Geologic Map of the Harrison and Maltbys Mound 7.5' Quadrangles, Madison County, Montana

by

William S. Elliott, Jr.[1]

Open File Report MBMG 375

Partial support provided by the National Cooperative Geologic Mapping Program of the U.S. Geological Survey; EDMAP Contract Number 1434-HQ-96-AG-01556.

[1] Department of Geological Sciences
Indiana University
1005 East Tenth Street
Bloomington, IN 47408

Geologic Map of the Harrison 7.5' Quadrangle, Madison County, Montana

by

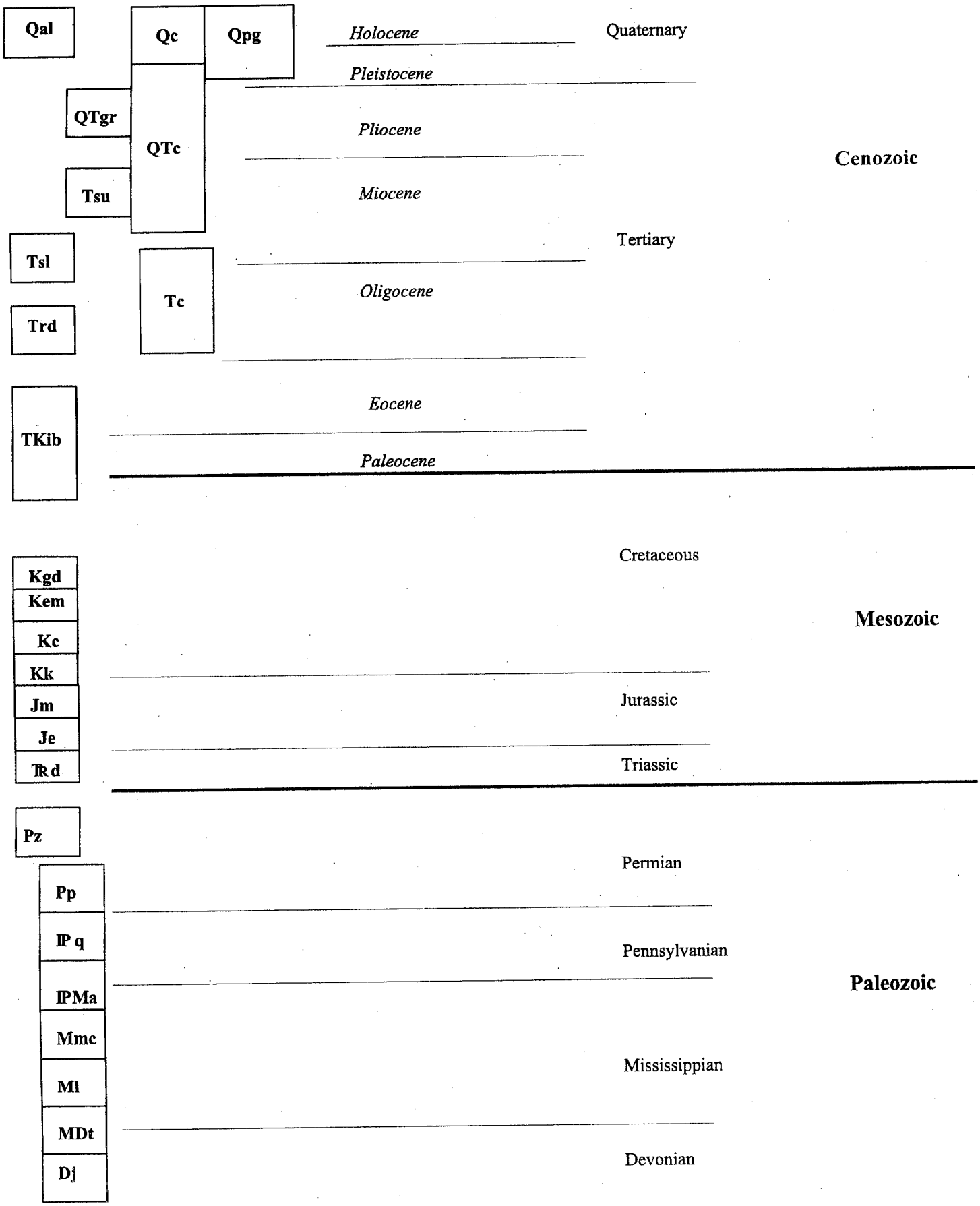
William S. Elliott, Jr.[1]

Open File Report MBMG 375, Text Part 1 of 2

Partial support provided by the National Cooperative Geologic Mapping Program of the U.S. Geological Survey; EDMAP Contract Number 1434-HQ-96-AG-01556.

[1] Department of Geological Sciences
Indiana University
1005 East Tenth Street
Bloomington, IN 47408

Age and Lateral Relationship of Map Units



Age and lateral Relationship of map Units (Continued)

Devonian

D∈dc		**Paleozoic**
∈pi		
∈p		
∈m	*Cambrian*	
∈w		
∈f		

Aam	**Aum**	**Aimb**	**Archean**
	Aqf		

Description of Map Units

CENOZOIC ROCKS AND SEDIMENTS

Qal Alluvium (Holocene)

Moderately to well-sorted, subrounded to well-rounded sand and gravel in a matrix of clay and fine silt, deposited in stream channels, along flood plains, and on terraces. Terraces rarely exceed 12 m above major drainages and 2 m above tributary streams (Kellogg and Vuke 1996). Average thickness of alluvial material in the South and North Willow Creek drainages range from 3 to 10 m.

Qc Colluvium (Late Pleistocene to Holocene)

Unstratified, unconsolidated material that has been intermixed by downslope movement, and is derived from a local source. Developed on slopes greater than 5 degrees. Thickness varies from 1 to 7 m.

Qpg Pediment gravel (Late Pleistocene to Holocene)

Stratified, sorted, angular- to rounded-gravel in a matrix of sand and silt. Developed on slopes less than 5 degrees. Thickness varies from 0.5 to 3 m.

