

GEOLOGIC MAP OF THE DICKIE HILLS
7.5' QUADRANGLE, SOUTHWESTERN MONTANA

by

Jeffrey D. Lonn and Catherine McDonald

Montana Bureau of Mines and Geology
Open File Report 501

2004

Revised

July, 2005: text and map

This report has had preliminary reviews for conformity with Montana Bureau of Mines and Geology's technical and editorial standards.

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 03HQAG0090.

Introduction

The Montana Bureau of Mines and Geology selected the Dickie Hills 7.5' quadrangle for mapping because it straddles the boundary between the high-grade metamorphic rocks of uncertain age in the West Pioneer Range and the unmetamorphosed sedimentary rocks to the north and east in the Lincoln Hills, Dickie Peak, and Wise River quadrangles. Previous detailed mapping (Moore, 1956; Fraser and Waldrop, 1972; Calbeck, 1975; Berger and others, 1983; Truckle, 1988; Zen, 1988; Lewis, 1990) surrounds much of the Dickie Peak quadrangle, making it an important link in the geology of southwestern Montana, but the character of the boundary between two distinctive geologic domains remained unresolved.

Stratigraphy

Metamorphic equivalents of middle Proterozoic Belt Supergroup quartzite units underlie most of the quadrangle, and have been assigned to the Missoula Group (Ruppel and others, 1993) and divided into five mappable units. With one exception, the relative stratigraphic positions of these metaquartzites are unknown. The youngest quartzite unit, here assigned a Cambrian-Proterozoic age, is a metaquartzite (€Yq) containing clean quartzite that is atypical of the Belt. Similar rocks in apparent depositional contact with the Cambrian Silver Hill Formation and with the Cambrian sequence of the Swamp Creek area on the adjacent Dickie Peak, Lincoln Gulch, and Wise River quadrangles (fig. 1), and the occurrence of a Cambrian conglomerate (Black Lion Formation) underlying the Silver Hill Formation nearby (Zen, 1988) suggest a Cambrian age for some of this quartzite. This unit contains middle Proterozoic quartzite as well.

Two new Cambrian metasedimentary units--quartzite (€q) and phyllite, quartzite, and calc-silicate rock of the Swamp Creek area (€q)--are introduced on the Dickie Hills quadrangle. They are equivalent to the Swamp Creek sequence (Zen, 1988; Ruppel and others, 1993) that lies stratigraphically beneath the Hasmark Formation and that was found to contain rare burrows. They are also equivalent to the quartzite and argillite of Dickie Peak (Lewis, 1990). These units are probably correlative with part of the Silver Hill Formation.

Cretaceous through Mississippian sediments and their metamorphic equivalents are also present on the Dickie Hills quadrangle. Unconsolidated Tertiary gravels and extensive glacial deposits obscure much of the bedrock geology.

Igneous Rocks

Snee (1982) and Berger and others (1983) described one major Cretaceous pluton, the Foolhen tonalite, on the Dickie Hills quadrangle; other plutonic rocks that appear to grade into orthogneiss were interpreted by them to be early Proterozoic cratonic rock. However, Ruppel and others (1993) assigned a Late Cretaceous age to these foliated plutons. This study noted that the plutons are in intrusive contact with Belt metasediments, and that they become foliated near their contacts with Phanerozoic metasediments (unit KMsm)

