GEOLOGIC MAP OF THE BELT 30' x 60' QUADRANGLE,

CENTRAL MONTANA

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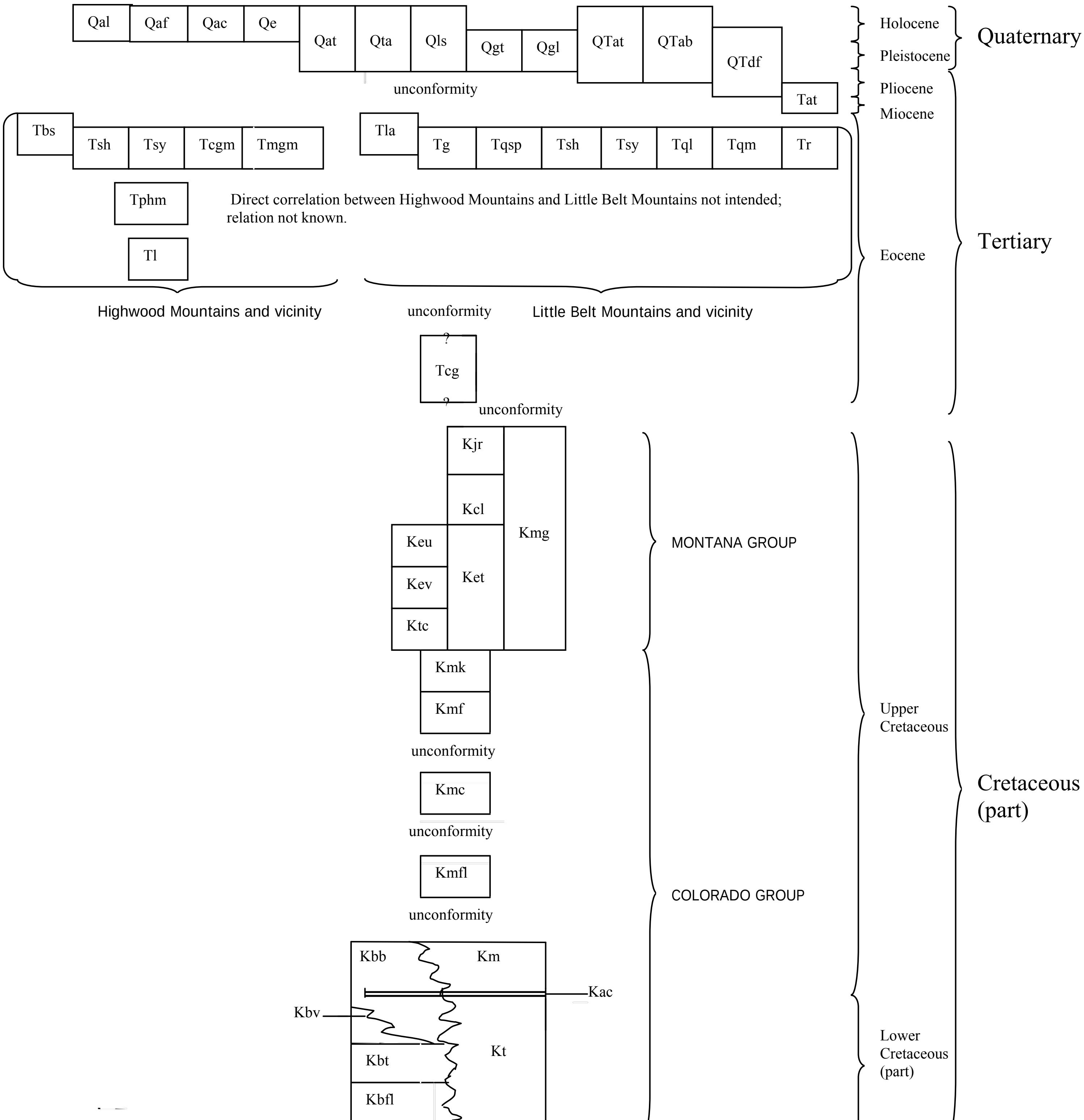
CORRELATION DIAGRAM
BELT 30'x 60' QUADRANGLE



