Preliminary Geologic Map of the Ringling 30’ x 60’ Quadrangle

Central Montana

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GEOLOGIC SUMMARY

The Ringling quadrangle is located in central Montana in parts of Gallatin, Park, Meagher, and Wheatland Counties. The Castle and Crazy Mountains occupy the central part of the quadrangle. The major drainages are the Smith and Shields Rivers to the west and the Musselshell River to the east (Figure 1).

Sedimentary bedrock exposed in the quadrangle forms a nearly complete stratigraphic section for central Montana. The youngest bedrock exposed is the Tertiary Fort Logan Formation. The oldest rocks are part of the Grayson Formation of the Late Proterozoic Belt Supergroup. Thick accumulations of non-marine and marine Late Cretaceous and Tertiary sedimentary rocks accumulated in the Crazy Mountains Basin that encompasses most of the quadrangle. Eocene intrusive rocks core the Castle and Crazy Mountains and are part of the central Montana alkalic province (Wolff, 1938a, b). Quaternary alluvial and glacial deposits are present in valley bottoms and on adjacent mountains.

Sources of Previous Geologic Mapping in the Quadrangle

This report integrates previous geologic mapping for the quadrangle from the numerous sources shown in Figure 2. An attempt was made to preserve as much detail as possible from earlier, larger-scale maps and to collect new reconnaissance geologic data in areas where no detailed mapping had been completed. The major areas lacking detailed mapping are along the perimeter of the Crazy Mountains, away from the major intrusive rocks, and the area between Gordon Butte and the Comb Creek stock. The existing maps for these areas focused primarily on the igneous geology with less emphasis on the surrounding Upper Cretaceous and Tertiary strata. Therefore, most of the contacts shown for this map are only approximately located and the Fort Union Formation is undivided. Limited reconnaissance mapping for this project indicates these areas are structurally more complex than previously mapped and that future detailed mapping will be needed to fully understand stratigraphic and structural relations.

Selected Stratigraphic Notes

Upper Cretaceous Rocks

Most of the maps units used to compile this map were taken directly from the original source maps. In some cases the original map units were modified or combined to simplify compilation or, in some cases, were combined if there were problems correlating specific maps units between different maps. Most of the changes involved the Upper Cretaceous units and the Pennsylvanian through Jurassic units as discussed below.

The Ringling quadrangle encompasses much of the Crazy Mountains Basin where Upper Cretaceous nonmarine rocks typical of the type Montana Group interfinger with and grade abruptly southwestward into coarse nonmarine volcaniclastic rocks approximately equivalent to lower part of the Livingston Group (Roberts, 1963). Depending on location, different workers in the Crazy Mountains Basin have adopted different

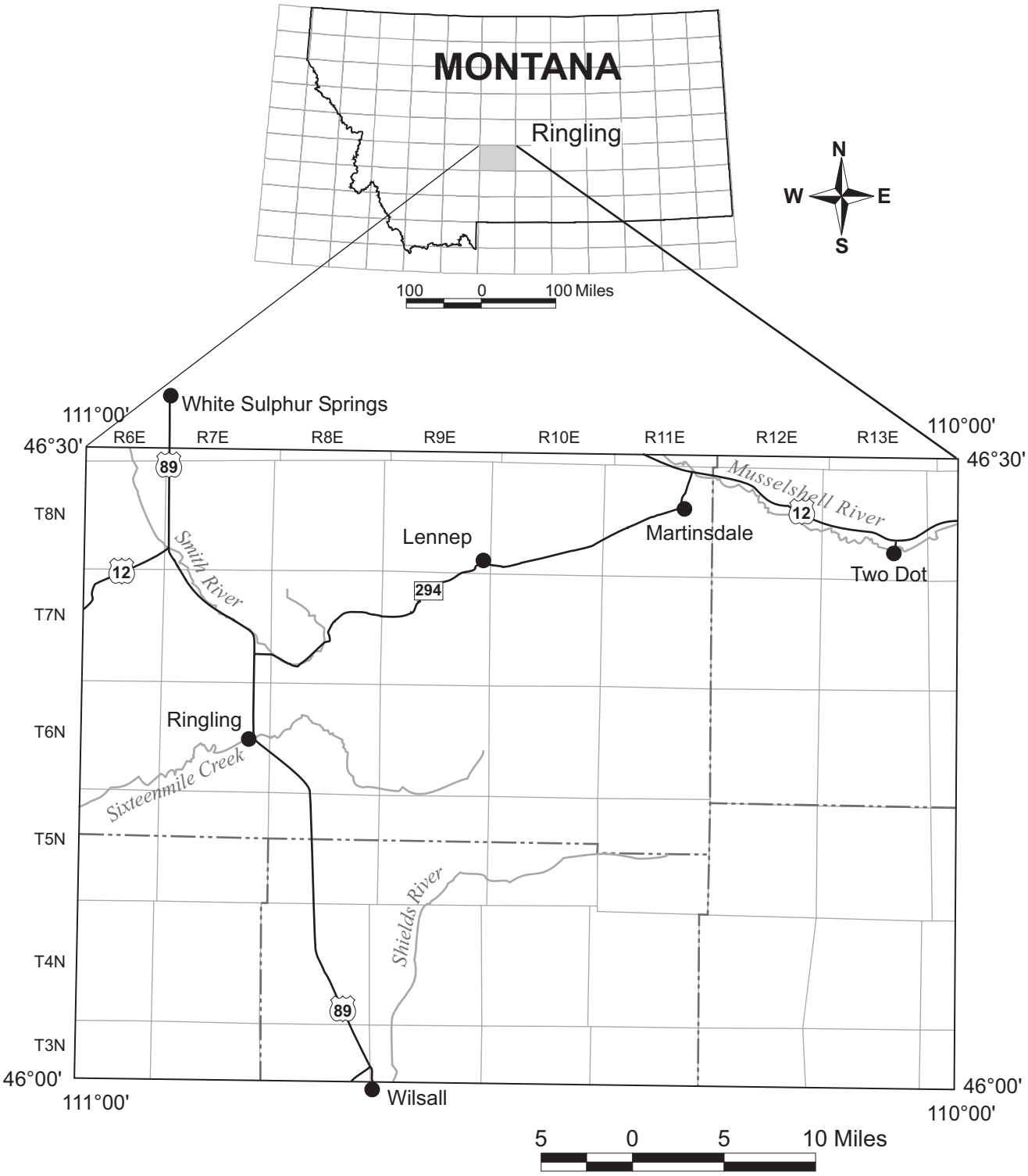


Figure 1. Location map of ringling 30'x60' quadrangle, central Montana.

stratigraphic nomenclature for the interval of rocks above the Eagle Sandstone and below the Tertiary Fort Union Formation (see Skipp and McGrew, 1977 for discussion). The units used for this interval for this map are shown on the accompanying correlation chart and selected units are discussed below.

