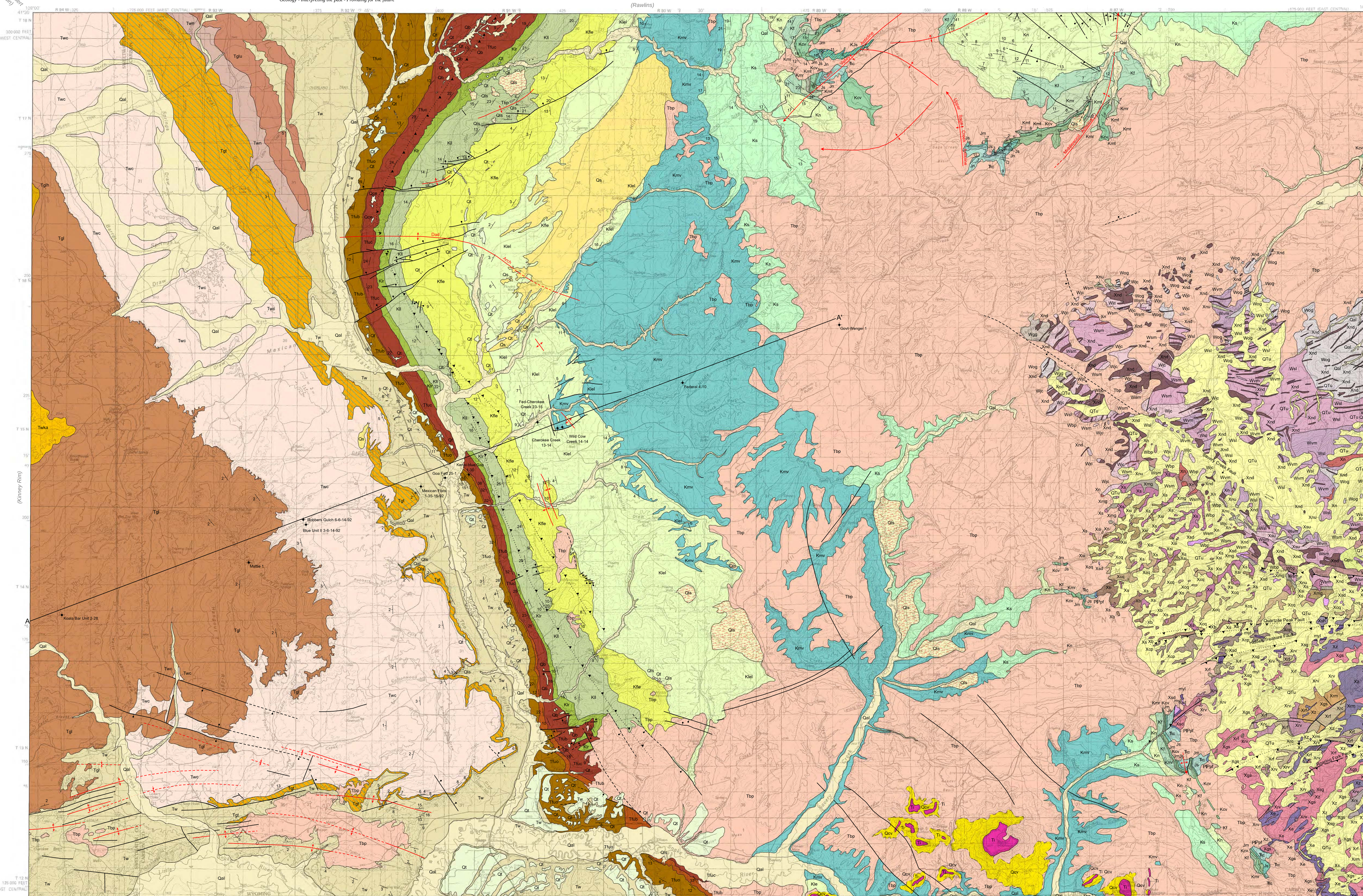
WYOMING STATE GEOLOGICAL SURVEY
Wallace L. Ulrich, Director and State Geologist
Laramie, Wyoming

Geology - Interpreting the past - Providing for the future

Prepared in cooperation with the
U.S. GEOLOGICAL SURVEY

MAP SERIES 95
Baggs 1:100,000 - scale
Bedrock Geologic Map



Base map from U.S. Geological Survey 1:100,000-scale metric topographic map of the Baggs, Wyoming-Colorado Quadrangle,1983.

Projection: Universal Transverse Mercator (UTM), zone 13
North American Datum of 1927 (NAD 27)
10,000-meter grid: UTM, zone 13
25,000-foot grid ticks: Wyoming State Plane Coordinate System, east central and west central zones
National Geodetic Vertical Datum of 1929

A digital version of this map is also available on CD-ROM.

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GN MN 1° 39' 29 MILS 13.5° 240 MILS
UTM grid convergence (GN) and 1983 magnetic declination (MN) at center of map
Diagram is approximate

0 1 2 4 6 8 10 12 14 16 18 20 Kilometers
0 1 2 4 6 8 10 12 Miles
SCALE 1:100,000
Contour interval 20 meters
0 1,000 2,000 4,000 6,000 8,000 10,000 12,000 14,000 16,000 18,000 20,000 Meters
0 2,500 5,000 10,000 15,000 20,000 25,000 30,000 35,000 40,000 45,000 50,000 55,000 60,000 65,000 Feet

GEOLOGIC MAP OF THE BAGGS 30' X 60' QUADRANGLE, CARBON AND SWEETWATER COUNTIES, WYOMING, AND MOFFAT AND ROUTT COUNTIES, COLORADO

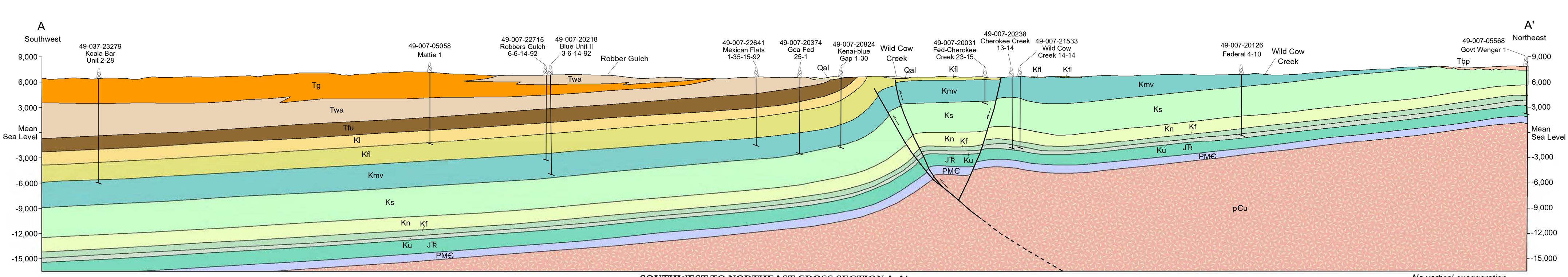
compiled and mapped by

Justin E. Scott, Wayne M. Sutherland, Joe Johnson, and J. Fred McLaughlin

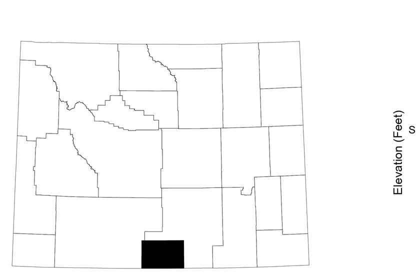
2011

Digital cartography by Justin E. Scott, Joe Johnson, and Robin W. Lyons
Map layout and design by Robin W. Lyons
Map editing by Suzanne C. Luhr

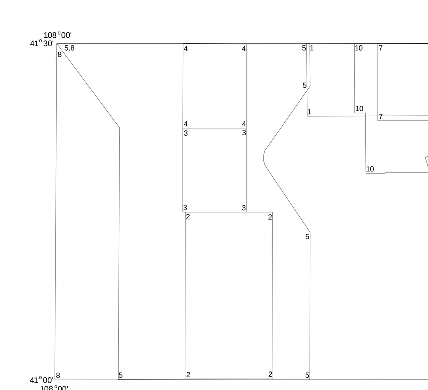
Prepared in cooperation with and research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G10AC00416. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.