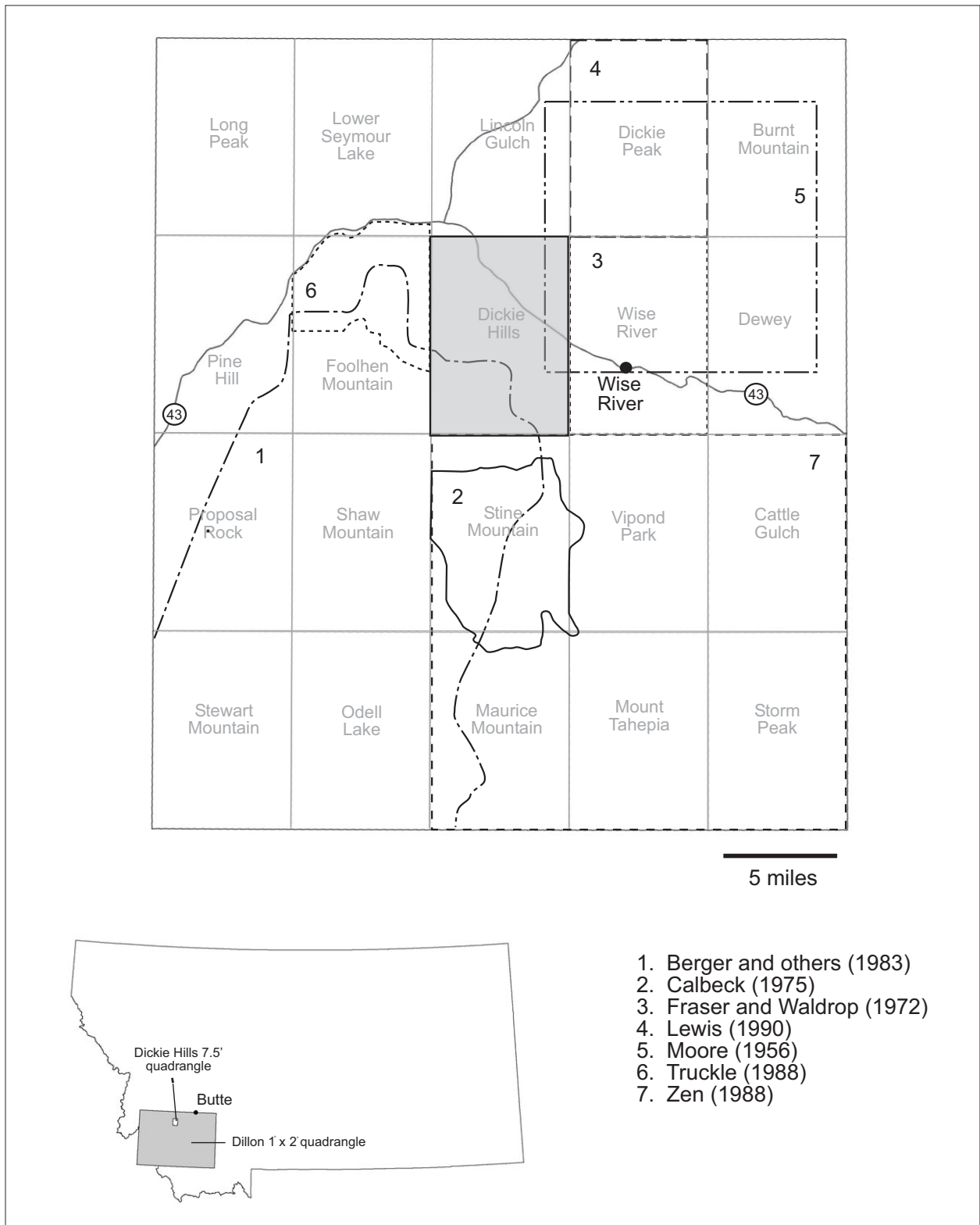


Figure 1. Location of Dickie Hills 7.5' quadrangle and index map of previous geologic maps in the nearby area.

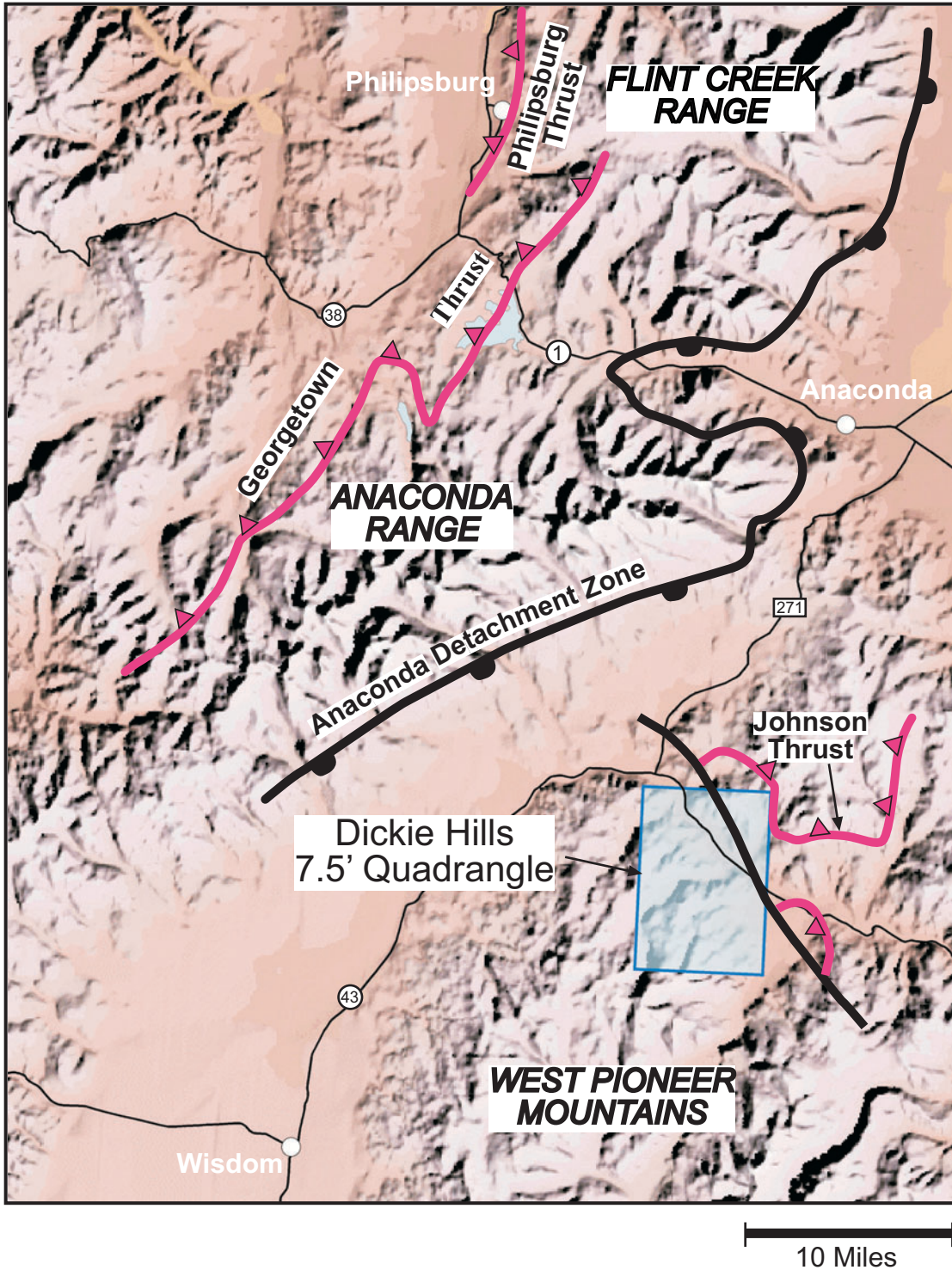


Figure 2. Map showing location of major regional structural features in the West Pioneer Mountains and Flint Creek and Anaconda Ranges.

and the foliations are parallel to those in the metasediments. Both observations support Ruppel and others' (1993) conclusions.

