U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Geologic map of the Willow Creek Reservoir and Norris NE quadrangles, Gallatin and Madison Counties, Montana

by

Karl S. Kellogg[1] and Susan M. Vuke[2]

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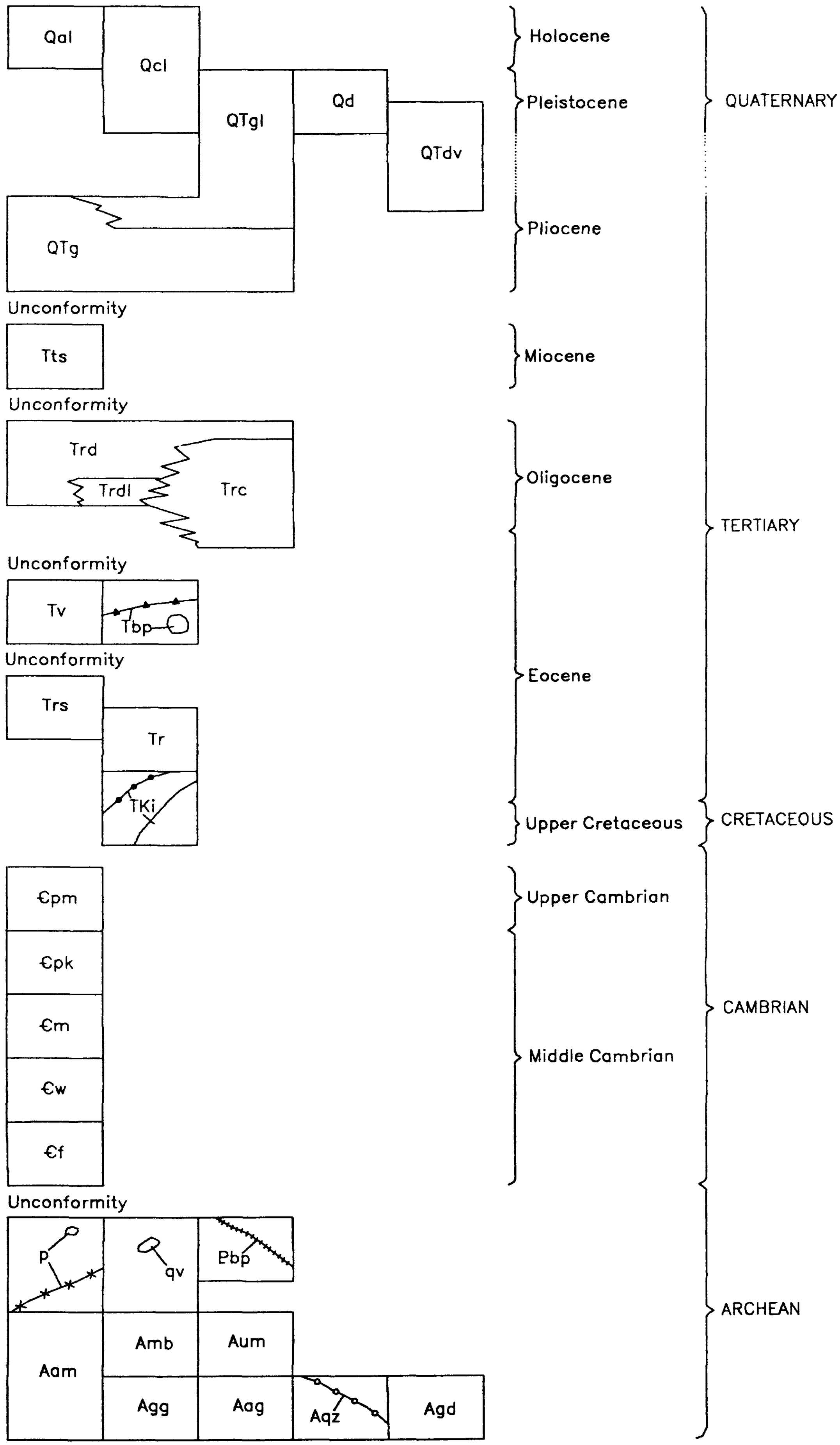
1 U.S. Geological Survey
Box 25046, MS 913
Denver Federal Center
Denver, CO 80225