SOUTHWEST TO NORTHEAST CROSS SECTION A-A'



WYOMING QUADRANGLE LOCATION



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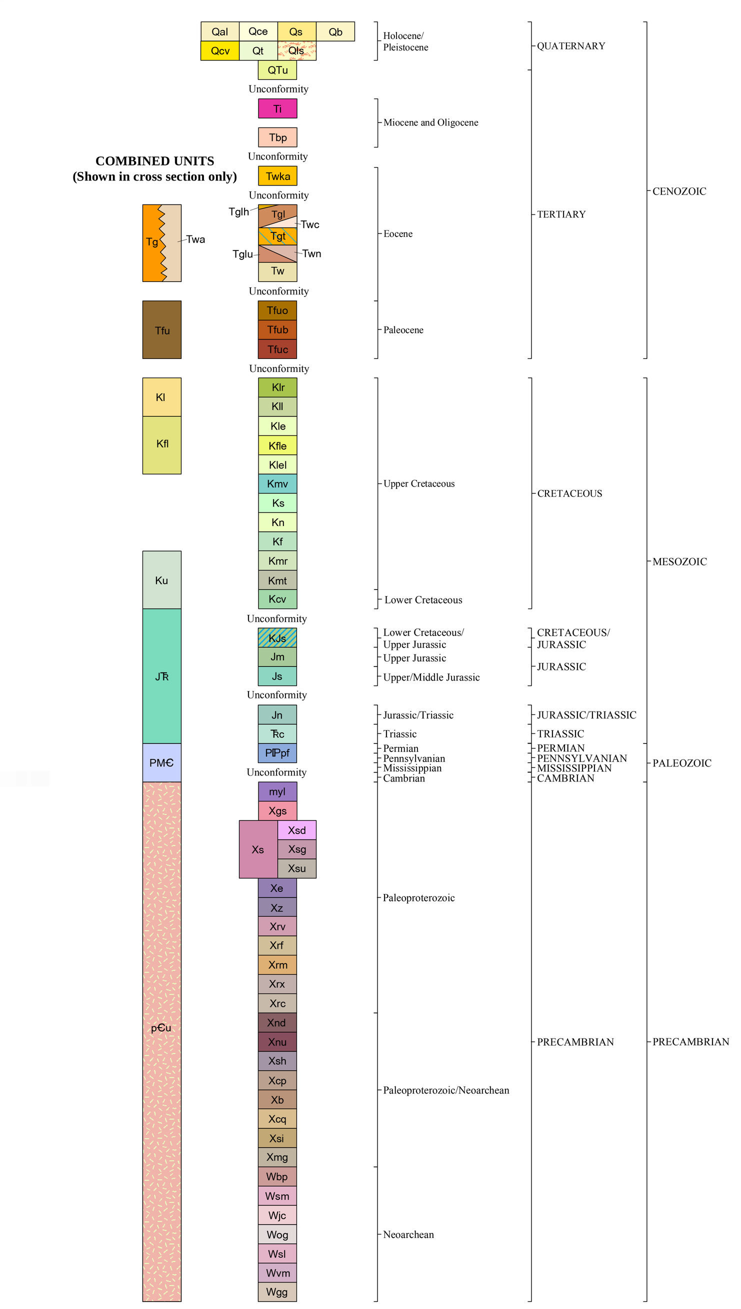
CORRELATION OF MAP UNITS



EXPLANATION

MAP SYMBOLS

DESCRIPTIONS OF MAP UNITS

Quaternary

Tertiary

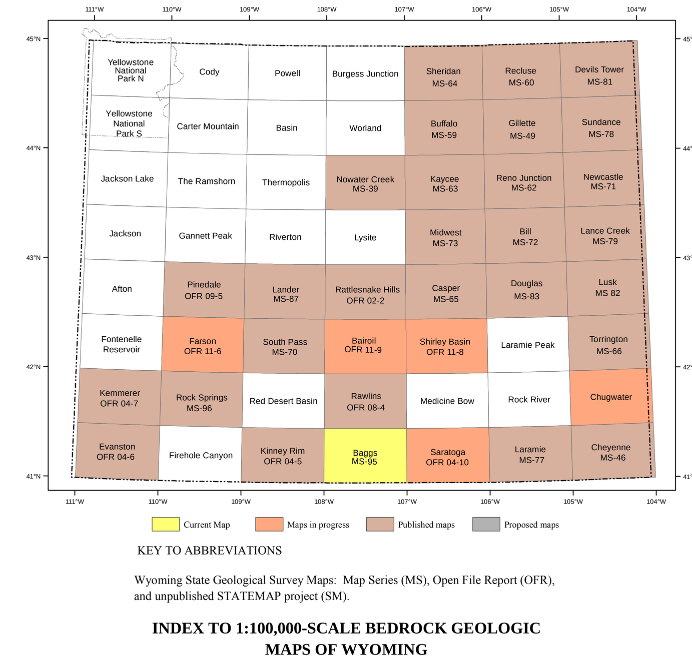
Mesozoic

Precambrian

Green Mountain Formation

Xrv **Mafic metavolcanic rocks of the Green Mountain Formation**—A sequence of mafic metavolcanic rocks of upper greenschist to lower amphibolite facies, with locally well-preserved primary texture in the central Sierra Madre; intermediate to felsic composition metavolcanic rocks and metagraywacke are interbedded with, and grade laterally eastward into, dominantly calc-alkaline metabasaltic rocks east of the quadrangle in the Green Mountain and Fletcher Park areas (Houston and Graff, 1995)

Xrf **Felsic metavolcanic rocks of the Green Mountain Formation, 1792 ± 15 Ma**—Felsic metavolcanic rocks that are predominately



Current Map | Maps in progress | Published maps | Proposed maps

KEY TO ABBREVIATIONS

Wyoming State Geological Survey Maps: Map Series (MS), Open File Report (OFR), and unpublished STATEMAP project (SM).

INDEX TO 1:100,000-SCALE BEDROCK GEOLOGIC MAPS OF WYOMING

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SELECTED REFERENCES AND SOURCES OF GEOLOGIC MAPPING
(Numbers refer to INDEX TO SOURCES OF GEOLOGIC MAPPING)

Shaw, H.F., Tracy, R.J., Niemeyer, S., and Colodner, D., 1986, Age and ND-SR systematics of the Spring Creek Lake body, Sierra Madre Mountains, Wyoming: EOS, v.67, p.1266.

Short, B.L., 1958, A geologic and petrographic study of the Ferris-Haggarty mining area, Carbon County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 138 p., scale 1:12,000.

Snyder, G.L., 1980, Geologic map of the northernmost Park Range and southernmost Sierra Madre, Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1113, scale 1:48,000.

Geologic Map of the Baggs 30’ x 60’ Quadrangle
Wyoming State Geological Survey Map Series 95

By
Justin E. Scott, Wayne M. Sutherland, Joe Johnson, and Fred McLaughlin,
With assistance from: Phyllis Ranz, and Suzanne Luhr
Photos by Wayne M. Sutherland.
September 29, 2011

Introduction

The Baggs quadrangle is located in Carbon and Sweetwater counties, Wyoming, and includes a thin sliver of Colorado. The map includes the towns of Baggs, Dixon, and Savery. The Sierra Madre, split by the continental divide, covers the southeastern third of the quadrangle. The western part of the quadrangle includes the Atlantic Rim, which is a topographically high region of uplifted Cretaceous sediments representing the border between the Sierra Madre and the Washakie and Great Divide Basins to the west.

Rising copper and gold prices continue to draw metals exploration interest to the Sierra Madre. The historic Ferris-Haggerty copper mine in the Sierra Madre was one of the World’s more important copper deposits during the early 1900s (Hausel, 1997). Uranium exploration, primarily in the Miocene Browns Park Formation, is active near Ketchum Buttes, in the central part of the quadrangle, and at Poison Basin in the southwestern part of the quadrangle. The map area also has the potential for the discovery of diamond deposits (Hausel and others, 2003).

The Atlantic Rim is currently the focus for extensive gas and petroleum condensate development, with 2000 wells (1800 coalbed methane, and 200 traditional oil and gas) planned for completion. Effects of this development dominate and heavily impact Savery and the surrounding area, with particular concern for the area’s ground water resources. Cretaceous exposures along the Atlantic Rim roughly define the area of gas development that focuses on the Cretaceous Mesaverde Formation, with additional oil and gas produced from units as old as the Pennsylvanian Tensleep Formation.

Geologic units within the Baggs 30′x 60′ quadrangle range in age from Archean to Quaternary. The western part of the map area is the eastern Washakie Basin, a northeast-trending Laramide syncline dominated by Tertiary sediments and bordered on the east by westward-dipping Cretaceous strata along the Atlantic Rim.

The Precambrian cored, Laramide, anticlinal uplift of the Sierra Madre in the southeastern part of the Baggs quadrangle is part of the Encampment mining district. The Encampment district produced mainly copper after its discovery in 1874. However, gold and silver were significant byproducts of copper mining (Hausel, 1989, 1997). The district is bisected by the east-trending Mullen Creek-Nash Fork shear zone, which is more than one-half mile wide in places. This shear zone forms part of the Cheyenne belt suture that separates the Archean Wyoming Province to the north from the Proterozoic basement of the Colorado Province to the south. Thick successions of Late Proterozoic miogeoclinal metasediments that overlie the Archean basement characterize the northern part of the district where mineralization includes copper-bearing quartzites, pegmatites, quartz veins, and unaniferous metaconglomerate. The southern part of the district is characterized by middle Proterozoic calc-alkaline metavolcanics intruded by granitic plutons, where eugeoclinal rocks host stratiform volcanogenic sulfides and related mineralization. Fracture-controlled, copper-dominated base metal deposits typify mineralization within the shear zone (Hausel, 1989; 1997).

North of the Cheyenne Belt, metaconglomerates found in several of the Precambrian units are considered potential sources for uranium and thorium as well as for copper-gold-silver mineralization. A significant copper deposit in a sheared metaconglomerate at the Ferris-Haggarty mine in the Magnolia Formation of the Snowy Pass Group metasediments in the southeastern part of the quadrangle was considered to be one of the more important copper deposits in the world in the early 1900s. This conglomerate also yields anomalous silver and gold (Hausel, 1989; 1997).

Late Miocene basaltic magmatism in the southeastern part of the quadrangle is the northwestern end of Colorado’s Elkhead Mountains volcanic field. Exposures include flows, pyroclastics, dikes, and plugs that stand out in high relief (Carey, 1955; Leat and Thompson, 1988).

Quaternary

Qal alluvium. Alluvium comprises unconsolidated sand, silt, clay, coarse gravels and cobbles, located in and along most drainages. This unit, compiled from many sources including air photo interpretation, may include eluvial deposits, lake sediments, slope wash and small alluvial and colluvial deposits (Qc) along drainages.