Eagle Sandstone and Claggett Shale

The Eagle Sandstone is mapped throughout the quadrangle and is overlain by the Claggett Shale. The Claggett Shale thins and becomes increasingly sandy from east to west and is not mapped as a separate unit west of the Corral Creek Anticline. In the western part of the quadrangle, lithologies similar to the Claggett Shale, including the Parkman Sandstone equivalent (Skipp and McGrew, 1977), are included with the lower part of the Sedan Formation or the upper part of the Eagle Sandstone.

Sedan Formation

In the western part of the quadrangle, the Sedan Formation was mapped by Skipp (1977), McGrew (1977a, b, c, d), and Freeman (1977) as the interval of rock above the Eagle Sandstone and below the Billman Creek Formation. The lower Sedan was variously divided into several informal members and the upper part included the Bearpaw Shale and Lennep Sandstone as formal members. In the Hatfield Mountain quadrangle, equivalent rocks were mapped by Skipp and Hepp (1968) as members H through A of the Maudlow Formation (Skipp and Peterson, 1965).

For this map, the Sedan Formation is restricted to just those strata above the Eagle Sandstone and below the Bearpaw Shale. The Bearpaw Shale and Lennep Sandstone are mapped as separate units. The lower, informal members are combined into an upper part (Kseu) and a lower part (Ksel), and, where present, a welded tuff member (Kset). The upper part consists of the mudstone members of Skipp (1977), McGrew (1977a, b, c, d) and Freeman (1977) and members H through F of Skipp and Hepp (1968). The lower part includes the middle and lower sandstone members of Skipp (1977), McGrew (1977a, b, c, d), Freeman (1977) and members E through A of Skipp and Hepp (1968). The Parkman Sandstone equivalent is within in the lower part. The welded tuff is the welded tuff member of Skipp (1977) and the laterally equivalent member D of Skipp and Hepp (1968). In the eastern part of the quadrangle, strata laterally equivalent to the Sedan Formation are mapped as the Judith River Formation.

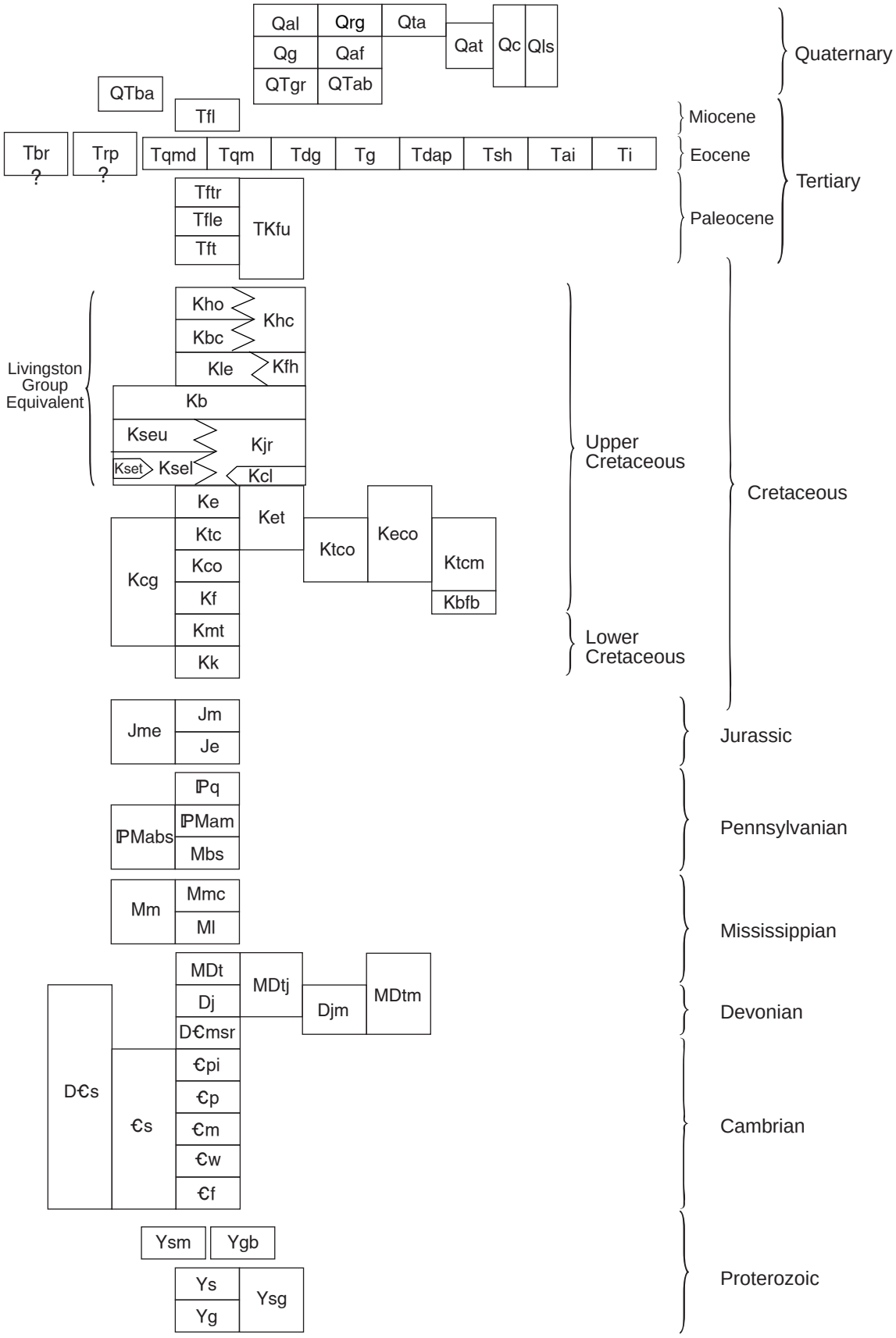
Lennep Sandstone

The Lennep Sandstone is a distinctive, easily mapped unit throughout most of the quadrangle. It is laterally equivalent to the Fox Hills Sandstone as mapped in the easternmost part of the quadrangle (Lopez and Berg, 2004) and in the adjacent Harlowton quadrangle (Wilde and Porter, 2001).