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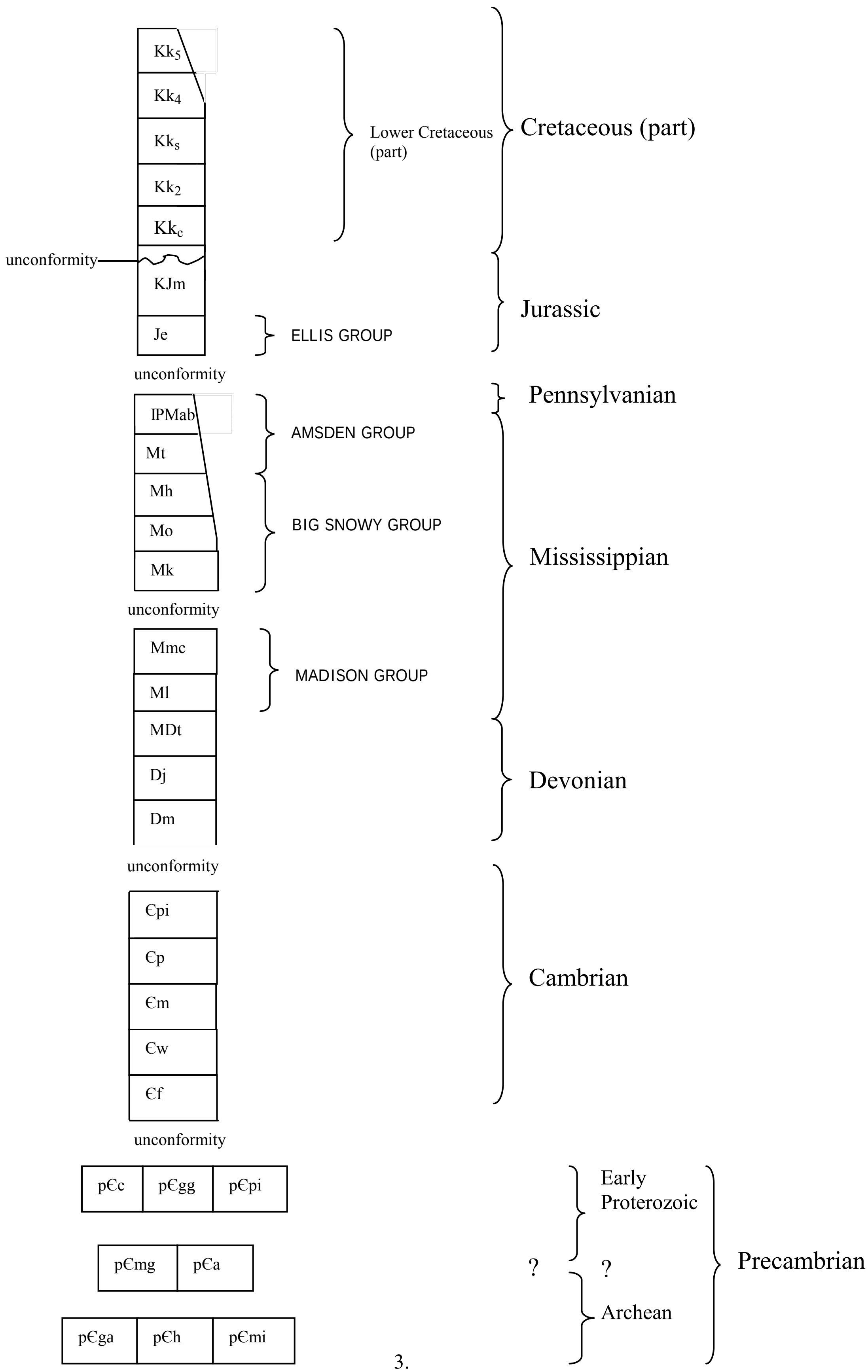
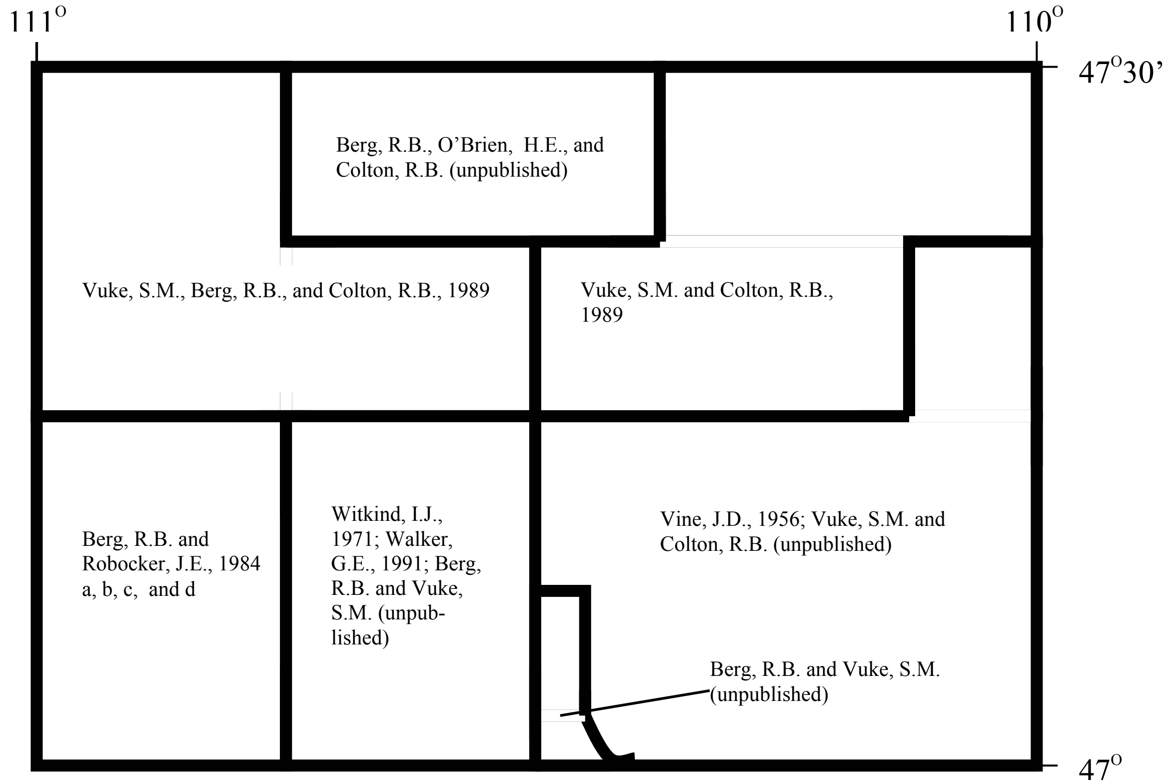
CORRELATION DIAGRAM (Continued)
BELT 30' x 60' QUADRANGLE



MAPPING CREDITS
BELT 30’ x 60’ QUADRANGLE



GEOLOGIC MAP SOURCES AND INDEX OF 7.5' QUADRANGLES
BELT 30' x 60' QUADRANGLE

111° 110°

47°30'