QTgr Gravel and sand (Pliocene and possible Pleistocene)

Stratified, unconsolidated, poorly to well-sorted, moderately to well-rounded pebbles and boulders in a nonindurated sandy matrix. Clasts of Archean metamorphic rocks, Cretaceous Tobacco Root batholith granodiorite, Cambrian Flathead Formation sandstone, Pennsylvanian Quadrant Formation sandstone, and Tertiary sandstones and mudstones range from 2 to 5 cm to 1 to 2 m in diameter. Locally interbedded with finer-grained mudstone, siltstone, and tuffaceous siltstone.

QTc Old colluvium (Miocene to early Pleistocene)

Unstratified, unconsolidated material that has been intermixed by downslope movement

and is derived from a local source. Thickness varies from 0 to 18 m.

Tsu Sediments, upper unit: gravel, sand, and mud (Miocene and possibly Pliocene)

Light brown to red-brown, stratified, consolidated, moderately to well-sorted, moderately to well-rounded pebbles and cobbles, interbedded with fine-grained mudstones and siltstones. Gravel and sand deposits contain planar and trough cross stratification. Thickness varies from 0 to 15 m.

Tsl Sediments and sedimentary rocks, undivided; lower unit: conglomerate, sandstone, and siltstone (Miocene)

White to tan, poorly to moderately indurated, bedded to massive, interbedded conglomerates, sandstones, siltstones, and mudstones. The sandstones and conglomerates contain trough cross stratification with occasional planar cross stratification. This unit correlates with the Six Mile Creek Formation of Kuenzi and Fields (1971) and "sequence 4" of Hanneman and Wideman (1991). Thickness varies from 10 to 40 m.

Tc Old colluvium (Oligocene)

Unstratified, consolidated material that has been intermixed by downslope movement and is derived from a local source. These deposits are well lithified and onlap the Paleozoic rocks on the west side of Little Antelope Creek valley. This map unit is a coarse-grained facies of the Dunbar Creek Member of the Renova Formation. Thickness varies from 0 to 18 m.

Trd Dunbar Creek Member of the Renova Formation (Oligocene)

White, yellowish-white, and light-gray, moderately to well-indurated siltstone, sandstone, limestone, clast-supported conglomerate, and matrix-supported conglomerate. In Antelope Creek valley, the conglomerates and sandstones are well lithified and contain quartz cement. The clasts increase in size (2-3 cm to 5-9 cm) toward the Tobacco Root Mountains (southwest) and consist of 50-60% gneiss and fine-grained quartzite, 0-10% vein quartz, 20-30% granodiorite, and 0-10% aplite. Imbricated clasts are common in

coarser-grained lenses. Originally described by Robinson (1963) as the Dunbar Creek Formation in the Three Forks 15' quadrangle, northeast of the map area. Oligocene age was assigned based on vertebrate fossils from the map area (Robinson 1963). Kuenzi and Fields (1971) redefined the Dunbar Creek as a member of the Renova Formation in the Jefferson basin. The upper part of this unit is well exposed in the northern part of the map area, especially in Antelope Creek valley and overlies rocks varying in age from Archean to Cretaceous.

TKib Intrusive basalts (Eocene, Paleocene, or Upper Cretaceous)

Black, gray, greenish-gray, grayish-brown, fine-grained basalts. Samples contain 60% calcic plagioclase, 25% clinopyroxene, 10% iddingsite (replaced olivine), and 5% opaque minerals (Kellogg, 1994). Dikes cut across Archean gneiss foliation in the southern part of the map area. The basalt crops out as a gray weathered, massive, nonporphyritic rock.

MESOZOIC ROCKS

Kgd Granodiorite of the Tobacco Root batholith (Upper Cretaceous)

Gray, coarse-grained, inequigranular to porphyritic, hypidiomorphic, massive hornblende-biotite granodiorite with lesser volumes of monzogranite and monzodiorite (Kellogg 1994). The granodiorite crops out in the southwest corner of the map area. There is little to no alteration of the country rock, but aplite and pegmatite dikes cut across the batholith and country rock within several hundred meters of the contact between the country rock and batholith. The age of the batholith is approximately 71 to 74 Ma (Vitaliano and Cordua 1979). The composition of a typical sample of granodiorite contains 50% zoned oligoclase, 15-25% green hornblende, 15-20% microcline, 10-20% quartz, 5% biotite, 0-1% clinopyroxene cores in hornblende, trace to 2% magnetite, traces of apatite, and conspicuous sphene and zircon; texture is hypidiomorphic (Kellogg 1994). The granodiorite weathers to dark gray, in rounded tors or grussy outcrops.

Kem Elkhorn Mountains Volcanics (Upper Cretaceous)

On cross section A-A'.

Kc Colorado Group (Upper Cretaceous)

On cross section A-A'. The lower 5-10 meters is a fine- to medium-grained, tan, laterally continuous, cross-stratified, quartz-rich sandstone. The upper part consists of fissile black shale. The total thickness is about 200 m.

Kk Kootenai Formation (Lower Cretaceous)

The lower 10-15 m is a medium- to coarse grained, gray, laterally continuous, cross-stratified, ledge-forming sandstone containing up to 35% detrital black and gray chert. The middle part is dominated by variegated red, purple, yellow, tan, and gray mudstone, siltstone, and sandstone. Upper 5-10 m are medium-bedded, light gray, micritic, fossiliferous limestone with interbedded gray shales. The fossils are primarily gastropods and are most abundant in the upper part of the limestone. The Kootenai unconformably overlies the Morrison Formation. The total thickness is about 90-130 m.

Jm Morrison Formation (Upper Jurassic)

Medium-grained sandstones, lacustrine limestones, variegated red, purple, tan, and gray mudstones and siltstones. Unit dominated by mudstones and siltstones interbedded with discontinuous sandstones and limestones. Sandstone bodies average 1-3 m thick and are laterally discontinuous. Conformably overlies the Ellis Group. Thickness ranges between 100 and 150 m.

Je Ellis Group, undivided (Jurassic)

Includes (1) the Swift Formation: trough cross-stratified, medium- to coarse-grained sandstone containing a basal conglomerate composed of chert and Rierdon Limestone clasts; unconformably overlies the Rierdon Limestone; thickness about 10 m; (2) the Rierdon Formation: thin- to thick-bedded, light gray, fine-grained, oolitic, fossiliferous limestone; fossils include *Pentacrinous sp.*, bivalves *Camptonectes* sp. and *Gryphaea* sp. (Kellogg 1993); chert clasts are abundant locally at the base of the Rierdon but may be

found throughout; unconformably overlies the Dinwoody Formation; thickness about 10 to 20 m.