Jurassic through Upper Mississippian Rocks

In most places in the Castle Mountains, the Upper Mississippian Big Snowy Group was combined with the Amsden Group and the Jurassic Ellis Formation was combined with the overlying Jurassic Morrison Formation. These units have been mapped separately on some of the maps used in this compilation but were combined for this map since there are some unresolved stratigraphic issues. For example, the Ellis Formation is not included as a map unit by Gierke (1987) on the west flank of the Castle Mountains although it has been recognized and mapped by others working in the same area (Tanner, 1949). Gierke (1987) and Glasheen (1969) also mapped Quadrant Formation in the Castle Mountains, whereas Tanner (1949) and Winters (1968) indicated there is no Quadrant present. Additional work is needed to resolve some of these stratigraphic questions.

CORRELATION DIAGRAM - RINGLING 30’ X 60’ QUADRANGLE



EXPLANATION OF MAP UNITS

Qal FLOOD PLAIN AND CHANNEL ALLUVIUM (HOLOCENE)
Unconsolidated to poorly consolidated clay, silt, sand, and gravel along channels of modern rivers, creeks, and tributaries. Thickness not measured.

Qta TALUS (HOLOCENE)
Angular, unconsolidated, poorly sorted to well-sorted rock fragments on steep slopes, especially along cirque walls in the Crazy Mountains; may include colluvium and some glacial deposits. Shown mostly in the area near the Crazy Mountains Stock where detailed mapping has been completed (du Bray and others, 1993) although similar, unmapped accumulations are common elsewhere in the alpine regions of the Crazy Mountains.

Qrg ROCK GLACIER DEPOSIT (HOLOCENE)
Lobate deposits of angular, poorly sorted rock fragments up to several meters in diameter. Surfaces locally display concentric ridges and merge with talus deposits in many places (from du Bray and others, 1993).

Qc COLLUVIUM (HOLOCENE AND PLEISTOCENE)
Unconsolidated, locally derived slope-wash deposits composed of sand, silt, clay, and angular fragments of underlying bedrock. Thickness not measured.

Qls LANDSLIDE DEPOSIT (HOLOCENE AND PLEISTOCENE)
Unconsolidated accumulations of angular debris including soil and blocks of bedrock. Transported down steep slopes by mass wasting.

Qaf ALLUVIAL FAN DEPOSIT (HOLOCENE AND PLEISTOCENE)
Unconsolidated, locally derived gravel, sand, silt, and clay deposited as fan-shaped accumulations near mouths of tributary streams.

Qat ALLUVIUM TERRACE DEPOSIT (HOLOCENE)
Unconsolidated clay, silt, sand, gravel, and occasional boulders occurring at slightly higher elevations than modern flood plain alluvium and dissected by modern drainages. Boulders are rounded to subrounded, composed of igneous and sedimentary rocks derived from the Castle and Crazy Mountains. Thickness not measured.

Qg GLACIAL DEPOSITS, UNDIVIDED (HOLOCENE AND PLEISTOCENE)
Poorly sorted, angular to rounded, unconsolidated clasts of dominantly cobbles and boulders, but also pebbles, sand, silt, and clay. Includes till, moraine, and outwash deposits. May include talus and colluvium in some places.

QTab ALLUVIUM OF BRAID PLAINS (QUATERNARY AND TERTIARY)

Angular and subangular cobbles, gravel, sand, and silt derived from local bedrock. Deposits appear to be coalesced alluvial braid plain sediments that accumulated down slope by fluvial processes from higher elevations on flanks of adjacent Crazy and Castle Mountains. Includes thin gravel veneer on pediment surfaces and several levels of thicker alluvial braid plain deposits now being dissected; may include some terrace deposits.

QTgr LAG GRAVEL (HOLOCENE)

Rounded to subrounded gravel interpreted by McGrew (1977b) as probably mostly lag gravels derived from the Fort Logan Formation. May include some colluvium.

QTba BASALT FLOW (QUATERNARY OR TERIARY)

Black basalt, weathering grayish brown; very finely crystalline containing sparse black glass inclusions. Brick-red scoria locally present at top of basalt. (from McGrew, 1977d)

Tfl FORT LOGAN FORMATION (LOWER MIOCENE)

Light-grayish-orange clay, sand, and conglomeratic tuffaceous siltstones interbedded with light-gray volcanic ash, light-gray to white, hard freshwater limestone, and numerous conglomerate and gravel lenses of rounded to angular pebbles and boulders derived from Belt Supergroup shales and sandstones, Paleozoic sandstones and limestones, and Tertiary igneous rocks. Abundant fossil mammal and turtle bone fragments present in gravels (Gierke, 1987; McGrew, 1977b). Thickness up to 200 feet.

Tbr BRECCIA (TERTIARY)

Brecciated fault blocks containing Spokane Formation and locally Greyson Formation. Associated with renewed movement on Battle Creek thrust fault (from McGrew, 1977b, c, d).

Trp RHYOLITE OF BLACK BUTTE MOUNTAIN (TERTIARY)

Light-pink to pale-red, light-gray to dark-gray, and yellowish-gray rhyolitic groundmass with feldspar and quartz phenocrysts; hornblende, augite, titanite, and biotite locally present. Phenocrysts appear to lack preferred orientation; may be an intrusive sheet or laccolith or internal part of a thick flow (from McGrew, 1977a, b).

Tg GRANITE (EOCENE)

Light- to dark-gray, fine- to medium-grained granite and granite porphyry of the Castle Mountain Stock. Can appear pinkish-red depending on alkali-feldspar content. Weathers into high crags or “castles” (Winters, 1968; Thompson, 2001).

Tqmd QUARTZ MONZODIORITE (EOCENE)

Light-gray to light-greenish-gray, fine- to medium-grained quartz monzodiorite, quartz monzonite, and minor granodiorite. Forms irregularly shaped mass at the center of the Big Timber stock. The Campfire Lake mass of the Big Timber stock is a fine-grained porphyry compositionally similar to the quartz monzodiorite phase of the Big Timber stock but forming a separate mass. (Tappe, 1958; du Bray and others, 1993).

Tqm QUARTZ MONZONITE (EOCENE)

Light-gray to pinkish-gray, medium-grained quartz monzonite. Forms perimeter of the Loco Mountain stock in the Crazy Mountains (Twyman, 1979). In the Castle Mountains, moderately porphyritic quartz monzonite forms the Blackhawk stock (conventionally referred to as the Blackhawk diorite) (Thompson, 2001; Winters, 1968).

Tdg DIORITE AND GABBRO (EOCENE)

Light- to medium-gray, fine- to coarse-grained diorite and gabbro. Forms volumetrically dominant mass of the Big Timber stock (du Bray and others, 1993). Diorite with large poikilitic biotite forms the central part of Loco Mountain stock (Twyman, 1979).

