike-slip fault; dashed where approximate; dotted where concealed



Anticline fold axis showing plunge



Syncline fold axis



Overturned anticline axis

Overturned syncline axis

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