Montana Bureau of Mines and Geology

# GEOLOGIC MAP OF THE GARDINER 30' x 60' QUADRANGLE,

# SOUTH-CENTRAL MONTANA

By

Richard B. Berg, Jeffrey D. Lonn, and William W. Locke*

Montana Bureau of Mines and Geology
Open File Report MBMG 387

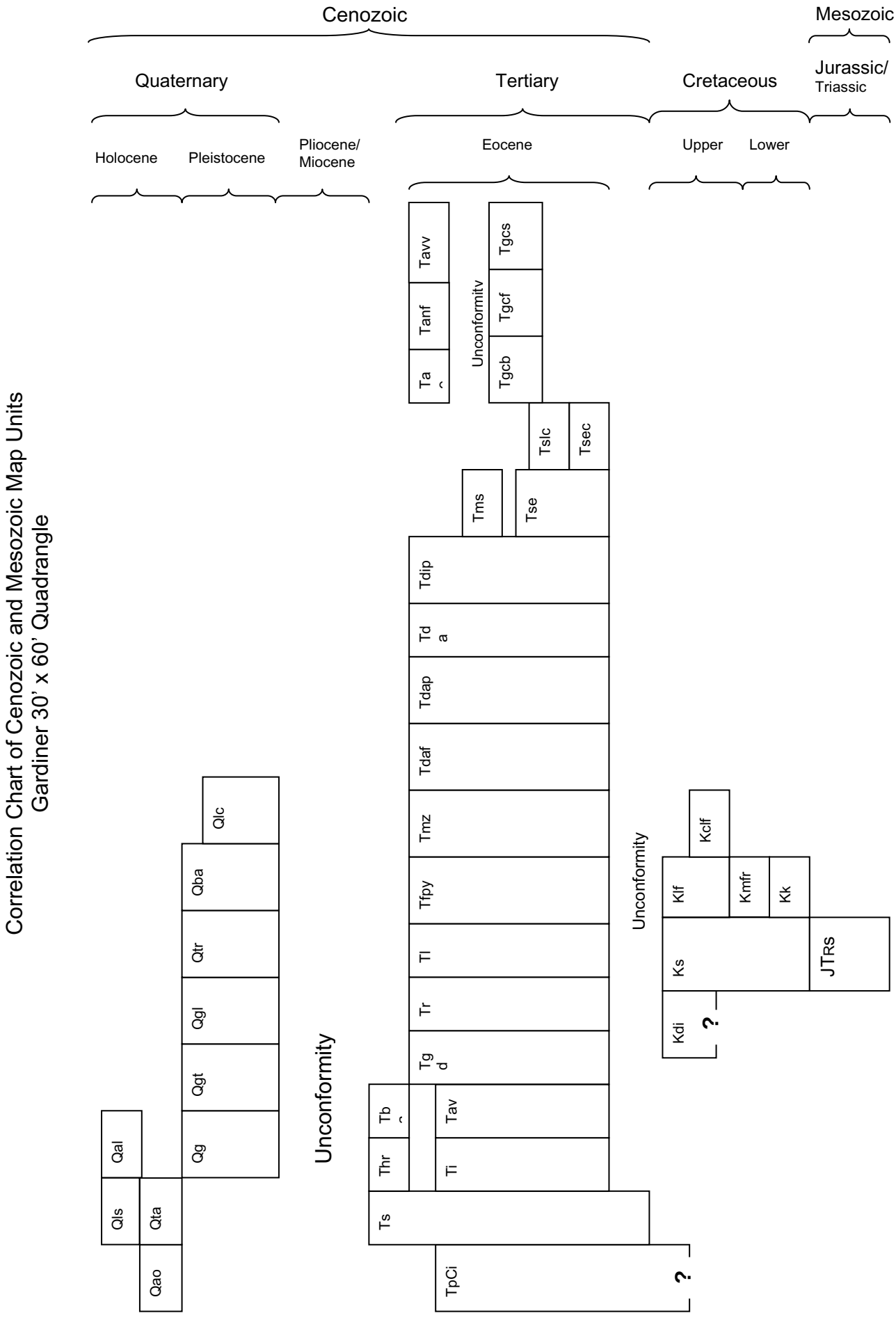
1999

REVISIONS
Map: 9/01
11/08
Map and text: 12/02
9/03
4/07

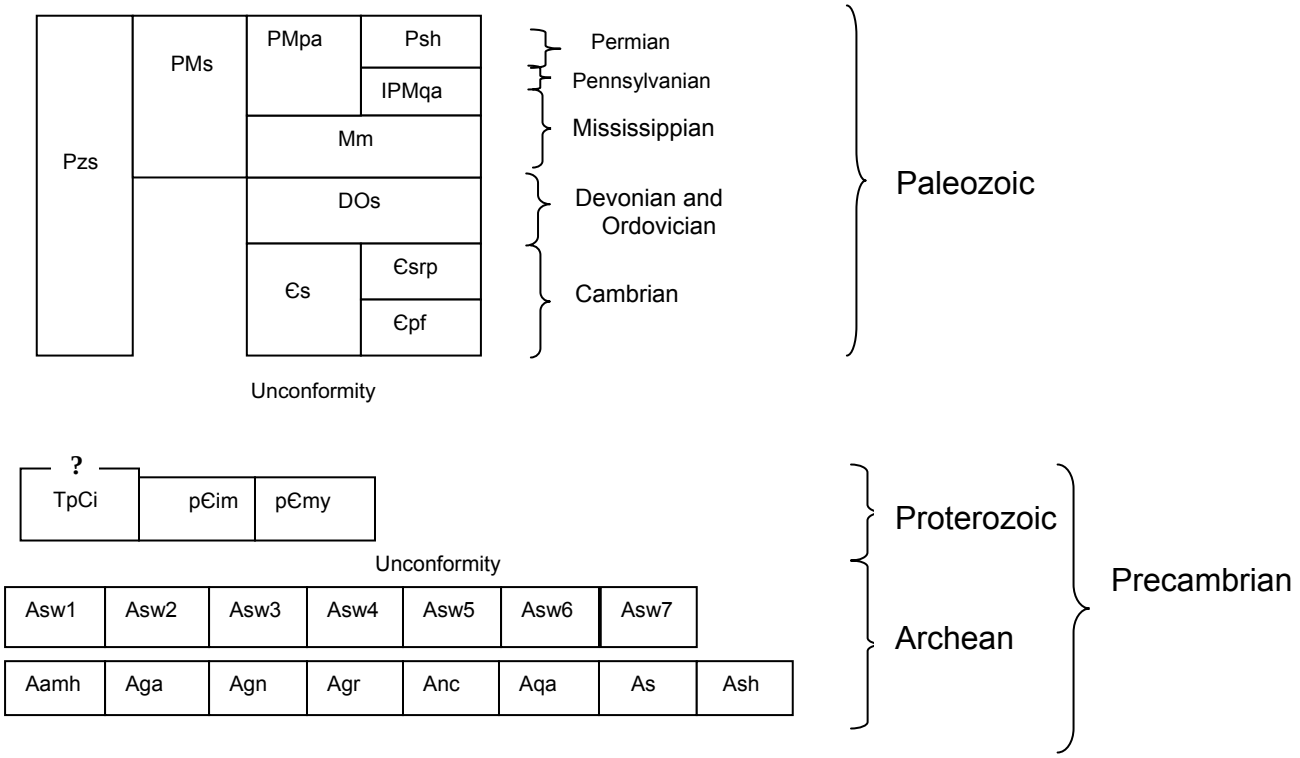
This report has been reviewed for conformity with Montana Bureau of Mines and Geology's technical and editorial standards.

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 98- HQ-AG 2080.

(*) Department of Earth Sciences, Montana State University, Bozeman, MT 59701


Correlation Chart of Cenozoic and Mesozoic Map Units
Gardiner 30' x 60' Quadrangle
Cenozoic
Mesozoic
Quaternary
Tertiary
Cretaceous
Jurassic/
Triassic
Holocene
Pleistocene
Pliocene/
Miocene
Eocene
Upper
Lower
Qlc
Qba
Qtr
Qgl
Qgt
Qg
Qal
Qls
Qta
Qao
Unconformity
Tavv
Tanf
Ta
Unconformity
Tgcs
Tgcf
Tgcb
Tslc
Tsec
Tms
Tse
Tdip
Td
a
Tdap
Tdaf
Tmz
Tfpy
Tl
Tr
Tg
d
Tb
Thr
Tav
Ti
Ts
TpCi
?
Unconformity
Kclf
Klf
Kmfr
Kk
Ks
JTRs
Kdi
?