T_Rd Dinwoody (Triassic)

Red-brown to dark brown, fossiliferous, silty, limestone. Abundant *Lingula* brachiopods. This unit crops out in the northern part of the map area, east of Antelope Creek valley. This unit unconformably overlies the Phosphoria Formation. Thickness varies from 30 to 40 m.

PALEOZOIC ROCKS

Pz Paleozoic rocks, undifferentiated

Pp Phosphoria Formation (Permian)

Consists of dolostone, conglomerate, fine- to medium-grained sandstone, phosphatic pisolithic rock, bedded chert, siltstone, and black shale. Thickness about 30-40 m.

IPq Quadrant Formation (Pennsylvanian)

Medium- to thick-bedded, white, well-sorted, fine- to medium-grained, well-cemented quartz sandstone. Dolostones are also present in the lower half and the upper 15 m of the formation (Kellogg 1993). Lower contact conformable with the underlying Amsden Formation. Thickness about 50-75 m.

IPMa Amsden Formation (Upper Mississippian to Middle Pennsylvanian)

Consists of red mudstone, light gray fossiliferous limestone, brown to tan dolostone, siltstone, and fine-grained sandstone. Fossils include brachiopods, crinoids, and bryozoans. Unconformably overlies the Mission Canyon Formation. Thickness about 100-110 m.

Madison Group

Mmc Mission Canyon Formation of Madison Group (Mississippian)

Massive-bedded, light gray, medium-grained, crystalline limestone. Chert stringers and nodules are common and some fossils may also be present, including brachiopods, horn corals, bryozoans, and crinoids. Solution breccias are common in the uppermost part. Prominent ridge-forming unit. Conformable with underlying Lodgepole Formation (Kellogg 1993). Thickness about 250 m.

Ml Lodgepole Formation of Madison Group (Mississippian)

Thin- to medium-bedded, light gray, fossiliferous to micritic limestone. Fossils include brachiopods, bryozoans, crinoids, horn corals, and ostracods. Unconformably overlies the underlying Three Forks Formation. Thickness about 200 m.

MDt Three Forks Formation (Mississippian and Upper Devonian)

Thin-bedded, gray-green, interbedded siltstones and shales. Middle fossiliferous limestone about 25 m from the base (Logan Gulch Member). Fossils include brachiopods, crinoids, and horn corals. Top 10 m consist of tan, highly-bioturbated, fine-grained quartz sandstone (Sappington Member). Excellent exposure of the Sappington Member near Little Antelope Creek valley in the northern part of the map area. Prominent valley-forming unit. Unconformably overlies the Jefferson Formation. Thickness about 80-90 m.

Dj Jefferson Formation (Upper Devonian)

Thick-bedded, dark gray, black, and light gray, petroliferous, medium- to coarse-crystalline dolostone. Top 10 m consist of a light gray dolostone. Unconformably overlies the Dry Creek Formation. Thickness about 200 m.

DЄmr Maywood Formation (Devonian) and Red Lion Formation (Cambrian), undivided

Gray-black to tan shale and white dolostone. The dolostone unconformably overlies the shale. Thickness is about 10-15 m.

∈pi Pilgrim Formation (Upper Cambrian)

Gray, light gray, medium- to massive-bedded limestone and medium-crystalline dolostone. Top 2 m contain stromatolites and some sand-size quartz grains. Upper 40 m represented by cross-bedded, intraclastic dolostone. Lower part of formation dominated by bioturbated, gold- and tan-mottled texture with silt stringers, wackestones and packstones. Prominent ridge-forming unit. Conformably overlies the Park Shale. Thickness about 100 m.

∈p Park Formation (Middle Cambrian)

Green-gray shale, poorly exposed. Conformably overlies the Meagher Formation and is 60 m thick in the map area.

∈m Meagher Formation (Middle Cambrian)

Thin- to massive-bedded, light gray, fine micritic limestone. Upper part contains oolites, intraclasts, and fossil fragments, is thinly bedded and contains tan mottles. The middle part contains abundant oolites and is thick bedded. The lower portion is thinly bedded and contains tan mottles. Conformably overlies the Wolsey Formation and is 100-120 m thick in the study area.

∈w Wolsey Formation (Middle Cambrian)

Thin-bedded, greenish-gray, olive green, micaceous shales, siltstones, and sandstones. Sandstone and siltstone beds are wavy and bioturbated, and are interbedded with green micaceous shales (Kellogg 1993). Near middle of unit is a 10- to 15-meter-thick dark gray, argillaceous limestone (Silver Hill Member). Prominent valley and slope former. Conformably overlies the Flathead Formation. Thickness about 60-70 m.

∈f Flathead Formation (Middle Cambrian)

Thin- to medium-bedded, medium- to coarse-grained, tan to brown, quartz-rich sandstone and green shale/mudstone (Kellogg 1993). The base of this unit is often dominated by a zone of weathering represented by a red-brown mudstone. Unconformably overlies the Precambrian crystalline rock. Thickness about 40-50 m.

PRECAMBRIAN ROCKS

Aam Amphibolite (Archean)

Gray to black, medium- to coarse-grained, hypidiomorphic equigranular, moderately foliated to well-foliated hornblende-plagioclase gneiss and amphibolite (Kellogg 1994). Minor amounts of other Archean units are intertongued with this unit.

Aum Meta-ultramafic rocks (Archean)

Black to greenish-gray, fine- to medium-grained, massive, variably serpentinized ultramafic rocks of various compositions. Occur in lenses, pods, sills, and irregular masses. Thickness varies in map area. Some sills are 20-30 m thick. Weather to dark gray to black, angular outcrops.

Aimb Intrusive metabasite (Archean)

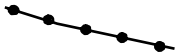
Black, fine-grained, equigranular, granoblastic, massive, serpentinized, pyroxene-hornblende-calcium plagioclase metabasalt and metagabbro. Occurs in sills up to 30 m thick. Composition varies: 15-45% plagioclase, 10-60% hornblende, 2-30% augite, 0-20% almandine, 0-10% biotite, 0-8% quartz, 0-5% orthoclase, 1-5% opaque minerals, and trace apatite (Kellogg 1994). Equivalent to orthoamphibolite of Vitaliano and Cordua (1979).

