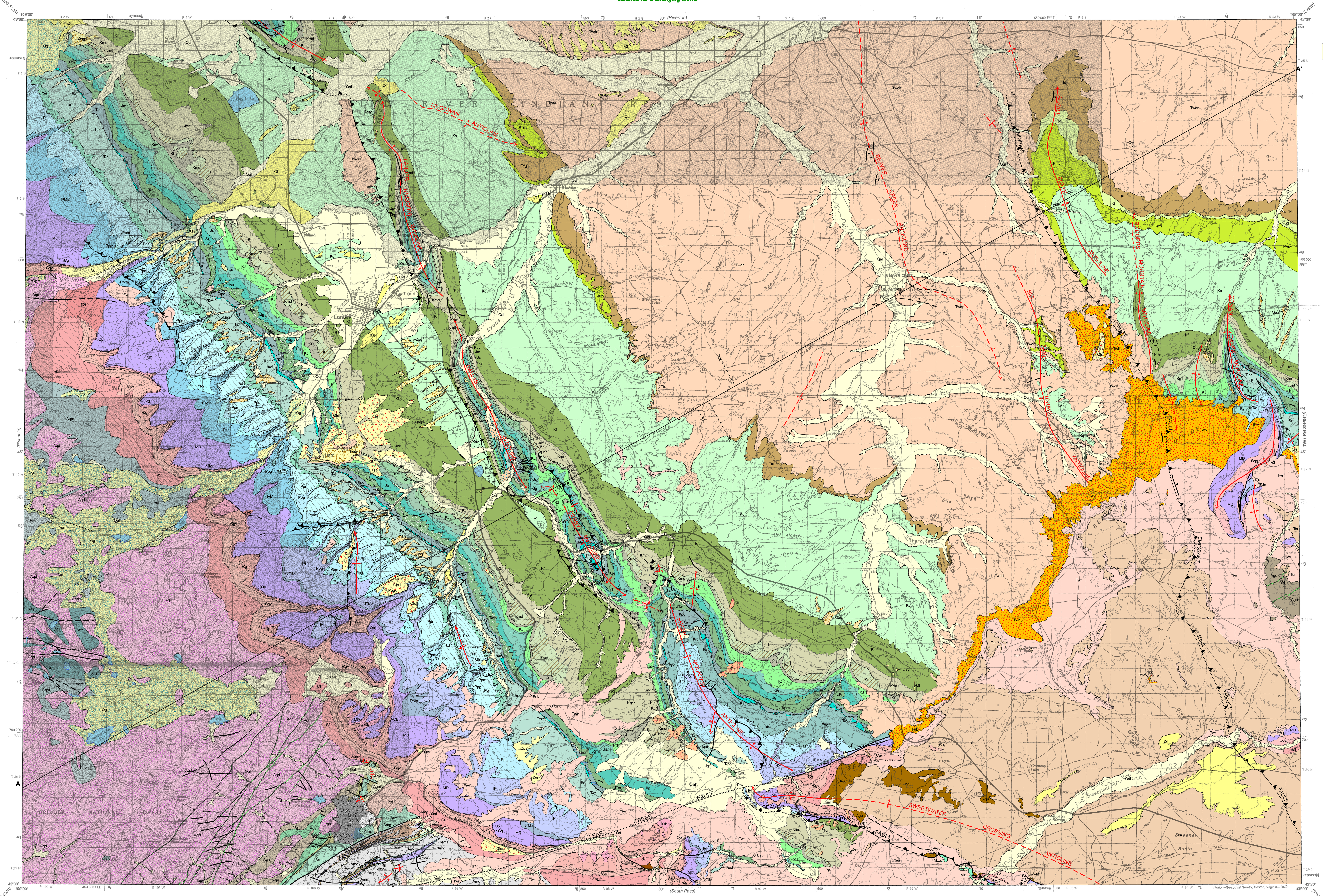
WYOMING STATE GEOLOGICAL SURVEY
Ronald C. Surdam, State Geologist
Laramie, Wyoming

Geology - Interpreting the past to provide for the future

Prepared in cooperation with the U.S. GEOLOGICAL SURVEY

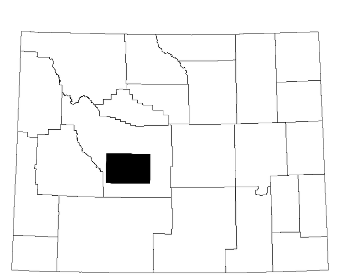
MAP SERIES 87
Lander 1:100,000 - scale
Bedrock Geologic Map
Version 1.0 July 2009



Base map from U.S. Geological Survey 1:100,000-scale metric topographic map of the Lander, Wyoming Quadrangle, 1978.
Projection: Universal Transverse Mercator (UTM), zone 12
North American Datum of 1927 (NAD 27)
10,000-meter grid: UTM, zone 12
50,000-foot grid ticks: Wyoming State Plane Coordinate System, east zone.

1°42' 30 MILS; 15 267 MILS

UTM GRID AND 1978 MAGNETIC NORTH DECLINATION AT CENTER OF MAP



WYOMING QUADRANGLE LOCATION

SCALE 1:100,000
Contour Interval 20 meters

GEOLOGIC MAP OF THE LANDER 30' X 60' QUADRANGLE, FREMONT COUNTY, WYOMING

by

Joseph F. Johnson and Wayne M. Sutherland

2009

Digital cartography by Thomas E. Ver Ploeg

Editing and map design by Richard W. Jones

Prepared in cooperation with and research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS cooperative agreements 07HQAG0144 and 08HQAG0083. The views and conclusions contained in this report 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.

People with disabilities who require an alternative form of communication in order to use this publication should contact the Editor, Wyoming State Geological Survey. TTY Relay Operator 1 (800) 877-9975.

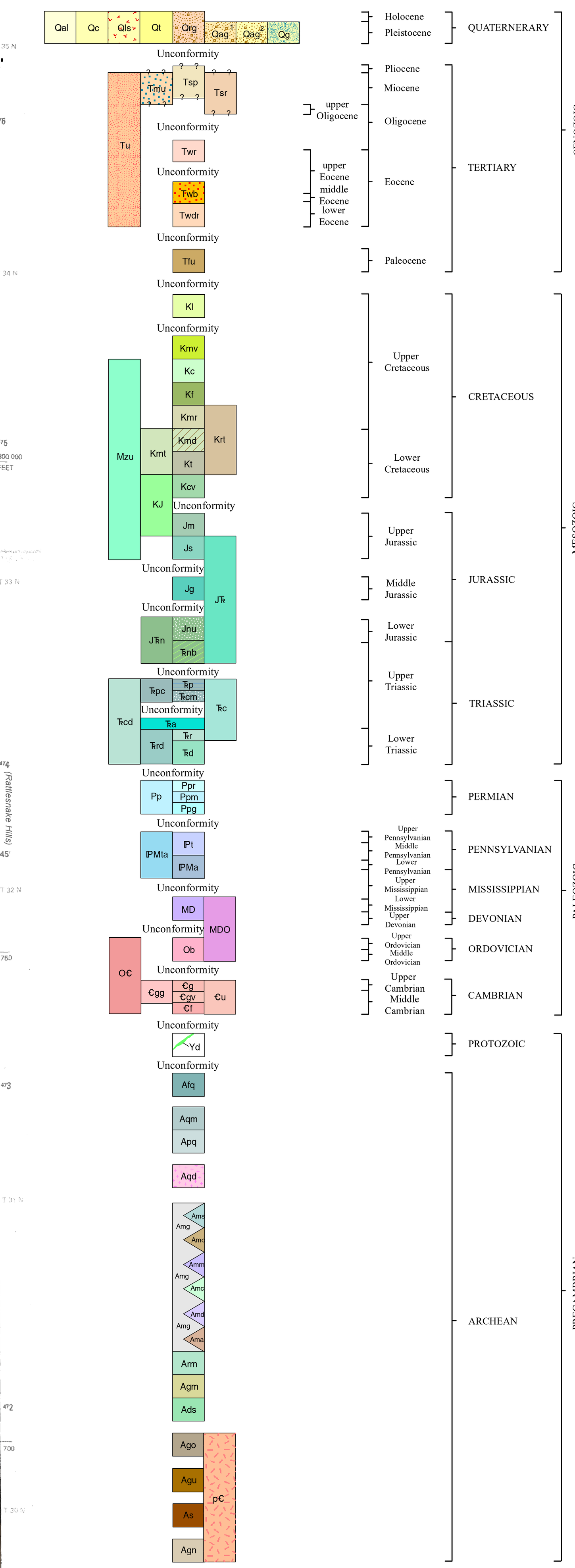
Additional copies of this map can be obtained from:
Wyoming State Geological Survey
P.O. Box 1347 Laramie, WY 82073-1347
Phone: (307) 766-2286 Fax: (307) 766 - 2605
Email: sales@wsgs.uwyo.edu

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

EXPLANATION

(See separate pamphlet for detailed descriptions)

CORRELATION OF MAP UNITS



MAP SYMBOLS

Formation contact

Fault—Dashed where approximately located, dotted where projected or inferred beneath younger units. Ball and bar on downthrown side; arrows indicate apparent horizontal displacement on strike-slip faults; no indication on fault trace indicates undetermined motion

Thrust fault—Dashed where approximately located, dotted where projected or inferred beneath younger units; sawteeth on upthrown block