2 Montana Bureau of Mines and Geology
1300 West Park Street
Butte, MT 95701-8997

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

CENOZOIC SEDIMENT AND ROCKS

Qal **Floodplain and channel alluvium (Holocene)**--Moderately sorted to well sorted, moderately rounded to well-rounded pebble to boulder gravel in a matrix as fine as silt. Includes deposits in stream and river channels, flood plains, small alluvial fans, terraces as high as 12 m above level of Madison River and 2 m above level of tributary streams. Maximum thickness probably greater than 30 m in Madison River flood plain

Qcl **Colluvium (Holocene and upper Pleistocene)**--Mostly massive, unconsolidated to weakly cemented, dark-brown to light-tan surficial deposits that have become intermixed by downslope movement. Contains cobbles and pebbles derived from weathering of bedrock and fine sand and silt reworked from loess. Horizontal surfaces underlain mostly by loess. Includes sheetwash alluvium on steeper slopes and channel alluvium in gulleys. Maximum thickness greater than 5 m

QTgl **Loess-mantled terrace gravel (upper Pleistocene to Pliocene?)**--Mixture of terrace gravel (unit QTg) and upper Pleistocene loess exposed on prominent surface (Madison Plateau) in eastern part of map area. Loess is light-tan silt and fine-grained sand that in many places mantles gravel; at other places, cobbles of lag gravel are embedded in loess; locally reworked by streams. Loess is as thick as 2 m

Qd **Heterolithologic diamicton (Pleistocene?)**--Subangular to subrounded clasts of Archean gneiss, Tertiary vesicular basalt (derived from unit Tv), and rhyolite (derived from unit Tr) as large in diameter as 0.5 m in nonindurated sandy matrix. Exposed in small dissected ridges north of Red Mountain in south-central part of map area. Probably debris flow deposits. Maximum thickness greater than 20 m

QTdv **Volcanic-clast diamicton (Pleistocene or Pliocene)**--Size and texture same as for unit Qdh, but position along ridge suggests topographic inversion and age of unit may be older than Pleistocene. Clasts are entirely Tertiary vesicular basalt. One deposit mapped mostly in SE¼, sec.21, T.2 S., R.1 E. Thickness probably greater than 20 m

QTg **Terrace gravel (lower Pleistocene and/or Pliocene)**--Very well rounded clast-supported alluvial gravel with clasts as large as 0.3 m, composed of about 65 percent gray to purple quartzite of Belt Supergroup, about 30 percent light- to medium-gray Archean gneiss, and white vein quartz. Mostly calcite cemented, especially near top of unit. Equivalent to "old alluvium" of Robinson (1963, p. 82) and represents alluvial deposits of ancestral Madison River. Caps prominent terrace that is as much as 330 m above present Madison River. Includes younger calcite-cemented gravels in benches that are as much as 130 m above present Madison River. Debris from capping terrace forms extensive aprons of loose cobbles that mantle underlying Dunbar Creek Member of Renova Formation. By analogy with geomorphically similar, dated terraces in Montana and Wyoming (Reheis and others, 1991), age of capping terrace deposits may be as old as Pliocene. Unit about 35 m thick in south part of Norris NE quadrangle and thins to about 5 m thick in northern part of same quadrangle