Qt terrace deposits. These include thin to thick, unconsolidated to locally cemented, deposits of silt, sand, gravel, and cobbles distributed over a wide range of elevations above the present drainage systems. A wide variety of rock types are found in rounded clastic materials that cover these surfaces. Cobbles are generally less than 4 in. (10 cm) in diameter, but boulders up to 1.5 feet (0.5 m) are found close to the mountains along the Little Snake River (Honey and Hettinger, 2004; Hettinger and others, 2008).

Qce colluvium and eolian sand, undifferentiated. Minor deposits in the north-central part of the quadrangle are dominated by slope wash and wind-blown sand, but may include thick soils and minor alluvium. Small deposits of this type are locally abundant, but due to considerations of scale, are depicted only in a few areas where they obscure coal beds.

Qcv colluvium derived from Miocene igneous rocks. Large amounts of colluvium derived from Miocene igneous rocks covers slopes surrounding Battle Mountain and other hills near the southeastern edge of the quadrangle. This unit may also include some alluvial material dominated by Miocene igneous rocks. The topographic highs are due to greater resistance to weathering than the underlying Browns Park Formation, and the Steele Shale in one location.

Qs sand dunes. Wind-blown sand and sand dunes occur primarily within the north central part of the quadrangle in an area known as The Sand Hills (Hettinger and others, 2008).

Qpu Upper Pinedale glacial deposits. These includes undifferentiated till, protalus, and moraine as mapped by Price (1973).

Qb clinker and baked rock. Areas of clinker and baked rock derive from past coal fires along the outcrop of the China Butte Member of the Fort Union Formation (Hettinger and others, 2008).

Qls landslide deposits. Landslides consisting of mixed debris from soils and clasts of bedrock are mapped mainly in areas of steep topography where bedrock is dominated by clay lithologies. Sources include air photo interpretation, field observation, and mapping by Honey and Hettinger (2004) and by Hallberg and Case (2006).

Quaternary/Tertiary

QTu Quaternary and/or Tertiary deposits, undifferentiated. These may include alluvial, colluvial, terrace, landslide, and glacial deposits, and outcrops of various Tertiary formations (Price, 1973; Snyder, 1980; Houston and Graff, 1995), however details were unavailable for the separation of these units during this project.

Tertiary

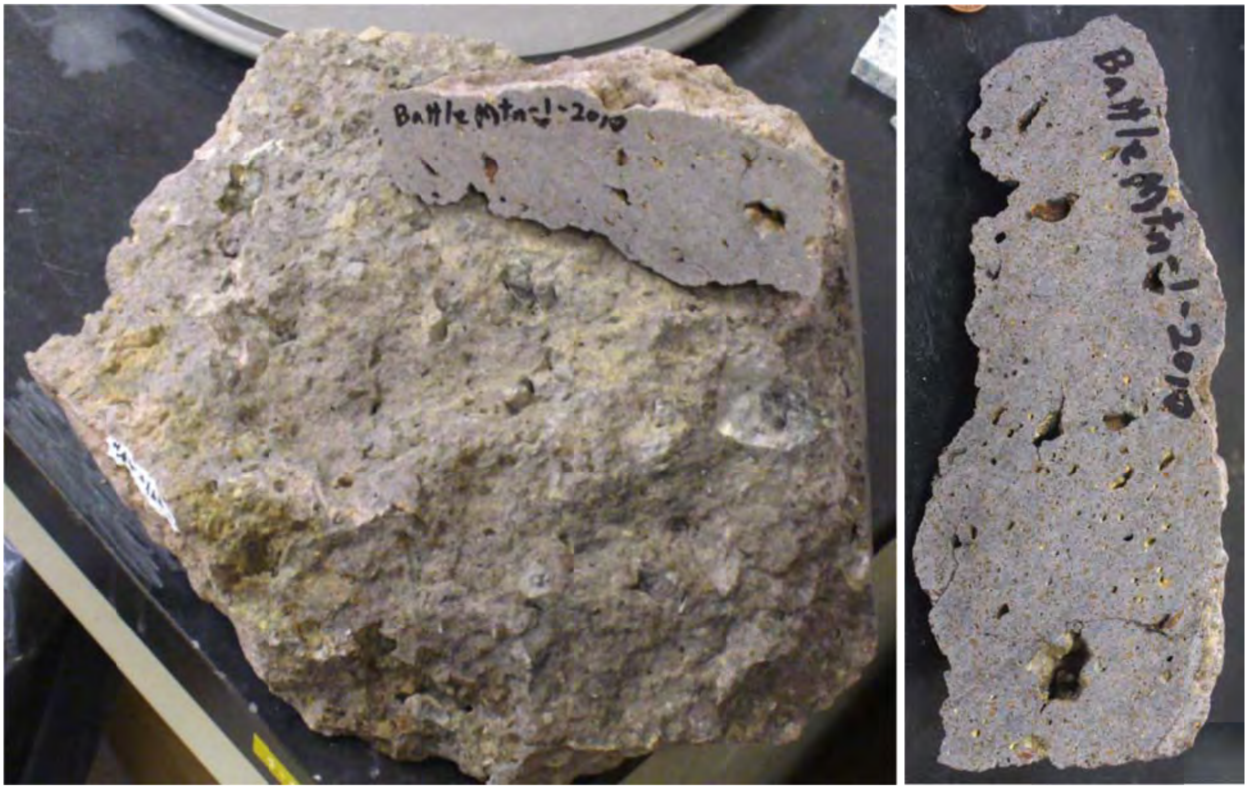
Ti Late Miocene igneous intrusive and extrusive rocks (11.6-8.7 Ma). Basaltic magmatism in the vicinity of Battle Mountain in the southeastern part of the Baggs quadrangle is the northwestern end of the Elkhead Mountains volcanic field and is interpreted to represent the northern end of the Rio Grande Rift (Gibson and others, 1993; Thompson and others, 1993). The Wyoming portion of this volcanic field is not thoroughly studied, but is represented by flows, pyroclastics, dikes, and plugs that tend toward high relief (Carey, 1955; Leat and Thompson, 1988). These rocks intrude and overlie the Browns Park Formation at Battle Mountain. Rock types catalogued to the south in Colorado are dominated by basalts, but include rhyolite, syenite, trachyte, and minette (Carey, 1955; Leat and others, 1988). A date of 11.6-8.7 Ma for these rocks is a re-interpretation of pre-1977 K-Ar and fission track methods by Thompson and others (1993) for rocks from Colorado; no radiometric dating has been done on samples from Wyoming.

East end of Battle Mountain (view south) with lava flows on top, Browns Park Formation at left, and colluvium derived from igneous rocks at right above trees.

West side of Battle Mountain showing multiple flows with colluvium derived from igneous rocks covering lower slopes.

Colluvial piece of pahoehoe lava on west flank of Battle Mountain.

Sample BattleMtn-1-2010 is a colluvial sample of vesicular agglomerate from the west flank of Battle Mountain below the major volcanic outcrops. Location: 41.032737N, -107.299453W.



Sample BattleMtn-1 (L) and cut surface of the same ®.

Table 1. Sample BattleMtn-1-2010 Trace Elements (ppm)

Ag	Ba	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Ga	Gd	Hf
<1	2500	112.5	37.4	320	1.23	54	4.98	2.46	2.74	21.9	7.8	6.3

Ho	La	Lu	Mo	Nb	Nd	Ni	Pb	Pr	Rb	Sm	Sn	Sr
0.87	55.5	0.3	<2	29	56.3	195	14	13.75	14.7	9.95	2	1535

Ta	Tb	Th	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
1.4	1.08	4.22	<0.5	0.3	1.68	192	1	24	1.9	116	244

Tbp Miocene Browns Park Formation. The Browns Park Formation is the most wide-spread outcrop in the eastern half of the Baggs quadrangle. Some early workers identified many Browns Park outcrops as North Park Formation, but re-evaluation indicates that these are probably all Browns Park Formation (Snyder, 1980; Montagne, 1991). It is variable in lithology, and includes tan, gray, and olive drab calcareous to siliceous and tuffaceous sandstone and siltstone, with some thin limestones, marlstone, and white pumicite beds (Luft, 1985; Montagne, 1991).

Browns Park Formation contains an upper sandstone unit that generally overlies, but in places intertongues with, a basal conglomerate. The upper sandstone member is white to yellowish-gray to yellowish-orange, very fine- to medium-grained tuffaceous sandstone. Locally, near Browns Hill, this sandstone includes a few thin beds of tuffaceous, light-gray, ripple laminated, lacustrine limestone (Love, 1953).

A basal conglomerate that varies in thickness up to 100-feet (30 m) is loosely consolidated, crossbedded and sandy, with a characteristic ferruginous-yellow orange matrix accompanied by conspicuous white quartz pebbles. This layer also typically hosts angular to subrounded cobbles of Precambrian and Paleozoic rocks, with local boulders up to four feet (1.2 m) in diameter (Love, 1953; Montagne, 1991). The Browns Park unconformably overlies all older formations within the quadrangle.

Basal conglomerate of the Browns Park Formation showing prominent white quartz pebbles in the southwestern part of the quadrangle.

Uneven contact between overlying basal conglomerate of the Browns Park Formation and muddy sandstone of the Main Body of the Wasatch Formation in the southwestern part of the quadrangle. View north.

The Browns Park varies from about 600- to more than 1000-feet (183-305 m) thick within the quadrangle (Love, 1953; Hettinger and others 2008). However, east of the quadrangle in the Saratoga Valley, it exceeds 2400 feet (732 m) in thickness (Montagne, 1991; Sutherland and Hausel, 2004).