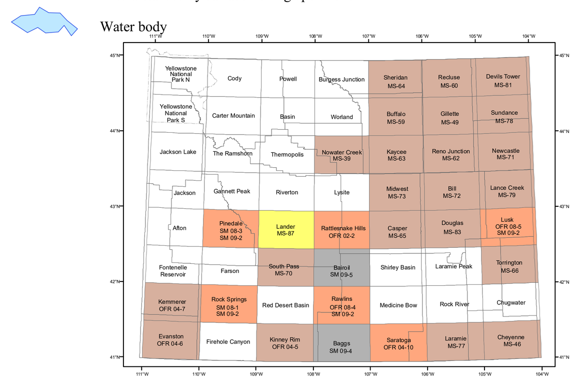
Anticline—Approximately located; dashed where axis is inferred; trace of axial plane and direction of plunge (shown by arrow on end) compiled from source mapping, determined by field dip measurements, or determined by photo interpretation

A——A' **Line of cross section**

Drill hole—Dashed line indicates projected to cross section

Area disturbed by surface mining operations

Water body



KEY TO ABBREVIATIONS

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

DESCRIPTION OF MAP UNITS

Quaternary surficial deposits

Qal **Alluvial deposits (Holocene and Pleistocene)**—Unconsolidated and poorly consolidated clay, silt, sand, and gravel; includes deposits underlying current flood plains and bordering alluvial terraces

Qc **Colluvium (Holocene and Pleistocene)**—Unconsolidated detritus derived from steep slopes or cliffs; includes slope wash, talus, and scree

Qls **Landslide debris (Holocene and Pleistocene)**—Locally derived landslide debris from unstable, generally steep slopes

Qt **Terrace deposits (Holocene and Pleistocene)**—Unconsolidated and poorly consolidated gravel, sand, and silt

Qrg **Residual gravel (Holocene and Pleistocene)**—Gravels known to be derived from Wind River Formation (Thompson, 1950); occurs near downdropped block of Wind River on north end of Lander anticline

Qag1 **Alluvial gravel (Pleistocene)**—High level alluvium on pediment surfaces; commonly contains abundant angular pebbles and cobbles of Paleozoic rock; lower few feet locally cemented by calcium carbonate; thickness from 0 to 20 feet (0 to 6 m) (description and thickness from Rohrer, 1973)

Qag2 **Alluvial gravel (Pleistocene)**—Locally derived fragments of sedimentary, igneous and metamorphic rocks; contains significant amounts of soil and alluvial material; coarsens toward Wind River Range (modified from Thompson, 1950)

Qg **Glacial debris (Pleistocene)**—Unconsolidated silt, sand, gravel, cobbles, and boulders derived from Precambrian and some Paleozoic rocks; occurs as lateral and terminal moraines and outwash below moraines in glacial valleys; thickness 0 to 200+ feet (0 to 61+ m) (from Rohrer, 1973)

Tertiary sedimentary rocks

Tu **Tertiary rocks undifferentiated**—Includes Miocene, Oligocene, and Eocene sedimentary deposits in south-central part of quadrangle (from Abercrombie, 1989)

Tsp **South Pass Formation (Pliocene/Miocene)**—Calcareous conglomerate, white volcanic ash, and light-gray to white tuffaceous sandstone; 0 to 350 feet (110 m) thick in the adjacent South Pass 1:100,000-scale quadrangle (Sutherland and Hausel, 2003)

Tsr **Split Rock Formation (Miocene) [or Miocene/late Oligocene (?)]**—Yellowish-gray to pale-orange conglomerate and well sorted volcanic sandstone, few beds of vitric tuff; resistant and cliff-forming; thickness approximately 150 feet (46 m)

Tmu **Miocene (?) rocks undifferentiated**—Conglomerate on terraces associated with the Little Popo Agie River; age uncertain

Twr **White River Formation (Oligocene and upper Eocene)**—Lithologically variable, gray to orangish/yellowish-gray, bentonitic and tuffaceous mudstone, arkose and conglomerate; Thickness from 0 to 650 feet (0 to 200 m)

Twb **Wagon Bed Formation (upper and middle Eocene)**—Greenish-yellow to yellowish-gray sandstone, siltstone, and mudstone containing volcanic debris and bentonite; thickness from 130 to 700 feet (40 to 210 m)

Twdr **Wind River Formation (lower Eocene)**—Yellowish-gray to variegated mudstone, sandstone, and conglomerate in lenticular beds; sandstones are commonly poorly sorted and feldspathic to arkosic; thickness from 0 to greater than 2,400 feet (0 to 730 m)

Tfu **Fort Union Formation (Paleocene)**— Basal conglomerate overlain by a series of interbedded, white, gray, tan, buff and brown sandstones, lenticular conglomerates, carbonaceous shales, siltstones and coal; thickness from 0 to greater than 1,000 feet (0 to 300 m)

Mesozoic sedimentary rocks

Kl **Lance Formation (Upper Cretaceous)**—Interbedded white, gray, and buff, fine- to coarse-grained, in part conglomeratic, lenticular sandstones; gray to black shale and claystone; brown to black carbonaceous shale; and coal; thickness 0 to 900 feet (0 to 270 m)

Kmv **Mesaverde Formation (Upper Cretaceous)**—Massive white basal sandstone overlain by variable, lenticular, interbedded white to yellowish-gray and brown sandstones, gray carbonaceous shales, and coal beds; forms conspicuous light-colored escarpments; thickness from 50 to 300 feet (15 to 91 m) in outcrops, up to 1,500 feet (460 m) in the subsurface. An upper tongue of Cody Shale is mapped with the Mesaverde on Alkali Butte Anticline but is shown separately in subsurface on east flank of that anticline

Mzu **Upper Mesozoic rocks, undifferentiated—**Sedimentary units exposed south of Sweetwater Crossing Anticline. Includes units from Jurassic Sundance to Cretaceous Cody Shale mapped by Bell (1955)

Kc **Cody Shale (Upper Cretaceous)**—Gray, interbedded sandstone and shale; variably grades from lower silty and sandy shales to siltstone and shaly sandstones above; generally slope-forming, although upper sandstones may form cliffs; thickness from 4,000 to 5,000 feet (1,200 to 1,500 m)

Kf **Frontier Formation (Upper Cretaceous)**—Gray, tan, and brown, fine- to medium-grained, thin-bedded to massive, sometimes cross-bedded and lenticular sandstones interbedded with gray to black, fissile, silty and sandy shales; forms hogbacks and narrow strike valleys; thickness from 600 to 1,000 feet (180 to 300 m)

Krt **Mowry Shale, Muddy Sandstone, and Thermopolis Shale undivided (Upper and Lower Cretaceous)—**On cross section only

Kmr **Mowry Shale (Upper Cretaceous)**—Black to dark-gray, hard siliceous shale, containing thin, gray to brown sandstone beds; weathers to distinctive bare, silver-gray ridges with bands of vegetation along interspersed bentonite beds; thickness from 430 to 580 feet (130 to 180 m)

Kmd **Muddy Sandstone and Thermopolis Shale undivided (Lower Cretaceous)**

Kmt **Muddy Sandstone**—Prominent gray, fine- to coarse-grained, cliff-forming sandstone, containing sporadically distributed chert pebbles, dark minerals, and chalky grains, overlain by softer sandstones and dark-gray to black shales; thickness from 10 to 150 feet (3 to 46 m). In areas where unit is very thin, the outcrop is shown as a line

Kt **Thermopolis Shale**—Soft, black, fissile shale; thin bentonite layers often found in upper and lower part with few non-persistent, thin, silty sandstones sometimes found in middle of unit; thickness from 95 to 135 feet (29 to 41.1 m)

KJ **Cloverly and Morrison formations undivided (Lower Cretaceous and Upper Jurassic)**—Total thickness for both units is approximately 350 feet (110 m)

Kcv **Cloverly Formation (Lower Cretaceous)**—Basal unit is a distinctive pebble conglomerate overlain by buff to gray to brown, fine-grained, cross-bedded, slabby sandstone with interbedded variegated shales and siltstones; weathers to a distinctive rusty-tan or brown; thickness from 100 to 150 feet (30 to 46 m)

Jm **Morrison Formation (Upper Jurassic)**—Poorly sorted, silty sandstone containing interbeds or channels of coarse-grained cross-bedded sandstone overlain by finer-grained red, maroon, green, and brown claystone, mudstone, and siltstone, with interspersed lenses of coarser channel sandstones; thickness of about 200 feet (60 m)

JTR **Sundance and Gypsum Spring formations and Nugget Sandstone undivided (Jurassic and Triassic)**—On cross section only

Js **Sundance Formation (Upper Jurassic)**—Sequence of greenish-gray, brown, and buff, glauconitic and non-glauconitic sandstones, limestones, and shales; belemnite fossils are common; thickness from 210 to 265 feet (64 to 80.8 m)

Jg **Gypsum Spring Formation (Middle Jurassic)**—White, thick-bedded to massive, ledge-forming gypsum with red siltstone interbeds. Upper part consists of an alternating sequence of thin-bedded gypsum, reddish-brown shale, and light-gray to gray limestones; thickness from 120 to 200 feet (37 to 60 m)

JTRn **Nugget Sandstone [Lower Jurassic and Upper Triassic(?)]**—Includes both upper part and lower Bell Springs Member combined