Metamorphism

Metamorphic grade and degree of deformation decrease gradually northward and eastward from the central West Pioneer Range, with quartz-feldspar-biotite gneiss grading into rocks clearly recognizable as feldspathic quartzite of the Belt Supergroup. In addition, sedimentary rocks as young as Cretaceous (Truckle, 1988) have undergone the same degree of metamorphism. Therefore, it appears that metamorphism occurred in the Late Cretaceous and that early Proterozoic, pre-Belt rocks are not present (Ruppel and others, 1993).

Foliation appears to be parallel to bedding where primary sedimentary features are still visible; in some conglomeratic layers this foliation is defined by deformed, flattened pebbles. However, a later axial planar foliation may have overprinted the bedding-parallel foliation in the southwestern part of the map area, as reported by Desmarais (1983) for an area of the western Anaconda Range to the northwest.

Structure

The Dickie Hills quadrangle contains numerous faults, but for most the sense of movement and direction of dip are unknown. A regional-scale, gently dipping thrust fault, the Johnson thrust, that places Proterozoic rocks over Cretaceous Colorado Group rocks is exposed to the northeast (Fraser and Waldrop, 1972). Although this thrust does not appear to be exposed in the Dickie Hills quadrangle, the Mississippian through Cretaceous sedimentary rocks in the northeastern part of the quadrangle are part of its footwall, while the Cambrian through Proterozoic rocks are probably contained within its hanging wall. Metamorphic grade decreases northeastward equally in both hanging wall and footwall, suggesting that metamorphism occurred after thrusting. Emplacement of the 77-Ma Foolhen tonalite (Snee, 1982) and the 76-Ma Dodsens Creek tonalite (Marvin and others, 1983) also postdates the thrusting. Northwest-trending open to tight folds affect the metasedimentary and sedimentary units. Northwest-striking high-angle faults cut the thrusts and folds, and are postulated to be left-lateral strike-slip faults (Ruppel, 1993). These faults probably formed the Tertiary basins that filled with conglomerate and tuffaceous muds (unit Tcg). Still younger northeast-striking faults offset the northwest faults.

Implications for Regional Tectonics

Thrust faults in the Dickie Hills region appear to be part of a regional system of nearly bedding-parallel thrusts that extend into the East Pioneer Range (Pearson and Zen, 1985; Zen, 1988). Metamorphism and bedding-parallel foliations may have developed synchronously in response to burial by higher-level thrusts and intrusion by the Cretaceous plutons.

Metamorphic rocks in the West Pioneer Range grade into unmetamorphosed rocks that are structurally continuous with those of the hanging wall of the Anaconda detachment

fault near Mill Creek Pass. Therefore, the Eocene Anaconda detachment and associated mylonite must swing southwest from the Mill Creek Pass area to bound the southeast flank of the Anaconda Range (confirmed by T.J. Kalakay, Rocky Mountain College, 2003, oral communication). The high-grade metamorphic rocks of the West Pioneer Range are in the hanging wall of the Anaconda detachment system.

The northwest-striking sinistral faults do not extend into the Anaconda detachment footwall. However, they do have the same strike as stretching lineations within the Anaconda mylonite on the northwest side of the Big Hole Valley (T.J. Kalakay, oral communication, 2003), indicating that these faults developed in association with Eocene movement of the Anaconda detachment system.