Belt 6, 7, 8, 9, 11, 17	Belt NE 6, 7, 8, 9, 10, 17	High- wood Baldy 9, 10	Arrow Peak 9, 10	Palisade Butte 9, 10	Jiggs Flat 9, 10, 16	Pownal 9, 10, 16	Strouf Island 10, 16
Arming- ton 7, 8, 9, 11, 17	Blythe 7, 8, 9, 10, 11, 17	Raynes- ford 7, 8, 9, 10, 11, 17	Byrne Creek 7, 8, 9, 10, 11, 17	Geyser 7, 8, 9, 11, 13, 15, 16	Leiberg Coulee 9, 10, 11, 13, 15, 16	Arrow Creek 9, 11, 13, 15, 16	Coffee Creek 11, 13, 15, 16
Riceville 2, 19	Monarch NE 4, 19	Lime- stone Butte 1, 11, 19, 20	The Arch 1, 11, 19, 20	Wolf Butte NW 1, 11, 13, 15, 19	Merino 1, 11,13, 15, 19	Stanford 1, 11, 13, 15, 19	Stanford NE 11, 13, 15, 19
Thunder Moun- tain 5, 12, 19	Monarch 3, 12, 19	Barker 18, 19, 20	Mixes Baldy 18, 19, 20	Wolf Butte 1, 11, 13, 15 19	Cayuse Basin 1, 11, 13, 15, 19	Wind- ham 1, 11, 13, 15, 19	Bench- land 11, 13, 14, 15, 19

47°

Numbers below correspond to index map above.

1. Ballard, W.W., 1961, scale 1:250,000.
2. Berg, R.B., and Robocker, J.E., 1984a, scale 1:24,000.
3. Berg, R.B., and Robocker, J.E., 1984b, scale 1:24,000.
4. Berg, R.B., and Robocker, J.E., 1984c, scale 1:24,000.
5. Berg, R.B., and Robocker, J.E., 1984d, scale 1:24,000.
6. Cannon, J.L., 1966, p. 71–111, Fig. 1, scale 1:42,240.
7. Fisher, C.A., 1909a, Pl. 1, scale 1:90,000.
8. Fisher, C.A., 1909b, Pl. 1, scale 1:90,000.
9. Pirsson, L.V., 1905, Pl. 3, scale1:250,000.
10. Reeves, F., 1929, Pl. 1, scale 1:250,000.
11. Silverman, A.J., and Harris, W.L., 1967, Pl. 1, scale 1:253,440.
12. Vaskey, G.T., 1980, Pl. 1, scale 1:24,000.
13. Vine, J.D., 1956, scale 1:62,500.
14. Vine, J.D., and Hail, W.J., Jr., 1950, scale 1:62,000.
15. Vine, J.D., and Johnson, W.D., 1954, scale 1:63,360.
16. Vuke-Foster, S.M., Berg. R.B., and Colton, R.B., 1989, scale 1:24,000.
17. Vuke-Foster, S.M., and Colton, R.B., 1989, scale 1:24,000.
18. Walker, G.E., 1991, Fig. 3, scale 1:26,667
19. Weed, W.H., and Pirsson, L.V., 1895, Fig. 4, scale 1:125,000.
20. Witkind, I.J., 1971, scale 1:62,500.

DESCRIPTION OF MAP UNITS
BELT 30' x 60' QUADRANGLE

Note: Thicknesses are given in feet because original field maps were on 7.5' quadrangles with contour intervals in feet. To convert feet to meters (the contour interval unit on this map), multiply feet x 0.3048.
Many units are combined on the cross sections. The explanation for the cross sections is shown at the bottom of the map.

Qal **Alluvium of modern channels and flood plains (Holocene)—**Yellowish-brown to gray gravel, sand, silt, and clay beneath flood plains and in valleys of active streams. Deposits are well to poorly stratified and moderately well sorted. Maximum clast diameter 12 ft. Thickness as much as 15 ft.

Qaf **Alluvial fan deposit (Holocene)**—Yellowish-brown to gray, poorly stratified and poorly sorted clay, silt, sand, and sandy gravel in small fans at mouths of tributary streams. Thickness as much as 15 ft.

Qac **Alluvium-colluvium (Holocene)**—Grayish-orange to brownish-gray, poorly sorted to moderately well sorted, locally derived sediment deposited on slopes; particle size ranges from clay and silt to gravel depending on source. Colluvium generally present only on slopes steeper than 8 percent. Contains a significant component of glacial-lake and loess deposits near glaciated areas. Thickness as much as 200 ft.

Qe **Eolian deposit (Holocene)**—Light-brown to light-gray, stratified wind-blown sand and silt in dunes on windward sides of some benches. Thickness of dunes as much as 55 ft.

Qat **Alluvium of terrace deposit (Holocene and Pleistocee)**—Light-brown to light-gray, unconsolidated crudely to well-stratified and moderately to well-sorted sand and gravel in alluvial terraces adjacent to and higher than modern meandering streams. Thickness as much as 29 ft.

Qta **Talus deposit (Holocene and Pleistocene)**—Locally derived angular rock fragments, generally cobble size or larger that occur in piles or aprons on mountain slopes; color reflects parent rock. Includes boulder fields developed where frost action has formed slabby boulders from the underlying igneous rock in the Little Belt Mountains. Thickness as much as 20 ft.

Qls **Landslide deposit (Holocene and Pleistocene)**—Mass-wasting deposit that consists of stable to unstable, unsorted mixtures of clay- to boulder-size particles or rotated blocks of bedrock. Includes block-glide masses of bedrock, slumped blocks of bedrock and surficial sediment, earthflow deposits, and mudflow deposits. Color and lithology reflect parent rock and transported surficial materials. Thickness as much as 200 ft, but generally less than 100 ft.

Qgt **Glacial till (Pleistocene, Illinoian)**—Reddish-brown, brownish-gray, and gray, unstratified, compact, unsorted clay, silt, sand, and gravel with sparse matrix-supported granules, pebbles, cobbles, and boulders. Deposits mark approximate limit of Illinoian continental glaciation in northern part of quadrangle. Matrix dominantly calcareous clay loam, silty clay loam, and loam. Typically, 2 to 10 percent pebbles, cobbles, and boulders by volume. Glacial erratics are chiefly limestone, dolostone, orthoquartzite, and igneous and metamorphic rocks. Not mapped where thin and discontinuous. In northwest corner of quadrangle, unit includes outcrops of pre-Illinoian till not mappable at scale of map, and is covered by a veneer of glacial-lake clay, silt, and fine sand in many places. Thickness as much as 50 ft, but generally 30 to15 ft thick.