Jnu **Upper part (Lower Jurassic)**—Red, hematite-stained siltstone and slabby sandstone, overlain by salmon-pink and light-gray fine- to medium-grained, cliff-forming sandstone, exhibits massive bedding to large scale cross-beds; thickness from 0 to 285 feet (0 to 86.9 m)

TRnb **Bell Spring Member [Upper Triassic (?)]**—Orange-brown and gray, fine-grained, thin to thick-bedded sandstone interbedded with reddish-brown, pale-green and purplish-maroon siltstone and shale; thickness of approximately 80 feet (20 m)

TRcd **Chugwater Group and Dinwoody Formation undivided**

TRc **Chugwater Group undivided (Upper and Lower Triassic)**—Includes (from top to base) the Popo Agie Formation, Crow Mountain Sandstone, Alcova Limestone, and Red Peak Formation

TRpc **Popo Agie Formation and Crow Mountain Sandstone undivided (Triassic)**

TRp **Popo Agie Formation—**Purple and red shale, red siltstone and red silty sandstone; distinctive layers of bright ocher-colored and red dolomitic claystones bearing analcime are common in upper sections; thickness of approximately 100 feet (30.5 m)

TRcm **Crow Mountain Sandstone—**Reddish-brown, very fine to fine-grained limey argillaceous, thin to thick-bedded and massive sandstone, interbedded with reddish-brown fissile shale and sandy siltstone; thickness of approximately 189 feet (57.6 m)

TRa **Alcova Limestone (Lower Triassic)**—Pinkish to grayish-white, finely crystalline, thinly laminated resistant limestone; thickness from 3.5 to 10 feet (1.1 to 3 m). In areas where unit is very thin, the outcrop is shown as a line

TRr **Red Peak Formation (Lower Triassic)—**Reddish-brown, commonly calcareous, thin- to thick-bedded siltstone, sandstone, and shale; thickness from 800 to 1,000 feet (200 to 300 m)

TRd **Dinwoody Formation (Lower Triassic)**—Gray to drab greenish gray, thin-bedded, ripple-marked, sandy siltstone and silty sandstone, in part dolomitic to limy; readily weathers to a yellowish-gray or yellowish-brown; thickness from 40 to 60 feet (10 to 20 m)

TRrd **Red Peak and Dinwoody Formations undivided**

Paleozoic sedimentary rocks

Pp **Phosphoria and Park City formations undivided (Permian)**

Ppr **Ervay Member of the Park City Formation and Tosi Chert and Retort Phosphatic Shale members of the Phosphoria Formation (Permian)**—Brownish-gray to black oolitic to pelletal phosphorite, phosphatic dolomite, and brownish gray dolomitic shale overlain by gray to greenish-gray nodular massive chert and light gray weathering resistant dolomite with scattered chert lenses; thickness approximately 100 feet (30 m)

Ppm **Franson Member of the Park City Formation and Meade Peak Phosphatic Shale Member of the Phosphoria Formation (Permian)**—Light-gray to grayish-black interbedded series of granular phosphorite, dolomite, limestone, sandstone, shale, claystone, and nodular chert; often fossiliferous, phosphatic to limy to dolomitic, resistant to slope-forming; thickness approximately 156 feet (47.5 m)

Ppg **Grandeur Member of the Park City Formation (Permian)**—Sandy, argillaceous, fossiliferous, dolomitic limestone and limy dolomite, weathers light-gray to brownish-gray, interbedded with sandstone, minor shale, and claystone; carbonate rocks generally contain small irregular lenses or nodules of chert; 30 to 50 feet thick (9 to 20 m)

PMta **Tensleep Sandstone and Amsden Formation undivided (Middle and Lower Pennsylvanian and Upper Mississippian)**

Pt **Tensleep Sandstone (Upper and Middle Pennsylvanian)**—Gray to buff to brown, fine- to medium-grained, calcareous, cliff-forming sandstone, exhibits massive bedding to large-scale cross-beds; thin beds of quartzite and chert are common; thickness 300 to 400 feet (90 to 100 m)

PMa **Amsden Formation—[Middle and Lower Pennsylvanian and Upper Mississippian (?)]**—Red, gray, and white, fine- to medium-grained, cross-bedded to massive, cliff-forming sandstone overlain by red and green shales and white, light-gray, red, and purple cherty and sandy dolomites; thickness is highly variable from 100 to 400 feet (30 to 100 m)

MDO **Madison Limestone, Darby Formation, and Bighorn Dolomite undivided (Mississippian, Devonian, and Ordovician)—**On cross section only

MD **Madison Limestone and Darby Formation undivided**

Madison Limestone (Lower and Upper Mississippian)—Bluish-gray, massive to thin-bedded, crystalline limestone and dolomitic limestone with abundant cherty layers and nodules, red staining on many outcrops; thickness from 235 to 600 feet (71.6 to 200 m)

Darby Formation (Upper Devonian)—Tan crystalline dolomite, imbedded with large fragments of white, medium- to course-grained quartzitic sandstone; occurs along the eastern flank of the Wind River Range, thins and pinches out to the south and east; thickness from 0 to 20 feet (0 to 6 m)

O€ **Ordovician and Cambrian rocks undifferentiated**

Ob **Bighorn Dolomite (Ordovician)**—Composed of buff to gray, hard, cliff-forming, uniform granular dolomite; typically weathers to a pitted or "fretwork" pattern; thickness from 0 to approximately 200 feet (0 to 60 m)

€u **Cambrian rocks undifferentiated (Upper and Middle Cambrian)**—Includes the Gallatin and Gros Ventre formations and the Flathead Sandstone

€gg **Gallatin and Gros Ventre Formations undivided**

€g **Gallatin Formation (Upper Cambrian)**—Gray, resistant, cliff-forming, thinly bedded to massive, glauconitic and oolitic limestone with flat-pebble limestone conglomerates and soft, greenish-gray shale; upper part is often mottled in appearance; outcrops may be red stained; thickness from 209 to 365 feet (63.7 to 111 m)

€gv **Gros Ventre Formation (Middle and Upper Cambrian)**—Lithologically variable green, sometimes red, sandy or silty glauconitic shales with some sandstone and significant limestone; flat-pebble limestone conglomerates are common; forms slopes with little exposures; thickness from 300 to 700 feet (90 to 200 m).

€f **Flathead Sandstone (Middle Cambrian)**—Brownish to reddish-maroon, coarse- to medium-grained, cross-stratified sandstone; contains minor amounts of arkose and shale; upper section composed of reddish-gray to reddish-brown, fine- to coarse-grained, hard, ledge-forming orthoquartzite; thickness from 200 to 350 feet (60 to 110 m)

Precambrian rocks

Proterozoic rocks

Yd **Diabase dike**—Dark-gray to black, fine- to medium-grained mafic dikes; laterally continuous and generally strike in a northeasterly direction. Dikes in the southwest corner of the map area have been dated at ~2,060 Ma (mega-annum or millions of years before present); thickness from 10 to 200 feet (3 to 60 m) (description and thickness from Hausel, 1991)

Archean rocks

Afq **Fine-grained quartz monzonite (Archean?)**—Gray, fine-grained, equigranular quartz monzonite, consists principally of biotite, quartz, microcline, and oligoclase

Aqm **Biotite quartz monzonite of the Bears Ear Pluton**—Irregular bodies of leucocratic rock; texturally heterogeneous, ranging from pegmatite to alaskite to fine- and medium-grained biotite quartz monzonite; forms anastamosing dikes and veins; dated at 2,545±30 Ma (Stuckless and others, 1985)

Apq **Porphyritic quartz monzonite of the Bears Ear Pluton**—Consists principally of phenocrysts of microcline set in a ground mass of oligoclase, quartz, biotite, and locally, hornblende; dated at 2,545±30 Ma (Stuckless and others, 1985).

Aqd **Quartz diorite of the Louis Lake Batholith**—Gray, even-grained, weakly porphyritic biotite-hornblende quartz diorite; locally includes granodiorite; may contains small, widely-spaced disk-shaped clots of amphibolite; dated at 2,630± Ma (Frost and others, 1998)

Miners Delight Formation—Group of diversified lithologies dominated by metagreywacke; hosts many epigenic shear zones and vein gold deposits; approximate age of 2.8 Ga (giga-annum or billions of years before present), but relative ages of the subunits are unknown [Note: the Correlation of map units (above) is not intended to show age relationships]. Total thickness not determinable but greater than 5,000 feet (2,000 m) and possibly up to 20,000 feet (6,000 m) (Hausel, 1991). Sub-divided into several mappable units based on dominant lithology (ies)

Amg **Metagreywacke**—Feldspathic and biotitic metagraywacke interbedded with mica schist; greywacke is fine-grained, bedded, proximal and distal turbidite with bedding-parallel foliation; rocks are only slightly metamorphosed

Ams **Graphitic schist**—Black, iron-stained schist; commonly sheared; locally contains quartz stringers, veins, and gold mineralization

Amo **Mafic amphibolite**—Black hornblendic amphibolite with fine- and medium-grained texture; includes metamorphosed gabbro dikes and sills and basalt flows; locally hosts auriferous shear zones

Amm **Mixed member**—Mixed unit of fine-grained mafic metavolcanics, metagraywacke, tremolite-actinolite schist, and chlorite schist, with local interbeds of metaconglomerate

Amc **Metachert**—Interlayered cherty metagraywacke, ultramylonite, and metagraywacke

Amd **Metadacite**—Black metadacite porphyry flows and sills (?) with plagioclase phenocrysts (porphyroblasts) aligned in trachytic texture