Correlation of Paleozoic and Precambrian Map Units
Gardiner 30’ x 60’ Quadrangle



Description of Map Units

**Qls** **Landslide deposit (Holocene)** - Landslides are typically developed at the unconformity between Tertiary volcanic units and the Precambrian basement, possibly in bentonite beds situated at the base of the Tertiary volcaniclastic sequence.

**Qal** **Alluvium of modern channels and flood plains (Holocene)** - Younger alluvium, generally confined to the present flood plain developed along active rivers and streams.

**Qao** **Alluvium, older, undivided (Holocene and Pleistocene?)** - Includes gravel deposits at elevations above present active flood plains and some deposits that contain a significant glaciofluvial component.

**Qta** **Talus deposit (Holocene and Pleistocene?)** - Angular and subangular cobbles and boulders at base of steep valley walls or cliffs.

**Qg** **Glacial deposits, undivided (Holocene and Pleistocene)** - Dominantly unsorted and unstratified sediment of Pleistocene glacial moraines and other associated glacial and glaciofluvial deposits. Also includes Holocene glacial deposits and rock glacier deposits. May include subordinate alluvium, colluvium, talus, landslide deposits, and boulder fields (after Wilson and Elliott, 1977); also shown for those areas mapped by Van Gosen and others, 1993, and U.S. Geological Survey, 1972).

**Qgt** **Glacial till (Pleistocene)** – Unsorted to poorly sorted sediment ranging for cobble to sand and silt size. Unit may not be significantly different than Qg.

**Qgl** **Glacial lake deposit (Pleistocene)** - Glacial lake deposits shown only in the Tom Miner and Cinnabar basins and along the Yellowstone Valley where they consist of varved silt and clay.

**Qtr** **Travertine deposit (Pleistocene)** - Deposits of travertine on the east side of the Yellowstone Valley above Gardiner have been quarried for many years for decorative stone. Two distinct Uranium-Thorium (U-Th) ages have been reported for this travertine deposit: 19.57 ± 0.12 Ka, and 22.64 ± 0.17 Ka (Pierce and others, 1991). Modern travertine deposits at La Duke hot springs and at Chico hot springs are too small to show at the scale of this map.

**Qlc** **Lava Creek Tuff , undivided (Pleistocene)** - Welded ash flows. Shown in Yellowstone National Park (after U.S. Geological Survey, 1972).

**Qba** **Basalt (Pleistocene)** - Basalt flows in the Gardiner area (after Van Gosen, and others, 1993).

**Ts** **Sediment or sedimentary rocks, undivided (Tertiary)** - Includes the middle Miocene Hepburn's Mesa Formation (exposed at the mesa of the same name) that consists of sediments deposited in and adjacent to a perennial saline lake (Barnosky, 1989). Also included are tan-weathering silty claystones that contain unaltered volcanic glass that are poorly exposed west of the Yellowstone Valley in the northwestern part of the Gardiner quadrangle.

**Thr** **Huckleberry Ridge Tuff of Yellowstone Group (Pliocene)** - Welded ash flows. Shown for Yellowstone National Park (after U.S. Geological Survey, 1972). Since publication of this U.S.

Geological Survey map, an Argon-Argon ($^{40}Ar/^{39}Ar$) date of 2.0 Ma has been obtained on this unit (Christiansen, 2001, p. G22).

**Tba** **Basalt (Pliocene/Miocene?)** - Two basalt flows are exposed on Hepburn's Mesa. A Potassium-Argon date on the upper flow yields a date of 8.4 Ma (Bush, 1967). However Locke and others (1995) suggest that the basalt on Hepburn's Mesa is correlative with basalt west of Emigrant that has a 2.2 Ma date. The upper flow exposed on Hepburn's Mesa is black to dark gray and generally contains scattered plagioclase and olivine phenocrysts whereas the lower flow contains labradorite, augite, and olivine phenocrysts (Bush, 1967).