Tdap DACITE PORPHYRY (EOCENE)

Dark- to light-gray to white (depending on degree of alteration) porphyry with phenocrysts of plagioclase, alkali feldspar, and amphibole (Thompson, 2001; Winters, 1968). Forms isolated exposures between the Castle and Blackhawk stocks.

Tai ALKALIC INTRUSIVE (EOCENE)

Mafic alkalic rocks (including malignite, nepheline syenite, analcite syenite, and theralite), trachyte porphyry, quartz latite, and related intrusive rocks. Typically these rocks are sodium-rich, silica-undersaturated, and strongly alkaline (Harlan, 1986). Includes dikes, sills, phaccoliths, and laccoliths that are generally located north of the Shields River in the Crazy Mountains.

Tsh SHONKINITE OF GORDON BUTTE (EOCENE)

Coarse-grained, mafic alkaline intrusive with subequal amounts of potassium feldspar and augite. Forms a circular laccolith with associated sills and a main feeder dike (Emmart, 1981).

Ti INTRUSIVE ROCKS, UNDIVIDED (EOCENE)

Includes undifferentiated dikes, sills, and other small intrusive bodies. In the Castle Mountains, undifferentiated intrusive rocks are primarily granodiorite, monzonite, quartz monzonite, andesite, rhyodacite, rhyolite, dacite porphyry, and syenite porphyry (Thompson, 2001; Winters, 1968) In the Crazy Mountains, compositions of dikes and sills associated with the Big Timber and Loco Mountain stocks generally range in composition from basaltic

andesite to rhyolite (du Bray and others, 1993; Starmer, 1972; Simms, 1966). North of the Shields River, the undifferentiated dikes, sills, and other small intrusive bodies are generally alkaline (including nepheline syenite, latite, trachyte, and malignite) (Harlan, 1986; Fink, 1975; Larsen and Simms, 1972; Wolff, 1938b).

Fort Union Formation (Paleocene)

Tftr TONGUE RIVER MEMBER (PALEOCENE)
Yellowish-gray to gray, fine- to medium-grained, trough cross-bedded, planar bedded or massive sandstone interbedded with lesser amounts of brownish-gray, carbonaceous shale, yellowish-gray siltstone, and coal beds. Gray, limestone beds weathering reddish-brown, and scattered brown weathering concretions locally developed several hundred feet above base. Contains well-developed channel sequences that range from 20 to 100 ft in thickness. Channel sandstones grade laterally into interbedded siltstone and sandstone, carbonaceous claystone, and coal. Rocks are poorly consolidated to unconsolidated. (Wilde and Porter, 2001) Thickness not measured.

Tfle LEBO MEMBER (PALEOCENE)
Medium- to dark-gray and olive-gray shale that is commonly smectitic or carbonaceous, interbedded with silty shale, yellowish-gray sandstone and siltstone, and thin, lenticular, shaly coal beds. Contains small-scale (5- to 40-ft thick), light-gray, fine- to medium-grained channel sandstones (Wilde and Porter, 2001). Thickness not measured.

Tft TULLOCK MEMBER (PALEOCENE AND UPPER CRETACEOUS)
Yellowish-gray, fine-to medium-grained, trough cross-bedded, planar-bedded or massive sandstone interbedded with lesser amounts of gray to greenish-gray claystone, siltstone, and minor carbonaceous shale. Sandstones often form laterally discontinuous channel sequences (from Wilde and Porter, 2001). Thickness not measured.

TKfu FORT UNION FORMATION, UNDIVIDED (PALEOCENE)
Grayish-green, dusky-yellow-green to yellowish-gray, thin- to thick-bedded sandstone interbedded with yellowish-brown and brownish-gray siltstone, mudstone, dark-gray carbonaceous shale, thin coal beds, and minor pebble conglomerate. Sandstones commonly feldspathic with volcanic, metamorphic, and sedimentary lithic fragments, and locally magnetite-rich laminations. Contains reddish-brown calcareous concretions, fresh-water mollusks, and plant fragments. West of Shields River, probably includes lithologies equivalent to underlying Hoppers Formation. Metamorphosed to hornfels in the vicinity of the larger intrusive bodies (Big Timber stock, Loco Mountain stock). Thickness more than 6,500 feet (Roberts, 1972).

Kho HOPPERS FORMATION OF LIVINGSTON GROUP (UPPER CRETACEOUS)

Light-greenish-gray, light-olive-gray, and pale-yellowish-brown, fine- to coarse-grained, generally massive to thin-bedded, calcareous, friable sandstone; interbedded with minor olive-gray and dark-gray, commonly calcareous, mudstone and siltstone. Volcaniclastic granule- and pebble-conglomerate in thin beds and lenses, some sandstones with magnetite-rich laminae. East of Shields River, Hoppers Formation and Fort Union Formation are not differentiated. Thickness not measured in map area but just south of the quadrangle it is as much as 2,400 feet thick (Skipp and McGrew, 1972).

Kbc BILLMAN CREEK FORMATION OF LIVINGSTON GROUP (UPPER CRETACEOUS)

Poorly exposed gray, greenish-gray, grayish-brown, and grayish-red volcaniclatic mudstone and siltstone interbedded with minor volcaniclastic sandstone, conglomerate, and vitric tuff. Mudstone and siltstone contain carbonaceous material, fresh-water mollusks, zeolites, calcareous concretions, limestone nodules, and dinosaur bones. Sandstone mostly volcaniclastic, grayish-green and olive-gray, fine-grained to conglomeratic, calcareous, with “cannonball” concretions. Conglomerate pebbles and cobbles mostly andesite and rhyodacite volcanic rocks with minor Paleozoic limestone and quartzite (from Skipp, 1977). Thickness as much as 2,500-3,000 feet.

Khc HELL CREEK FORMATION (UPPER CRETACEOUS)

Poorly exposed, interbedded light-brownish-gray to yellowish-gray, cliff- and ledge-forming, fine- to coarse-grained, thin- to thick-bedded sandstone and pale-greenish-gray, dusky-red-purple and grayish-red mudstone. Trough cross-bedded to massive channel sandstones as much as 40 feet thick grade laterally into interbedded tan to grayish-green mudstone, siltstone, and thin-bedded, rippled, yellowish-gray calcareous sandstone. (Wilde and Porter, 2001). Hell Creek is approximately equivalent to upper part of Livingston Group (Billman Creek and Hoppers Formation). Thickness not determined.

Kle LENNEP SANDSTONE (UPPER CRETACEOUS)

Grayish-yellow to yellowish-brown, tuffaceous, mostly very fine to medium-grained, contorted-bedded to cross-bedded, volcaniclastic sandstone with interbedded brown mudstone; locally contains lenses of andesite pebble conglomerate with some pebbles of Paleozoic quartzite and limestone, calcareous “cannonball” concretions, carbonaceous material, and occasional *Ophiomorpha* burrows. Forms sparsely vegetated ridges, weathers a distinctive yellowish-brown. The Lennep Sandstone is approximately equivalent to the Fox Hills Formation mapped in the eastern part of the quadrangle (Lopez and Berg, 2004). Thickness 400-600 feet.