Tts **Tuffaceous siltstone and sandstone (Miocene?)**--Mostly light-brown, poorly to moderately indurated, poorly bedded to massive, light tan, locally tuffaceous siltstone and fine- to medium-grained sandstone. Locally contains pebbly layers and lenses; pebbles mostly quartz and less common Archean gneiss. Mapped as Bozeman "lakebeds" of Peale (1896) in the Norris area (Winchell, 1914). Tentatively correlated with Sixmile Creek Formation of Kuenzi and Fields (1971) and "sequence 4" of Hanneman and Wideman (1991), both mainly of Miocene age, although unit may correlate with rocks as old as Oligocene Dunbar Creek Member of the Renova Formation. Beds horizontal in map area. Mapped only near western boundary of map area. Unconformably overlies both Archean gneiss and limestone and tuffaceous sandstone facies of the Dunbar Creek Member of the Renova Formation. Unit is more than 120 m thick in Norris quadrangle (Kellogg 1994), directly south of the Willow Creek Reservoir quadrangle, although about 80 m thick in map area

Renova Formation (Oligocene to upper Eocene)

Trd **Dunbar Creek Member (Oligocene)**--White, yellowish-white, and light-gray, moderately indurated to well-indurated siltstone, sandstone, limestone, and matrix-supported conglomerate. Most beds are tuffaceous, and some sandstone beds are composed mainly of water-laid ash; some sandstone is coarse grained and cross bedded. Conglomerate composes about 15 percent of exposed unit; clasts are moderately rounded to poorly rounded and as large as 30 cm in diameter, although most are less than 5 cm in diameter; about 90 percent of clasts are Archean gneiss and quartzite; remaining clasts are vesicular basalt (from unit Tv), rhyolite (probably from unit Tr), chert, aplite, fine-grained quartzite (probably from Middle Proterozoic Belt Supergroup), and limestone. Plant fossils (twig debris) present in some ash beds; bone fragments present in some pebbly beds. Beds typically 0.1-3 m thick. Mostly flat lying, but dips as much as about 50° north of northern splay of Cherry Creek fault. Forms ledgy outcrops in bluffs west of Madison River. Exposed in prominent flat-bedded to gently dipping well bedded, ledgy exposures in bluffs west of Madison River. Originally described by Robinson (1963) as Dunbar Creek Formation in Three Forks quadrangle, directly north of map area, and studied in map area by Feichtinger (1970); Oligocene age was assigned based on vertebrate fossils. Unit revised in Jefferson River basin area to Dunbar Creek Member of Renova Formation by Kuenzi and Fields (1971). Four mappable subunits of member recognized (S.M. Vuke, unpublished data, 1994). Unconformably overlies Archean basement in map area; deep weathering profile developed in Archean rocks beneath rocks considered to be basal conglomerate of Dunbar Creek Member in Bear Trap Creek quadrangle (Kellogg, 1995), just south of Norris NE quadrangle. Only upper part of unit well exposed. Maximum exposed thickness about 230 m

Trdl **Limestone and tuffaceous sandstone facies of the Dunbar Creek Member (Oligocene)**--Interbedded white, light-gray, and light-tan, locally vuggy, very fine-grained limestone, white to light-brown tuffaceous siltstone and sandstone, and massive white air-fall ash. Limestone beds 5-30 cm thick compose about 30-50 percent of sequence.

Unconformably overlies Archean basement. Considered to be equivalent to a lower subunit of Dunbar Creek Member (S.M. Vuke, unpublished data, 1994). Called "Norwegian Creek carbonate unit" by Feichtinger (1970). Neither top nor base of unit exposed where mapped. Unit considered to be equivalent to a lower tuffaceous mudstone and calcareous siltstone sequence exposed along the Madison River in the eastern part of the map area(S.M. Vuke, unpublished data, 1994); the limestone beds are interpreted as well developed paleosols. Thickness greater than 50 m thick

Trc **Climbing Arrow Member (Oligocene to upper Eocene)**--White and pale-green, massive to bedded smectitic claystone, siltstone, and sandstone. Tentatively correlated with Climbing Arrow Formation of Robinson (1963), which crops out about 2 km north of Willow Creek Reservoir quadrangle boundary. Unit revised to Climbing Arrow Member of Renova Formation by Kuenzi and Fields (1971). One outcrop in sec. 19, T. 1 S., R. 1 E. More than about 25 m thick in map area