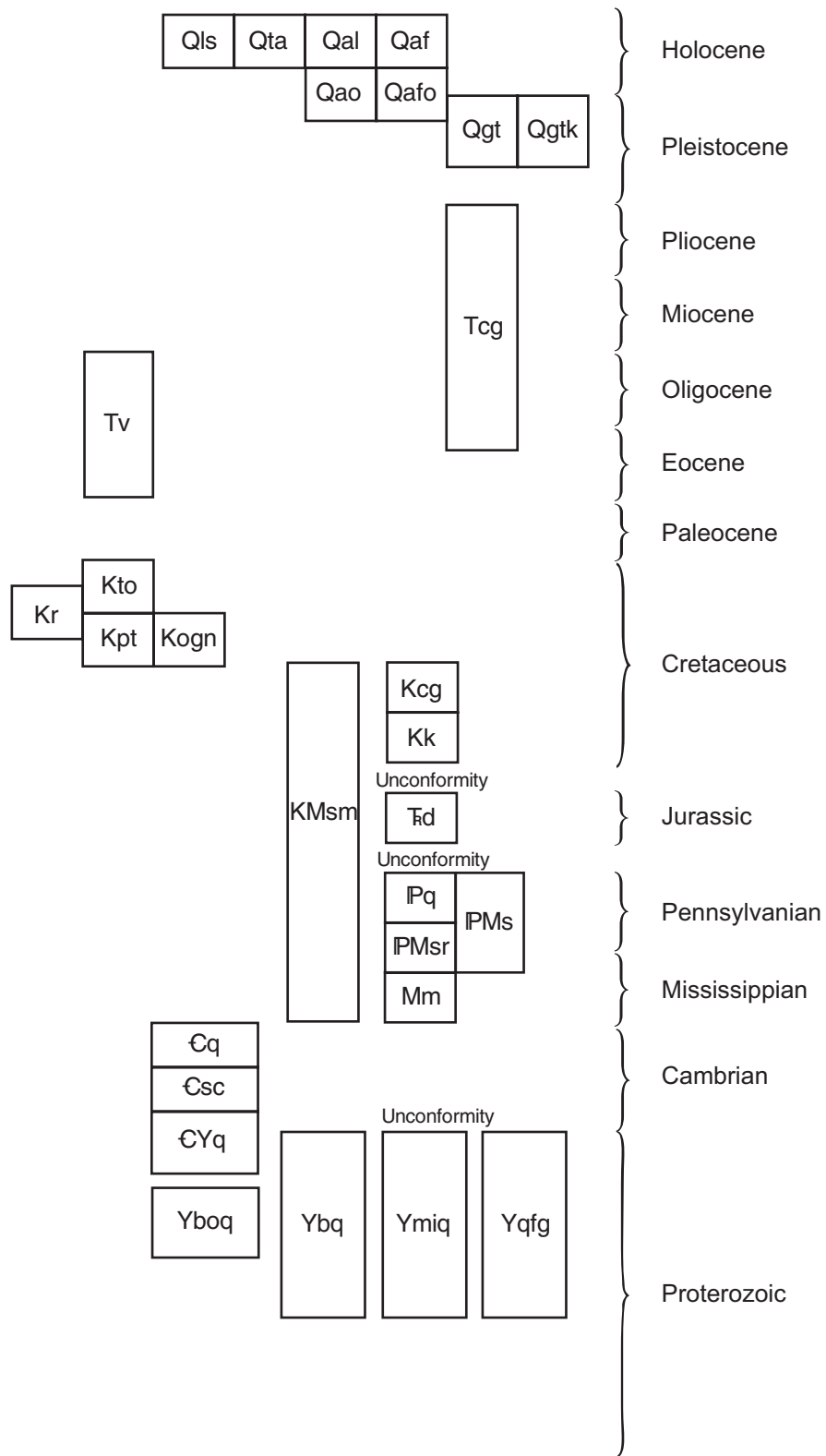


Figure 3. Age correlation of map units.

Description of Map Units

- Qal** **ALLUVIAL DEPOSITS OF ACTIVE CHANNELS AND PRESENT FLOOD PLAINS (HOLOCENE)**
Well-rounded, well-sorted bouldery gravel and sand with some thin beds of clayey silt along the Big Hole River and the larger tributaries. Probably less than 100 feet thick.
- Qaf** **ALLUVIAL FAN DEPOSITS (HOLOCENE)**
Poorly to moderately sorted, subrounded to subangular gravel, sand, silt, and clay. Deposited by both stream flow and debris flow processes in alluvial fan environments. Includes some poorly sorted deposits in the narrow valley bottoms of the Big Hole River tributaries. Clasts are locally derived. Less than 50 feet thick.
- Qls** **LANDSLIDE AND EARTHFLOW DEPOSITS (HOLOCENE)**
Unsorted and unstratified mixtures of mud and boulders transported by mass movement down slopes. Characterized by irregular hummocky topography. Most commonly develop on slopes underlain by interbedded fine-grained units within the Tertiary conglomerate (Tcg).
- Qta** **TALUS DEPOSITS (HOLOCENE)**
Accumulations of angular quartzite boulders on and beneath steep slopes. Thickness 5-30 feet.
- Qao** **ALLUVIUM, OLDER (HOLOCENE AND PLEISTOCENE)**
Mostly well-sorted, subrounded to well rounded, well stratified sand, pebbles, and boulders deposited by streamflow processes. Deposited in terraces 5-40 feet above modern streams. Thickness 5 to 50 feet.
- Qafo** **OLDER ALLUVIAL FAN DEPOSITS (PLEISTOCENE)**
Poorly to moderately sorted, subrounded to subangular gravel, sand, and silt with minor amounts of clay. Deposited by both stream flow and debris flow processes. Surfaces of these deposits are perched 10 to 30 feet above modern streams. Less than 100 feet thick.
- Qgt** **GLACIAL TILL (PLEISTOCENE)**
Unsorted, mostly unstratified clay, silt, sand, and gravel with subrounded boulders as much as 10 feet in diameter. Till is mostly found in thin ground moraine deposits overlying bedrock, but also occurs in some thicker end moraine and lateral moraine deposits.
- Qgtk** **GLACIAL TILL AND KAME DEPOSITS, UNDIVIDED (PLEISTOCENE)**
Glacial till consists of unsorted, mostly unstratified clay, silt, sand, and gravel with subrounded boulders as much as 10 feet in diameter. Kame deposits are moderately to well sorted, well stratified, subrounded to

rounded sand, pebbles, and boulders deposited by streams flowing within and on glaciers. Both types of deposits commonly have a hummocky surface, but kame deposits tend to contain more rounded and better sorted clasts, and are well drained, while till is characterized by unsorted, subangular clasts and poor drainage, creating extensive swampy areas. Thickness 20-100 feet.

- Tcg CONGLOMERATE (TERTIARY)
Maroon to light-brown, poorly sorted bouldery conglomerate interbedded with light-gray to tan tuffaceous siltstone and mudstone. Contains mostly angular to subangular quartzite clasts, but includes some interbeds of rounded to subrounded bouldery conglomerate with a heterogenous mixture of clast lithologies. Often capped by angular, locally derived boulders in deposits that appear to grade from the adjacent mountains and may be considerably younger than most of the unit. As much as 500 feet thick.
- Tv VOLCANIC ROCKS, UNDIVIDED (EOCENE AND OLIGOCENE)
Includes porphyritic intrusive rocks with biotite and hornblende phenocrysts, ash beds, and lava flows. Both Eocene and Oligocene volcanic rocks have been reported in adjacent quadrangles (Marvin and others, 1983; Zen, 1988).
- Kr RHYOLITE (UPPER CRETACEOUS)
Porphyritic rhyolite with phenocrysts of quartz and feldspar. Occurs as a thin, foliated sill.
- Kto TONALITE AND GRANODIORITE OF FOOLHEN RIDGE (UPPER CRETACEOUS)
Gray, fine- to medium-grained hypidiomorphic granular to porphyritic tonalite and granodiorite containing 10-20% biotite and hornblende and less than 5% potassium feldspar (Berger and others, 1983; Truckle, 1988). Called the Foolhen Mountain tonalite by Snee (1982) and Truckle (1988) and the tonalite of Foolhen Ridge by Berger and others (1983). Contacts are roughly concordant to compositional layering within the country rocks, and a foliation that is parallel to the contacts is developed in the border zone of the pluton. Contains numerous light-gray, fine-grained aplite dikes that contain up to 15% plagioclase and 5% biotite. Snee (1982) proposed an emplacement age of about 77 Ma for the Foolhen tonalite, with biotite $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages decreasing westward within this pluton from 69 to 65 Ma.
- Kpt PORPHYRITIC TONALITE (UPPER CRETACEOUS)
Gray, weakly foliated, coarse-grained porphyritic tonalite containing 50% feldspar phenocrysts in a matrix of quartz, biotite, and 25% hornblende. Includes some bluish-gray, fine-grained biotite-hornblende tonalite. Interpreted by Berger and others (1983) as early Proterozoic meta-hypabyssal rock (Xm); however, this unit appears to grade into the