Aqf Quartzofeldspathic gneiss (Archean)

Light gray to light pinkish-gray, medium- to coarse-grained, weakly to moderately foliated gneiss ranging from granodiorite to granite in composition. Composition varies: 10-60% plagioclase, 10-50% microcline, 3-40% quartz, trace to 15% biotite, 0-5%

yellow to greenish-brown hornblende, 0-5% almandine, 0-2% augite, 0-2% muscovite, and traces of zircon, epidote, and opaque minerals. Locally contains mylonitic and migmatitic texture (Kellogg 1994). This unit corresponds to Vitaliano and Cordua's (1979) quartzofeldspathic gneiss.

Map Symbols



Quartz vein: white massive quartz in lenticular, generally discordant veins and irregular pods. Locally grades into pegmatite (Kellogg 1994). Very widespread within the map area; only large bodies are mapped; age uncertain.

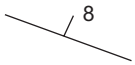
p

Pegmatite: concordant and discordant, white to pink, coarse-grained to very coarse-grained, massive dikes, sills, and plugs composed mostly of orthoclase, quartz, plagioclase and muscovite; age uncertain.

Contact between map units: dashed where approximate, dotted where concealed.

Normal fault: dashed where approximate, dotted where concealed. Bar and ball on downthrown side.

Strike and dip of beds



Inclined

Vertical

Horizontal

Strike and dip of foliation

Inclined

Vertical

Area of hydrothermal alteration

Sills and Dikes: Thickness is less than 30 m. The map unit represented is TKib unless otherwise noted on the map.

Previous Mapping and Investigations

A geologic map of the Bozeman 30'x 60' quadrangle (1:100,000 scale) was compiled by Vuke and others (1995). The Archean geology of the Harrison quadrangle was previously mapped by Vitaliano and Cordua (1979) at a scale of 1:62,500. The Paleozoic and Mesozoic rocks in the northern part of the map area were previously mapped by Schmidt (1975) at the 1:24,000 scale.

The geometry of the Dunbar Creek Member of the Renova Formation (Trd) on the Harrison quadrangle geologic cross section, and the location of the Cherry Creek and Elk Creek faults are based on gravity data (Elliott 1998).

Acknowledgements

I would like to thank my advisors, Dr. Bruce Douglas and Dr. Lee Suttner of Indiana University, for their involvement and assistance with this project. Discussions with James Brophy, Walt Coppinger, Debbie Hanneman, Glenn Kroeger, Sue McDonald, Jim Meyers, Greg Olyphant, Ed Ripley, and Susan Vuke pointed me in the right direction during my field work. I am grateful to Sally Letsinger for compiling the Harrison geologic map into ArcInfo. I would like to thank Dirk Vandervoort and Joel Hall of the Montana Bureau of Mines and Geology for compiling, editing, and completing the final GIS version of the Harrison quadrangle. I would also like to thank Karen Porter, Dirk Vandervoort, Debbie Hanneman, Susan Vuke, Dick Berg, Larry Smith, and Wayne Van Voast for careful reviews of the Harrison geologic map and report. The Indiana University Geologic Field Station provided a vehicle, a warm place to stay, food to eat, and a great atmosphere. Many thanks go to the numerous landowners who permitted me to collect data and samples from their property. I would also like to thank my parents for the support they have provided throughout this project. Partial field support has been provided by the National Cooperative Geologic Mapping Program of the U.S. Geological Survey.

References

Elliott, W. S., Jr. 1998. Tectono-stratigraphic control of Quaternary and Tertiary sediments and structure along the northeast flank of the Tobacco Root Mountains, Madison County, Montana. M. S. thesis. Bloomington: Indiana University. 113 p.

Hanneman, D. L., and Wideman, C. J. 1991. Sequence stratigraphy of Cenozoic continental rocks, southwestern Montana. Geological Society of America Bulletin 103: 1335-1345.

Kellogg, K. S. 1993. Geologic map of the Cherry Lake quadrangle, Madison County, Montana. U.S. Geological Survey Geologic Quadrangle Map GQ-1725. Scale 1:24,000.

Kellogg, K. S. 1994. Geologic map of the Norris quadrangle, Madison County, Montana. U.S. Geological Survey Geologic Quadrangle Map GQ-1738. Scale 1:24,000.

Kellogg, K. S., and Vuke, S. M. 1996. Geologic map of the Willow Creek Reservoir and Norris NE quadrangles, Gallatin and Madison counties, Montana. U. S. Geological Survey Open File Report 96-012. Scale 1:24,000.

Kuenzi, W. D., and Fields, R. W. 1971. Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana. Geological Society of America Bulletin 82: 3374-3394.

Robinson, G. D. 1963. Geology of the Three Forks quadrangle, Montana. U.S. Geological Survey Professional Paper 370. 143 p.

Schmidt, C. J. 1975. An analysis of folding and faulting in the northern Tobacco Root Mountains, southwest Montana. Ph.D. dissertation. Bloomington: Indiana University, Ph.D. 480 p.

Vitaliano, C. J., and Cordua, W. S. 1979. Geologic map of the southern Tobacco Root Mountains, Madison County, Montana. Geological Society of America Map and Chart Series MC-3. Scale 1:62,500.

Vuke, S. M., Berg, R. B., Lonn, J. D., and Kellogg, K. S. 1995. Geologic map of the Bozeman 30'x 60' quadrangle, Montana. Montana Bureau of Mines and Geology Open File Report MBMG-334. Scale 1:100,000.