Tv **Basalt flows (Eocene?)**--Black, very dark gray, and grayish-brown, fine-grained, intergranular basalt and basalt breccia flows. Where fresh, composed of about 60 percent calcic plagioclase phenocrysts as long as 0.2 mm, 25 percent clinopyroxene; 10 percent iddingsite (which replaced olivine), and about 5 percent opaque minerals (estimated percentages from three thin sections). Commonly vesicular; massive non-porphyritic basalt commonly flow banded. Vesicles in many places encrusted by fine-grained yellow zeolite. Most outcrops rubbly and bedding rarely observed. Base of unit not observed. Tentative Eocene age assigned by correlation with Eocene Absaroka Volcanic Supergroup (Smedes and Proska, 1972). Unit probably at least 200 m thick

Tbp **Basalt porphyry plug (Eocene?)**--Plug of black porphyritic rock of approximately basaltic composition in NW¼ sec.35, T.1 S., R.1 W. Contains euhedral clinopyroxene and plagioclase phenocrysts in an aphanitic sooty-black matrix. Composed of about 40 percent glassy matrix, 25 percent enstatite crystals (partially altered to white mica) as long as 2 mm, 10 percent calcic plagioclase (An_{70}) as long as 0.2 mm, 5 percent very fine grained magnetite, and mozaic of very fine-grained microlites composed of orthopyroxene, plagioclase, apatite, and white mica (estimated percentages from one thin section). May have been a feeder for basalt porphyry flows (unit Tv)

Trs **Rhyolitic sandstone and sedimentary breccia (middle or lower Eocene)**--Very light gray to white, well-bedded, well-indurated siltite, sandstone, and clast-supported sedimentary breccia composed almost entirely of glassy rhyolitic detritus; clasts angular and as long as 1 m. Interlayered and locally intermixed with abundant white air-fall tuff. Represents mostly stream and talus deposits from volcanic dome of rhyolite vitrophyre of Red Mountain (unit Tr) that were laid during or shortly following eruption. Ash layers indicate that eruptive column was active during dome formation.

Tr **Rhyolite vitrophyre (lower Eocene)**--White, pink, and gray, flow-banded, sparsely porphyritic rhyolite. Generally consists of about 70 percent brown cloudy glass, 25 percent sanidine, 2 percent plagioclase microlites that range in grain size from cryptocrystalline to 1 mm long, 1 percent very fine grained magnetite, and a few slightly altered biotite phenocrysts as large as 0.5 mm across (estimated percentages from two thin sections). Rock breaks with conchoidal fracture. Varicolored flow bands, defined by elongate lenses of devitrified glass, are parallel to fracture cleavage. Extensively brecciated, especially near contacts. Contact and most flow layering dip toward center of body, defining funnel shape which suggests that body is the near-surface root of a volcanic dome. Has a potassium-argon (K-Ar) biotite age of 52.7±2.0 Ma (Chadwick, 1980). Structurally, chemically, and petrographically similar to four smaller rhyolite vitrophyre intrusive bodies in Norris quadrangle, to west (Kellogg, 1994), and Bear Trap Creek quadrangle, to south (Kellogg, 1995)

TKi **Intrusive felsite (early Eocene or Cretaceous)**--Dikes, sills, and irregularly shaped intrusive bodies of gray, pinkish-gray, and purple porphyritic rhyolite or dacite that has an aphanitic, chert-like matrix. Felsite is composed of 5-25 percent white-weathering, tabular plagioclase phenocrysts as long as 8 mm (typically 3 mm), 0-15 percent subhedral and broken quartz as long as 2 mm, and 1-2 percent clots of opaque minerals, epidote, and chlorite; locally contains hornblende or biotite (estimated percentages from 2 thin sections). At most places unit is flow banded and in a few places it is brecciated. Well-developed fracture cleavage parallel to contacts; fracture surfaces commonly stained black by manganese oxide. Numerous biotite- and quartz-bearing felsite sills intrude Wolsey Formation and Flathead Sandstone. Just south of map area, intruded by lower Eocene rhyolite vitrophyre (unit Tr) (Kellogg, 1995). Not dated, but compositionally and texturally similar to Late Cretaceous dacite prophyry of Fan Mountain, about 25 km south of map area (Kellogg, 1992). Feichtinger (1970) reported that unit resembles 103-to 106-Ma (Early Cretaceous) sills that are widespread in southwestern Montana. May represent more than one period of magma injection. Where less than about 10 m wide, shown as a single line