Kfh FOX HILLS FORMATION (UPPER CRETACEOUS)

Thin layers of interbedded sandstone, siltstone, and mudstone overlain by well-sorted, very fine- to medium-grained, upward-coarsening, cross-bedded, poorly consolidated sandstone. Generally forms valleys. (Wilde and Porter, 2001). Thickness not measured.

Kb BEARPAW SHALE (UPPER CRETACEOUS)

Medium- to dark-gray fissile shale, greenish-gray and brownish-gray volcaniclastic mudstone and silty mudstone, thin beds of gray and green sandstone and yellowish-gray bentonite, minor thin beds of nodular limestone. Upper part: non-fissile mudstone and siltstone, sandy and somewhat tuffaceous, micaceous, increasingly silty and sandy to west. Reddish-brown to gray, fossiliferous, limestone concretions near top of formation. Forms valleys. Thickness 0-400 feet.

Kseu SEDAN FORMATION, UPPER (UPPER CRETACEOUS)

Mudstone member of Skipp and McGrew (1977). Grayish-green to brownish-gray volcaniclastic mudstone; interbedded light-gray and green to dark-green and brown, fine-grained, locally calcareous, volcaniclastic sandstone, siltstone, and light-yellowish-gray bentonite and light-gray-weathering altered vitric tuff. Rare lenses of volcaniclastic pebble and cobble conglomerate. Abundant orange zeolites (clinoptolite); sparse silicified wood, dinosaur bones, fresh-water mollusks, and carbonaceous plant remains. Thickness 600-900 feet.

Kset SEDAN FORMATION, WELDED TUFF MEMBER (UPPER CRETACEOUS)

Welded tuff member of Skipp and McGrew (1977). Welded tuff in three sheets: pale-yellowish-green, light-greenish-gray, grayish-red, and pale-yellowish-brown, and welded tuff conglomerate, separated by olive-gray to light-gray, volcaniclastic and quartzose sandstone, dark-colored conglomerate and mudstone, and altered vitric tuff. Welded tuff is dacite, fine grained, contains locally abundant golden-weathering biotite, and is largely devitrified; contains wood. Altered crystal vitric tuff interbedded with green, dark-gray-green, and brown sandstone. Unit thins to the north and is not mapped as a separate unit. (from Skipp, 1977). Thickness 50-500 feet.

Ksel SEDAN FORMATION, LOWER (UPPER CRETACEOUS)

Middle and lower sandstone members of Skipp and McGrew (1977). Gray-green and olive, volcaniclastic sandstone and conglomerate, weathering dark-brown; interbedded dark-gray-green to brown siliceous mudstone; lignite near base in some localities. Magnetite-rich sandstone lenses in lower part. Abundant leaf and twig impressions and carbonaceous plant debris; sparse silicified wood and dinosaur bone fragements. Light-gray, locally calcareous and micaceous, quartzose sandstone near middle of unit is interpreted as equivalent to the Parkman Sandstone (Skipp and McGrew, 1977). Thickness 1,200-2,800 feet.

Kjr JUDITH RIVER FORMATION (UPPER CRETACEOUS)

Upper part: Olive-green volcaniclastic mudstone, siltstone, and sandstone interbedded with thin beds of bentonite, volcanic ash, and conglomerate. West of Cottonwood Creek, a laterally discontinuous, light- to yellowish-gray, massive to cross-bedded, fine-grained, quartzose, calcareous sandstone underlain by oyster-shell coquina beds marks the top of the Judith River. Middle part: Interbedded dusky yellow green to greenish-black volcanic mudstone, siltstone, sandstone, and andesite volcanic conglomerates. Lower part: Alternating light and dark layers of grayish-brown and dusky-yellow weathering shales and minor sandstones. Judith River Formation locally contains abundant brackish-water fossils, petrified wood, disarticulated dinosaur bone fragments. Clastic volcanic content decreases to the east and beyond map area. Includes South Fork, Hamen, and Bruno Formations of Sims (1967). Thickness 600-1,200 feet.

Kcl CLAGGETT SHALE (UPPER CRETACEOUS)

Light-brownish to yellowish-gray shale, sandy shale, and thin sandstone, commonly rippled and calcareous. Brackish-water mollusks, calcareous concretions, some bentonitic layers. Locally capped by light-gray, partly calcareous and micaceous, quartzose, flaggy bedded sandstone (Parkman Sandstone equivalent of Skipp and McGrew, 1977). The Claggett thins and becomes increasing sandy from east to west and is difficult to distinguish from similar lithologies in the overlying Judith River Formation and underlying Eagle Formation. It was mapped separately only in eastern part of quadrangle but is present at least as far west as Bruno Siding. Lithologies similar to Clagget are included with the Eagle Sandstone, farther west they are within the upper Sedan Formation (Parkman Sandstone equivalent and underlying mudstone and siltstone). Thickness 0-450 feet.

Ke EAGLE FORMATION (UPPER CRETACEOUS)

Light-yellowish-gray, thin- to thick-bedded, fine-grained to conglomeratic, biotitic, largely calcareous, cross-bedded sandstone; locally with calcareous concretions and intercalated coal and shale. Lower part (Virgelle Sandstone Member) is massive or thinly bedded, cross-bedded, poorly to moderately well indurated, light-gray sandstone with greenish-gray and grayish-orange volcaniclastic sandstone and conglomerate beds and lenses, often capped with magnetite-rich sandstone; intercalated coal, siltstone, and shale, *Ophiomorpha* burrows common. Upper part is dusky-yellow weathering shale, siltstone, and several beds of volcaniclastic sandstone, carbonaceous shale, minor bentonite. May include lithologies equivalent to Parkman Sandstone and Claggett Shale. Thickness 150-500 feet.

Ktc TELEGRAPH CREEK FORMATION (UPPER CRETACEOUS)

Medium-gray, brownish-gray and light-yellowish gray weathering, sandy siltstone, shale, and thin-bedded, fine-grained sandstone, often friable, biotitic, and calcareous. Locally contains light-gray, often fossiliferous,

limestone concretions 1-2 feet wide near the base. Sandstone beds thicker and more abundant upward, grading into Eagle Sandstone. Thickness 200-600 feet.