orthogneiss unit (Kogn) and is also in intrusive contact with middle Proterozoic metasedimentary rocks in the Osborne Creek valley. Therefore, a Late Cretaceous age (Ruppel and others, 1993) is indicated. Unit is equivalent to Ruppel and others' (1993) Kfm, foliated meta-igneous rocks, and to Zen's (1988) Koc, porphyry and tonalite. This unit appears to pre-date, and be intruded by, the Foolhen Ridge tonalite (Kto).

- Kogn **ORTHOGNEISS (UPPER CRETACEOUS)**
Gray, strongly foliated, coarse-grained quartz-feldspar-hornblende-biotite gneiss that contains large feldspar porphyroblasts. Includes some bluish-gray, fine-grained, hornblende-rich gneiss. Berger and others (1983) proposed an early Proterozoic age, but Ruppel and others (1993) reinterpreted it as Cretaceous, and it appears as granite gneiss (Kfr) on their map. A Late Cretaceous age is appropriate because 1) the orthogneiss appears to be gradational with porphyritic tonalite (Kpt) that intrudes middle Proterozoic quartzite, and 2) foliations in the orthogneiss on Foolhen Ridge are parallel with those in the adjacent Phanerozoic metasediments (KMsm). The orthogneiss is intruded by and pre-dates the Foolhen tonalite (Kto).
- KMsm **MARBLE AND PHYLLITE OF METAMORPHOSED SEDIMENTARY ROCKS (CRETACEOUS THROUGH MIDDLE MISSISSIPPIAN)**
White, green, and gray, strongly foliated marble, phyllite, calc-silicate gneiss, and quartzite of metamorphosed sedimentary rocks. Truckle (1988) correlated these rocks with the Mississippian Madison through Cretaceous Colorado Group section.
- Kcg **COLORADO GROUP (LOWER CRETACEOUS)**
Poorly exposed, medium gray to dark gray mudstone, shale, and siltstone. Shale is fissile, often carbonaceous or bioturbated. Mudstone and shale is underlain by, and interbedded in the lower portion with, gray to yellow-brown calcareous siltstone, tan to gray, fine-grained calcareous sandstone, and gray to brown, fine-crystalline limestone. Basal contact placed at highest gastropod-bearing limestone.
- Kk **KOOTENAI FORMATION (LOWER CRETACEOUS)**
Upper portion consists of red, purple, and grayish green mudstone and siltstone interbedded with light to medium gray limestone and pale red calcareous siltstone. Mudstone and siltstone can have a red and green mottled appearance, limestone near top of formation often contains abundant gastropods. Lower portion consist of light gray to grayish orange-pink, medium- to coarse-grained sandstone with minor siltstone and mudstone interbeds. Basal part is a discontinuously exposed clast-supported conglomerate composed of rounded pebbles and cobbles of quartzite and chert in a matrix of medium- to coarse-grained, light- and dark-gray "salt & pepper" chert and quartz grains.
- T_{Rd} **DINWOODY FORMATION (LOWER TRIASSIC)**

Poorly-exposed yellowish-gray, grayish-brown, and pale-red, thin-bedded limestone, siltstone and shale. Siltstone and shale are commonly calcareous. Exposed only in northeast corner of quadrangle.

- IPq QUADRANT FORMATION (PENNSYLVANIAN)
Light-gray, fine- to medium-grained, quartzitic sandstone and vitreous quartzite. Weathers light yellow brown to pale reddish brown, forms resistant ridges and isolated knobs. Bedding is rarely visible. Commonly brecciated.
- IPMs SEDIMENTARY ROCKS, UNDIVIDED (PENNSYLVANNIAN AND MISSISSIPPIAN)
Includes the Quadrant Formation and Snowcrest Range Group.
- IPMsr SNOWCREST RANGE GROUP (UPPER MISSISSIPPIAN AND LOWER PENNSYLVANIAN)
Poorly-exposed, grayish red mudstone and siltstone, grayish yellow to grayish orange calcareous fine-grained sandstone, medium gray to light olive-gray limestone and reddish-orange limestone solution breccias. Sandstones are thinly bedded. Small yellow reduction spots are common in red siltstones which characterize upper portion of unit; limestones and calcareous sandstones are more common in lower portion. Equivalent to Amsden Formation mapped by Fraser and Waldrop (1972) in adjacent Wise River quadrangle.
- Eq QUARTZITE (CAMBRIAN)
White to purple, medium- to coarse-grained, well-sorted, feldspar-poor quartzite. Commonly massive, but locally contains heavy mineral layer laminae that define cross beds and flat laminations. Equivalent to the quartzite of Dickie Peak (Lewis, 1990; Ruppel and others, 1993), the white vitreous Belt quartzite of Fraser and Waldrop (1972), and the upper part of the Swamp Creek sequence of Zen (1988) and Ruppel and others (1993). Probably correlative with the upper part of the Silver Hill Formation.
- Esc PHYLLITE, QUARTZITE, AND CALC-SILICATE ROCKS OF THE SWAMP CREEK AREA(CAMBRIAN)
Rusty brown weathering, thinly laminated, grayish-green to dark gray phyllite, argillite, and siltite, interbedded with vitreous quartzite layers and lenses up to 2 feet thick. Locally includes greenish-tan, thinly laminated calc-silicate layers. Dessication cracks and mud chips are common. Burrows were found in this unit south of the study area near Swamp Creek, where it occurs stratigraphically beneath the Hasmark Formation (Zen, 1988), suggesting it is correlative with the Silver Hill Formation. Equivalent to the argillite of Dickie Peak (Lewis, 1990), the Belt argillite of Fraser and Waldrop (1972), the lower part of the Swamp Creek sequence of Zen (1988) and Ruppel and others (1993), and the Belt limestone of Moore (1956).