PALEOZOIC ROCKS

Cpm **Pilgrim Dolostone (Upper Cambrian)**--Gray, light-gray, and brownish-gray, medium-bedded to massive-bedded, locally oolitic, medium-crystalline dolostone. Weathers light gray and commonly contains irregular darker-gray mottles. Conformably overlies Park Shale. Upper part eroded from map area. Thickness in Bear Trap Creek quadrangle, directly south of Norris NE quadrangle, about 45 m (Kellogg, 1995)

Cpk **Park Shale (Middle Cambrian)**--Greenish-gray to tan fissile shale. Poorly exposed in grassy swale in SE ¼, sec. 28, T.2 S., R.1 E. Conformably overlies Meagher Limestone. Thickness about 25 m

Cm **Meagher Limestone (Middle Cambrian)**--Thin- to massive-bedded, light-gray to brownish-gray, finely crystalline limestone. Locally oolitic, especially in upper part. Upper 30 m mostly is thin-bedded gray limestone that contains conspicuous orange mottles; upper few meters contains fissile gray-green shale. Conformably overlies Wolsey Formation. About 100-120 m thick

Cw **Wolsey Formation (Middle Cambrian)**--Greenish-gray, gray, and gray-brown, thin-bedded sandstone, siltstone, shale, and argillaceous limestone; weathers brown. Clastic rocks micaceous; locally calcareous. Sandstone beds are wavy and bioturbated and contain green and gray mottled shale interbeds; animal trails common; locally glauconitic. Poorly exposed in map area.

Conformably overlies Flathead Sandstone. Thickness 55-70 m

Cf **Flathead Sandstone (Middle Cambrian)**--Pink, tan, and pinkish-gray, thin-bedded to medium-bedded, poorly sorted feldspathic quartzite and quartz-pebble conglomerate; locally prominantly crossbedded. Quartz-pebble conglomerate generally in lowermost 2 m, but pebbly lenses occur as high as middle of unit. Locally rusty weathering and contains hematitic spots. Thin beds of greenish-gray, fine-grained, micaceous argillaceous sandstone near top of unit. Unconformably overlies Archean rock. Thickness in map area about 65-85 m

PROTEROZOIC AND ARCHEAN ROCKS

p **Pegmatite (Early Proterozoic? and Archean?)**--White to pink, coarse-grained to very coarse grained, massive and foliated dikes and sills composed mostly of potassium feldspar, quartz, plagioclase, muscovite, and, rarely, biotite. In places, grades into quartz veins (unit qv). Found exclusively in Archean rocks. All foliated pegmatites that are concordant to gneissic layering probably are Archean in age; unfoliated, smassive or zoned, and discordant pegmatites probably are Early Proterozoic in age. Although common, pegmatite bodies are generally less than about 10 m across and most smaller bodies are not shown on map; shown on map as a single line

qv **Quartz veins (Early Proterozoic? and Archean?)**--White, massive, very coarse grained, fissure-filling quartz bodies in Archean gneiss. Where less than about 5 m wide, shown on map as a single line

Pbp **Basalt porphyry sill (Proterozoic?)**--Massive, black sill near northern boundary of Willow Creek Reservoir quadrangle contains about 10 percent euhedral hornblende phenocrysts as long as 8 mm in a black aphanitic matrix. About 3 m wide; concordant with foliation