Ket EAGLE FORMATION AND UPPER PART OF TELEGRAPH CREEK FORMATION, UNDIVIDED (UPPER CRETACEOUS)

Keco EAGLE FORMATION, TELEGRAPH CREEK FORMATION, AND CODY SHALE, UNDIVIDED (UPPER CRETACEOUS)

Ktco TELEGRAPH CREEK FORMATION AND CODY SHALE, UNDIVIDED (UPPER CRETACEOUS)

Ktcm TELEGRAPH CREEK FORMATION AND MARIAS RIVER FORMATION, UNDIVIDED (UPPER CRETACEOUS)

Includes Telegraph Creek Formation and the interval above Big Elk Sandstone Member of Belle Fourche Shale as mapped by Lopez and Berg (2004). Telegraph Creek Formation: medium-gray, brownish-gray, and light-yellowish-gray weathering, sandy siltstone, shale, and thin-bedded, fine-grained sandstone, often friable, biotitic, and calcareous. Limestone concretions near base. Marias River Formation: Includes dark-gray, partly calcareous, fissile to blocky shale; glauconitic, micaceous shale, mudstone, and sandstone; light-bluish-gray weathering, thin, micaceous siltstone and fine-grained sandstone interbedded with dark-gray, clayey shale, often with calcareous concretions; and medium-gray, very calcareous, bentonitic shale with zones of large (1-3 ft diameter) calcareous concretions. Lithologies correspond to (in ascending order) the Cone, Ferdig, and Kevin Members of the Marias River Formation as described by Wilde and Porter (2001). Thickness not measured.

Kco CODY SHALE (UPPER CRETACEOUS)

Shale and mudstone, gray, locally biotitic, contains ironstone nodules and cone-in-cone structures; interbedded with greenish-gray, fine-grained, quartzose sandstone and siltstone, glauconitic, calcareous, thin-bedded, locally cross-bedded, rippled and with lithic fragments. Fossiliferous intervals contain fish scales, starfish, mollusks, and ammonites. Persistent grayish-green, glauconitic, resistant sandstone near middle of formation is Eldridge Creek Member (from Skipp, 1977). Thickness about 500-1,000 feet.

Kf FRONTIER FORMATION (UPPER CRETACEOUS)

Light- to medium-gray, olive-gray, and dark-greenish-gray sandstone interbedded with dark-gray shale and siliceous mudstone, thin, dark-gray quartzite, dark-gray chert-pebble conglomerate containing shark teeth and bone fragments, siliceous limestone, and fossil oyster banks. Sandstone weathers dark-gray and brown with “salt-and-pepper” appearance, is fine to

coarse grained, quartzose, feldspathic, lithic, calcareous, argillaceous, thin to medium bedded, locally cross-bedded with heavy mineral concentrations on bedding planes (from Skipp, 1977). Chert-pebble conglomerate and sandstone interval likely correlates with Big Elk Sandstone as mapped on eastern part of quadrangle and on the east-adjacent Harlowton quadrangle (Wilde and Porter, 2001). Thickness approximately 500-700 feet.

Kbfb BIG ELK SANDSTONE MEMBER OF BELLE FOURCHE SHALE (UPPER CRETACEOUS)

Light-gray, hard, dense, calcareous to non-calcareous, medium- and coarse-grained, chert-rich, "salt-and-pepper" sandstone commonly stained dark-red and burrowed; interbedded with thin, dark-gray to black, clayey shale. Very well-cemented black chert pebble conglomerate interbeds. Occurs as multiple coarsening-upward sequences that are thicker in lower part and thinner and possibly discontinous in upper part (from Wilde and Porter, 2001).

Kmt MOWRY SHALE AND THERMOPOLIS FORMATION, UNDIVIDED (LOWER CRETACEOUS)

Dark-gray shale and siliceous mudstone with interbedded gray to greenish-gray, medium- to coarse-grained, thin-bedded, feldspathic, calcareous, argillaceous sandstone in upper part; grayish-orange, ledge-forming quartzitic sandstone at base (from McGrew, 1977). Skipp (1977) divided this interval into the Mowry Shale, Muddy Sandstone, Skull Creek Shale and Fall River Sandstone. Thickness 400-600 feet.

Kcg COLORADO GROUP AND TELEGRAPH CREEK FORMATION, UNDIVIDED, ALL OR PART (LOWER AND UPPER CRETACEOUS)

Includes Thermopolis Shale through Telegraph Creek Formation. In the north part of the quadrangle only.

Kk KOOTENAI FORMATION (LOWER CRETACEOUS)

Red, reddish-purple, greenish-gray and gray, poorly exposed mudstone with interbedded grayish-green sandstone, pebble conglomerate, and light-gray gastropod-bearing limestone nodules in upper part. Resistant, chert-rich, cross-bedded, fine-grained to conglomeratic sandstone at base. Conglomerate contains predominantly rounded, gray, black, and tan chert pebbles. Thickness 400-550 feet.

Jm MORRISON FORMATION (UPPER JURASSIC)

Upper part: Light-greenish-gray sandy siltstone, yellowish-orange, locally cross-bedded, calcareous sandstone and beds and nodules of freshwater, medium- and dark-gray limestone. Dark-gray carbonaceous shale, as much as 15 feet thick, with minor thin coal beds at or near top of formation. Lower part: Poorly bedded, reddish mudstone and siltstone with thin, brown-weathered sandstone. Generally poorly exposed, often recognized by reddish soil. Thickness 200-400 feet.

Je ELLIS GROUP, UNDIVIDED (UPPER AND MIDDLE JURASSIC)

Includes lithologies equivalent to the Swift Sandstone, Rierdon Formation, and Sawtooth Formation. Swift Sandstone: Yellowish-brown to grayish-brown, medium- to coarse-grained, cross-bedded, highly calcareous, glauconitic sandstone, often with chert-pebble conglomerate near base. Commonly iron-stained, locally fossiliferous. Rierdon Formation: Yellowish-gray, calcareous shale and limestone overlying lower gray weathering, medium- to thick-bedded, ledge-forming, oolitic limestone. Sawtooth Formation: Upper red and yellow calcareous mudstone and shale, middle gray weathering, dense, platy limestone and calcareous shale, and basal sandy to pebbly limestone or conglomeratic calcareous sandstone (from Skipp, 1977). Sawooth Formation and most of Rierdon have not been recognized in the northern part of the map area. Thickness about 50-200 feet.

Jme MORRISON FORMATION AND ELLIS GROUP, UNDIVIDED (UPPER AND MIDDLE JURASSIC)

IPq QUADRANT FORMATION (PENNSYLVANIAN)

Light-grayish-orange to light-gray, fine-grained, quartzose, locally calcareous sandstone. Thickness 0-150 feet. Not present in northern part of map area.