- €Yq METAQUARTZITE, UNDIVIDED (CAMBRIAN THROUGH MIDDLE PROTEROZOIC)
 Purple to light-gray, dense, fine- to medium-grained, feldspar-poor, massive quartzite that contains sparse floating pebbles of quartz, interbedded with and grading downward into fine- to coarse-grained feldspathic quartzite with abundant mud chips, trough and planar crossbeds, and flat laminations. The fine-grained quartzite has a flinty fracture and is micaceous and strongly foliated. Some of the feldspathic quartzite contains granule-sized grains and pebbles of quartz and quartzite. Slabbed and stained samples of this unit show feldspar content of 1-27%, with potassium feldspar content being much greater than plagioclase content. Because this unit was observed in apparent depositional contact with the Cambrian Silver Hill Formation and sequence of Swamp Creek on the adjacent Dickie Peak, Lincoln Gulch, and Wise River quadrangles, this unit is thought to include a Cambrian-age quartzite as well as middle Proterozoic Missoula Group quartzite. This unit may be equivalent to the Cambrian Black Lion Conglomerate (Zen, 1988; Ruppel, 1993), to the quartzite of Grace Lake of Ruppel and others (1993), and to the “Belt 3” of Calbeck (1975).
- Yboq QUARTZITE OF THE METAMORPHOSED BONNER FORMATION (MIDDLE PROTEROZOIC)
 Light gray to pink, poorly sorted, coarse-grained feldspathic metaquartzite and pebble metaconglomerate. Obvious chalky white feldspar grains, large trough cross beds, and abundant black hematitic and green mud chips characterize this unit in the field. The high potassium feldspar content (15-25%), lack of significant plagioclase, and lenses of conglomerate that contain well-rounded quartzite and jasper pebbles and angular potassium feldspar pebbles, suggest that this unit is equivalent to the Bonner Formation (Lewis, 1998; Don Winston, personal communication, 2003). The unit is also equivalent to “p€m₂” of Truckle (1988), to Calbeck’s (1975) “Belt 1”, and to Zen’s (1988) “Sequence of Boner Knob (Ybk)”. Some beds contain deformed, flattened grains and pebbles that define a prominent bedding-parallel foliation.
- Ybq BIOTITE QUARTZITE OF THE METAMORPHOSED BELT SUPERGROUP (MIDDLE PROTEROZOIC)
 White to light gray, fine- to medium-grained biotite-bearing feldspathic quartzite. Biotite-rich layers define flat laminations that may be relic sedimentary features, although isoclinal folds defined by biotite are also present. Stratigraphic tops could not be determined in this unit. The lack of granules or pebbles helps distinguish this unit. Slabbed and stained samples vary from 12 to 25% feldspar, with plagioclase usually predominating over potassium feldspar, a characteristic of the Mount Shields Formation (Lewis, 1998; Lonn and others, 2003). Equivalent to the plagioclase-rich “p€m₃” of Truckle (1988). Truckle described this unit as stratigraphically higher than the Bonner Formation quartzite (Yboq),

but in the Dickie Hills quadrangle the contact between the two is always a fault.

Ymiq

**QUARTZITE OF THE METAMORPHOSED MISSOULA GROUP
(MIDDLE PROTEROZOIC)**






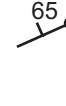


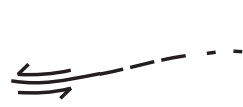







Light-gray to pink, feldspar-rich (16-25%), fine- to coarse-grained quartzite, with minor muscovite and biotite. Contains no pebbles or granules, and mud chips are rare. Contains flat laminations and both planar and trough cross beds. Feldspar composition is variable, but most samples contained more potassium feldspar than plagioclase. Unit found in the southwestern part of the map area. Zen (1988) considered this unit (his "Ymm, Sequence of Maurice Mountain") to be stratigraphically below the Bonner Formation equivalent (Yboq). Lack of exposure and gentle variable dips obscure the relationship in the Dickie Hills quadrangle. This unit may actually be equivalent to unit CYq.

Yqfg

**QUARTZOFELDSPATHIC GNEISS OF THE BELT SUPERGROUP
(MIDDLE PROTEROZOIC)**

Strongly foliated, thinly layered quartz-feldspar-biotite-muscovite-hornblende gneiss that also contains sillimanite and chlorite (Truckle, 1988). Severely deformed, with isoclinal folds common. Metaquartzite and schist interlayers suggests a sedimentary protolith, and it appears to be gradational with the biotite quartzite unit (Ybq) and therefore thought to be a Missoula Group equivalent. Berger and others (1983) and Truckle (1988) mapped this unit as early Proterozoic in age, but Ruppel and others (1993) reinterpreted it as a metamorphosed Belt unit.