Aam **Hornblende-plagioclase gneiss and amphibolite (Archean)**--Gray to black, medium-grained, hypidiomorphic equigranular, moderately foliated to well-foliated hornblende-plagioclase gneiss and amphibolite. Contains as much as 5 percent quartz and a trace of zircon, opaque minerals, and apatite; locally garnetiferous. Plagioclase (typically An_{30}) weathers white. Commonly contains white, migmatitic leucosomes of plagioclase leucogneiss as thick as 10 cm. Possible protoliths include (1) clay-rich dolomite

(Vitaliano and Cordua, 1979), (2) mafic extrusive rock (Vitaliano and Cordua, 1979), (3) water-laid mafic ash (G.S. Snyder, U.S. Geological Survey, written commun., 1992), and (or) (4) metabasic intrusive rock (unit Amb). Unit includes minor amounts of other Archean units

Amb **Intrusive metabasite (Archean)**--Black, fine-grained, equigranular, granoblastic, weakly foliated to massive hornblende-augite-almandine metagabbro and metadiorite. Commonly speckled with white-weathering feldspar and pink garnet. Composition of correlative rocks located south of map area (21 thin sections; Kellogg, 1992, 1993a, 1993b, 1994, 1995) is 15-45 percent plagioclase (mostly andesine), 10-60 percent yellowish-green to brown hornblende, 2-30 percent diopsidic augite, 0-20 percent almandine, 0-10 percent reddish-brown biotite, 0-8 percent quartz, 0-5 percent potassium feldspar, 1-5 percent opaque minerals, and a trace of apatite. In places, relict porphyritic texture is preserved as white secondary clusters of fine-grained plagioclase as long as 1 cm; garnet and augite formed preferentially around relict plagioclase (corona texture). Unit occurs in sills as thick as about 150 m; shows pinch-and-swell structure (boudinage) in places, that produced circular or oval outcrops that typically form topographic highs. Many larger sills (wider than about 50 m) are partially retrograded, especially along margins, to medium-grained, foliated amphibolite. Intrusive metabasite is equivalent to orthoamphibolite of Vitaliano and Cordua (1979) in Tobacco Root Mountains

Aum **Ultramafic rocks (Archean)**--Black to dark-greenish-gray, fine- to medium-grained, well-foliated to massive, variably metamorphosed and serpentinized ultramafic rocks of variable composition; detailed descriptions given for quadrangles directly south of map area (Kellogg, 1994, 1995). Occur as lensoid bodies inferred to have been tectonically incorporated during period of ductile deformation and high-grade metamorphism

Agg **Plagioclase-microcline-quartz-biotite gneiss (Archean)**--Light-gray to light-pinkish gray, generally tan- weathering, medium-grained, weakly to moderately foliated gneiss ranging from tonalite to syenogranite in composition. Composition of corelative unit to south of map area (38 thin sections; Kellogg, 1992, 1993a, 1993b, 1994, 1995) is 10-60 percent plagioclase (oligoclase or andesine), 0-50 percent microcline, 3-40 percent quartz, trace to 15 percent yellowish-brown biotite, 0-5 percent yellow to greenish-brown hornblende, 0-5 percent almandine, 0-2 percent augite, 0-2 percent muscovite, and traces of zircon, epidote, allanite, and opaque minerals. Hypidiomorphic to xenomorphic texture; locally blastomylonitic. Commonly migmatitic. Corresponds approximately to "quartzofeldspathic gneiss" of Vitaliano and Cordua (1979) in the Tobacco Root Mountains, which, on the basis of zircon morphology, was interpreted to be of sedimentary origin (Hess, 1967). Elsewhere, some weakly foliated to massive quartzofeldspathic gneiss of granitic to tonalitic composition has been interpreted as intrusive (Mogk and others, 1988, 1989; Kellogg, 1993, 1994)