Qgl **Glacial Lake Great Falls deposit (Pleistocene) and reworked G.L.G.F. deposit (Pleistocene and/or Holocene)**—Dark-gray to reddish-brown, massive (in northwestern part of quadrangle) or grayish-orange, thinly bedded (in northeastern part of quadrangle) clay, silt, and fine sand with scattered boulders, cobbles, pebbles, and granules. Northeast of Square Butte, unit probably includes many small areas of Illinoian till, and lake deposits locally veneered by sheetwash alluvium. Thickness as much as 20 ft.

QTab **Alluvium of braid plains (Pleistocene and/or Pliocene)**—Light-brown to light-gray, crudely to well-stratified, and moderately to well-sorted sand and gravel that is older than alluvium of active stream channels (Qal). Occurs as remnants of braided-plain alluvial deposits and dissected deposits of coarse sediment derived from coalesced alluvial fans adjacent to Highwood Mountains (dominantly volcanic clasts), Little Belt Mountains (dominantly limestone clasts), Square Butte and Round Butte (dominantly shonkinite and syenite clasts), or from reworked older alluvium. Underlies at least five different topographic surfaces of different ages. On all but lowest surfaces upper part of deposit is in many places cemented by calcium carbonate. Unit is covered by loess as much as 4 ft thick on all but the very lowest (youngest) surfaces. Thickness ranges from 20 inches to 100 ft.

QTat **Alluvium of alluvial terrace deposit (Pleistocene and/or Pliocene)**—Light-brown to light-gray, unconsolidated, crudely to well-stratified, and moderately to well-sorted sand and gravel in alluvial terraces adjacent to and higher than modern meandering streams. Thickness as much as 30 ft.

QTdf **Debris flow deposit (Pleistocene and/or Pliocene)**—Brownish-gray, dissected, mass-wasting deposits of poorly sorted sediment. Contains abundant angular and subangular, locally derived, matrix-supported clasts ranging from pebbles to boulders; matrix dominantly mud. Matrix locally eroded, leaving lag deposit of larger clasts. Thickness ranges from 10 to 50 ft.

Tat **Alluvium of alluvial terrace deposit (Pliocene)**—Light-brown to light-gray, crudely to well sorted, coarse sand and gravel. Upper part locally cemented by calcium carbonate. Thickness as much as 40 ft, but generally about 20 ft.

Tbs **Block-slide deposit (Eocene)**—Gravity-slide blocks of bedrock (up to several kilometers wide) that have maintained internal integrity, but in most cases have rotated during transport so that beds strike at angles to, and have dips from 5^0 to 35^0 steeper than the dips of adjacent undisturbed rock. **Tbs(Kmu)** and **Tbs(Kmk)** indicate block-slide deposits composed primarily of Montana Group rocks and of upper Kevin Member, respectively, along the flanks of the Highwood Mountains. These blocks probably slid on bentonite beds in the lower part of the Kevin Member. **Tbs(Tmmc)** indicates block-slide deposit composed primarily of contact-metamorphosed Colorado and Montana Group rocks. **Tbs(Tl)** indicates block-slide deposits composed primarily of latite, and **Tbs(Tphm, Tl)** indicates block-slide deposits composed primarily of both mafic phonolite and latite south of Highwood Mountains. Many Eocene dikes were partially detached, transported, and rotated within block-slide deposits. Age of block-slides inferred from younger Eocene dikes that cut across the blocks.

Tla **Lamprophyre (Eocene)**—Gray- to dark-gray-weathered, fine-grained igneous alkalic rock characterized by prominent biotite phenocrysts and less abundant pyroxene phenocrysts; includes vogesite and minette-kersantite. Vogesite contains biotite and clinopyroxene phenocrysts in a groundmass of orthoclase, plagioclase, biotite, and clinopyroxene. Minette-kersantite contains biotite, feldspar, and some hornblende.

Tsy **Syenite (Eocene)**—Light-gray-weathered, medium- to coarse-grained igneous rock composed of orthoclase, plagioclase, and diopsidic augite phenocrysts in an orthoclase-rich groundmass. Locally contains sparse quartz phenocrysts.

Tsh **Shonkinite (Eocene)**—Dark-gray-weathered alkalic igneous rock composed of more than 50 percent mafic minerals, primarily diopsidic augite with some biotite and olivine. Barium sanidine and lesser nepheline make up the felsic component.

Tqsp **Quartz syenite porphyry (Eocene)**—Light-brown- to light-gray-weathered igneous intrusive rock of Tiger Butte that contains potassium feldspar, quartz, plagioclase, and biotite phenocrysts in a fine-grained groundmass that consists mainly of potassium feldspar and quartz. Sphene, apatite, and pyrite are accessory minerals. Miarolitic cavities several millimeters across are common (Berg, 1991). Exposed thickness 500 ft.

Tqm **Quartz monzonite (Eocene)**—Dark-brown- to grayish-brown-weathered igneous rock near Hughesville (T15N, R9E) with scattered large, brown feldspar phenocrysts. Dominant minerals are feldspar, quartz, biotite, and augite.

Tql **Quartz latite (Eocene)**—Light-gray- to medium-gray-weathered igneous rock that contains tabular phenocrysts of white feldspar and dark mafic minerals scattered in a fine-grained to aphanitic groundmass. In the Highwood Mountains, unit is intruded by numerous shonkinite and syenite dikes that are too closely spaced to show at scale of map.

Tphm **Mafic phonolite (Eocene)**—Dark-reddish-brown-, dark-gray-, and black-weathered extrusive rock and associated dikes and sills. Extrusive rocks are primarily flows, but map unit also includes some clastic rocks. Pyroxene is most abundant phenocryst, with less abundant pseudoleucite phenocrysts and relatively sparse olivine phenocrysts that typically are altered. Some vesicles are filled with zeolites.