Geologic Map of the Maltbys Mound 7.5' Quadrangle, Madison County, Montana

by

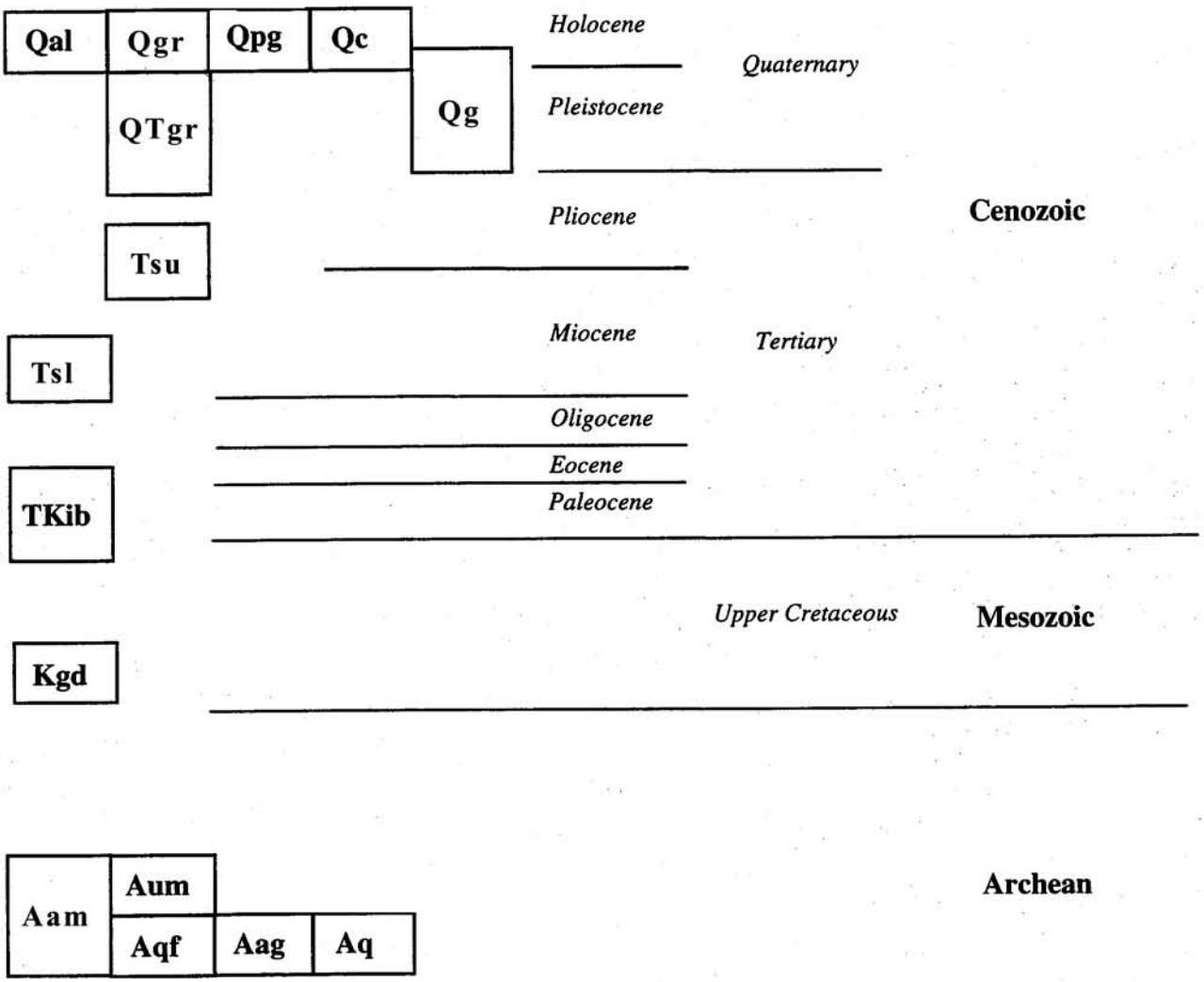
William S. Elliott, Jr.[1]

Open File Report MBMG 375, Text Part 2 of 2

Partial support provided by the National Cooperative Geologic Mapping Program of the U.S. Geological Survey; EDMAP Contract Number 1434-HQ-95-AG-01556.

[1] Department of Geological Sciences
Indiana University
1005 East Tenth Street
Bloomington, IN 47408

Age and Lateral Relationship of Map Units



Description of Map Units

CENOZOIC ROCKS AND SEDIMENTS

Qal **Alluvium (Holocene)**

Moderately to well-sorted, subrounded to well-rounded sand and gravel in a matrix of clay and fine silt, deposited in stream channels, along flood plains, and on terraces. Terraces rarely exceed 12 m above major drainages and 2 m above tributary streams (Kellogg and Vuke 1996). Average thickness of alluvial material in the South and North Willow Creek drainages ranges from 3 to 10 m.

Qgr **Gravel deposit (Late Pleistocene to Holocene)**

Moderately to well-sorted, subrounded to well-rounded gravel in a matrix of coarse to medium sand. These deposits represent alluvial terraces and dissected valley fill (Vuke et al. 1995).

Qpg **Pediment gravel (Late Pleistocene to Holocene)**

Stratified, sorted, angular to rounded gravel in a matrix of sand and silt. Thickness varies from 0.5 to 3 m.

Qc **Colluvium (Late Pleistocene to Holocene)**

Unstratified, unconsolidated sediment that has been intermixed by downslope movement and is derived from a local source.

Qg **Glacial deposits, undifferentiated (Pleistocene)**

Stratified to unstratified, unconsolidated, poorly sorted, angular to rounded boulders, cobbles, in a matrix of sand, silt, and clay. Deposits include both till and stratified drift. Queried where uncertain.

QTgr **Gravel and sand (Pliocene and possible Pleistocene)**

Stratified, unconsolidated, poorly sorted to well-sorted, moderately to well-rounded

pebbles and boulders in a nonindurated sandy matrix. Clasts of Archean metamorphic rocks, Cretaceous Tobacco Root batholith granodiorite, Cambrian Flathead Formation sandstone, Pennsylvanian Quadrant Formation sandstone, and Tertiary sandstones and mudstones ranging from 2 cm to 2 m in diameter. Locally interbedded with mudstones and siltstones.

Tsu **Sediments, upper unit: gravel, sand, and mud deposits (Miocene and possible Pliocene)**

Light brown to red-brown, stratified, consolidated, moderately to well-sorted, moderately to well-rounded pebbles and cobbles. Interbedded with mudstones and siltstones. Sand and gravel deposits contain planar and trough cross stratification.