Aag **Aluminous gneiss and schist (Archean)**--Gray to dark-brownish- gray, medium-grained, inequigranular, generally well foliated, commonly micaceous gneiss and schist that contain sillimanite. Composition of correlative map units south of map area (26 thin sections; Kellogg, 1993a, 1993b, 1994, 1995) is 5-90 percent anhedral, undulatory quartz, 0-30 percent microcline, 0-35 percent plagioclase, 0-30 percent almandine, 0-40 percent muscovite, trace to 50 percent sillimanite, 0-25 percent reddish-brown biotite, 0-10 percent gedrite, 0-3 percent opaque minerals, including graphite, and a trace of zircon. Kyanite or corundum not observed in map area, but both have been observed in Bear Trap Creek quadrangle (Kellogg, 1995), directly south of Norris NE quadrangle. Commonly quartz-rich and locally grades into metaquartzite

Aqz **Quartzite (Archean)**--White, gray, and brown, medium- to coarse-grained, inequigranular, moderately foliated to massive quartzite. Occurs as several layers less than 10 m thick in NW¼, sec. 25, T.2 S., R.1 W.

Agd **Gedrite gneiss (Archean)**--Brown to grayish-brown, moderately well foliated, medium-grained gedrite-bearing gneiss. Composition for correlative units to south of map area (11 thin sections; Kellogg, 1993a, 1993b, 1994, 1995) is 40-70 percent clove-brown gedrite, 0-40 percent quartz, 0-30 percent plagioclase, 0-20 percent sillimanite, 0-10 percent biotite, 0-10 percent cordierite, trace to 2 percent magnetite, and trace to 2 percent rutile. Generally occurs in small lenses and concordant layers in other Archean units

Contact--Showing dip. Dashed where approximately located; dotted where concealed

Normal fault--Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side where known

Normal fault soling large landslide block--Rocks of Dunbar Creek Member of Renova Formation rotated and variably deformed; dotted where concealed

Reverse fault--Dashed were approximately located; dotted where concealed. Teeth on upper plate

Reverse fault reactivated as normal fault--Dashed where approximately located; dotted where concealed. Teeth on upper plate of reverse fault; bar and ball on downthrown side of normal fault. Reverse movement was Late Cretaceous to pre-middle Eocene; normal movement was post Eocene; about 60 m of down-to-the-northeast movement along the Elk Creek fault postdates deposition of lower Pleistocene or Pliocene gravel deposits (Feichtinger, 1970; Kellogg, 1995). Net movement is reverse

Antiform--Showing trace of axial surface and direction of plunge of fold axis; dashed where approximately located. Mapped only in Archean rocks

Overturned antiform--Showing trace of axial surface and direction of plunge of fold axis; dashed where approximately located. Small arrows show dip directions of limbs. Mapped only in Archean rocks

Syncline--Showing trace of axial surface and direction of plunge of fold axis; dashed where approximately located. Not mapped in Archean rocks

Overturned synform--Showing trace of axial surface; dashed where approximately located. Small arrows show dip directions of limbs. Mapped only in Archean rocks

Strike and dip of bed

70 **Inclined**

60 **Overturned**

Horizontal

60 **Approximate strike and dip of inclined bed**

Strike and dip of foliation

80 **Inclined**

Vertical

Approximate strike and dip of inclined foliation

Bearing and plunge of small fold

Bearing and plunge of lineation--Lineation defined by aligned minerals, fold axes, mullions, or crenulations

Strike and dip of foliation combined with bearing and plunge of lineation

Strike and dip of flow foliation in rhyolite vitrophyre intrusive rock (unit Tr)

Linear feature observed on aerial photograph--Mostly parallel to strike of metamorphic foliation

Breccia zone

Zone of hydrothermal alteration

PREVIOUS MAPPING AND INVESTIGATIONS

The geology of the map area, exclusive of the Archean rocks, was previously mapped by Feichtinger (1970). Archean rocks in parts of the southern half of the map area had been mapped by J.D. Carl (unpublished mapping; written commun., 1990). The rhyolite vitrophyre underlying Red Mountain was mapped and briefly described by Kavanagh (1965) and dated isotopically by Chadwick (1980).

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Geology mapped in 1992-93; assisted by Angela M. Vasquez, David A. Taylor, and Robert L. Burger.