Tqm **Quartz monzonite (Eocene)**—Southwestern corner of quadrangle: Light-brown- to light-gray-weathered intrusive rock that contains abundant large, round phenocrysts of smoky quartz and white feldspar. Hughesville area (T15N, R9E, Sec. 6 and 7): Hughesville quartz monzonite (Walker, 1991) is brownish-gray, fine- to coarse-grained, generally equigranular, but porphyritic in peripheral areas of the intrusion with phenocrysts of feldspar laths or clots of microcline (Walker, 1991).

Tl **Latite (Eocene)**—Pale-reddish-brown-, brownish-gray- to light-gray-, and medium-gray-weathered flows, tuff, breccia, and agglomerate that contain abundant hornblende phenocrysts, and less common biotite and small tabular feldspar phenocrysts.

Tr **Rhyolite (Eocene)**—Light-gray-weathered, dense, aphanitic volcanic rock that contains widely scattered feldspar, biotite, and rare topaz phenocrysts. Gold Run Tuff (Walker, 1991) in a diatreme near Hughesville (T15N, R9E, sec. 18) is a light-brown- to gray-weathered, heterogeneous mixture of angular to well rounded clasts in a finer-grained groundmass. Typical clast compositions are granite, quartz monzonite, quartz rhyolite, and sedimentary and metamorphic rock. (Walker, 1991)

Tmgm **Montana Group rocks metamorphosed to quartzite, siltite, and hornfels (Eocene)**— Upper Cretaceous Montana Group rocks metamorphosed by adjacent Eocene intrusions to light-gray-weathered quartzite, dark-brownish-gray-weathered siltite, and dark-gray-weathered hornfels. In areas transitional between metamorphosed and unmetamorphosed rock, sandstone is unchanged but shale is metamorphosed to hornfels. As much as 1,150 ft of section is metamorphosed. Shonkinite and syenite dikes in some areas of hornfels constitute more than 30 percent of the bedrock, but are too closely spaced to show at scale of map.

Tcgm **Colorado Group rocks metamorphosed to hornfels, siltite, and quartzite (Eocene)**—Upper and Lower(?) Cretaceous Colorado Group rocks metamorphosed to light-gray-, dark-gray-, and dark-brownish gray-weathered hornfels by adjacent Eocene intrusions. As much as 1,640 ft of section is metamorphosed. Shonkinite and syenite dikes in some areas of hornfels constitute more than 30 percent of bedrock, but are too closely spaced to show at scale of map.

Tcg **Conglomerate (Eocene ?)**—Poorly exposed and poorly sorted conglomerate in the Highwood Mountains composed of abundant limestone (Madison Group?) and quartzite clasts. Typically recognized by an abundance of clasts in residual soil. Thickness as much as 400 ft.

Kmg **Montana Group undivided (Upper Cretaceous)**—Includes Telegraph Creek, Eagle, Claggett, and Judith River Formations in areas of poor exposure. May include Kevin Member of the Marias River Shale (upper Colorado Group).

Kjr **Judith River Formation (Upper Cretaceous)**—Yellowish-brown- to gray-weathered, ledge-forming quartzose sandstone interbedded with poorly exposed black-weathered shale. Prominent very pale-orange-weathered, cross-bedded feldspathic sandstone at base; top not exposed. Thickness may be more than 500 ft.

Kcl **Claggett Formation (Upper Cretaceous)**—Dark-brown- to black-weathered, poorly exposed shale. Thickness ranges from 200 to 400 ft.

Ket **Eagle and Telegraph Creek Formations, undivided (Upper Cretaceous)**

Eagle Formation

Keu **Upper member of Eagle Formation (informal)(Upper Cretaceous)**—Dark-gray- to brownish-gray-weathered shale that contains thin, discontinuous coal beds, and yellowish-brown-weathered, fine- to medium-grained, trough-cross-bedded sandstone beds with scour bases. Thickness about 490 ft.

Kev **Virgelle Member of Eagle Formation (Upper Cretaceous)**—Very light-gray, yellowish-brown-, or grayish-brown-weathered, fine- to medium-grained sandstone. Planar bedded, trough cross-bedded, hummocky bedded, or bioturbated; contains rip-up clasts of siltstone and shale. Sandstone is well-sorted to moderately well sorted and contains small clay chips and organic fragments. Liesegang banding is common. Member generally weathers to form steep fluted surfaces. Uppermost bed of member is carbonaceous shale or coal. Thickness ranges from 65 to 130 ft.

Ktc **Telegraph Creek Formation (Upper Cretaceous)**—Interbedded, yellowish-brown or brownish-gray-weathered, planar-bedded sandstone and siltstone, and dark-gray- to brownish-gray-weathered shale. Abundance of sandstone and bed thickness increase upward. Thickness ranges from 60 to 148 ft.

Marias River Shale

Kmk **Kevin Member of Marias River Shale (Upper Cretaceous)**—Dark-gray-weathered, partly calcareous shale with abundant gray septarian limestone concretions. Lower part of member contains many thin bentonite beds and medium-gray to moderate-yellowish-brown-weathered fossiliferous limestone concretions. Middle part of member contains ferruginous and calcareous fossiliferous concretions and beds, and a conglomeratic limestone bed with black, well-rounded chert pebbles. Upper part of member contains thin siltstone beds. Thickness about 660 ft.

Kmf **Ferdig Member of Marias River Shale (Upper Cretaceous)**—Noncalcareous, dark-gray-weathered, fissile shale that contains lenticular-bedded siltstone, fine-grained sandstone, and distinctive reddish-orange ferruginous dolostone concretions that weather into small chips. Thin beds of fine-grained, planar-bedded sandstone or siltstone are present in upper part. Thickness about 200 ft.