Outcrops of the Browns Park Formation in the Sierra Madre may be included in Quaternary and/or Tertiary deposits, undifferentiated (Qtu) due to lack of details.

Unconformity

Twka Eocene Washakie Formation, Adobe Town Member. This member at the top of the Washakie Formation crops out along the west-central edge of the map area and consists of about 140 feet (43 m) of brown sandstone. The Adobe Town Member unconformably overlies all lower parts of the Washakie Formation and the Laney Member of the Green River Formation (Roehler, 1973, 1992; Love and Christiansen, 1985). This is the only part of the Washakie Formation that crops out within the Baggs quadrangle.

Unconformity

Eocene Green River Formation. The Green River Formation as described by Bradley (1964) is a pile of lenses of lacustrine sediments surrounded by a large mass of shallow basin-filling fluviatile sediments, represented within the Baggs quadrangle by the Wasatch formation, with which the Green River interfingers. Lithologically, the Green River Formation within the Baggs Quadrangle is represented by gray to buff, thin-bedded and varved, occasionally organic-rich, marlstone, along with shale, oil shale, oolites, algal limestones, and limey sandstone (Bradley, 1945; 1961; 1964). The Green River Formation crops out only in the western part of the Baggs Quadrangle where its cumulative maximum thickness is on the order of 2000 feet (610 m) (Bradley, 1964; Hettinger and others, 2008).

The Green River formation is subdivided into three units within the Baggs quadrangle and interfingers, sometimes complexly, with the Wasatch Formation. The Laney Member at the top of the Green River Formation, with its separately mapped Hartt Cabin bed at the top, is underlain by the Cathedral Bluffs Tongue of the Wasatch Formation. The Cathedral Bluffs overlies The Tipton Tongue of the Green River Formation, which in turn is above the Niland Tongue of the Wasatch Formation. The Niland overlies the Luman Tongue of the Green River Formation, which in turn overlies the Main Body of the Wasatch Formation. (Bradley, 1964; Hettinger and others, 2008; Love, Christiansen, and Ver Ploeg, 1993).

> **Tgl Laney Member of the Green River Formation.** The Laney Member is the most wide-spread outcropping of the Green River Formation within the Baggs quadrangle, and generally is the most extensive and thickest member of the Green River Formation across the entire Green River Basin (Bradley, 1964; Hettinger and others, 2008). Outside the map area, the Laney is subdivided into: the Hartt Cabin Bed, the LaClede Bed, and the Godiva Rim Member. However, only the Hartt Cabin Bed is mapped as a separate unit within the Baggs quadrangle.

Laney Member of the Green River Formation in the west-central part of the quadrangle. View east.

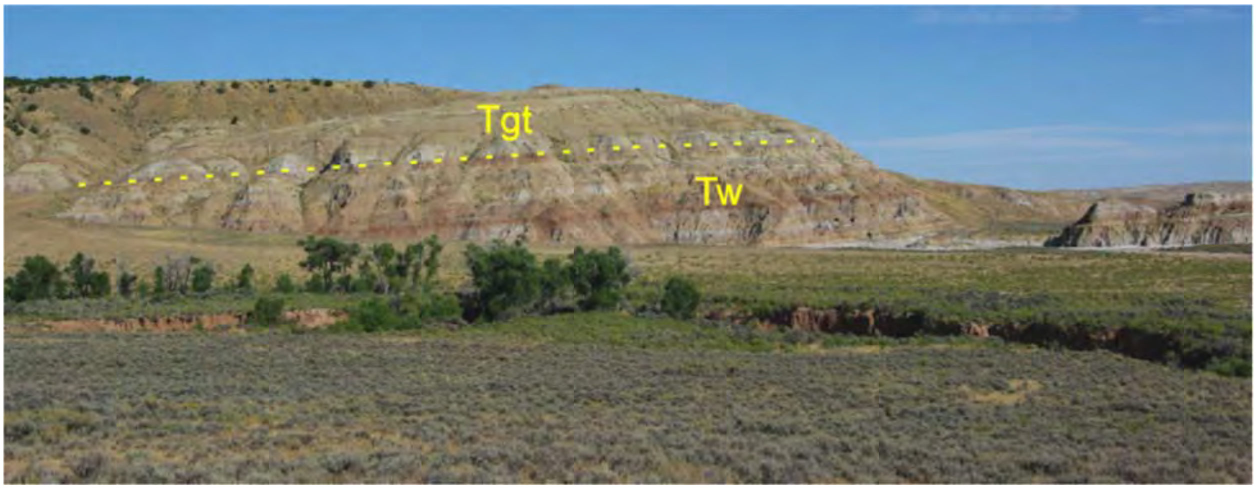
The Laney is dominated by buff to gray and brown, papery to massive, marlstone, shale, and muddy sandstone, with some white to brown tuff and tuffaceous sandstones, and oil shale (Bradley, 1961, and 1964; Roehler, 1973). The estimated maximum thickness of the Laney is about 1175 feet (358 m) in the west-central part of the quadrangle (Hettinger and others, 2008).

Tglh Hartt Cabin Bed of the Laney Member. The Hartt Cabin Bed is the upper part of the Laney Member, and is mapped only in one outcrop along the northwestern edge of the quadrangle. It is composed of green and brown shale and mudstone interbedded with gray sandstone, siltstone, mudstone, limestone, along with lesser amounts of oil shale, tuff, and dolomite (Roehler, 1973). Poor exposures of this bed are normal, and are generally covered by sand dunes and alluvial deposits.

Tgt Tipton Tongue of the Green River Formation. The Tipton Tongue is dominated by light bluish-gray, flakey organic marlstone in the upper part and soft brown to buff organic shale in the lower part. Outside of the map area, the Tipton is subdivided into: the Wilkins Peak Member, the Rife Bed, and the Scheggs Bed. None of these are mapped separately within the Baggs Quadrangle. Beds mapped as Tipton that are equivalent to the Wilkins Peak include drab, greenish-gray to nearly white dolomitic mudstone, marlstone, shale, oil shale, siltstone, and algal limestone (Bradley, 1961 and 1964). The estimated maximum thickness of the Tipton is about 400 feet (122 m) in the west-central part of the quadrangle (Hettinger and others, 2008).

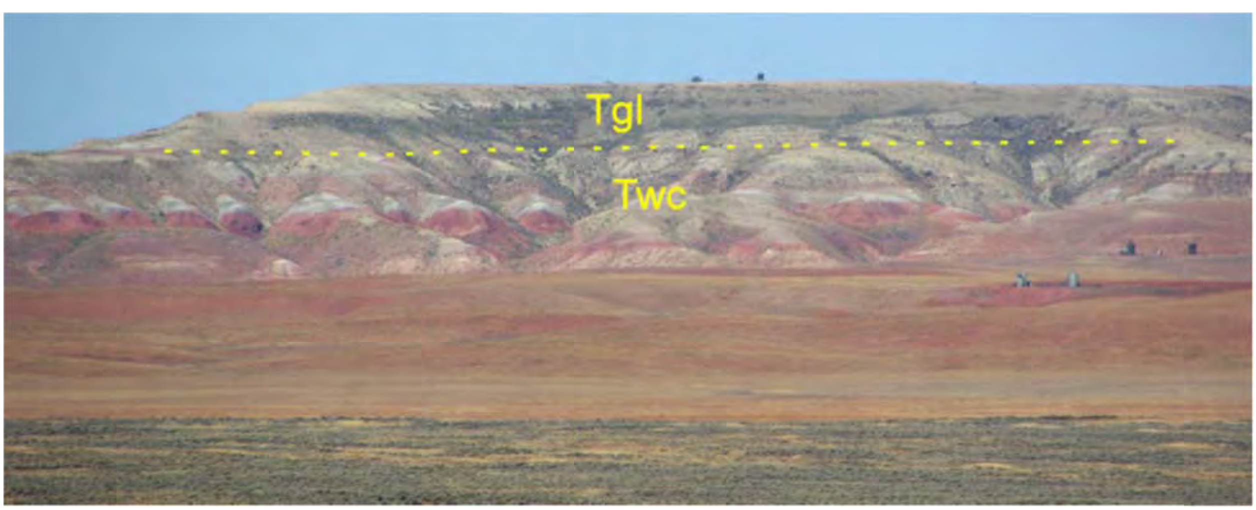
Tglu Luman Tongue of the Green River Formation. The Luman Tongue crops out only in the northwestern part of the quadrangle. It is made up of brown to gray-brown, flaky shale, oil shale, marlstone, carbonaceous shale, and limey sandstone beds that contain a few thin local coal beds (Bradley, 1961 and 1964; Roehler 1992). It intertongues with the Main Body of the Wasatch Formation, and has an estimated maximum thickness of about 375 feet (114 m) in the west-central part of the quadrangle (Hettinger and others, 2008).

Eocene Wasatch Formation. The Wasatch Formation crops out in the western part of the Baggs quadrangle and is subdivided into three units: the Cathedral Bluffs Tongue at the top of the formation, the Niland Tongue, and the main body or lower part. The Wasatch intertongues with the Green River Formation such that the Cathedral Bluffs lies below the Laney Member of the Green River, but is separated from the Main Body of the Wasatch by the Tipton Tongue of the Green River. The Niland Tongue of the Wasatch lies below the Tipton, but is separated from the upper part of the Main Body by the Lumen Tongue of the Green River Formation in the northwestern part of the map area (Bradley, 1964; Hettinger and others, 2008).



Tipton Tongue of the Green River Formation (Tgt) on top of the Main Body of the Wasatch Formation in the west central part of the quadrangle. View north.