**Ti** **Intrusive rocks, undivided (Eocene)** - Dikes, sills, and irregular-shaped bodies; andesite, quartz latite, dacite, and rhyolite; commonly porphyritic (after Van Gosen and others, 1993).

**Tav** **Absaroka Volcanics Supergroup (Eocene)** - Volcanic and volcaniclastic rocks including basaltic, andesitic, and dacitic flows and flow breccias, rhyolitic ash-flow tuff and vitrophyre, tuff breccias, lahars, agglomerates, agglutinates, conglomerate, and minor andesitic and dacitic intrusive bodies (in part after Van Gosen and others, 1993).

**Tgd** **Granodiorite porphyry of Emigrant area (Eocene)** - Stock near head of Emigrant Creek (after Van Gosen and others, 1993).

**Tr** **Rhyolite or rhyolitic sediment (Eocene)** - Generally massive and porphyritic with large quartz and feldspar phenocrysts in a chocolate brown, glassy matrix. At some localities unit appears altered with green alteration product. May be associated with welded tuff included within Tfpy unit.

**Tl** **Latite and porphyritic latite (Eocene)**

**Tfpy** **Felsic pyroclastic rocks (Eocene)** - Includes thin planar pumiceous beds that are interpreted as air fall deposition. These beds also contain a few andesite pebbles. Also included in Tfpy is welded tuff with large phenocrysts of quartz and feldspar. These tuffaceous beds are altered to mottled purple and gray bentonitic clay that contains sand-size material consisting of quartz, biotite, and lithic fragments.

**Tmz** **Monzodiorite of Independence area (Eocene)** - Stock composed of multiple phases of andesitic intrusive breccia, monzodiorite, quartz monzodiorite, and quartz monzonite; cut by minor granite dikes (after Van Gosen and others, 1993).

**Tdaf** **Dacite? flows (Eocene)** - Reddish to gray, altered, hornblende porphyry with sparse feldspar laths. In hand specimen the rock appears massive, but when viewed from a distance, flow geometry is obvious. Some flow breccia. Shown in area west of the Yellowstone River.

**Tdap** **Dacite porphyry (Eocene)** - Stock, laccoliths, sills, dikes, plugs, and irregular-shaped bodies; includes some andesitic and rhyolitic rocks (After Van Gosen and others, 1993).

**Tda** **Dacite? intrusive (Eocene)** - Pink to light gray, fine-grained, feldspar-hornblende porphyry. Small hornblende phenocrysts much more abundant than feldspar phenocrysts. Shown in area west of the Yellowstone River.

**Tdip** **Diorite porphyry (Eocene)** - Also exposed west of the Absaroka Beartooth Study Area (after Van Gosen and others, 1993).

**Tms** **Slough Creek Tuff Member, Mount Wallace Formation (Eocene)** - Light-colored ash flow tuff.

**Tse** **Sepulcher Formation (Eocene)** - Dominantly light-colored andesitic rocks.

**Tslc** **Lost Creek Tuff Member of Sepulcher Formation (Eocene)** - Light-colored rhyodacite ash flow tuff.

**Tsec** **Elk Creek Basalt Member of Sepulcher Formation (Eocene)**

**Tae** **Andesite, epiclastic, of Hyalite Peak Volcanics (Eocene)** - Well to poorly stratified. This unit is thought to be correlative with the Sepulcher Formation of the Washburn Group as mapped by the U.S. Geological Survey near the northern boundary of Yellowstone National Park (1972) (after Chadwick, 1982).

**Tanf** **Andesite flows of Hyalite Peak Volcanics (Eocene)** - Commonly autobrecciated; includes some epiclastic lenses. This unit is thought to be correlative with the Mount Wallace Formation of the Sunlight Group as mapped by the U.S. Geological Survey near the northern boundary of Yellowstone National Park (1972) (after Chadwick, 1982).

**Tavv** **Vent facies of Hyalite Peak Volcanics (Eocene)** - (After Chadwick, 1982).

**Tgcb** **Andesite breccia of Golmeyer Creek Volcanics (Eocene)-** (After Chadwick, 1982).

**Tgcf** **Volcanic andesite flows of Golmeyer Creek Volcanics (Eocene)** - (After Chadwick, 1982). Unit includes minor intrusions.