Ama **Meta-andesite**—Ellipsoidal and non-ellipsoidal meta-andesite flows

Arm **Round Top Mountain Greenstone**—Dominantly greenstone, greenschist, and mafic-amphibolite; includes mica schist, hornblende-mica schist, and metabasalt with lesser metagreywacke, metatuff, chlorite schist, and actinolite schist

Agm **Goldman Meadows Formation**—Consists of two members mapped as one. Iron formation member consists of black to dark-gray, hard, dense and laminated alternating layers of magnetite and metachert with varying amounts of amphibole. Schist member consists of principally porphyroblastic pelitic schist, thin quartzites, and massive to schistose amphibolites

Ads **Diamond Springs Formation**—Contains metabasalt, metagabro and serpentinite; formation is dominated by serpentinite, tremolite-talc-chlorite schist, and mafic amphibolite

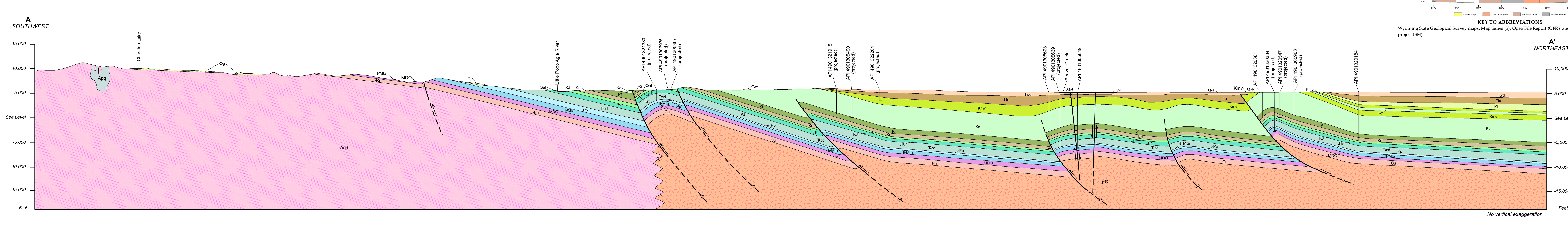
p€ **Precambrian rocks undifferentiated**—On cross section only

Ago **Gneissic granite and orthogneiss**—Fine- to coarse-grained, sometimes veined and banded, granodiorite, granite, and tonalite gneiss, orthogneiss and red granite

Agu **Archean gneisses undifferentiated**—Dominantly pink, varying to tan and gray, coarse-grained and coarsely foliated granitic gneiss with minor amounts of amphibolite gneiss, biotite schist, chlorite schist, and sillmanite schist. Crosscut by aplite, pegmatite, mafic dikes, and small ultramfic intrusions

As **Unnamed metasedimentary group**—Crops out only in small area in extreme south-central part of the quadrangle

Agn **Gneiss**—Felsic gneiss and granitic migmatite interlayered with supracrustal rocks and intruded by granodiorite. Encloses concordant amphibolite, tonolite gneiss and ultramafic enclaves. Exhibits common augen and migmatitic textures



SOUTHWEST - NORTHEAST CROSS SECTION A - A'

DISCLAIMERS

Users of these maps are cautioned against using the data at scales different from those at which the maps were compiled. Using this data at a larger scale will not provide greater accuracy and is, in fact, a misuse of the data.

The Wyoming State Geological Survey (WSGS) and the State of Wyoming make no representation or warranty, expressed or implied, regarding the use, accuracy, or completeness of the data presented herein, or from a map printed from these data. The act of distribution shall not constitute such a warranty. The WSGS does not guarantee the digital data or any map printed from the data to be free of errors or inaccuracies.

The WSGS and the State of Wyoming disclaim any responsibility or liability for interpretations made from these digital data or from any map printed from these digital data, and for any decisions based on the digital data or printed maps. The WSGS and the State of Wyoming retain and do not waive sovereign immunity.

The use of or reference to trademarks, trade names, or other product or company names in this publication is for descriptive or informational purposes, or is pursuant to licensing agreements between the WSGS or State of Wyoming and software or hardware developers/vendors, and does not imply endorsement of those products by the WSGS or the State of Wyoming.

NOTICE TO USERS OF INFORMATION FROM THE WYOMING STATE GEOLOGICAL SURVEY

Most information produced by the Wyoming State Geological Survey (WSGS) is public domain, is not copyrighted, and may be used without restriction. We ask that users credit the WSGS as a courtesy when using this information in whole or in part. This applies to published and unpublished materials in printed or electronic form. Contact the WSGS if you have any questions about citing materials or preparing acknowledgements. Your cooperation is appreciated.

WYOMING STATE GEOLOGICAL SURVEY
Ronald C. Surdam, State Geologist

Pamphlet to Accompany MAP SERIES 87

Geologic map of the Lander 30′ x 60′ Quadrangle, Fremont County, Wyoming

Compiled and mapped
by
Joseph F. Johnson and Wayne M. Sutherland

Laramie, Wyoming
2009

TABLE OF CONTENTS

INTRODUCTION

Acknowledgements

This map and report was prepared in cooperation with, and research was supported by, the U.S. Geological Survey, National Cooperative Geologic Mapping Program. STATEMAP is part of this program involving cooperation between state geological surveys and the U.S. Geological Survey. The Wyoming State Geological Survey (WSGS) used funds from the STATEMAP 2007 and 2008 programs under U.S. Geological Survey Cooperative Agreements 07HQAG0144 and 08HQAG0, as well as matching funds from the State of Wyoming, to complete this project. A preliminary version of this map was prepared for STATEMAP 2007 and published as WSGS Open File Report 08-2 (Johnson and Sutherland, 2008). 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.

Location

The Lander 30′ x 60′ (1:100,000-scale) Quadrangle is located in Fremont County, central Wyoming and includes the southwestern Wind River Basin, the southeastern Wind River Range, and part of the Beaver Divide. It encompasses the area from lat 42°30′ to 43° N. and long 108° to 109°W. The Lander 1:100,000-scale map comprises 32 1:24,000-scale quadrangles (**Figure 1**). The quadrangle is bounded on the north, south, east, and west by the Riverton, South Pass, Rattlesnake Hills, and Pinedale 30′ x 60′ quadrangles, respectively. The WSGS has compiled and published bedrock geologic maps of the South Pass quadrangle (Sutherland and Hausel, 2006) and the Rattlesnake Hills quadrangle (Sutherland and Hausel, 2003).

Geography

The communities of Lander and Hudson, and the settlements of Arapaho and Sweetwater Station are located within the Lander 1:100,000-scale Quadrangle. Ranching, farming, oil and gas activity, and recreation characterize current land use within the quadrangle. Popular multiple use areas include Sinks Canyon State Park, the Shoshone and Bridger-Teton National Forests, and part of the Popo Agie Wilderness. The Wind River Indian Reservation occupies much of the northern part of the map area. U.S. Highway 287/State Highway 789 and State Highway 28 serve the southern part of the quadrangle into the town of Lander; State Highway 789 continues northeast to Hudson and on to Riverton; U.S. Highway 287 continues north to Fort Washakie and Dubois; and State Highway 135 in the eastern map area extends north from Sweetwater Station to Riverton. The highest elevation in the Lander 30′ x 60′ Quadrangle is approximately 12,260 feet (3,737 m) on the west edge of the quadrangle in the Wind River Range southwest of Lander and the lowest elevation is 4,925 feet (1,501 m) near the north edge of the quadrangle along the Little Wind River.

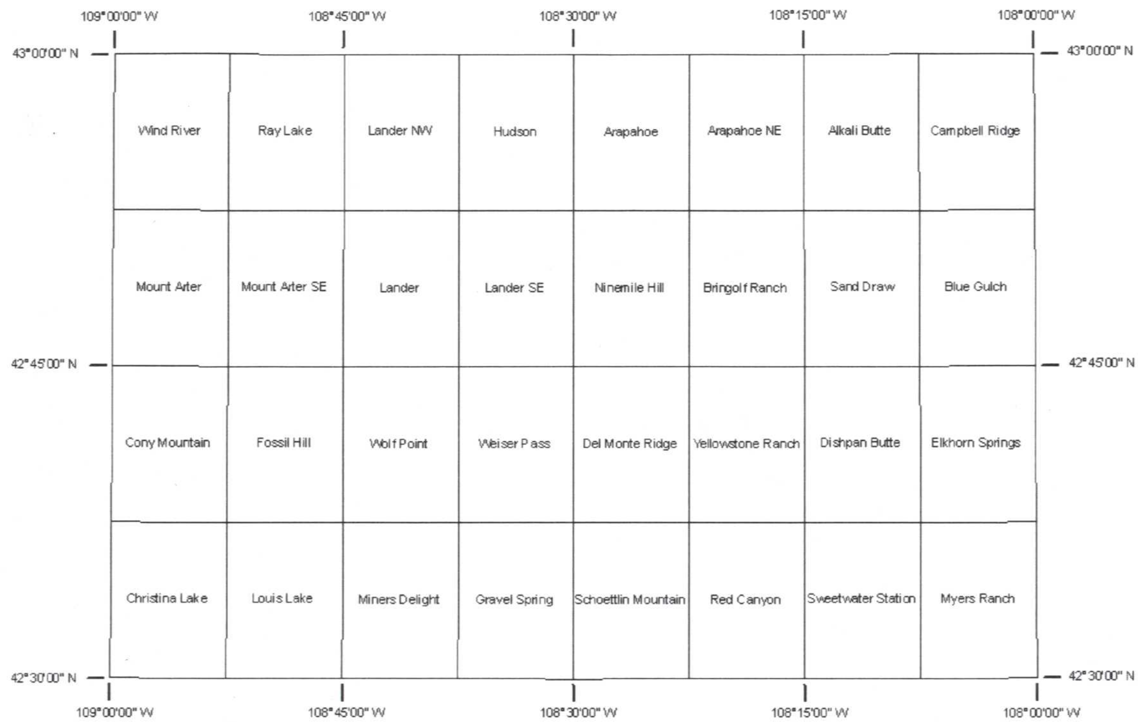


Figure 1. Index to 7.5-minute U.S. Geological Survey topographic maps of the Lander 30′ x 60′ Quadrangle.