Twc Cathedral Bluffs Tongue of the Wasatch Formation. Cathedral Bluffs Tongue of the Wasatch Formation is dominated by gray to greenish-gray, sandy mudstone marked with easily recognizable pink and red layers. Interbedded with the mudstone are massive lenses and beds of brown to yellow muddy sandstone (Bradley, 1945, 1961, 1964). Vertebrate Trace fossils as well as wood and vertebrates are relatively abundant in the Cathedral Bluffs Tongue (Roehler, 1992). Outcrops of the Cathedral Bluffs tend to form badland slopes.



Laney Member of the Green River Formation (Tgl) on top of the Cathedral Bluffs Member of the Wasatch Formation (Twc) in the west central part of the quadrangle. View northwest.

Roehler (1992) divided the Cathedral Bluffs into three parts in the Washakie Basin, which includes the western edge of the Baggs qaudrangle. The upper part comprises grey and green mudstone and shale, with interbedded thin red mudstone, gray to tan sandstone and siltstone, brown carbonaceous shale, and tan to grey oolitic and algal limestones. The middle part is dominated by red and maroon variegated mudstone interbedded with brown, orange, green, and gray mudstone, and gray sandstone and claystone. The lower Cathedral Bluffs is mostly green and gray mudstone interbedded with thin maroon and red mudstone, gray and tan siltstone and sandstone, tan oolitic and algal limestone, and brown carbonaceous shale.

The Cathedral Bluffs reaches a maximum thickness of about 1300 feet (400 m) within the Baggs quadrangle (Bradley, 1945; Hettinger and others, 2008).

Twn Niland Tongue of the Wasatch Formation. The Niland Tongue, which grades into the upper part of the Main Body of the Wasatch, crops out in the northwestern part of the quadrangle. It is dominated by gray mudstone and gray to white lenticular sandstone with some interbedded carbonaceous shale and subbituminous coal (Bradley, 1961). The Niland Tongue reaches a thickness of about 375 feet 110 m), and is locally separated from the upper part of the Main Body by the Lumen Tongue of the Green River Formation in the northwestern part of the Baggs quadrangle.

Tw Main Body of the Wasatch Formation. The Main Body of the Wasatch is dominated by gray to green, and locally red-banded, sandy mudstone and irregular beds and lenses of muddy sandstone. Carbonaceous shale and subbituminous coal occur in the upper part of the Main body. The unit may also include thin interbedded tan to gray limestone and brown, green, gray, or black shale. The Main Body may in places become conglomeratic near mountain ranges (Bradley, 1961; Roehler, 1992).

Conglomeratic muddy sandstone of the Main Body of the Wasatch Formation in the southwestern part of the quadrangle.

South of Dad Arch, the Main Body forms badland topography; north of the arch, it forms gentle slopes. The base of the Wasatch is generally a coarse-grained arkosic sandstone that lies unconformably on top of the Paleocene Fort Union Formation (Hettinger and others, 2008). Between Dad Arch and the Little Snake River this basal unit is up to 12 feet (4 m) thick and conglomeratic, with cobbles up to 2.5 inches (6.4 cm) in diameter; cobbles include chert, quartzite, quartz, limestone, and igneous rocks (Honey and Hettinger, 2004).

The Main body of the Wasatch Formation reaches a maximum thickness of about 2100 feet (640 m) in the southwestern part of the quadrangle (Hettinger and others, 2008).

Unconformity

Paleocene Fort Union Formation. The Fort Union Formation outcrops extend from north to south in a wide gentle curve over Dad Arch across the west-central part of the Baggs quadrangle. The Fort Union is made up of brown to gray sandstone, siltstone, mudstone, shale, carbonaceous shale and coal, representing flood plain, fluvial channel, paludal and possibly some lacustrine environments. A wide-spread conglomerate to conglomeratic sandstone with cobbles up to two-inches (5 cm) in diameter, marks the base of the formation where it lies unconformably on top of the Upper Cretaceous Lance Formation (Hettinger and others, 2008).

The Fort Union is subdivided into three members within the Baggs quadrangle. The Overland Member, at the top of the formation, unconformably overlies the Blue Gap Member, which conformably overlies and intertongues with the China Butte Member in the lower part of the formation (Hettinger and others, 2008).

Tfuo Overland Member of the Fort Union Formation. The Overland Member, at the top of the formation, is dominated by fine-grained, light-gray, massive to locally cross bedded sandstone, along with some siltstone, mudstone, and sandy ironstone. This is underlain by a basal coarse-grained, gray sandstone that increases in coarseness southward where chert clasts may be as large as one-inch near the southern edge of the map. The Cherokee coal zone, near the top of the Overland does not crop out within the quadrangle, but is about 10 feet (3 m) thick in the subsurface in the northwestern part of the map area. The Overland is about 1000 feet (305 m) thick near Dad Arch, but thins southward to 425 feet (130 m) near the Wyoming-Colorado border (Hettinger and others, 2008).

Tfub Blue Gap Member of the Fort Union Formation. The Blue Gap Member comprises olive- to brownish-gray mudstone and claystone, accompanied by thin beds of fine-grained sandstones, siltstone, ironstone, and carbonaceous shale. The Blue Gap is about 570 feet (170 m) thick near the Wyoming-Colorado border, thinning northward to just over the crest of Dad Arch, where it pinches out (Hettinger and others, 2008).

Tfuc China Butte Member of the Fort Union Formation. The China Butte Member is made up of light yellowish-gray, to white, and medium-brown, fine- to coarse-grained, thick- to thin-bedded, crossbedded sandstone, interbedded with siltstone, mudstone, carbonaceous shale, and coal. The China Butte is about 735 feet (224 m) thick near Baggs, increasing in thickness northward to greater than 1000 feet (305 m) near Dad Arch and more than 2000 feet (610 m) north of the quadrangle. Conglomeratic sandstone with cobbles up to two-inches (5 cm) in diameter, marks the base of the formation where it lies unconformably on top of the Upper Cretaceous Lance Formation (Hettinger and others, 2008).

Unconformity

Mesozoic

Upper Cretaceous Lance Formation. The Lance Formation is dominated by fine- to medium-grained fluvial sandstones interbedded with related claystone and mudstones flood plain deposits. It is subdivided into the upper Red Rim Member that overlies and in places intertongues with an unnamed lower member (Hettinger and others, 2008).

Klr Red Rim Member of the Lance Formation. The Red Rim Member is characterized by light yellowish-gray to gray, fine- to medium-grained, trough-crossbedded sandstone beds up to 200 feet (61 m) thick that form discontinuous cliffs. Grain sizes generally increase toward the upper part, which may contain chert pebbles up to 0.5 inch (1.3 cm) in diameter. Lenses of claystone and mudstone, varying from 20 to 100 feet (6-30 m) thick form splits in the sandstones. The Red Rim is about 685 feet (209 m) thick near Dad Arch, but thins southward to about 370 feet (113 m) near the town of Baggs (Hettinger and others, 2008).

Kll Lower member of the Lance Formation. The upper part of the lower member hosts fine-grained, light-gray, trough-crossbedded sandstones up to 200 feet (61 m) thick separated by dark- to medium-gray and brown mudstone and claystone. The lower part of this member is dominated by similar mudstone and claystone separated by thin, fine- to very fine-grained, ripple-laminated or trough-crossbedded sandstones up to 50-feet (15 m) thick. Several lenticular coal beds up to 10-feet (3 m) thick are found near the base of the formation, which intertongues with, or conformably overlies the Fox Hills Sandstone. The lower member of the Lance is about 1300 feet (396 m) thick near Dad Arch and near the Wyoming-Colorado border, but swells to 1675 feet (510 m) between these two locations (Hettinger and others, 2008).

Kle Upper Cretaceous Fox Hills Sandstone and Lewis Shale, undivided. The Fox Hills Sandstone is an upward-coarsening succession of grayish-orange to to yellowish gray, fine- to medium-grained, trough-crossbedded, massive sandstones interbedded with silty, gray shales. The Fox Hills lies on top of, is gradational with, and intertongues with the upper part of the Lewis Shale (Hettinger and others, 2008). Because of these relationships, the Fox Hills is mapped with the Lewis rather than as a separate unit.

The combined thickness of the Fox Hills and the Lewis, six miles south of Dad Arch, is 1635 feet(498 m) , with the Fox Hills contributing 400-feet (121 m) of thickness. About 14 miles (23 km) farther south toward Baggs, the Lewis is only 960-feet (293 m) thick, including 240-feet (73 m) of the Fox Hills (Hettinger and others, 2008).

The Lewis Shale is a marine and near-shore unit of gray shale interbedded to varying degrees with brown and gray, fine- to very fine-grained and silty, massive to laminated lenticular sandstones that often host abundant concretions (Love and Christiansen, 1985; Hettinger and others, 2008). The upper part of the Lewis intertongues with the underlying Dad Sandstone Member of the Lewis, which in turn lies on top of and partially intertongues with the lower part of the formation, which is designated as a separate map unit. The Dad Sandstone Member varies from 555-feet to 700-feet (169-213 m) thick, but is not mapped as a separate unit within the quadrangle. Only one Fox Hills Sandstone and Lewis Shale undivided outcrop is mapped in an area just southeast of Savery.

Kfle   Fox Hills Sandstone, upper part of the Lewis Shale, and Dad Sandstone Member of the Lewis Shale, undivided. The Fox Hills Sandstone, described above, is mapped together with the upper part of the Lewis and the Dad Sandstone. The poorly exposed, valley-forming upper Lewis comprises olive-gray, silty shale interbedded with thin, very fine-grained, yellowish-gray silty sandstone. The Dad Sandstone Member, expressed in outcrop as small rounded hills and cuestas, is made up of light yellowish-gray to light brown, thick-bedded sandstone and olive-gray mudstone (Hettinger and others, 2008).