MAP SYMBOLS

	Contact: dashed where approximately located; dotted where concealed		Strike and dip of bedding
	Fault: unknown sense of movement; dotted where concealed		Strike and dip of overturned bedding
	Normal fault: dotted where concealed; bar and ball on downthrown side		Strike and dip of bedding where stratigraphic tops were confirmed using primary sedimentary structures
	Reverse or thrust fault: teeth on upthrown (hanging wall) block		Horizontal bedding
	Strike-slip fault: dashed where approximately located; dotted where concealed. Arrows along fault trace indicate relative strike-slip displacement		Vertical bedding
	Syncline: showing trace of axial plane and plunge direction where known; dotted where concealed		Foliation
			Foliation parallel to layering, usually bedding
			Cleavage
			Small-scale fold axis
			Rhyolite dike (Kr)

References Cited

- Berger, B.R., Snee, L.W., and Hanna, William, 1983, Mineral resource potential of the West Pioneer wilderness study area, Beaverhead County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1585, scale 1:50,000.
- Calbeck, J.M., 1975, Geology of the central Wise River valley, Pioneer Mountains, Beaverhead County, Montana: Missoula, University of Montana, M.S. thesis, 89 p., map scale 1:31,685.
- Desmarais, N.R., 1983, Geology and geochronology of the Chief Joseph plutonic-metamorphic complex, Idaho-Montana, Seattle, University of Washington, Ph.D. dissertation, 150 p., map scale 1:50,000.
- Fraser, G.D., and Waldrop, H.A., 1972, Geologic map of the Wise River quadrangle, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-988, scale 1:24,000.
- Lewis, R.S., 1998, Stratigraphy and structure of the lower Missoula Group in the Butte 1⁰ x 2⁰ and Missoula West 30' x 60' quadrangles, Montana: Northwest Geology, v. 28, p. 1-14.
- Lewis, S.E., 1990, Geologic map of the Dickie Peak quadrangle, Montana: Montana Bureau of Mines and Geology Geologic Map GM-51, scale 1:24,000.
- Lonn, J.D., McDonald, C., Lewis, R.S., Kalakay, T.J., O'Neill, J.M., Berg, R.B., and Hargrave, P., 2003, Preliminary geologic map of the Philipsburg 30' x 60' quadrangle, western Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 483, 29 p., scale 1:100,000.
- Marvin, R.F., Zen, E-An, Hammarstrom, J.M., and Mehnert, H.H., 1983, Cretaceous and Paleocene potassium-argon mineral ages of the northern Pioneer batholith and nearby igneous rocks in southwest Montana: *Isochron/West*, n. 38, p. 11-16.
- Moore, G.T., 1956, The geology of the Mount Fleecer area, Montana: Bloomington, Indiana University, Ph.D. dissertation, 88 p., map scale 1:25,000.
- Pearson, R.C., and Zen, E-An, 1985, Geologic map of the eastern Pioneer Mountains, Beaverhead County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1806-A, scale 1:50,000.
- Ruppel, E.T., 1993, Cenozoic tectonic evolution of southwest Montana and east-central Idaho: Montana Bureau of Mines and Geology Memoir M 65, 62 p.
- Ruppel, E.T., O'Neill, J.M., and Lopez, D.A., 1993, Geologic map of the Dillon 1⁰ x 2⁰ quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1803-H, scale 1:250,000.

Snee, L.W., 1982, Emplacement and cooling of the Pioneer batholith, southwestern Montana: Columbus, Ohio State University, Ph.D. dissertation, 320 p.

Truckle, D.M., 1988, Geology of the Calvert Hill area, Beaverhead County, Montana: Butte, Montana Tech, M.S. thesis, 94 p., map scale 1:24,000.

Zen, E-An, 1988, Bedrock geology of the Vipond Park 15', Stine Mountain 7.5', and Maurice Mountain 7.5' quadrangles, Pioneer Mountains, Beaverhead County, Montana: U.S. Geological Survey Bulletin 1625, 49 p., map scale 1:62,500.

DICKIE HILLS QUADRANGLE

Map Units and Symbols (see text for descriptions)

- Qal Alluvial deposits of active channels and modern flood plains (Holocene)
- Qaf Alluvial fan deposits (Holocene)
- Qls Landslide and earthflow deposits (Holocene)
- Qta Talus deposits (Holocene)
- Qao Alluvium, older (Holocene and Pleistocene)
- Qafo Older alluvial fan deposits (Pleistocene)
- Qgo Glacial outwash (Pleistocene)
- Qgt Glacial till (Pleistocene)
- Qgtk Glacial till and kame deposits, undivided (Pleistocene)
- Tcg Conglomerate (Tertiary)
- Tv Volcanic rocks, undivided (Eocene and Oligocene)
- Kr Rhyolite (Upper Cretaceous)
- Kto Tonalite and granodiorite of Foolhen Ridge (Upper Cretaceous)
- Kpt Porphyritic tonalite (Upper Cretaceous)
- Kogn Orthogneiss (Upper Cretaceous)
- Kcg Colorado Group (Lower and Upper Cretaceous)
- Kk Kootenai Formation (Lower Cretaceous)
- Td Dinwoody Formation (Lower Triassic)
- Pq Quadrant Formation (Pennsylvanian)
- PMsr Snowcrest Range Group (Lower Pennsylvanian and Upper Mississippian)
- Mm Madison Group (Mississippian)
- PMs Pennsylvanian and Mississippian rocks, undivided
- KMsm Marble and phyllite of metamorphosed sedimentary rocks (Cretaceous through Middle Mississippian)
- Cq Metaquartzite (Cambrian)
- Csc Phyllite, quartzite, and calc-silicate rocks of the Swamp Creek area
- CYq Metaquartzite, undivided (Cambrian through Middle Proterozoic)
- Yboq Quartzite of the metamorphosed Bonner Formation (Middle Proterozoic)
- Ybq Biotite quartzite of the metamorphosed Belt Supergroup (Middle Proterozoic)
- Ymiq Quartzite of the metamorphosed Missoula Group (Middle Proterozoic)
- Yfg Quartzofeldspathic gneiss of the Belt Supergroup (Middle Proterozoic)