Tsl **Sediments and sedimentary rocks, undivided; lower unit: conglomerate, sandstone, and siltstone (Miocene ?**)

White to tan, poorly to moderately indurated, bedded to massive, interbedded conglomerates, sandstones, siltstones, and mudstones. The sandstones and conglomerates are dominantly trough cross-stratified with occasional planar cross sets. This unit correlates with the Six Mile Creek Formation of Kuenzi and Fields (1971) and "sequence 4" of Hanneman and Wideman (1991).

TKib **Intrusive basalts (Eocene, Paleocene, or Upper Cretaceous)**

Black, gray, greenish-gray, grayish-brown, fine-grained basalts. Samples contain 60% calcic plagioclase, 25% clinopyroxene, 10% iddingsite (replaced olivine), and 5% opaque minerals (Kellogg 1994). Dikes cut across Archean gneiss foliation in the southern part of the map area. The basalt crops out as a gray weathered, massive, nonporphyritic rock.

MESOZOIC ROCKS

Kgd **Granodiorite of the Tobacco Root batholith (Upper Cretaceous)**

Gray, coarse-grained, inequigranular to porphyritic, hypidiomorphic, massive

hornblende-biotite granodiorite, with lesser volumes of monzogranite, and monzodiorite (Kellogg 1994). The granodiorite crops out in the southwest corner of the map area. There is little to no alteration of the country rock, but aplite and pegmatite dikes cut across the batholith and country rock within several hundred meters of the contact between the country rock and batholith. The age of the batholith is approximately 71 to 74 Ma (Vitaliano and Cordua 1979). The composition of a typical sample of granodiorite contains 50% zoned oligoclase, 15-25% green hornblende, 15-20% microcline, 10-20% quartz, 5% biotite, 0-1% clinopyroxene cores in hornblendes, trace to 2% magnetite, traces of apatite, and conspicuous sphene and zircon (Kellogg 1994). The granodiorite weathers to dark-gray, in rounded tors or grussy outcrops.

PRECAMBRIAN ROCKS

Aam Amphibolite (Archean)

Gray to black, medium- to coarse-grained, hypidiomorphic equigranular, moderately foliated to well-foliated hornblende-plagioclase gneiss and amphibolite (Kellogg 1994). Protolith may be either sedimentary (clay-rich dolomite) or mafic extrusive rock (Vitaliano and Cordua 1979). Minor amounts of other Archean units are intertongued with this unit.

Aum Meta-ultramafic rocks (Archean)

Black to greenish-gray, fine- to medium-grained, massive, variably serpentinized ultramafic rocks of various compositions. Probably intruded and deformed during period of peak deformation and metamorphism. Occur in lenses, pods, sills, and irregular masses. Thickness varies in map area. Some sills are 20-30 m thick.

Aqf Quartzofeldspathic gneiss (Archean)

Light-gray to light pinkish-gray, medium- to coarse-grained, weakly to moderately foliated gneiss ranging from granodiorite to granite in composition. Composition varies: 10-60% plagioclase, 10-50% microcline, 3-40% quartz, trace to 15% biotite, 0-5% yellow to greenish-brown hornblende, 0-5% almandine, 0-2% augite, 0-2%

muscovite, and traces of zircon, epidote, and opaque minerals. Locally contains mylonitic and migmatitic texture (Kellogg 1994). This unit corresponds to Vitaliano and Cordua's (1979) quartzofeldspathic gneiss.

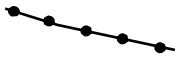
Aag **Aluminous gneiss and schist (Archean)**

Gray to dark brownish-gray, medium- to coarse-grained, inequigranular, generally well foliated, commonly micaceous gneiss and schist containing some sillimanite and kyanite. Composition varies: 5-90% anhedral undulatory quartz, 0-30% microcline, 0-35% plagioclase, 0-30% almandine, 0-40% muscovite, trace to 50% sillimanite or kyanite, 0-25% biotite, 0-3% opaque minerals (Kellogg 1994). Commonly rich in quartz and grades laterally into metaquartzite.

Aq **Quartzite (Archean)**

White to gray, coarse-grained to massive quartzite. Composed almost entirely of undulatory quartz, but contains up to 30% microcline, 20% muscovite, 15% sillimanite, 10% cummingtonite, 8% almandine, 2% actinolite, and traces of zircon, opaque minerals, and bright-green chrome mica (Kellogg 1994). Interlayered with amphibolite in the map area.

Map Symbols



Quartz vein: white massive quartz in lenticular, generally discordant veins and irregular pods. Locally grades into pegmatite (Kellogg 1994). Very widespread within the map area; only large bodies are mapped.

Contact between map units: dashed where approximate, dotted where concealed.

Normal Fault: dashed where approximately located, dotted where concealed. Bar and ball on downthrown side of fault.

Orientation of structural joint planes:

Inclined

Vertical

Strike and dip of foliation:

Inclined

Vertical

Sills and Dikes (TKib): Thickness is less than 30 m. The map unit represented is TKib (basaltic intrusions) unless otherwise noted on the map.

Previous Mapping and Investigations

A geologic map of the Bozeman 1:100,000 quadrangle was completed by Vuke and others (1995). The Archean geology of the Maltbys Mound quadrangle was previously mapped by Vitaliano and Cordua (1979) at the 1:62,500 scale.

Acknowledgements

I would like to thank my advisors, Dr. Bruce Douglas and Dr. Lee Suttner of Indiana University, for their involvement and assistance with this project. Discussions with James Brophy, Walt Coppinger, Debbie Hanneman, Glenn Kroeger, Sue McDonald, Jim Meyers, Greg Olyphant, Ed Ripley, and Susan Vuke pointed me in the right direction during my field work. I am grateful to Sally Letslinger for compiling the Maltbys Mound geologic map into ArcInfo. I would like to thank Dirk Vandervoort and Joel Hall of the Montana Bureau of Mines and Geology for compiling, editing, and completing the final GIS version of the Maltbys Mound quadrangle. I would also like to thank Karen Porter, Dirk Vandervoort, Debbie Hanneman, Susan Vuke, Dick Berg, Larry Smith, and Wayne Van Voast for careful reviews of the Maltbys Mound geologic map and report. The Indiana University Geologic Field Station provided a vehicle, a warm place to stay, food to eat, and a great atmosphere. Many thanks go to the numerous landowners who permitted me to collect data and samples from their property. I would also like to thank my parents for the support they have provided throughout this project. Partial field support has been provided by the National Cooperative Geologic Mapping Program of the U.S. Geological Survey.