**Tgcs** **Andesite sills of Golmeyer Creek Volcanics (Eocene)** - (After Chadwick, 1982). Unit added during present mapping.

**TpЄi** **Intermediate and mafic intrusive rocks (Eocene and Precambrian)** - Dikes and sills of andesite and basalt (After Van Gosen and others, 1993).

**Kdi** **Diorite (Upper Cretaceous)**

**Ks** **Sedimentary rocks, undivided (Cretaceous)** – (After Wilson and Elliott, 1997; U.S. Geological Survey, 1972).

**Klf** **Landslide Creek Formation through Frontier Formation (Upper Cretaceous)** – Exposed in southwest map area, south of Corwin Springs. Includes, in descending order: Landslide Creek Formation, Everts Formation; Eagle Sandstone, including Virgelle Sandstone in lower part; Telegraph Creek Formation; Cody Shale; and Frontier Formation.

**Kclf** **Cody Shale, lower part, and Frontier Formation, undivided (Upper Cretaceous)** – Exposed in northwest part of map. Cody Shale: Gray shale and mudstone interbedded with grayish-green and olive-gray sandstone and siltstone and minor brown-weathering nodular limestone and yellowish-gray bentonite. Entire formation is locally fossiliferous and contains fish scales, starfish, ammonites and other mollusks. Frontier Formation: Brownish-gray, fine-grained, thin- to thick-bedded, locally fossiliferous and/or glauconitic sandstone with dark gray interbedded shale; forms one or two prominent ledges with an intervening dark, silty shale.

**Kmfr** **Mowry Shale through Fall River Sandstone, undivided (Upper and Lower Cretaceous)** – Mowry Shale: Interbedded, siliceous, very fine- to fine-grained sandstone, siltstone, and shale. Contains several prominent bentonite beds. Sandstones and siltstones mostly light gray to medium gray, with a silvery sheen. Fish scales on bedding planes of sandstones and siltstones are characteristic of this formation. Thermopolis Shale: Dominantly dark-gray fissile shale, bentonitic shale, and several beds of bentonite. Has hematitic concretionary zone near base. Fall River Sandstone: Brownish-gray, thin-bedded, argillaceous, fine-grained, quartz sandstone. Generally poorly exposed in map area, mostly covered by glacial deposits. Total thickness is approximately 1,300 ft.

**Kk** **Kootenai Formation (Lower Cretaceous)** - Red and green sandstone, mudstone, limestone, and fresh-water fossiliferous limestone; massive chert pebble conglomerate at base (After Roberts, 1964).

**JTR s** **Sedimentary rocks, undivided (Jurassic and Triassic)** - (After Wilson and Elliott, 1997).

**Pzs** **Sedimentary rocks, undivided (Paleozoic)** - (After Van Gosen and others, 1993).

**PMs** **Sedimentary rocks undivided (Permian, Pennsylvanian, and Mississippian)** - Includes Phosphoria, Quadrant, and Amsden Formations, and Madison Group limestone, shale, sandstone, and dolomite (After Van Gosen and others, 1993).

**PMpa** **Phosporia Formation through Amsden Formation (Permian, Pennsylvanian and Mississippian) –** Includes Phosphoria, Shedhorn, Quadrant, and Amsden Formations.

**Psh** **Shedhorn Sandstone (Permian)** - Sandstone, dolomite, and chert (after U.S. Geological Survey, 1972).

**lPMqa** **Quadrant Sandstone and Amsden Formation (Upper Mississippian and Pennsylvanian)** - (After Wilson and Elliott, 1997).

**Mm** **Madison Group, undivided (Mississippian)** - Limestone and dolomite (after U.S. Geological Survey, 1972).

**DOs** **Sedimentary rocks, undivided (Devonian and Ordovician)** - Includes Three Forks Shale, Jefferson Formation, and Bighorn Dolomite; shale, limestone, and dolomite (after Van Gosen and others, 1993 and U.S. Geological Survey, 1972).

**Cs** **Sedimentary rocks, undivided (Cambrian)** - Includes Grove Creek Formation, Snowy Range Formation, Pilgrim Limestone, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone; limestone, sandstone, siltstone, and shale (after Van Gosen and others, 1993).