The largest stream in the quadrangle is the Little Wind River, which enters the quadrangle from the north and is joined by the Popo Agie River and Beaver Creek before exiting the quadrangle northeast of Arapahoe. The Popo Agie River and its primary tributaries North Popo Agie, Middle Popo Agie, and Little Popo Agie rivers flow eastward off the Wind River Range, draining the western third of the quadrangle. This drainage system is the most important water source on the Lander 30′ x 60′ Quadrangle. Of secondary importance are Beaver Creek and its tributaries, which drain much of the eastern two-thirds of the quadrangle. Beaver Creek heads just north of the abandoned and reclaimed Atlantic City iron ore mine, draining the southern end of the Wind River Range; it continues east above Beaver Rim before turning north in the middle of the quadrangle where it crosses Beaver Divide and then flows north across the quadrangle, finally entering the Little Wind River near Arapahoe. The Sweetwater River cuts across the southeastern corner of the quadrangle (but drains very little of the quadrangle) and Conant Creek drains the extreme northeastern corner of the quadrangle.

Geologic setting

Exposed geologic units in the Lander 30′ x 60′ Quadrangle range in age from Precambrian to Quaternary. The granitic core of the Wind River Range represents the majority of exposed Precambrian rocks in the quadrangle with smaller exposures of granitic gneiss cropping out in the southern part of the quadrangle. Paleozoic and Mesozoic sedimentary rocks are present along the northeastern flank of the Wind River Range and southeast of Beaver Divide. Tertiary rocks dominate much of the central and eastern parts of the quadrangle. Quaternary alluvium can be found throughout the map area in most major drainages. A series of gravel terraces on pediment surfaces (Qag[1] on the map) flank the Wind River Range along the western part of the quadrangle. Glacial deposits (Qg on the map) atop the high mountains and in the deeper valleys of the range represent deposits from both the Bull Lake, Pinedale, and post-Pinedale glacial advances (Pearson and others, 1971). Landslides (which include mass movements of various types) are common in the map area (Case and others, 1991), but only the largest examples have been delineated in this report. Extensive mass wasting along the Beaver Rim, as well as many deposits of scree and talus in the Wind River Range, are not shown. Surficial geologic maps that show these mass wasting and other deposits were published by the Wyoming State Geological Survey (Wittke, 2008; 2009).

Structurally, the Lander 1:100,000-scale Quadrangle includes the southwestern Wind River Basin, the extreme western part of the Granite Mountains, and the southeastern part of the Wind River Range. Structures in the map area, including uplift of the Wind River Range primarily by southwestern displacement along the low angle Wind River thrust (southwest of the Lander Quadrangle), and basin margin deformation features, are dominated by the Late Cretaceous - early Tertiary Laramide orogeny (Keefer, 1970). Granitic exposures and glacial deposits in the Wind River Range give way to outcrops of Paleozoic and Mesozoic units along the northeastern flank of the range. These units produce prominent dip slopes that change to flank fold structures and related faults along the base of the range (see Cross section A-A′ on map). Farther eastward into the basin, exposures generally consist of gently folded or flat-lying Upper Cretaceous and Tertiary rocks. In the eastern part of the quadrangle, the east-dipping, westward-directed Emigrant Trail thrust, the complex Conant Creek anticline, and the Alkali Butte anticline all affect Precambrian through Tertiary rocks.

The southern core of the Wind River Range comprises an Archean synclinorium of metamorphosed volcanic, sedimentary, and plutonic rocks intruded by the granitic plutons extensively exposed to the north. Only the northern part of this terrain, known as the South Pass granite-greenstone belt (Bayley and others, 1973; Hausel, 1991), is exposed along the southern edge of the Lander 30′ x 60′ Quadrangle. Northeast of the dip slope developed in Permian rocks along the eastern flank of the Wind River Range, a series of Laramide-related anticlines is aligned sub-parallel to the mountain front. These structures generally trend northwest, are southwest-verging and asymmetric with a slightly en echelon alignment (Brocka, 2007). In the map area, the Eocene Wind River Formation (Twdr on the map) in the southern Wind River Basin unconformably overlies rocks as old as the Upper Cretaceous Cody Shale and as young as the Paleocene Fort Union Formation (Cross section A-A′ on the map). The Wind River Formation is overlain to the south and east by younger rocks on Beaver Divide.

ECONOMIC GEOLOGY

Gold and iron ore

The South Pass region is considered one of Wyoming's most important sources of gold and iron ore. The northern part of the South Pass-Atlantic City mining district lies within the map area of the Lander 30′ x 60′ Quadrangle and is home to numerous mines and prospects, including the historic Atlantic City iron mine. Commercial mineral extraction, beginning in the mid-1800s, originally focused on gold (Hausel, 1991). Multiple small- to medium-scale operations sporadically exploited paleoplacer, placer, and lode gold deposits until shortly after the World War II, when the focus shifted to iron ore (Hausel, 1991). Major exploration of the Precambrian banded iron formation north of Atlantic City began in 1954 and culminated in the construction of the Atlantic City open pit mine and mill. From 1962 until operations ceased in 1983, 90 million short tons of taconite (iron ore) were extracted from the Atlantic City mine (Hausel, 1984). The mill product was sent by a private railroad (now abandoned) to Rock Springs, where the railroad joined the Union Pacific tracks, and on to a smelter in Provo, Utah. Substantial potential for extraction of gold and iron ore minerals still exists in this region.

Opal

The Cedar Rim opal deposit is located approximately eleven miles north of Sweetwater Station in the east-central part of the Lander Quadrangle. The deposit consists primarily of white to very light blue, translucent to opaque, common opal, with some additional translucent to opaque yellow and yellow-orange to orange fire opal, and clear hyalite opal. Trace amounts of precious (both white and black) opal have been identified in samples collected by the Wyoming State Geological Survey (Hausel and Sutherland, 2005).

Jade

Nephrite jade (the Wyoming state gemstone) has been identified in both lode and detrital deposits in the Lander 30′ x 60′ Quadrangle (Hausel and Sutherland, 2000). Precambrian outcrops in T. 30 N., R. 95 W., host both reported occurrences and historically mined primary jade deposits. Detrital jade, likely related to more significant deposits in the Granite Mountains region, can be found in the Tertiary Wind River Formation and in some Quaternary deposits.

Corundum (Ruby and Sapphire)

Minor corundum occurrences have been found associated with mica schists in T. 30 N., R. 96 W. These include both sapphires and rubies (Hausel and Sutherland, 2000).

Diamond

A placer diamond was reportedly found during the late 1800s in the Beaver Creek Placers of the South Pass-Atlantic City mining district (Hausel, 1998). However, this report has not been independently confirmed. There have been no investigations to assess the potential for diamonds in the Lander 30′ x 60′ Quadrangle.

Zeolite

Substantial zeolite deposits have been identified in the Eocene Wagon Bed Formation west of Beaver Divide. These deposits consist chiefly of clinoptilolite, which is widespread in zeolitic zones that can exceed 100 feet (30 m). Erionite is found in combination with clinoptilite and composes less that 15 percent of the total zeolite fraction. Lesser amounts of chabazite, phillipsite, and analcime are also present in the Wagon Bed (King and Harris, 2002).

Uranium

Limited uranium mining occurred within the Lander 30′ x 60′ Quadrangle during the mid 1950s with less than 200 short tons of ore mined. Of that total, 103 short tons was produced from the Tertiary Wagon Bed Formation in sec. 3, T. 32 N., R. 94 W. Additional small mines and occurrences of radioactive anomalies are found in the Tertiary White River, Wagon Bed, and Wind River formations, the Permian Phosphoria Formation, the Pennsylvanian Tensleep Formation, and Precambrian igneous rocks.

Phosphates

Extensive phosphate deposits exist in the Phosphoria and Park City formations along the eastern flank of the Wind River Range. Phosphate beds of economically viable thickness and purity are located at the base of both the Meade Peak and Retort Phosphatic Shale Members. These beds reach 6 feet (2 m) in thickness and contain up to 28 percent phosphate (Rohrer, 1973).

Oil and gas

The Mike Murphy #1 well was drilled in the SW ¼ of Sec. 13, T.32N, R.99W, on the Dallas anticline in 1884, becoming the first oil well drilled in Wyoming (Mullen, 1989). Significant historical and contemporary oil and gas resources are located in the Lander 30′ x 60′ Quadrangle. Oil and gas reservoirs within the quadrangle range in age from Mississippian (Madison Limestone) to Tertiary (the Paleocene Fort Union Formation) (De Bruin, 2008). Significant petroleum resources are currently being recovered from multiple oil fields across the map area. The Lander 30’x 60’ Quadrangle has potential for further development of oil and natural gas resources including coalbed natural gas.