References

Hanneman, D. L., and Wideman, C. J. 1991. Sequence stratigraphy of Cenozoic continental rocks, southwestern Montana. Geological Society of America Bulletin 103: 1335-1345.

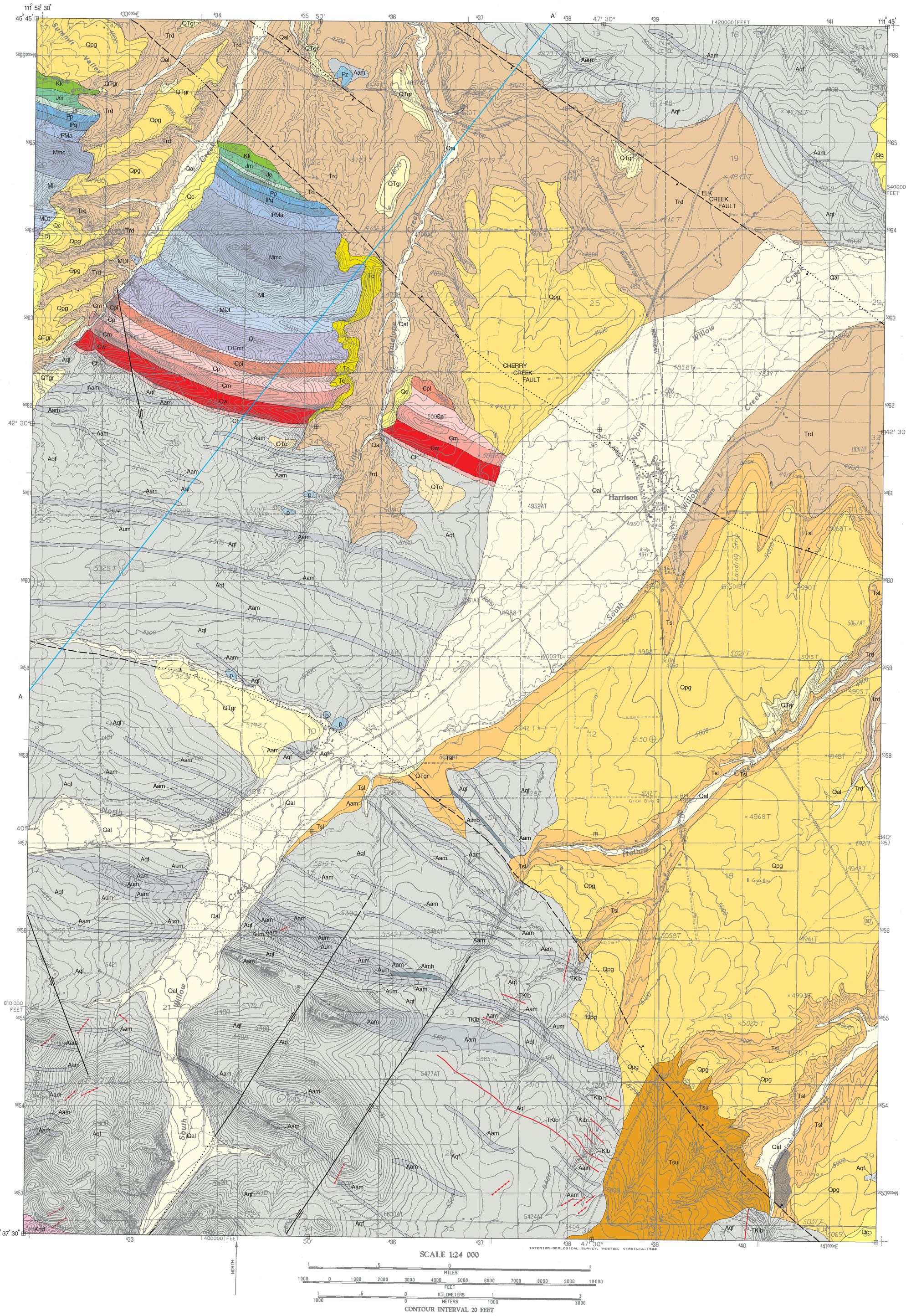
Kellogg, K. S. 1994. Geologic map of the Norris quadrangle, Madison County, Montana. U.S. Geological Survey Geologic Quadrangle Map GQ-1738. Scale 1:24,000.

Kellogg, K. S., and Vuke, S. M. 1996. Geologic map of the Willow Creek Reservoir and Norris NE quadrangles, Gallatin and Madison counties, Montana. U. S. Geological Survey Open File Report 96-012. Scale 1:24,000.

Kuenzi W. D., and Fields, R. W. 1971. Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana. Geological Society of America Bulletin 82: 3374-3394.

Vitaliano, C. J., and Cordua, W. S. 1979. Geologic map of the southern Tobacco Root Mountains, Madison County, Montana. Geological Society of America Map and Chart Series MC-3. Scale 1:62,500.

Vuke, S. M., Berg, R. B., Lonn, J. D., and Kellogg, K. S. 1995. Geologic map of the Bozeman 30'x 60' quadrangle, Montana. Montana Bureau of Mines and Geology Open File Report 334. Scale 1:100,000.