IPMam AMSDEN GROUP, UNDIVIDED (PENNSYLVANIAN)

Light-gray, thin- to thick-bedded dolomite with lesser amounts of white to gray, fossiliferous limestone; interbedded with tan, silty and calcareous sandstones, red mudstones, and thin beds of gray and purplish-gray limestone. Lower part is predominantly red mudstone with a few thin beds of limestone and sandstone, locally brecciated. Dolomite and limestone beds are probably equivalent to Devils Pocket Formation and Alaska Bench Limestone. Thickness about 250-600 feet.

Mbs BIG SNOWY GROUP (MISSISSIPPIAN)

Includes lithologies equivalent to Heath, Otter, and Kibbey Formations. The Otter and Heath are not easily differentiated in this area and the combined lithologies are referred to as the Lombard facies of the Big Snowy Group (Blake, 1959). Heath(?) and Otter Formations: Predominantly gray, gray-tan, pink, or purplish limestone, locally with black chert, oolites, stromatolites and other algal structures, often with mottled appearance; interbedded with minor yellowish-green, dark-greenish-gray- and brilliant green-weathered shale and siltstone. Kibbey Formation: Dark-reddish-brown, moderate-red, and light-reddish-brown weathering, poorly resistant mudstone interbedded with pale yellowish-orange-weathering, locally calcareous, quartzose sandstone and minor siltstone. Estimated thickness of Big Snowy Group is 300-700 feet.

lPMabs AMSDEN AND BIG SNOWY GROUPS, UNDIVIDED (PENNSYLVANIAN AND MISSISSIPPIAN)

Includes the Kibbey Formation and overlying undifferentiated Heath and Otter Formations (Lombard facies) of Big Snowy Group and the overlying Amsden Group. Undivided in northern part of map in the Castle Mountains where additional work is needed to resolve apparent differences in the location of the contact between the Amsden and Big Snowy Group as mapped by previous workers. (Gierke, 1987; Glasheen, 1969; Winters, 1968; Tanner, 1949).

Mmc MISSION CANYON LIMESTONE (MISSISSIPPIAN)

Light-gray to dark-gray, massive, cherty limestone that forms resistant ridges and cliffs. Beds of reddish-gray limestone breccia and dolomite in upper part. Breccia consists chiefly of limestone blocks (up to 15 feet long) in a red mudstone and tan to black sandstone matrix. Fossiliferous. Thickness 450-1,400 feet.

Ml LODGEPOLE LIMESTONE (MISSISSIPPIAN)

Gray to light-gray, thin, evenly bedded limestone, locally cherty, with minor silty limestone and yellow to tan weathering silty shale interbeds. Abundant fossils including crinoids, bryozoan, brachiopods and corals. Thickness 300-700 feet.

Mm MADISON GROUP, UNDIVIDED (MISSISSIPPIAN)

Includes Mission Canyon Limestone and Lodgepole Limestone. Undivided only in some areas of Castle Mountains.

MDt THREE FORKS FORMATION (MISSISSIPPIAN AND DEVONIAN)

Light-gray and greenish-gray weathering, poorly resistant mudstone and shale that contains yellowish to reddish-gray weathering, thin-bedded, calcareous siltstone and brownish-gray weathering dolomite beds. Thickness 150-200 feet.

Dj JEFFERSON FORMATION (DEVONIAN)

Dark-gray to brownish-gray, fine-grained, fetid dolomite and interbedded gray limestone. Thick-bedded to massive, some stromatolites. Capped by poorly exposed, white, coarse-grained, surgary dolomite. Thickness 400-500 feet.

Djm JEFFERSON AND MAYWOOD FORMATIONS, UNDIVIDED (DEVONIAN)

MDtj THREE FORKS AND JEFFERSON FORMATIONS, UNDIVIDED (MISSISSIPPIAN AND DEVONIAN)

MDtm THREE FORKS, JEFFERSON, AND MAYWOOD FORMATIONS, UNDIVIDED (MISSISSIPPIAN AND DEVONIAN)

DЄmsr MAYWOOD (UPPER AND MIDDLE DEVONIAN) AND SNOWY RANGE (UPPER CAMBRIAN) FORMATIONS, UNDIVIDED
Poorly exposed, red siltstone, locally drab-green, and reddish-gray dolomite, weathering yellowish-gray. (from McGrew, 1977a). May include lithologies assigned to the Dry Creek Shale or Red Lion Formation by Tanner (1949), Winters (1968), and Gierke (1987). Thickness 60-200 feet.

Єpi PILGRIM LIMESTONE (CAMBRIAN)
Light-gray to medium-gray limestone that contains characteristic intraformational flat-pebble limestone conglomerate. Locally oolitic and glauconitic. Thickness 300-400 feet.

Єp PARK SHALE (CAMBRIAN)
Grayish-green to gray, micaceous shale; sparse, irregular thin-beds of light-gray limestone in upper part. Poorly exposed, nonresistant; forms valleys. Thickness 100-300 feet.

Єm MEAGHER LIMESTONE (CAMBRIAN)
Medium-gray to light-gray weathering, thin- and irregular-bedded limestone with irregular-shaped, yellowish-orange, silty claystone mottles. Minor interbeds of greenish shale. Forms low, rounded ridges. Thickness 150-400 feet.

Єw WOLSEY SHALE (CAMBRIAN)
Olive, brownish-gray, and grayish-purple, micaceous shale and interbedded, fine-grained, thin-bedded sandstone. Minor, thin limestone beds. Abundant burrows in shaly beds. Poorly exposed, nonresistant; forms valleys. Thickness 200-500 feet.

Єf FLATHEAD FORMATION (CAMBRIAN)
Sandstone and quartzite, gray to reddish-gray, fine- to coarse-grained, locally cross-bedded. Quartz-pebble conglomerate near base. Forms resistant ridges. Thickness 50-300 feet.

DЄs SEDIMENTARY ROCKS (DEVONIAN THROUGH CAMBRIAN)
Metamorphosed sedimentary rocks adjacent to igneous intrusions in the Castle Mountains. Probably includes Jefferson Formation, Maywood Formation, Pilgrim Limestone, Park Shale, Meagher Formation, Wolsey Shale, and Flathead Formation.

Єs SEDIMENTARY ROCKS, UNDIVIDED (CAMBRIAN)
Includes Pilgrim Limestone, Park Shale, Meagher Formation, Wolsey Shale, and Flathead Formation. Mapped as a single unit in parts of Castle Mountains.

Ygb GABBRO SILL (MIDDLE PROTEROZOIC)

Dark-greenish-gray on fresh surfaces, weathering yellowish- to reddish-brown, coarse-grained gabbro. Top of sill is about 1,100 feet below top of Spokane Formation. (from McGrew, 1977a, b). Thickness about 200-350 feet.