Coal

The northeastern quarter of the Lander 30′ x 60′ Quadrangle overlaps the southwestern Wind River Coal Field. This area includes the Hudson and Alkali Butte mining districts, as well as the Big Sand Draw and Beaver Creek coal occurrences (Jones and others, 2009). Coals in the Upper Cretaceous Mesaverde Formation within the quadrangle are subbituminous in rank (Rieke, 1981); information on the rank of coals in other formations is lacking (Glass and Roberts, 1978). Numerous small-scale underground coal mines exist on Alkali Butte anticline and in the vicinity of the town of Hudson, which was the center of most of the historical coal mining activity in the coal field. There are currently no active coal mines in the quadrangle. Coal beds occur within the Frontier, Cody, Lance, Fort Union, and Wind River formations; however, thicker coal beds are limited to the Mesaverde Formation (Glass and Roberts, 1978).

Additional mineral resources

Additional resources such as sand and gravel, decorative stone, and dimensional stone, as well as several other industrial minerals, including bentonite, gypsum, limestone, and dolomite are found in the quadrangle (Harris, 2004). Characterization and the potential for development of these resources have not been assessed.

GEOLOGIC MAP UNITS

The geology of the Lander 30′ x 60′ Quadrangle was compiled from existing mapping (**Figure 2**) and supplemented by aerial photo interpretation and cursory field checks. The rock units described here apply to the thirty-two 1:24,000 scale quadrangles that comprise the Lander 1:100,000-scale Quadrangle. Some rock units were generalized and combined; very small outcrops were exaggerated to allow depiction at the map scale. Some contacts between units, particularly Quaternary and Tertiary units, are uncertain, but are shown as solid rather than dashed lines. A preliminary version of this map was published by the Wyoming State Geological Survey (WSGS) as Open File Report 08-2 (Johnson and Sutherland, 2008).

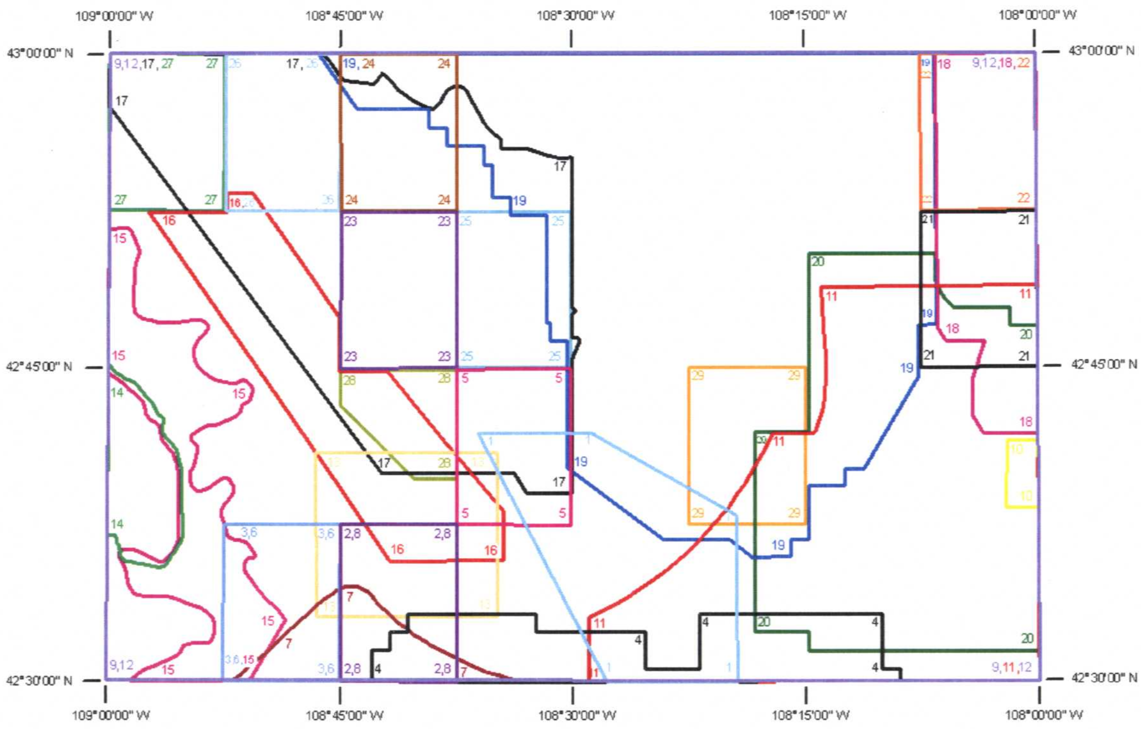


Figure 2. Index to sources of geologic mapping, Lander 30′ x 60′ Quadrangle. Numbers are those listed in the REFERENCES CITED AND SOURCES OF GEOLOGIC DATA.

Because the detailed descriptions of map units which follow could not be placed in their entirety on the geologic map sheet, only abbreviated descriptions of the geologic formations, the hierarchy of units, and a correlation chart of map units appear on the map sheet. For the descriptions below, the text in parentheses following the unit or formation name includes the symbol used on the geologic map and its geologic series or system.

CENOZOIC UNITS

Quaternary surficial deposits

Alluvial deposits (Qal) (Holocene and Pleistocene)—Alluvium is unconsolidated and poorly consolidated clay, silt, sand, and gravel and includes deposits underlying current flood plains and bordering alluvial terraces.

Colluvium (Qc) (Holocene and Pleistocene)—Colluvium includes unconsolidated detritus derived from steep slopes or cliffs such as slope wash, talus, and scree.

Landslide debris (Qls) (Holocene and Pleistocene)—This unit is made up of locally derived landslide debris from unstable and generally steep slopes.

Terrace deposits (Qt) (Holocene and Pleistocene)— Terrace deposits are unconsolidated and poorly consolidated gravel, sand, and silt.

Residual gravel (Qrg) (Holocene and Pleistocene)—These residual gravels are derived from the Wind River Formation (Thompson and others, 1950) and occur near the downdropped block of the Wind River Formation on north end of Lander anticline.

Alluvial gravel (Qag^1) (Pleistocene)—These gravels consist of high level alluvium on pediment surfaces and commonly contains abundant angular pebbles and cobbles of Paleozoic rocks. The lower few feet (0.6 m) are locally cemented by calcium carbonate. Thickness of these gravels varies from 0 to 20 feet (0 to 6 m) (Rohrer, 1973).

Alluvial gravel (Qag^2) (Pleistocene)—This material becomes coarser and more angular toward the mountains. These gravels contain significant amounts of soil and alluvial material and consist of locally derived rock fragments, limestone, chert, sandstone, quartzite, and igneous and metamorphic rocks (Thompson and others, 1950).

Glacial debris (Qg) (Pleistocene)— Glacial debris is represented by unconsolidated silt, sand, gravel, cobbles, and boulders derived from Precambrian and some Paleozoic rocks. Glacial debris occurs as lateral and terminal moraines and outwash below moraines in glacial valleys; its thickness varies from 0 to 200+ feet (0 to 61+ m) (Rohrer, 1973).

Unconformity

Tertiary sedimentary rocks

Tertiary rocks undifferentiated (Tu)—This unit includes Miocene, Oligocene, and Eocene sedimentary deposits in the south-central part of the quadrangle (Abercrombie, 1989).

South Pass Formation (Tsp) [Pliocene-Miocene or **lower Miocene(?)-upper Oligocene** (Sutherland and Hausel, 2006)**]**—The South Pass Formation is a highly variable and poorly sorted calcareous conglomerate with white volcanic ash and light-gray to white tuffaceous sandstone (Hausel, 1988). Within the map area this unit crops out at only one location in Secs. 11 and 12, T. 29 N., R. 101 W. The formation is 0 to 350 feet (110 m) thick in the adjacent South Pass 1:100,000-scale Quadrangle (Sutherland and Hausel, 2006).

Split Rock Formation (Tsr) [Miocene (Love, 1970) or **lower Miocene(?)-upper Oligocene** (Sutherland and Hausel, 2006)**]**—The uppermost part of the Split Rock Formation consists of interbedded, very light gray limestone and calcareous tuffaceous sandstone. Thin beds of chert, irregular concretions of opaline silica, and fibrous siliceous aggregates commonly occur in the sandstone. The sandstone is irregularly calcareous and contains scattered thin lenses of pebble conglomerate and thin bedded sandy limestone. Beneath this is 15 to 20 feet (4.6 to 6.1 m) of massive, well-sorted, fine-grained tuffaceous sandstone. The basal conglomerate is composed of up to 15 feet (4.6 m) of pink-stained pebbles, cobbles, and angular fragments as well as abundant fragments of black igneous and metamorphic rocks. Delineation of the basal conglomerate from the underlying White River Formation can be difficult. The base of the Split Rock in the vicinity of Dishpan Butte, north of Sweetwater station, is a light gray sandy limestone rather than conglomerate. The total thickness of the Split Rock Formation is greater than 150 feet (46 m) (Van Houten, 1964).

Unconformity—Between Split Rock (Tsr) and Wind River (Twr) formations (Van Houten, 1964)

Miocene(?) rocks undifferentiated (Tmu)—These rocks are represented by conglomerate on terraces associated with the Little Popo Agie River in the northwest corner of the Weiser Pass 7.5′ Quadrangle (Brocka, 2007) and in the southeast corner of the Lander 7.5′ Quadrangle (Clements, 2008). This unit of uncertain age is of limited extent and has not been identified in previous studies.