MAP UNITS

- Qal — Alluvium of modern channels and floodplains
- Qpg — Pediment gravel
- Qc — Colluvium
- QTgr — Gravel and sand
- QTc — Colluvium
- Tc — Colluvium
- Tsu — Sediment or sedimentary rock, undivided; upper
- Tsl — Sediment or sedimentary rock, undivided; lower
- Trd — Dunbar Member of Renova Formation
- TKlb — Intrusive basalt
- Kgd — Granodiorite
- Kk — Kootenai Formation
- Jm — Morrison Formation
- Je — Ellis Group, undivided
- Td — Dinwoody Formation
- Pz — Paleozoic rocks, undifferentiated
- Pp — Phosphoria Formation
- IPq — Quadrant Formation
- IPMa — Amsden Formation
- Mmc — Madison Group - Mission Canyon Formation
- Ml — Madison Group - Lodgepole Formation
- MDt — Three Forks Formation
- Dj — Jefferson Formation
- DCmr — Maywood Formation and Red Lion Formation, undivided
- Cpi — Pilgrim limestone
- Cp — Park shale
- Cm — Meagher limestone
- Cw — Wolsey shale
- Cf — Flathead Formation
- Aum — Meta-ultramafic rocks
- Aqf — Quartzofeldspathic gneiss
- Aimb — Intrusive metabasite
- Aam — Amphibolite
- p — Pegmatite

Geologic Map of the Harrison 7.5' Quadrangle, Madison County, Montana
By William S. Elliott, Jr.
Year: 1998
EDMAP: USGS Contract Number: 1434-HQ-96-AG-01556
Montana Bureau of Mines and Geology Open File Report MBMG 375, Plate 1 of 3

MBMG 375 Plate 2

MAP UNITS

Qal	Alluvium of modern channels and floodplains
Qgr	Gravel
Qpg	Pediment gravel
Qc	Colluvium
Qg	Glacial deposits, undivided
QTgr	Gravel and sand
Tsu	Sediment or sedimentary rock, undivided; upper
Tsl	Sediment or sedimentary rock, undivided; lower
Kgd	Granodiorite
Aum	Meta-ultramafic rocks
Aqf	Quartzofeldspathic gneiss
Aam	Amphibolite
Aag	Aluminous gneiss and schist
Aq	Quartzite
TKib	Intrusive basalt

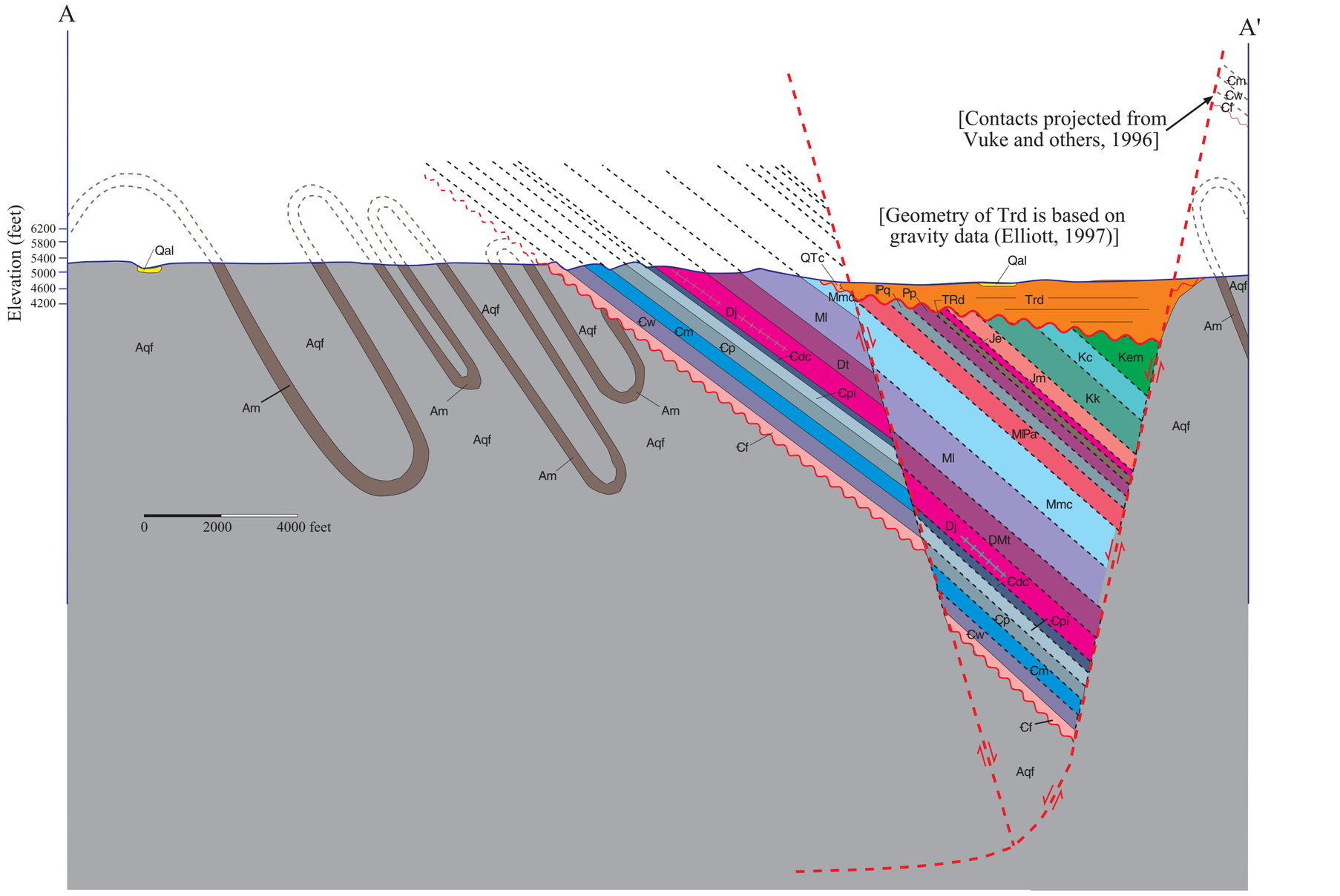
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

INTERIOR-GEOLOGICAL SURVEY, RESTON, VIRGINIA-1988

Geologic Map of the Maltbys Mound 7.5' Quadrangle, Madison County, Montana
By William S. Elliott, Jr.
Year: 1998
EDMAP: USGS Contract Number: 1434-HQ-95-AG-01556
Montana Bureau of Mines and Geology Open File Report MBMG 375, Plate 2 of 3

Geologic Cross-Section of the Harrison Quadrangle, Madison County, Montana
1997
William S. Elliott, Jr.
[Partial support provided by the National Cooperative Geologic Mapping Program]



Geologic Cross Section of the Maltbys Mound Quadrangle, Madison County, Montana
1997
William S. Elliott, Jr.
[Partial support provided by the National Cooperative Geologic Mapping Program]