Klel   Lower part of the Lewis Shale. The lower part of the Lewis Shale is poorly exposed and forms valleys beneath its dark-gray, sandy marine shale. It conformably overlies, and intertongues with the underlying Almond Formation of the Mesaverde Group. The lower part of the Lewis is 410 feet (125 m) thick six miles (10 km) south of Dad Arch, and thickens southward to 1605 feet (489 m) near Baggs; thickening as the Dad Sandstone thins in the same direction (Hettinger and others, 2008).

Southwest dipping Lewis Shale under soil cover; northwest central part of quadrangle. View northwest.


Methane bubbles from one of several springs along a north-trending fault in the Lewis Shale in the northwest central part of quadrangle. View west.

Kmv Upper Cretaceous Mesaverde Formation. The Mesaverde Formation is mapped as a single unit within the Baggs quadrangle, whereas to the north and west of the quadrangle, the Mesaverde Group encompasses several subdivisions including the Almond Formation, the Pine Ridge Sandstone, the Allen Ridge Formation and the Haystack Mountains Formation. The total thickness of the Mesaverde within the map area is on the order of 2700-2900 feet (828-884 m).

The Mesaverde is made up of gray to yellow-orange, fine-grained, thin to thick, massive to crossbedded sandstone interbedded with gray sandy shale, mudstone, and thin coal beds (Love and Christiansen, 1985; Hettinger and others, 2008).

Mesaverde Formation with angular unconformity; baked red after coal seams burned; northwest central part of quadrangle. View north.

Ripple marks in the Mesaverde Formation; northwest central part of quadrangle. View north.

Ks Upper Cretaceous Steele Shale. The Steele Shale comprises soft, gray marine shale interbedded with numerous bentonite beds and thin, lenticular fine-grained sandstones (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). The Steele crops out in the central, northeastern, and southeastern parts of the quadrangle. A thickness for the Steele of 3100 feet (945 m) was measured by Ritzma (1949) in the southeastern part of the map area.

Kn Upper Cretaceous Niobrara Formation. The Niobrara Formation is dominated by black to gray to yellow calcareous shale interbedded with light-colored limestone and chalk (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). Niobrara outcrops occur in the northeastern and southeastern parts of the quadrangle where they are not unconformably buried beneath the Browns Park Formation. The Niobrara is included within undifferentiated Cretaceous and Jurassic rocks in outcrops in the valley of Sandstone Creek in the southeastern part of the map area. Ritzma (1949) showed a thickness of about 1200 feet (366 m) for the Niobrara in the southeastern part of the quadrangle.

Kf Upper Cretaceous Frontier Formation. The Frontier Formation is made up of dark-gray to black marine shale and sandy shale interbedded with gray to tan, fine-grained sandstones, and thin bentonite beds (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). Frontier outcrops are found in the northeastern and southeastern parts of the quadrangle. Ritzma (1949) showed a thickness of about 690 feet (210 m) for the Frontier in the southeastern part of the quadrangle.

Kmr Upper Cretaceous Mowry Shale. The Mowry Shale is a siliceous, hard, dark-gray to gray shale that weathers to a silver-gray, flaky outcrop. The shale is interbedded with numerous bentonite beds, and contains abundant fish scales (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). Limited Mowry outcrops are found in the northeastern and southeastern parts of the map area. The thickness of the Mowry is about 130 feet (40 m) in the southeastern part of the quadrangle (Ritzma, 1949).

Kmt Upper Cretaceous Muddy Sandstone and Thermopolis Shale, undivided. The Muddy Sandstone is about 35 feet (11 m) of gray to light-tan, medium-grained sandstone interbedded with gray carbonaceous shale and sandy shale at the top of the Thermopolis Shale. The Thermopolis Shale is about 35 feet (11 m) of medium- to dark-gray and brown, fissile shale that contains thin lenses of sandstone and bentonite (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). Small outcrops of the Muddy are found in the northeastern and southeastern parts of the quadrangle.

Kcv Lower Cretaceous Cloverly Formation. The Cloverly Formation is made up of 84 to 139 feet (26-42 m) of rusty-gray to brown, fine- to coarse-grained sandstone in the upper part, which is underlain by a middle, variegated purple to black, bentonitic claystone and shale. The base is a white to tan, ridge-forming sandstone that locally grades to a chert pebble conglomerate (Ritzma, 1949; Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). The Cloverly crops out in limited exposures in the northeastern and southeastern parts of the quadrangle.

Unconformity

KJs Lower Cretaceous Cloverly Formation and Upper Jurassic Morrison and Sundance Formations, undivided. These formations are mapped together as one unit along McKinney Creek in the north-central part of the quadrangle.

Jm Upper Jurassic Morrison Formation. The Morrison Formation is represented by calcareous to bentonitic, pale-green to dark blue-green, maroon, and chalky-white, variegated claystones interbedded with thin, drab, nodular limestones, and gray to buff, non-resistant, silty sandstones (Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010; Ritzma, 1949). The thickness of the Morrison varies from 210 to 241 feet (64-73 m) in the southeastern part of the quadrangle (Ritzma, 1949).

Morrison Formation outcrop along Big Sandstone Creek in the southeastern part of the quadrangle. View West.

Js Upper and Middle Jurassic Sundance Formation. The Sundance Formation is made up of creamy-white to greenish-gray, variegated, glauconitic, fine-grained, calcareous sandstone, siltstone, shale, and thin limestones, underlain by red and gray, nonglauconitic sandstone and shale (Ritzma, 1949; Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). The Sundance Formation ranges in thickness from 200 to 240 feet (61-73 m) in the southeastern part of the quadrangle (Ritzma, 1949).

Unconformity

Jn Jurassic and Triassic Nugget Sandstone. The Nugget Sandstone is a dull-red to gray, massive to coarsely crossbedded, fine- to medium-grained sandstone (Love and Christiansen, 1985). The Nugget thins eastward, and is not mapped east of the Baggs quadrangle. It crops out in the central-northeast part of the map area, but is either absent or merges with, or may be mistaken for the Jelm Formation in the Chugwater Group in the southeastern part of the quadrangle (Ritzma, 1949). The thickness of the Nugget is not measured, but is estimated to be less than 100 feet (30 m) where it crops out.

Ҧc Triassic Chugwater Group (or Formation). The Chugwater, variously mapped as a single formation or as a group of formations, is dominated by red to salmon and buff, siltstone and shale interbedded with red, fine-grained sandstones, thin limestones, and thin gypsum partings near the base. The Chugwater is subdivided into the Jelm Formation (or Member) in the upper part, the Alcova Limestone, and Red Peak Formation (or Member) in the lower part. The Jelm is 362 to 398 feet (110-121 m) of red, fine-grained, crossbedded sandstone interbedded with shale and mudstone. Locally, in the southeastern part of the map area, the base of the Jelm is marked by a shale chip and limestone pebble conglomerate. The Alcova is a gray to lavender, resistant, stromatolitic limestone about 15 feet (5 m) thick. The Red Peak is dominated by dark-red, fine-grained sandstone interbedded with mudstone and shale, and has a thickness of 350 to 398 feet (107-121 m) (Ritzma, 1949; Love and Christiansen, 1985; McLaughlin and Fruhwirth, 2010). The Chugwater crops out in the north-central part, and in the southeastern part of the quadrangle where its overall thickness was measured by Ritzma (1949) at 1141 feet (348 m).

Chugwater Formation outcrop along Big Sandstone Creek in the southeastern part of the quadrangle. View east.

Paleozoic

PIPpf Permian Phosphoria Formation and Forelle Limestone, and Pennsylvanian Fountain Formation, undivided. The Phosphoria Formation, equivalent to the Goose Egg Formation east and north of the quadrangle, is made up of alternating beds of purple to orange-red and gray-green shale, thin gray to yellowish limestone, and thin evaporate beds (Love and Christiansen, 1985; Love and others, 1993; McLaughlin and Fruhwirth, 2010). In the southeastern part of the quadrangle, the Phosphoria is dominantly petroliferous, thick-bedded cherty limestone overlain by thinner yellowish, sugary limestones and platy limestone, with a prominent breccia/conglomerate 3 to 17 feet (1-5 m) below the top (Ritzma, 1949). The prominent, thin, purple-gray Forelle Limestone, within the Phosphoria, is not distinguished farther westward, and is one of the most continuous and recognizable limestone beds within the Goose Egg. The Phosphoria and Forelle crop out only in limited areas adjacent to the Sierra Madre in the southeastern part of the quadrangle. The combined thickness of the Phosphoria and Forelle is 56 to 84 feet (17-26 m) (Ritzma, 1949). The Fountain Formation, described with some question as to its correct identity by Ritzma (1949), consists of discontinuous outcrops, up to 126 feet (38 m) thick, of red to brown and gray, highly variable, locally crossbedded, arkosic to quartzitic sandstone and conglomerate. The Fountain underlies the Phosphoria with an angular unconformity, and either grades downward into unweathered Precambrian granitic rocks or is in sharp contact with more resistant underlying Precambrian quartzites.

Unconformity

Precambrian

Terminology and units are based on those used by Sutherland and Hausel (2004) for the Saratoga 30’ x 60’ quadrangle, which lies just east of the Baggs quadrangle. All Precambrian outcrops occur in the eastern part of the map area.