White River Formation (Twr) (Oligocene)—The upper part of this lithologically variable formation consists principally of gray to grayish-orange tuffaceous siltstone, arkose, and arkosic conglomerate composed of Paleozoic rock fragments (Van Houten, 1964). Along the east flank of the Wind River Range these fragments locally make up the whole of the White River Formation (Rohrer, 1973). In the vicinity of Wagon Bed Springs, the basal unit of the White River is composed of the Big Sand Draw Sandstone Lentil. The lentil consists of yellowish-gray volcanic mudstone and sandstone overlain by pale greenish-yellow to yellowish-gray volcanic arkose containing lenses and layers of pebble conglomerate (Van Houten, 1964). Where the Big Sand Draw Sandstone Lentil is present, the Beaver Divide Conglomerate conformably overlies it; in other locations, the Beaver Divide Conglomerate lies unconformably on the Wagon Bed Formation.

The upper part of the Beaver Divide Conglomerate is composed of light-gray to yellowish-gray, crudely bedded, calcite-cemented volcanic sandstone and tuff with conglomerate interbeds composed principally of Tertiary volcanic fragments derived from the Yellowstone-Absaroka volcanic field. Locally, beds of pumice lapilli tuff are present. The lower Beaver Divide Conglomerate consists of many distinct lenses of conglomerate in a sandy matrix, exhibiting parallel bedding and cross stratification. In the vicinity of the Big Sand Draw

Sandstone Lentil, the lower conglomerate consists of grayish-orange, poorly sorted volcanic-rich sandstone with lenses of angular pebbles, cobbles, and uncommonly, boulders of white, gray, and black Precambrian rocks. Pebbles and cobbles of Tertiary volcanic rocks may also be present. East of the Big Sand Draw Sandstone Lentil, the lower part of the Beaver Divide Conglomerate consists of light-gray and very pale yellowish- to greenish-gray mudstone and sandstone containing scattered angular fragments of Precambrian rock. The White River Formation is variable in thickness with a maximum exposure of 650 feet (200 m) along Beaver Rim (Van Houten, 1964).

Unconformity (Van Houten, 1964)

Wagon Bed Formation (Twb) (upper and middle Eocene)—The Wagon Bed Formation is composed of bluish-green to greenish-yellow to yellowish-gray sandstone, siltstone, and mudstone with lesser amounts of bentonite, arkose, conglomerate, and vitric tuff. Beds of chert and limestone are present locally. Volcanic ash and detritus are common throughout the formation. Volcanic debris is especially abundant at the eastern and western ends of the Beaver Rim, originating from the Rattlesnake Hills and Yellowstone-Absaroka volcanic fields, respectively. The formation chiefly crops out along Beaver Divide in the southeastern part of the Lander 1:100,000-scale Quadrangle with additional exposures at Oil Mountain. Along most of the Beaver Rim, beds and lenses of silica-cemented sandstone and conglomerates form conspicuous cliffs at the top of the formation. The formation is 130 to 700 feet (40 to 210 m) thick (Van Houten, 1964).

The Wagon Bed conformably overlies the Wind River Formation along the majority of the Beaver Rim except where it overlaps older rocks in the vicinity of Conant Creek anticline. Angular unconformities between the Wagon Bed and Wind River formations observed by Bauer (1934, p. 676) and Wood (1934, p. 246-247), were not seen by Van Houten (1964). Van Houten did however note a "difference of several degrees between the dip of the Wind River Formation and nearly horizontal strata of the nearest exposed Wagon Bed Formation suggests a local angular unconformity" in the vicinity of Rodgers Mountain anticline. (Van Houten, 1964)

Wind River Formation (Twdr) (lower Eocene)— The Wind River Formation consists principally of yellowish-gray to yellowish-orange lenticular deposits of poorly-sorted feldspathic to arkosic sandstone, pebble conglomerate, and variegated mudstone, commonly exhibiting red banding. Rocks of the Wind River Formation are commonly poorly cemented with calcium carbonate and limonite. Layers of carbonaceous shale and coal are found locally. Acidic volcanic debris from the Yellowstone-Absaroka volcanic field is present in the upper part of the Wind River, largely concentrated in three layers of light to greenish-gray pumiceous tuff and tuffaceous bentonitic mudstone. The formation ranges in thicknesses from a wedge-edge to greater than 2,400 feet (730 m) in the subsurface on the Riverton anticline (north of the map area).

The Wind River Formation is generally equivalent to the lower Eocene Wasatch Formation in other Wyoming basins and outcrops extensively in the northeastern half of the Lander 30′ x 60′ Quadrangle. Sandstones and conglomerates of the Wind River generally form small cliffs on slopes of badland-type topography. The formation is angularly unconformable with underlying rocks of the Fort Union Formation, as well as Upper Cretaceous and older rocks. Coarser detrital materials within the formation commonly consist of subangular quartz, quartzite, chert, white feldspar, white graphitic granite, gneiss, schist, muscovite, and biotite with scarce amounts of limestone and black Precambrian dike rocks (Van Houten, 1964).

Unconformity

Fort Union Formation (Tfu) (Paleocene)—The Fort Union Formation comprises a series of interbedded, white, gray, tan, buff, and brown sandstones, conglomerates, carbonaceous shales, siltstones, and coal overlie a basal conglomerate (Keefer and Rich, 1957; Keefer, 1965). Upper conglomerates are often lenticular and consist of Precambrian pebbles and cobbles in an arkosic sandstone matrix. Sandstone beds can be massive, lenticular, and ferruginous (Thompson and others, 1950; Van Houten, 1957). The base of the Fort Union is marked by a conspicuous and widespread conglomerate (Thompson and others, 1950). In the area east of Alkali Butte, the conglomerate is composed almost entirely of fragments of quartzite, chert, and siliceous shale in a nonarkosic sandstone matrix (Keefer, 1965, p. A29).

Within the Lander 1:100,000-scale Quadrangle, the Fort Union ranges in thickness from a wedge-edge to greater than 1,000 feet (300 m). In some locations the Fort Union was completely eroded before the deposition of lower Eocene rocks. The Fort Union formation unconformably overlies (and in some places truncates) the Upper Cretaceous Lance and Mesaverde formations (Keefer and Rich 1957; Van Houten, 1964). Locally the basal conglomerate of the Fort Union occupies channels cut into the uppermost sandstones of the Mesaverde Formation (Thompson and others, 1950).

MESOZOIC UNITS

Upper Mesozoic rocks, undifferentiated (Mzu)—These sedimentary rocks are exposed south of Sweetwater Crossing anticline and include units from the Cretaceous Cody Shale to the Jurassic Sundance Formation mapped by Bell (1955).

Upper Cretaceous sedimentary rocks

Lance Formation (Kl)—The Lance Formation consists chiefly of interbedded white, gray, and buff, fine- to coarse-grained, in part conglomeratic, friable, lenticular sandstones (Keefer and Rich, 1957; Keefer, 1965); gray to black shale and claystone; brown to black carbonaceous shale; and coal. Many of the shale and claystone beds are bentonitic and weather to characteristic smooth rounded hills and slopes strewn with large selenite crystals (Keefer, 1965). Largely due to the unconformable relationship with the overlying Fort Union Formation, the thickness of the Lance is highly variable (Keefer and Rich, 1957), ranging from a wedge-edge up to 900 feet (270 m) thick. The formation thins to the south and west from the only outcrops on the Lander 30′ x 60′ Quadrangle at Alkali Butte and is completely absent along the western part of the Wind River Basin.

Mesaverde Formation (Kmv)—The upper part of the Mesaverde Formation is a series of interbedded soft, massive, white sandstones and thin, brown, hard ledgy sandstones with numerous thin, gray carbonaceous shales and coal beds (Van Houten, 1964). The base of the formation is marked by a massive white sandstone bed. The unit contrasts sharply with the underlying beds both in color and in topography as it forms conspicuous light-colored escarpments (Thompson and others, 1950). Keefer (1972) described the Mesaverde as a highly variable sequence, noting that most individual beds are lenticular and can only be traced a short distance. Lower sandstones are typically tan, gray, and yellowish-gray, very fine to medium-grained, irregularly bedded to cross-bedded to massive, and friable to well-cemented. Many beds are highly ferruginous and exhibit limonite staining. Locally, the basal sandstone beds incorporate lenses of "black sand" where dark minerals (chiefly oxides of iron and titanium) can compose as much as 80% of the rock. Thickness of the Mesaverde ranges from 50 to 300 feet (15 to 91 m) in truncated outcrops along the western edge of the Wind River Basin (Thompson and others, 1950) but varies from 1,200 to 2,000 feet (370 to 610 m) thick in outcrops at Alkali Butte (Keefer, 1965; 1972) and in the subsurface (Hogle and Jones, 1991).