Ysm SPOKANE FORMATION, METAMORPHOSED (MIDDLE PROTEROZOIC)

Dark-gray, dark-grayish-red, and black, hard flinty hornfels. Produced by contact metamorphism of Spokane Formation above and below the intruded gabbro sill (Ygb). (from McGrew, 1977a, b).

Ys SPOKANE FORMATION (MIDDLE PROTEROZOIC)

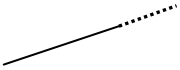
Grayish-red argillite with occasional light-grayish-green argillite interbeds; gray, grayish-red, and yellowish-gray quartrzite and fine-grained sandstone; sparse, thin, gray to reddish-gray limestone. Mostly thin-bedded, commonly with ripple marks and mud cracks. Gradational contact with underlying Grayson Formation. Incomplete sections range in thickness from about 2,200 to 3,200 feet.

Yg GREYSON FORMATION, (MIDDLE PROTEROZOIC)

Gray to yellowish-gray quartzite and sandstone. Interbedded greenish-gray micaceous argillite, grayish-red argillite, and thin gray limestone and stromatolite beds in upper part. Thickness not measured.

Ysg SPOKANE AND GREYSON FORMATION, UNDIVIDED (MIDDLE PROTEROZOIC)

MAP SYMBOLS



Contact--Dotted where concealed.

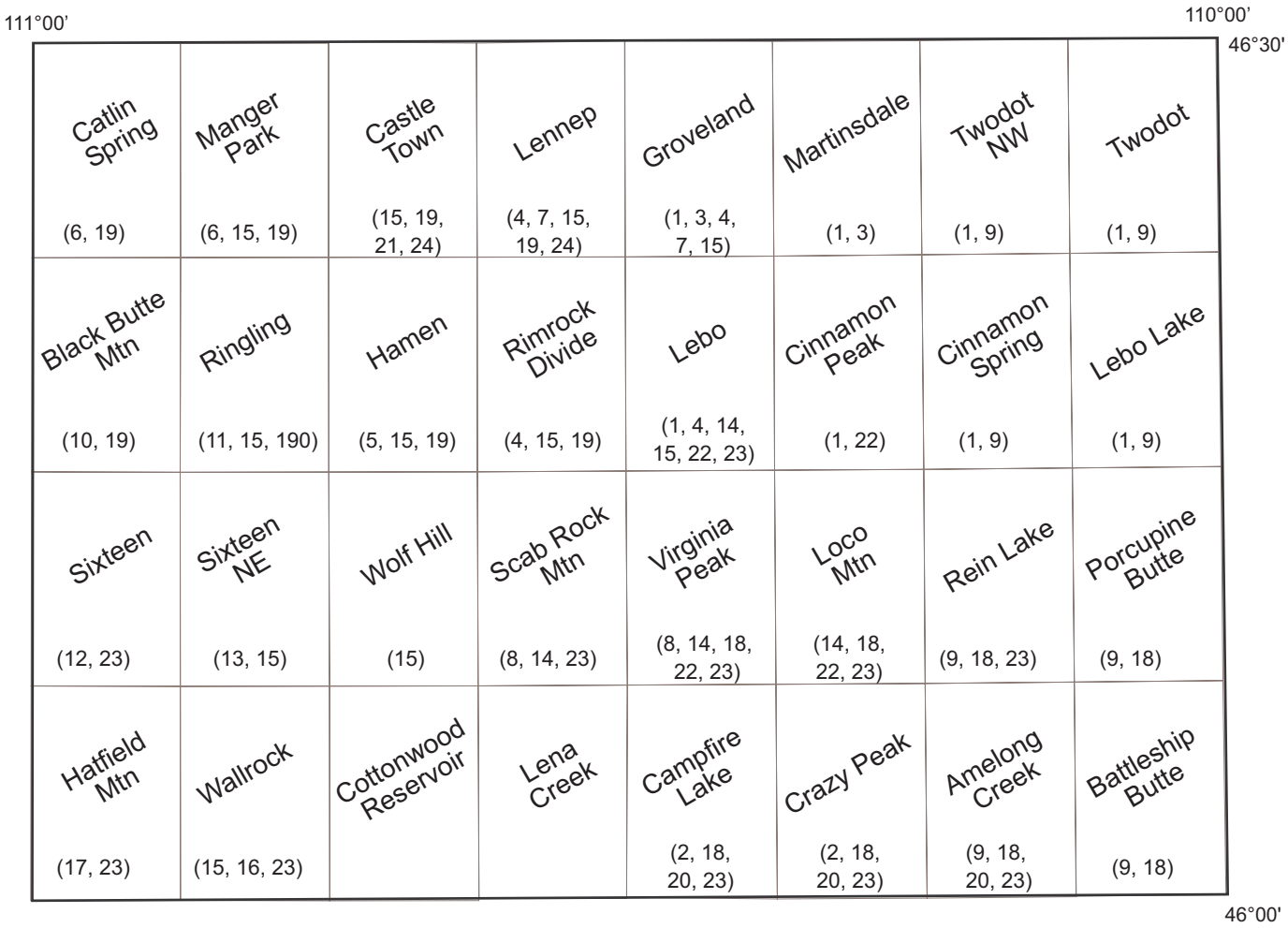
Fault--Dashed where approximately located, dotted where concealed, queried where uncertain. Bar and ball on down-thrown side.

Anticline--Showing trace of axial plane and direction of plunge; dotted where concealed.

Syncline--Showing trace of axial plane and direction of plunge; dashed where approximately located, dotted where concealed.

Dikes and sills

Strike and Dip of Bed



Major Sources of Geologic Data

1. Bowen, 1918
2. du Bray and others, 1993
3. Emmart, 1981
4. Fink, 1975
5. Freeman, 1977
6. Gierke, 1987
7. Glasheen, 1969
8. Harlan, 1986
9. Lopez and Berg, 2004
10. McGrew, 1977a
11. McGrew, 1977b
12. McGrew, 1977c
13. McGrew, 1977d
14. Simms, 1966
15. Sims, 1967
16. Skipp, 1977
17. Skipp and Hepp, 1968
18. Starmer, 1972
19. Tanner, 1949
20. Tappe, 1958
21. Tech Comminco American, Inc, 2004
22. Twyman, 1979
23. Wilson and Elliott, 1995
24. Winters, 1968

Figure 2. Index showing quadrangles and major sources of geologic mapping. Numbers in boxes correspond to references listed above. Geologic mapping by Roberts (1972) and Weed (1899) cover the entire Ringling 30’ x 60’quadrangle.

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