Paleoproterozoic rocks within or south of the Cheyenne Belt

myl mylonitic and cataclastic rocks, undifferentiated. The Cheyenne Belt is an ~1.78 Ga suture zone representing collision of island-arc terranes of the Colorado province with the Archean Wyoming craton (Graff, 1978; Hills and Houston, 1979). The collision responsible for the suture was termed the Medicine Bow orogeny by Chamberlain (1998). This event produced numerous interrelated shear zones, cataclasis and intense zones of granulation and mylonization.

Xgs Sierra Madre Granite, 1744-1763 Ma. Well-foliated to medium-grained to faintly foliated and coarse-grained, pink to red granite and quartz monzonite plutons, dikes, and sills in the Sierra Madre (Houston and Graff, 1995). A facies of the Sierra Madre Granite was dated as 1744 ± 14 Ma, 1749 ± 8 Ma, and 1763 ± 6 Ma, by Premo and Van Schmus (1989) using the uranium/lead zircon method.

Xs mafic intrusive rocks ~1800 Ma. Dark-gray to black mafic, generally sill-like and conformable intrusives up to a mile (1.6 km) long, and varying from a few feet to several hundred feet (~1-100 m) wide. Cross-cutting intrusive relationships occur locally. Complete conversion to amphibolite dominates these rocks, and where interlayered with amphibolitized mafic volcanic rocks, distinction between these intrusives and flows and tuffs is difficult. Therefore, some mafic bodies may be included within one of the Green Mountain Formation subunits in general and within the mafic metavolcanic rocks in particular (Houston and Graff, 1995). Where original textures are preserved or where chemical composition and mineralogy are known, these mafic intrusives are designated as follows:

Xsd diabase

Xsg gabbro and metagabbro

Xsu ultramafic

Xe Elkhorn Mountain Gabbro. Large bodies, dikes, and sills of medium-grained, dark-brown to black clinopyroxene-hornblende gabbro in the southern Sierra Madre. This gabbro also occurs as inclusions in the Sierra Madre Granite (Houston and Graff, 1995).

Xz Encampment River Granodiorite, 1779 ± 5 Ma. Foliated, dark-gray intrusive rock varying in composition from granodiorite to quartz diorite to diorite, and characterized by inclusions of volcanic rocks of the Green Mountain Formation (Houston and Graff, 1995). Premo and Van Schmus (1989) determined a 1779 ± 5 Ma uranium/lead zircon age for the intrusion.

Green Mountain Formation.

Xrv Mafic metavolcanic rocks of the Green Mountain Formation. A sequence of mafic metavolcanic rocks of upper greenschist to lower amphibolite facies, with locally well-preserved primary texture in the central Sierra Madre. Intermediate to felsic composition metavolcanic rocks and metagraywacke are interbedded with, and grade laterally eastward into, dominantly calc-alkaline metabasaltic rocks east of the quadrangle in the Green Mountain and Fletcher Park areas (Houston and Graff, 1995).

Xrf Felsic metavolcanic rocks of the Green Mountain Formation, 1792 ± 15 Ma. Felsic metavolcanic rocks that are predominately fine-grained, white to gray to black metarhyolite and metadacite (Houston and Graff, 1995). A uranium/lead zircon age of 1792 ± 15 Ma was reported by Premo and Van Schmus (1989) on zircon separated from metadacite porphyry from this unit on the east side of Green Mountain.

Xrm Metagraywacke of the Green Mountain Formation. Dark-gray biotite-chlorite-quartz-feldspar schist in the northern Sierra Madre (Houston and Graff, 1995).

Xrx Mixed metavolcanic and metasedimentary rocks of the Green Mountain Formation. A succession of interbedded felsic and mafic metavolcanic and metasedimentary rocks in the Sierra Madre (Houston and Graff, 1995).

Xrc Chemical metasedimentary rocks of the Green Mountain Formation. Fine-grained metaquartzite (chert?), metalimestone, oxide-facies magnetite-rich iron formation, and massive and disseminated sulfide deposits that are interlayered with, or disseminated in, volcanogenic metasedimentary rocks, and some sedimentary exhalative sulfide deposits (Houston and Graff, 1995).

Paleoproterozoic and Neoarchean rocks north of the Cheyenne Belt

Xn mafic intrusive rocks ~1700-2300 Ma. Dark-gray to black to purple mafic dikes and sills metamorphosed to varying degrees, but with many preserved gabbroic and diabasic textures; these are mostly altered to amphibolite (Matus, 1958; Houston and Graff, 1995). Age range cited is from Houston and others (1992), although Houston and Graff (1995) suggest a probable range of ages from 1990 to 2092 Ma in the Sierra Madre. The Houston and Graff (1995) range is based on a uranium/lead zircon age of 2090 ± 9 Ma by Premo and Van Schmus (1989) of a pegmatitic phase of a metagabbro that intrudes the Cascade Quartzite, and a Sm/Nd whole rock date of 1990 ± 30 Ma by Shaw and others (1986) of an ultramafic sill intruded into Vulcan Mountain Metavolcanics west of Spring Lake. More detailed rock identifiers and descriptions where available are as follows:

Xnd diabasic rocks.
Xnu ultramafic rocks.

Paleoproterozoic Snowy Pass Group. This group of formations, as described by Houston and Graff (1995) includes: Slaughterhouse Formation, Copperton Formation, Bottle Creek Formation, Cascade Quartzite, Singer Peak Formation, and Magnolia Formation.

Xsh Slaughterhouse Formation. This is a severely deformed and only partially preserved remnant of an estimated 4000+ feet (1219 m+) succession consisting of fine-grained, interbedded, red, yellow, and green metalimestone containing layers of buff metadolomite, quartzite, and dark-green phyllite. Fine-grained, chlorite-calcarious schist is underlain by dark-gray graphitic phyllite, which is underlain by metalimestone (Houston and Graff, 1995).

Xcp Copperton Formation. The Copperton Formation, which has been structurally thinned by thrust faults, is made up of three units: an upper 500 feet (152 m) of white massive quartzite; a middle laminated phyllite exhibiting an upper section of alternating beds of coarser-grained schist and crossbedded quartzite, underlain by 1000 feet (305 m) of gray, thin alternating quartz and fine-grained mica-rich laminae; and a basal, coarse-grained, highly sheared, kyanite-bearing, white quartzite as much as 2000 feet (610 m) thick (Houston and Graff, 1995).

Xb Bottle Creek Formation. The 1300 feet (396 m) thick Bottle Creek Formation is best expressed in the western Sierra Madre where an upper slabby and buff quartzite containing interbeds of phyllite is successively underlain by units of diamictite and quartzite. The diamictite units are paraconglomerate within a matrix of tan or green phyllite interbedded with pale-green schistose and feldspathic, medium- to coarse-grained quartzite (Houston and Graff, 1995).

Xcq Cascade Quartzite >2092 ± 9 Ma. The 5000+ feet (1524+ m) thick Cascade Quartzite is a locally crossbedded, predominately white, arkosic quartzite containing layers of quartz-pebble conglomerate and black chert-pebble conglomerate (Houston and Graff, 1995). Premo and Van Schmus (1989) constrained the age of the Cascade Quartzite with their 2092 ± 9 Ma U-Pb zircon date from a gabbroic intrusion cutting the Cascade Quartzite.

Xsi Singer Peak Formation. A discontinuous upper part of this unit consisting of poorly sorted paraconglomerate with angular granite clasts, green phyllite beds, and thin quartzite is restricted to the western part of the Sierra Madre. The lower part, about 2800 feet (853 m) thick to the west, and thinning out east of Silver Lake, consists of blue and green phyllite, buff to orange quartzite, and thick silvery phyllite that hosts red garnet at the base (Houston and Graff, 1995).

Phyllite in the Singer Peak Formation. View northeast.

Xmg Magnolia Formation, 2451 ± 9 Ma. The Magnolia Formation is primarily coarse-grained white to gray quartzite marked by small-scale trough-crossbeds and thin layers of phyllite, with lenticular beds of radioactive quartz-pebble conglomerate near the base (Houston and Graff, 1995). The Magnolia Formation tapers from a thickness of 1500 feet (457 m) south of Dexter Peak to almost nothing south of Encampment. Zircons dated by Premo and Van Schmus (1989) give a depositional age of 2451 ± 9 Ma.

Neoarchean rocks north of the Cheyenne Belt

Late Archean (Neoarchean) Phantom Lake Metamorphic Suite. All three subunits of the Phantom Lake metamorphic suite in the Sierra Madre have been subjected to multiphase deformation that has obscured stratigraphic relationships. Its separation into three units has allowed for easy correlation between the Sierra Madre and Medicine Bow Mountains. However, petrological, geochemical, and isotopic evidence presented by Souders and Frost (2006) indicates that the Jack Creek Quartzite and Bridger Peak Quartzite may actually be the same geologic unit, and that the Phantom Lake metamorphic suite was deposited in an intra-ocean arc basin between 2.71 and 2.68 Ga.

Wbp Bridger Peak Quartzite. The Bridger Peak Quartzite is 2600 feet (790 m) of gray to white quartzite varying from quartz arenite to argillaceous and arkosic quartzite with well-developed lenticular beds of quartz-pebble conglomerate at the base in the Vulcan Mountain area, and common interlayered sericite schist in the upper part toward its eastern outcrops (Houston and Graff, 1995).