**Csrp** **Snowy Range and Pilgrim Formations (Cambrian)** - Limestone and shale (after U.S. Geological Survey, 1972).

**Cpf** **Park, Meagher, Wolsey, and Flathead Formations**.

**pCim** **Mafic intrusive rocks (Archean and Proterozoic)** - Includes sills, dikes., stock, and irregular-shaped bodies of alkali olivine dolerite, metadolerite, metanorite, metagabbro, and quartz dolerite, and dikes of uncertain or unknown affinities (after Van Gosen and others,1993).

**pЄmy Mylonite (Precambrian)** - The mylonite of the Snowy shear zone separates high-grade gneisses to the southeast from andalusite-bearing biotite-staurolite schists to the northwest (Erslev, 1992).

**Asw 1 Peridotite zone, Stillwater Complex (Archean)**.

**Asw 2 Bronzitite zone, Stillwater Complex (Archean)**

**Asw 3 Norite and lower gabbro zones, Stillwater Complex (Archean)**.

**Asw 4 Lower anorthosite zone, Stillwater Complex (Archean)**.

**Asw 5 Lower mixed, middle gabbro, and middle mixed zones, Stillwater Complex (Archean)**.

**Asw 6 Middle anorthosite zone, Stillwater Complex (Archean)**.

**Asw 7 Upper mixed, upper gabbro, and upper anorthosite zones, Stillwater Complex (Archean)**.

**Aamh Amphibolite and hornblende gneiss, Stillwater Complex (Archean)** - Mostly tabular and lensoid bodies enclosed in granitic gneiss and migmatite (after Van Gosen and others, 1993).

**Aga Amphibolite and gneiss (Archean)** - Includes trondhjemitic gneiss-amphibolite paragneiss, and heterogeneous gneiss sequences; trondhjemitic gneiss, tonalitic gneiss, amphibolite; minor schist, quartzite, and iron formation (after Van Gosen and others,1993).

**Agn Gneissic rocks (Archean)** - Predominately granitic gneiss and migmatite; commonly consists of alternating bands of more felsic and more mafic gneiss; contains inclusions of metasedimentary and metaigneous rocks (after Van Gosen and others, 1993).

**Agr Granitic rocks (Archean)** - Includes stocks and irregular-shaped bodies of fine-, medium-, and coarse-grained quartz monzonite and aplite of the Stillwater area and of granite in the Gardiner area (after Van Gosen and others, 1993).

**Anc Nappe core complex (Archean)** - Includes Barney Creek amphibolite, George Lake marble, and Jewel quartzite; amphibolite, dolomitic marble, and marble and quartzite; minor schist and iron formation (after Van Gosen and others, 1993).

**Aqa Quartzite and amphibolite (Archean)** - Interlayered quartzite and orthoamphibolite; minor schist (after Van Gosen and others, 1993).

**As Biotite schist (Archean)** - Includes minor quartzite, iron formation, and amphibolite (after Van Gosen and others,1993).

**Ash Schist and hornfels (Archean)** - Metasedimentary rocks consisting predominately of schist and hornfels with minor quartzite, amphibolite, and iron formation; contact metamorphosed to hornblende hornfels and pyroxene hornfels facies at and near the base of the Stillwater Igneous Complex; host for Homestake-type gold deposits near Jardine (after Van Gosen and others, 19930.

## MAP SYMBOLS


Strike and dip of bedding or flow layering in volcanic rocks.

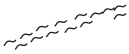

Strike and dip of foliation or schistosity in metamorphic rocks.

Contact - Dashed where approximately located or inferred, sdotted where concealed.

Fault - Sense of movement unknown. Dashed where approximately located, dotted where concealed.

Normal fault - Dashed where approximately located, dotted where concealed. Ball and bar on downthrown side.

Thrust fault or reverse fault - Dashed where approximately located, dotted where concealed. Sawteeth on upper plate or upthrown side.



Mylonitic shear zone

Major Sources of Geologic Mapping


1. Bush, J.H., 1967, The basalts of Yellowstone Valley, southwestern Montana: Bozeman, Montana State University, M.S. thesis, 66 p.

2. Chadwick, R.A., 1982, Igneous geology of the Fridley Peak quadrangle, Montana: Montana Bureau of Mines and Geology Geologic Map 31, 9 p., scale1:62,500.