Kmc **Cone Member of Marias River Shale (Upper Cretaceous)**—Lower part consists of dark-gray-weathered, calcareous shale that contains a basal zone of gray septarian concretions and a thick persistent bentonite bed. Upper part consists of thin beds of platy, medium-gray- or grayish-orange-weathered petroliferous limestone with blue fish scales, *Inoceramid*, and oyster fragments. Thickness about 60 ft.

Kmfl **Floweree Member of Marias River Shale (Upper Cretaceous)**—Dark-gray-weathered, fissile shale that contains several thin beds of grayish-orange-weathered siltstone, fine-grained sandstone, and also light-yellowish-gray, low-swelling, thin bentonite beds. Locally contains septarian concretions and ferruginous dolostone concretions that weather to small chips similar to those in the Ferdig Member. Thickness about 60 ft.

Km **Mowry Formation (Upper and Lower Cretaceous)**—Dark-gray-weathered, thinly interbedded siliceous shale, siltstone, and fine-grained sandstone. Pale-yellowish-brown to light-olive-gray, medium-grained sandstone that grades laterally into a chert-granule conglomerate with local concentrations of fish scales and bones present at top of formation. The formation grades laterally into the upper part of the Bootlegger Member of the Blackleaf Formation (exposed in western part of quadrangle). Thickness about 260 ft.

Kac **Arrow Creek Bed of Mowry and Blackleaf Formations**—Very light-gray and yellowish-gray-weathered porcellanite, locally zeolitized tuff, and bentonite. Some porcellanite contains contorted bedding produced by soft-sediment deformation. Unit occurs at base of the Mowry Formation where Mowry is present, or is within the Bootlegger Member of the Blackleaf Formation. Thickness ranges from 5 inches to 65 ft.

Kt **Thermopolis Shale (Lower Cretaceous)**—Dark-gray-weathered, fissile shale that contains many thin bentonite beds and several sandstone beds including a yellowish brown-weathered, thin-bedded, and fine-grained basal sandstone bed. Middle of formation contains a brownish-gray-weathered, medium-grained, trough-cross-bedded, hummocky or ripple-bedded sandstone bed and a reddish-brown, lenticular, fine- to medium-grained, limonite-cemented sandstone bed. Formation grades laterally into lower Bootlegger Member of Blackleaf Formation (western part of quadrangle). On Windham Dome (T16N, R12E, Sec. 18) a small area of sandstone preserved overlying hornfels is probably in Thermopolis Shale, but possibly is in Mowry Formation. Thickness about 600 ft.

Blackleaf Formation

Kbb **Bootlegger Member of Blackleaf Formation (Upper and Lower Cretaceous)**—Dark-gray-weathered, fissile shale that contains 2 to 6 prominent sandstone beds, each 10 to 40 ft thick, separated by 50 to 100 ft of shale. Many thin bentonite beds and an unnamed porcellanite bed similar to the Arrow Creek Bed (but stratigraphically below it), are present near top of member in central part of quadrangle. The light-brown- to yellowish-brown-weathered, fine- to medium-grained sandstone beds commonly are ripple-laminated, with abundant trace fossils on bedding surfaces. Trough cross-bedding and hummocky bedding are common in upper part of member, and fish scales and bones are common in the uppermost sandstone beds. Tops of sandstone beds locally contain black chert pebbles. A well-cemented chert-pebble conglomerate or coarse-grained sandstone is present at top of member. Sandstone beds are laterally persistent over many square kilometers. In the eastern part of the quadrangle, the upper part of the Bootlegger Member grades laterally into the Mowry Formation and the lower part of the Bootlegger Member grades laterally into the Thermopolis Shale. Thickness ranges from 60 to 330 ft.

Kbv **Vaughn Member of Blackleaf Formation (Lower Cretaceous)**—Poorly exposed, very bentonitic, silty, gray-weathered shale with thin bentonite beds. Member present only in western part of quadrangle. Thickness about 100 ft.

Kbt **Taft Hill Member of Blackleaf Formation (Lower Cretaceous)**—Medium-dark-gray- to medium-light-gray-weathered, bentonitic silty shale with several thin, glauconitic sandstone beds. Member grades laterally into the Thermopolis Shale (eastern part of quadrangle). Thickness about 120 ft.

Kblf **Flood Member of Blackleaf Formation (Lower Cretaceous)**—Black- to dark-gray-weathered fissile shale that contains pods and lenses of bioturbated sandstone at its base. Lacks two prominent sandstone beds that are present west of the quadrangle. Member grades laterally into the Thermopolis Shale (eastern part of quadrangle). Thickness ranges from 100 to 130 ft.

Kootenai Formation

Kk_5 **Fifth member of Kootenai Formation (informal)(Lower Cretaceous)**—Red-weathered mudstone that contains lenses of sandstone and limestone. Uppermost part of member consists of massive, color-banded, greenish-gray, grayish-red-purple, moderate-red and very dark red mudstone with lenses of fine- to medium-grained, trough-cross-bedded, greenish-gray-weathered sandstone. Not present in southeastern part of quadrangle. Thickness about 120 ft.

Kk_4 **Fourth member of Kootenai Formation (informal)(Lower Cretaceous)**—Dusky-red to pale-reddish-brown-weathered, fine- to medium-grained, thin- to medium-bedded, ripple-laminated, argillaceous, platy-bedded sandstone interbedded with very-dark-red-weathered mudstone. In the southern part of quadrangle, light-brown-weathered, medium-grained, trough-cross-bedded sandstone beds are also present. Thickness about 100 ft.

Kk_s **Sunburst Sandstone Member of Kootenai Formation (Lower Cretaceous)**—Light-yellowish-brown-weathered, well-sorted, resistant quartzose sandstone with interspersed limonite specks. Scour base with rip-up clasts and chert pebbles cuts into second member and locally into Cutbank Sandstone Member. As much as 20 percent interstitial dark chert at base, but dark chert is almost completely lacking higher in the section. Member pinches out east of Raynesford. Thickness from 0 to 80 ft.