- Contact: dashed where approximately located; dotted where concealed
- Fault: unknown sense of movement; dotted where concealed
- Normal fault: dotted where concealed; bar and ball on downthrown side
- Reverse or thrust fault: teeth on upthrown (hanging wall) block
- Strike-slip fault: dashed where approximately located; dotted where concealed. Arrows along fault trace indicate relative strike-slip displacement
- Syncline: showing trace of axial plane and plunge direction where known; dotted where concealed

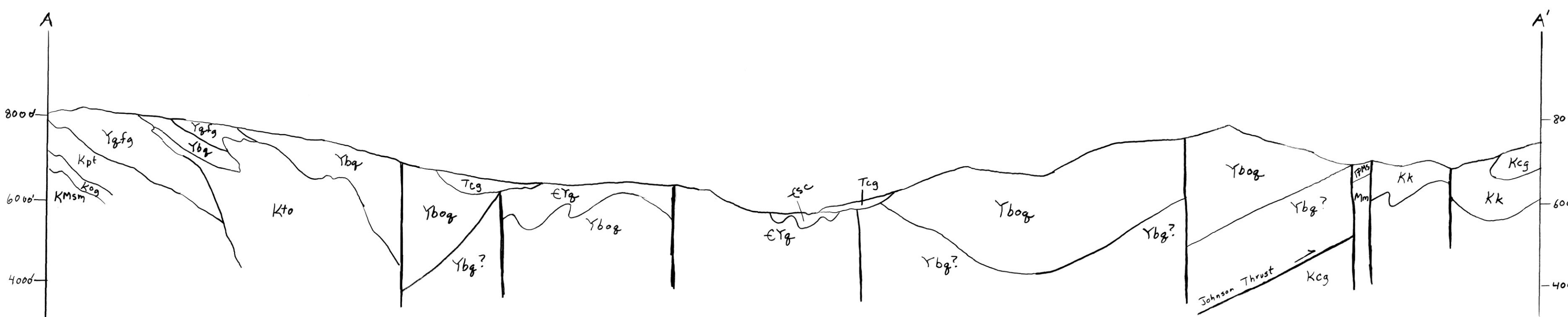
- Strike and dip of bedding
- Strike and dip of overturned bedding
- Strike and dip of bedding where stratigraphic tops were confirmed using primary sedimentary structures
- Horizontal bedding
- Vertical bedding
- Foliation
- Foliation parallel to layering, usually bedding
- Cleavage
- Small-scale fold axis
- Rhyolite dike (Kr)



Base from U.S. Geological Survey
 Dickie Hills 7.5' topographic quadrangle
 Map date: 1997
 Projection: Lambert Conformal Conic
 UTM zone 12; 1927 NAD

SCALE 1:24,000

CONTOUR INTERVAL 40 FEET
 DOTTED LINES REPRESENT 20-FOOT CONTOURS
 NATIONAL GEODETIC VERTICAL DATUM OF 1929



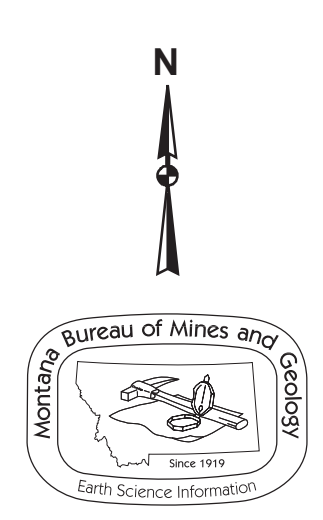
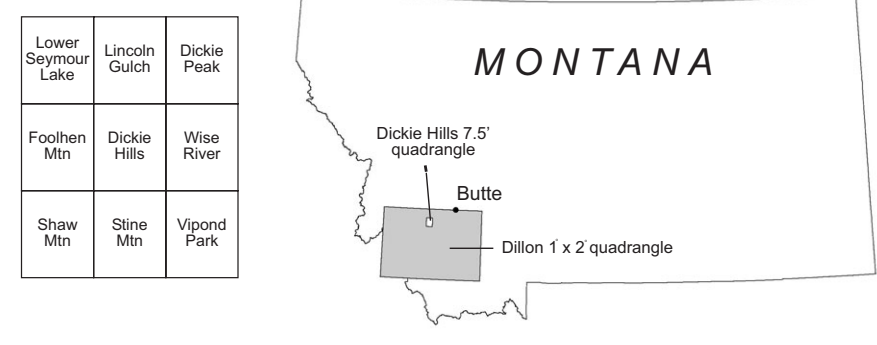
No vertical exaggeration
 Datum: mean sea level
 Quaternary deposits not shown

MBMG Open File 501
 Geologic Map of the Dickie Hills
 7.5' Quadrangle
 Southwestern Montana

Jeffrey D. Lonn and Catherine McDonald

2004

Revised	Date
Map and text	7/05



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 03HQAG0090.

Map layout: Susan Smith, MBMG.

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.mbm.mtech.edu