Wsm Silver Lake Metavolcanics 2,680 ± 18 Ma. The most abundant rocks in this complex metavolcanic sequence include gray quartz-plagioclase-mica schist, fine-grained amphibolite, dark amphibole gneiss, pelitic schist, white feldspathic quartzite, calcareous quartzite, and paraconglomerate. Some fragmental textures can be observed, graded bedding is preserved locally, and abrupt facies changes are common. A lack of marker horizons, poor preservation, and ambiguous top and bottom criteria lead to stratigraphic confusion within the Silver Lake metavolcanics (Souders and Frost, 2006). Granite-boulder paraconglomerate interbedded with feldspathic quartzite and pelitic schist throughout the unit is noteworthy. Thickness varies dramatically from 3300 feet (1000 m) in the central Sierra Madre to 1000 feet (305 m) in the eastern Sierra Madre (Houston and Graff, 1995). U-Pb zircon geochronology by Souders and Frost (2006) from a porphyritic metadacite in the Silver Lake metavolcanic suite give an estimated crystallization age of 2,680 ± 18 Ma. Personal communication (2009) with K. Chamberlain suggested that zircon grain morphology may indicate a sedimentary origin rather than volcanic for the dated material.

Wjc Jack Creek Quartzite. The Jack Creek Quartzite is dominated by white quartzite and contains lenses of paraconglomerate, quartz-pebble conglomerate, gray and green phyllite, metagraywacke, and marble. This unit is 1650 feet (503 m) thick in the northwestern Sierra Madre, including the Deep Gulch Conglomerate Member at the base, which consists of 328 feet (100 m) of well-developed pyritic and radioactive quartz-pebble conglomerate. The unit is finer grained in the north-central Sierra Madre where conglomerate layers are missing, and thins to a 'feather edge' about five miles (8 km) west of Encampment (Houston and Graff, 1995). Souders (2004) states that the Jack Creek Quartzite and the Bridger Peak Quartzite are indistinguishable in the field, and suggests that they may actually be the same geologic unit as opposed to the interfingering, time-transgressive sequence as described by Graff (1978).

Wog Red-pink orthogneiss, 2683 ± 6 Ma. This unit consists of well-foliated to massive, red to pink granitic to tonalitic orthogneiss in the northern and east-central Sierra Madre. More massive phases of this unit intrude the Spring Lake Granodiorite (Houston and Graff, 1995). Radiometric date is after Premo and Van Schmus (1989).

Sample SM7 was collected by R.S. Houston and Kevin Chamberlain from the type locality for the red-pink orthogneiss near Methodist Creek. It is a medium-grained, equigranular granite dominated by potassium feldspar and quartz with minor to no mafic minerals. The sample is generally massive with some coarser pegmatitic zones, is weakly foliated, and has been interpreted as one of the youngest granitic phases in the region (K. Chamberlain, personal communication, 2011). Location: 41.335556N, -107.043056W.

Sample SM7. Red-pink orthogneiss; Penny at top for scale.

New data by K. Chamberlain (personal communication 2011) displays a distinct example of nearly complete thermal resetting of apatite at ca. 2.1 Ga, though the original magmatic age is partially preserved. The timing of apatite resetting suggests the influence of local thermal deformation, possibly rift-related, prior to the suture event along the Cheyenne belt.
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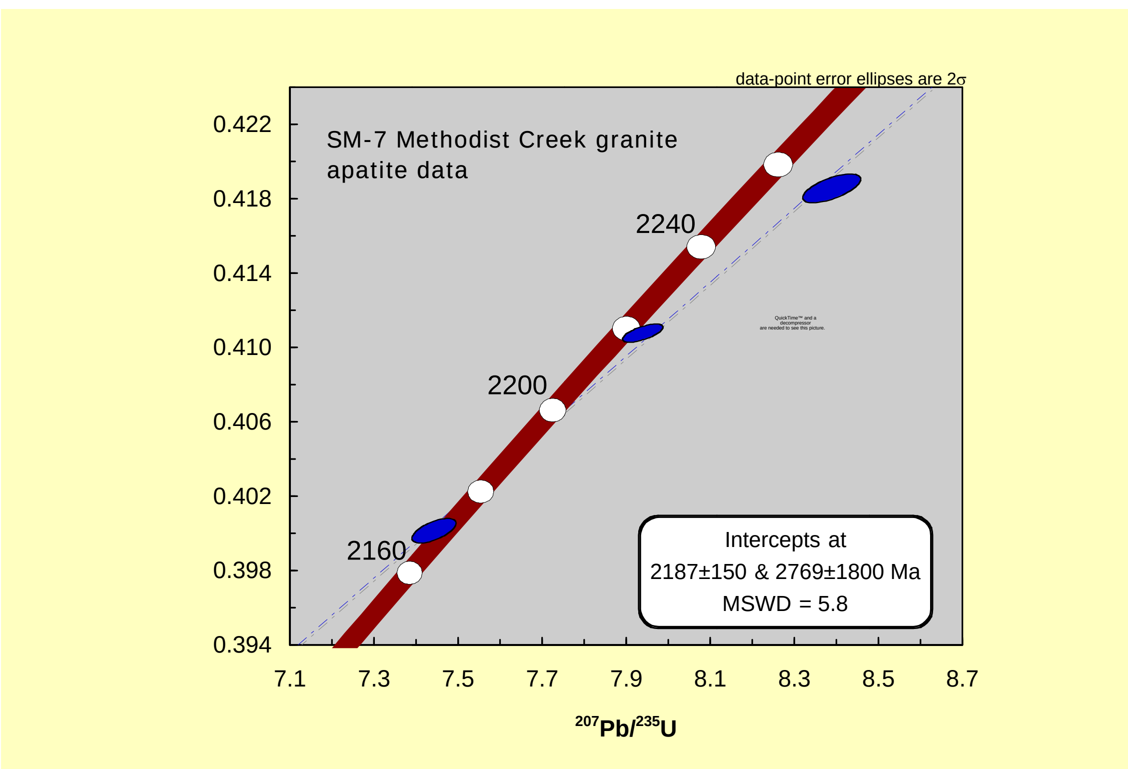

Concordia plot of U-Pb apatite data from SM-7 (K. Chamberlain, personal communication 2011). Uncertainty on U-decay constants is depicted by the width of the red swath for Concordia.

K. Chamberlain (personal communication, 2011) interprets the U-Pb data to define a mixing line from ca. 2.7 Ga to 2.19 Ga and to represent nearly complete resetting at ca. 2.0 to 2.2 Ga of magmatic apatite, which originally crystallized ca. 2.68 Ga (Premo and Van Schmus, 1989). Apatite U-Pb dates reset thermally at about 450 °C (Chamberlain and Bowring, 2000, and references therein). The timing of thermal resetting of the apatite corresponds to the timing of widespread emplacement of mafic dikes and sills in the Sierra Madre (Premo and Van Schmus, 1989; Duebendorfer and others, 2006) related to rifting of the Archean margin of the Wyoming craton. During subsequent Paleoproterozoic (1.78 Ga) accretion along the Cheyenne belt, 20 km to the south, this portion of the foreland remained cooler than 450 °C at this level of exposure. When coupled with previously determined cooling dates (Harper, 1997; Duebendorfer and others, 2006), this new cooling date suggests that the pattern of tectonic burial related to the Medicine Bow orogeny and the thermal histories of the foreland in the Sierra Madre are strongly controlled by faults with only minimal overthrusting and unroofing. In contrast, the foreland history in the Laramie Mountains, 150 km along strike to the east, records tectonic burial of at least 10 km depth and block uplift and unroofing in a 60 km-wide swath north of the Cheyenne belt during the Medicine Bow Orogeny (Chamberlain and others, 1993; Patel and others, 1999; Chamberlain, 1998; Chamberlain and Bowring, 2000).

Geochronological zircon studies of the red-pink orthogneiss are pending.

Wsl Spring Lake Granodiorite, 2710 ± 10 Ma. This well-foliated gray granodiorite was dated using U-Pb zircon techniques by Premo and Van Schmus (1989). It crops out extensively in the northern Sierra Madre (Houston and Graff, 1995), and intrudes both the Vulcan Mountain metavolcanics and the lower part of the Phantom Lake Metamorphic Suite (Houston and others, 1992).

Wvm Vulcan Mountain Metavolcanics, Sierra Madre. The Vulcan Mountain Metavolcanics are an estimated 1148 feet (350 m) of highly deformed mafic metavolcanic succession in the Sierra Madre that is primarily made up of fine-grained amphibolite and hornblende-plagioclase gneiss with isolated interlayers of chlorite schist, quartzite, paraconglomerate, and marble. Pillow structures and amygdules are locally preserved in the amphibolite, which also hosts conformable interlayered intrusions of ultramafic and gabbroic composition. Although the contact is obscured, the Vulcan Mountain metavolcanics are interpreted to lie unconformably on top of the basement quartzofeldspathic gneiss and correlate with the Overland Creek Gneiss in the Medicine Bow Mountains (Houston and others, 1992; Houston and Graff, 1995).

Wgg Quartzo-feldspathic gneiss. This unit is a well foliated to massive and faintly foliated, pink to gray felsic gneiss primarily composed of plagioclase, potash feldspar, and quartz. In the Sierra Madre, the felsic gneiss includes interlayered pink granite gneiss, gray biotite-quartz-feldspar gneiss, tan garnet-quartz-feldspar gneiss, white quartz-microcline gneiss, and local layers of kyanite gneiss, hornblende gneiss, and amphibolite (Houston and Graff, 1995). Based on the intrusion of this unit by 2.71 Ga granodiorite and granite, dated by Premo (1982), Houston and Graff (1995) assign an early Archean age for the gneiss.

Souders and Frost (2006) state that is unlikely that this basement gneiss could predate the 2.71 Ga Spring Lake granodiorite by >100 million years based on Nd isotopic studies. The possibility exists for unmapped units of diverse ages to be included within the designation of the quartzo-feldspathic gneiss.

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