Kk_2 **Second member of Kootenai Formation (informal)(Lower Cretaceous)**—Red-weathered, poorly resistant mudstone that contains dense, medium-gray micrite and argillaceous, light-brownish-gray micritic concretions that laterally become lenticular, irregular beds. Thin, lenticular, chert-rich quartzose sandstone beds are present locally. A bed of intraformational, micrite-clast conglomerate is present near top of member. Thickness about 110 ft.

Kk_c **Cutbank Sandstone Member of Kootenai Formation (Lower Cretaceous)**—Basal, resistant, festoon-cross-bedded, moderately well sorted quartz sandstone with 20 to 50 percent black, dark-gray, and light-gray chert; appears to be depositionally related to underlying Morrison Formation coal bed. Coarse-grained sandstone, chert-granule conglomerate, or chert-pebble conglomerate present at scour base of member, typically with rip-up clasts of coal, plant fragments, and plant impressions. Becomes finer-grained upward, and in some areas upper part of sandstone contains very little chert. Thickness ranges from 20 to 100 ft.

KJm **Morrison Formation (Lower Cretaceous and Jurassic)**—Light-greenish-gray mudstone or locally light-red weathered-sandstone with interbedded lenses of medium-gray micrite, and fine- to medium-grained, calcareous, thin-bedded, yellowish-brown-weathered sandstone. Subbituminous coal bed as much as 12 ft thick at or near top of formation. Gradational contact with underlying Swift Formation and overlying

Kootenai Formation, but contains a significant unconformity below the dark shale and coal of the upper Morrison (Lloyd Furer, Indiana Geological Survey, personal communication, 1999.) Thickness ranges from 100 to 200 ft.

Je **Ellis Group,** undivided

Swift Formation—Grayish-orange-weathered, calcareous, fine- to coarse-grained, glauconitic sandstone that contains interbeds of gray-, red-, and green-weathered shale with fragments of oysters and pelecypods, and a basal chert-pebble conglomerate. Thickness ranges from 50 to 120 ft.

Piper and Rierdon Formations—Grayish-green shale, dusky-red and grayish red-purple gypsiferous shale, and gray limestone beds. Thickness ranges from 0 to 30 ft.

Amsden Group*

ⅣMab **Alaska Bench Formation (Pennsylvanian and Mississippian)**—Medium-gray-, light-gray-, and yellowish-gray-weathered resistant limestone and dolostone in beds ranging from 10 inches to 3 ft thick, interbedded with red mudstone. Formation not present in part of quadrangle because of pre-Jurassic erosion. Thickness ranges from 0 to 230 ft.

Mt **Tyler Formation (Mississippian)—**Pale-reddish-brown, dusky-red, and grayish-red-weathered mature quartzose sandstone and conglomerate beds that range from 1 to 7 ft thick, interbedded with dark-gray-, grayish-red-, and dusky-red-weathered shale. Formation not present in part of quadrangle because of pre-Jurassic erosion. Thickness ranges from 0 to 300 ft.

Big Snowy Group

Mh **Heath Formation (Mississippian)**—Dark-gray-weathered, fissile, locally petroliferous shale that contains dark-gray- and light-gray-weathered, micritic limestone beds. Locally contains dark-gray chert and a very-light-gray-weathered gypsum bed. Generally intruded by one or more basic sills. Highly prone to landsliding. Formation not present in western part of quadrangle because of pre-Jurassic erosion. Thickness ranges from 0 to 500 ft.

Mo **Otter Formation (Mississippian)**—Brilliant-green-, moderate-yellowish-green-, and dark-greenis-gray-weathered shale and siltstone with thin platy micrite beds that locally contain black chert, oölites, stromatolites, and other algal structures. Thickness ranges from 300 to 500 ft.

Mk **Kibbey Formation (Mississippian)**—Light-red, moderate-red, and dark-reddish-brown-weathered, interbedded sandstone, siltstone, and shale. Pale-yellowish-orange, mature quartzose sandstone in upper part. Contains gypsum bed as much as 30 ft thick, and thin lenses of gypsum interbedded with shale. Thickness ranges from 65 to 100 ft.

Madison Group

Mmc **Mission Canyon Limestone (Mississippian)**—Light-gray- to dark-gray-weathered, resistant, massive, or thick-bedded, fossiliferous limestone that contains black or dark-orange chert and solution breccia. Thickness about 800 ft.

Ml **Lodgepole Limestone (Mississippian)**—Light-gray, brownish-gray-, and dark-gray-weathered, dominantly thin-bedded fossiliferous limestone that contains abundant black chert. Thickness about 700 ft.

MDt **Three Forks Formation (Mississippian and Devonian)**—Light-gray- and greenish-gray-weathered shale that contains reddish-gray-weathered, thin-bedded siltstone beds and brownish-gray-weathered dolomite beds. Formation rarely exposed. Thickness about 65 ft.

Dj **Jefferson Formation (Devonian)**—Upper unit (Birdbear Member) light-gray-weathered resistant dolomite with saccharoidal texture, about 60 ft thick. Middle unit medium- to dark-gray-weathered, coarsely crystalline dolomite with petroliferous odor. Lower unit light-gray-weathered limestone that contains black chert, corals, and algal structures. Total thickness about 250 ft.

Dm **Maywood Formation (Devonian)**—Yellowish-brown- and reddish-brown-weathered, thin-bedded siltstone interbedded with medium-gray-weathered shale. Thickness about 80 ft.

Ꞓpi **Pilgrim Limestone (Cambrian)**—Light-gray- to medium-gray-weathered limestone and thin beds of dark-gray-weathered shale. Intraformational flat-pebble conglomerates common. Thickness about 148 ft.

Ꞓp **Park Shale (Cambrian)**—Light-gray to greenish-gray-weathered, micaceous shale that contains irregular thin beds of light-gray limestone in upper part. Metamorphosed to dark gray hornfels near intrusions. Thickness ranges from 170 to 250 ft.