3. Erslev, E.A., 1992, Precambrian geology and ductile normal faulting in the southwest corner of the Beartooth Uplift, Montana, *in* Bartholomew, M.J., and others , eds., Basement Tectonics 8, Proceedings of the Eighth International Conference on Basement Tectonics, p. 313-322.

4. Fraser, G.D., Waldrop, H.A., and Hayden, H.J., 1969, Geology of the Gardiner area, Park County, Montana: U.S. Geological Survey Bulletin 1277, 118 p., map scale 1:24,000.

5. Reid, R.R., McMannis, W. and Palmquist, J.C., 1975, Precambrian geology of the North Snowy block, Beartooth Mountains, Montana: Geological Society of America Special Paper 167, 135 p., map scale 1:24,000.

6. Todd, S.G., 1969, Bedrock geology of the southern part of Tom Miner Basin, Park and Gallatin counties, Montana: Bozeman, Montana State University, M.S. thesis, 63 p., map scale1:24,000.

7. U.S. Geological Survey, 1972, Geologic map of Yellowstone National Park: U.S. Geological Survey Map I-711, scale 1:125,000.

8. Van Voast, W.A., 1964, General geology and geomorphology of the Emigrant Gulch-Mill Creek area, Park County, Montana: Bozeman, Montana State University, M.S. thesis, 65 p., map scale 1:24,000.

9. Vandeberg, G.S., 1993, Temporal and spatial relations of late Quaternary valley and piedmont glaciers in Tom Miner Basin, Montana: Bozeman, Montana State University, M.S. thesis, 146 p., map scale 1:24,000.

10. Van Gosen, B.S., Elliott, J.E., LaRock, E.J., du Bray, E.A., Carlson, R.R., and Zientek, M.L., 1993, Generalized geologic map of the Absaroka-Beartooth Study Area, southcentral Montana: U.S. Geological Survey Open-File Report 93-207, scale1:126,720.


## Additional Sources of Geologic Information


Barnosky, A.D., and Labar, W.J., 1989, Mid-Miocene (Barstovian) environmental and tectonic setting near Yellowstone Park, Wyoming and Montana: Geological Society of America Bulletin, v. 101, p. 1448-1456.

Christiansen, R.L., 2001, Geology of Yellowstone National Park—The Quaternary and Pliocene Yellowstone Plateau volcanic field of Wyoming, Idaho, and Montana: U.S Geological Survey Professional Paper 729-G, 145 p.

Erslev, E.A., 1992, Precambrian geology and ductile normal faulting in the southwest corner of the Beartooth Uplift, Montana, *in* Bartholomew, M.J., and others, eds., Basement Tectonics 8, Proceedings of the Eighth International Conference on Basement Tectonics: Dordrecht, Kluwer Academic Publishers, map scale 1:125,000.

Locke, W.W., and eight other authors, 1995, The middle Yellowstone valley from Livingston to Gardiner, Montana: a microcosm of northern Rocky Mountain geology, *in* Mogk, D.W., ed., Field guide to geologic excursions in southwest Montana, 1995, Bozeman, Montana, Northwest Geology, v. 24, p.1-65.

Pierce, K.L., Adams, K.D., and Sturchio, N.C, 1991, Geologic setting of the Corwin Springs known geothermal resources area - Mammoth Hot Springs area in and adjacent to Yellowstone National Park, *in* Sorey, M.L., ed., Effects of potential geothermal development in the Corwin Springs known geothermal resources area, Montana on the thermal features of Yellowstone National Park: U.S. Geological Survey Water-Resources Investigations Report 91-4052, p. C-1 - C-37.

Roberts, A.E., 1964, Geologic map of the Mystic Lake quadrangle, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-398, scale 1:24,000.

Struhsacker, E.M., 1976, Geothermal systems of the Corwin Springs-Gardiner area, Montana: Possible structural and lithologic controls: Bozeman, Montana State University, M.S. thesis, 93 p.

Van Gosen, B. S., 1993, Bibliography of geologic references (1872-1992) to the Absaroka-Beartooth Study Area in the Custer and Gallatin National Forests, south-central Montana: U.S. Geological Survey Open-file report OF 93-285-A (paper copy), OF 93-285-B (digital text files on diskette), 71 p.