Ꞓm **Meagher Limestone (Cambrian)**—Medium-gray- to light-gray-weathered, thin- and irregular-bedded, glauconitic limestone with irregular yellowish-orange, silty claystone mottles. Metamorphosed to skarn and marble near intrusions. Thickness about 75 ft.

Ꞓw **Wolsey Shale (Cambrian)**—Dark-gray- and dark-greenish-gray-weathered, glauconitic and micaceous shale. Metamorphosed to very dark-gray hornfels near intrusions. Thickness about 150 ft.

Ꞓf **Flathead Formation (Cambrian)**—Pinkish-gray to reddish-brown-weathered, well-cemented and indurated, cross-bedded, coarse- to medium-grained, conglomeratic sandstone and conglomerate. Contains thin shale beds in middle part and very-light-gray-weathered sandstone in upper part. Thickness about 50 ft.

pꞒpi **Pinto Diorite (Early Proterozoic)**—Mottled gray to greenish gray, massive, locally gneissic, medium- to coarse-grained diorite. Clusters of hornblende phenocrysts in a feldspathic groundmass. Dominant minerals are hornblende, sodic and calcic plagioclase, microcline, quartz, and augite-salite.

pꞒgg **Granite gneiss (Archean)**—Gray, massive, locally gneissic, medium- to coarse-grained orthogneiss(?). Dominant minerals are quartz, microcline, sodic plagioclase, biotite, hypersthene, and augite.

pꞒc **Amphibolite and pegmatite (Archean)**—Complex assemblage of dark-gray to black foliated amphibolite and white, massive, coarsely crystalline pegmatite.

pꞒmg **Metagabbro (Archean)**—Grayish brown to gray, massive (little to no foliation), medium- to coarse-grained metagabbro. Dominant minerals are andesine, hypersthene, augite-salite, and biotite.

pꞒa **Augen gneiss (Archean)**—Red- to reddish-brown-weathered, gray, with prominent gneissic structure locally and large orthoclase porphyroblasts. Dominant minerals are alkalic feldspar, oligoclase, biotite, quartz, hornblende, hypersthene, and augite-salite. Includes thin band of light-gray-foliated rock that encircles reddish-brown augen gneiss and contains many small feldspar porphyroblasts.

pꞒga **Garnet gneiss (Archean)**—Gray paragneiss(?). Narrow layer rich in garnets and pyroxenes that may be a result of contact metamorphism by Precambrian intrusions. Dominant minerals are garnet, andesine, biotite, hypersthene, augite-salite, and quartz.

pꞒh **Hornblende biotite gneiss (Archean)**—Gray to dark-gray, well-layered, locally severely contorted fine- to medium-grained paragneiss(?). Dominant minerals are hornblende, biotite, oligoclase, quartz, and alkalic feldspar.

pꞒmi **Microcline gneiss (Archean)**—Light-gray quartzofeldspathic, well-foliated, light-gray paragneiss(?). Contains polycrystalline blebs of quartz, xenoblastic grains of microcline and albite, and small amounts of biotite, epidote, and opaque iron ores.

Precambrian unit descriptions from Witkind, 1971.

MAP SYMBOLS

Belt 30′ x 60′ QUADRANGLE

Contact between geologic units— dotted where concealed.

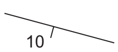
Contact between Precambrian metamorphic rock types— Irregular and gradational.

Fault, high-angle normal or reverse— Dashed where approximately located, dotted where concealed. Ball and bar on downthrown side.

Fault, thrust—Sawteeth on upper plate.

Fault, dextral stroke-slip— Dotted where concealed. Arrows indicate relative lateral movement.

Graben —Ball and bar on downthrown side.

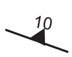


Strike and dip of bedding— Number indicates angle of dip in degrees.

Vertical beds.

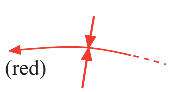
Overturned beds— Number indicates angle of dip in degrees.

Horizontal beds.

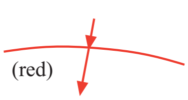


Strike and dip of foliation— Number indicates angle of dip in degrees.

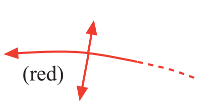
Vertical foliation.



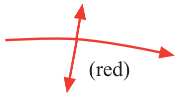
Syncline — Showing trace of axial plane and direction of plunge; dotted where concealed. Plunge arrow omitted where not plunging or plunge direction unknown.



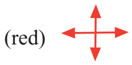
Monocline, synclinal bend— Showing trace of axial plane; short arrow on more steeply dipping limb.



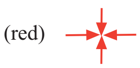
Anticline— Showing trace of axial plane and direction of plunge; dotted where concealed. Plunge arrow omitted where not plunging or plunge direction unknown.



Asymmetric anticline— Showing trace of axial plane and direction of plunge. Short arrow on more steeply dipping limb.



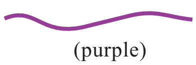
Small dome— (~ $1km^2$), center where arrows cross.



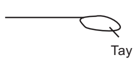
Depression— Arrows point to center in direction of bedding dip.

Diatreme.

Dike—Shonkinite, syenite, mafic phonolite, minette aand related compositions with steep dip, and width typically less than 13 ft, dotted where low straight topographic ridge in surficial deposits suggests a concealed dike.



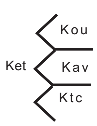
Sill— Sheet-like bbody of syenite, mafic phonolite, or rocks of related compositions that are conformable to, or nearly conformable to bedding in adjacent sedimentary rocks; 3-10 ft. thick



Cross section of sill shown on map. Composition indicated where thickness can be shown with two lines.

Surface of sill shown on map, with composition indicated.

Facies Change— From unit on one side of symbol to unit on other side.



Symbol change—from area where two or more units are combined, to area where they are mapped individually or fewer units are combined.

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