Cody Shale (Kc)—Two informal subdivisions of the Cody Shale are recognized in the map area, an upper sandy member dominated by interbeds of shale and sandstone, and a lower shaley member, with shale the predominant rock. These "members" are generally distinguishable in the western Wind River Basin; however, the two major lithologies show all degrees of gradation so that the contact can only be selected arbitrarily in most places (Keefer, 1972; Keefer and Rich, 1957). The upper sandy member is composed of gray to buff, thin-bedded, platy and limey sandstone, interbedded with gray to black fissile shale. The shaley member is characterized by gray to black fissile shale that is often bentonitic to limey (Keefer and Rich, 1957). The shaley member is easily eroded and tends to form broad flat valleys while the upper sandstones may be resistant enough to form cliffs. Upper strata of the Cody Shale are extensively intertongued with the Mesaverde Formation in the Alkali Butte-Conant Creek area (Keefer, 1972). In this area, an upper tongue of the Cody is shown on Cross section A-A' but this tongue is combined with the Mesaverde on the map. The Cody Shale represents 4,000 to 5,000 feet (1,200 to 1,500 m) of marine shale and sandstone.

Frontier Formation (Kf)—The Frontier Formation is an alternating sequence of marine and nonmarine sandstone and shale (Abercrombie, 1989). Sandstones tend to be gray, tan, and brown, fine- to medium-grained, thin-bedded to massive, in part cross-bedded, and lenticular. Within the sandstones a moderate proportion of dark grains often create a salt-and-pepper appearance. Sandstones are locally coarse-grained and conglomeratic; shales are gray to black, fissile, silty or sandy, and locally carbonaceous. The Frontier Formation commonly erodes to form hogbacks and narrow strike valleys, with the hogbacks consisting of resistant sandstone beds in the upper part of the formation. Thickness ranges from 600 to 1,000 feet (180 to 300 m).

Mowry Shale (Kmr)—The Mowry Shale consists of black to dark-gray, hard siliceous shale, containing a few beds of thin, gray to brown, fine- to medium-grained sandstone. The formation weathers to distinctive bare, silver-gray ridges with bands of vegetation along interspersed bentonite beds (Cobban, 1957). Thickness varies from 430 to 500 feet (130 to 150 m).

Mowry Shale, Muddy Sandstone, and Thermopolis Shale undivided (Krt) (Upper and Lower Cretaceous)—These units combined are only on Cross section A-A′ (see map).

Lower Cretaceous sedimentary rocks

Muddy Sandstone and Thermopolis Shale undivided (Kmt)

Muddy Sandstone (Kmd)—The Muddy Sandstone is a prominent gray, fine- to coarse-grained, cliff-forming sandstone, containing sporadically distributed chert pebbles, dark minerals, and chalky grains overlain by softer sandstones and dark-gray to black shales. Rapid lateral changes in lithology, from porous sandstone to siltstone, are not uncommon. The Muddy Sandstone thins to the east until, in the vicinity of the Conant Creek anticline, it becomes too thin and shaley to easily distinguish from the Thermopolis and Mowry shales. Thickness of the Muddy Sandstone ranges from 10 to 150 feet (3 to 46 m) (Skipp, 1957). In areas where unit is very thin, the outcrop is shown as a line.

Thermopolis Shale (Kt)—The Thermopolis Shale is composed of soft, black, fissile shale with thin bentonite layers often found near the top and bottom of the formation. A few discontinuous, thin silty sandstones are sometimes found in the middle part. Ironstone concretions are characteristic of the Thermopolis Shale but not indicative of it, as they may also occur in the Mowry Shale and Cloverly Formation. The Thermopolis Shale ranges in thickness from 95 to 135 feet (29 to 41 m) (Skipp, 1957).

Cloverly Formation (Kcv)—The Cloverly Formation consists of buff to gray to brown, fine-grained, cross-bedded, slabby sandstone with interbedded variegated shales and siltstones overlying a pebble conglomerate at the base. The Cloverly weathers to a distinctive rusty-tan or brown (Abercrombie, 1989; Sutherland and Hausel, 2006). The thickness of the Cloverly Formation ranges from 100 to 150 feet (30 to 46 m) (Burk, 1957).

Cloverly and Morrison formations undivided (KJ) (Lower Cretaceous/Upper Jurassic)—Total thickness for both units is approximately 350 feet (110 m).

Unconformity

Jurassic sedimentary rocks

Morrison Formation (Jm) (Upper Jurassic)—The Morrison Formation consists of red, maroon, green, and brown claystone, mudstone, and siltstone, with interspersed lenses of coarser channel sandstones underlain by coarser-grained deposits of poorly sorted silty sandstone containing interbeds or channel deposits of coarse-grained, cross-bedded sandstone (Brocka, 2007). The formation is approximately 200 feet (61 m) thick (Brocka, 2007).

Sundance Formation (Js) (Upper Jurassic)—The upper part of the Sundance Formation is greenish-gray glauconitic siltstone, limey sandstone, shale, and brownish-gray, glauconitic, silty to sandy coquinoid limestone that locally forms resistant ledges grading downward into reddish-brown siltstone, sandy siltstone, and silty sandstone. Belemnites are common in the upper part of the Sundance (Rohrer, 1973). The lower part of the Sundance is gray shale, oolitic limestone, and sandy limestone. The base of the formation is a gray marlstone that locally contains limy claystone inclusions, identified by Brocka (2007) as rip-up clasts, and chert pebbles originating from the upper Gypsum Spring Formation. The Sundance ranges in thickness from 210 to 265 feet (64 to 81 m) and grades upward through its contact with the overlying Morrison Formation (Brocka, 2007).

Pipiringos (1968) described seven members of the Sundance Formation in central Wyoming. The uppermost of these, the Windy Hill Sandstone Member, was later reassigned to the Morrison Formation by Peterson (1994). Of the remaining six members, Rohrer (1973) recognized just four (the Stockade Beaver Shale, Hulett Sandstone, Lak, and Redwater Shale members) along the eastern flank of the Wind River Range. For this quadrangle, the Sundance is depicted as one unit due to its lateral variability and insufficient delineation of the submembers within the map area.

Unconformity (Rohrer, 1973)

Gypsum Spring Formation (Jg) (Middle Jurassic)—The upper part of the Gypsum Spring Formation consists of an alternating sequence of thin-bedded gypsum, reddish-brown shale, and light-gray to gray, thin-bedded slabby limestone. The lower part of the Gypsum Spring formation is composed of thick-bedded to massive, ledge-forming gypsum underlain by reddish-brown blocky siltstone. The Gypsum Spring locally contains algal limestone and, at the top of the formation, thin lenses of chert. The formation is greater than 200 feet (61 m) thick on the flank of the Wind River Range but thins to the east before wedging out just east of the map area (Peterson 1957; Pipiringos, 1968).

Jurassic and Triassic sedimentary rocks

Sundance and Gypsum Spring formations and Nugget Sandstone undivided (JŦR)—Used only on Cross section A-A′ (see map).

Nugget Sandstone (JŦRn) [Lower Jurassic and Upper Triassic (?)]—This includes both the unnamed upper part and the lower Bell Springs Member combined. Assignment of the upper part to the Lower Jurassic and the Bell Springs Member to the Upper Triassic is based on stratigraphic relationships and has been the subject of some debate. For example, Pipiringos (1968) noted that the Bell Springs Member may correlate with the upper part of the Triassic Chinle Formation; High and Picard (1969) suggested a Jurassic age based on the time required to fold and truncate the underlying Late Triassic Popo Agie Formation; and Picard (1978), on the basis of a regional unconformity, assigned the Nugget Sandstone entirely to the Jurassic. Other studies by Knapp (1978) and Love (1957) did not concede the significance of the unconformity at the base of the Nugget in regards to its age, assigning the lower part to the Triassic. It is assumed in this report that the contact between the Nugget Sandstone and the Popo Agie Formation is the regional unconformity as described by Picard (1978, p. 126), but does not preclude a Late Triassic age for at least the lower part of the Nugget.

Upper part (Jnu) (Lower Jurassic)—The unnamed upper part of the Nugget Sandstone is composed salmon-pink and light-gray, fine- to medium-grained, massive to conspicuously cross-bedded, cliff-forming sandstone, underlain by red, hematite-stained siltstone and slabby sandstone. Differential erosion locally results in the upper beds resembling huge conical beehives (Rohrer, 1973). The upper unit thins from a maximum thickness of about 285 feet (87 m) along the flanks of the Wind River Range to 0 just east of the map area (Pipiringos, 1968, p. D17). The contact with the overlying Gypsum Spring Formation is gradational.

Bell Spring Member (₸nb) [Upper Triassic (?)]—The Bell Springs Member of the Nugget Sandstone consists of orange-brown and gray, fine-grained, thin- to thick-bedded sandstone with interbeds of reddish-brown, pale-green, and purplish-maroon siltstone and shale (Rohrer, 1973). The upper few feet locally contain thin beds of dense, light-gray oolitic limestone. The basal layer contains chert grains, inclusions of ocher claystone, and analcime-bearing rocks that Pipiringos (1968) suggested were derived from reworked deposits at the top of the Popo Agie Formation. Thickness is approximately 80 to 100 feet (24 to 30 m) (Rohrer, 1973).

Unconformity(Rohrer, 1973)

Triassic sedimentary rocks

Chugwater Group and Dinwoody Formation undivided (₸cd)

Chugwater Group undivided (₸c) (Upper and Lower Triassic)—The Chugwater Group includes from top to base, the Popo Agie Formation, Crow Mountain Sandstone, Alcova Limestone, and Red Peak Formation in areas of steep dips where these units could not be mapped separately. Picard (1978) described another unit, the Jelm Formation, as present in the area of the Lander 30′ x 60′ Quadrangle between the overlying Popo Agie Formation and the underlying Crow Mountain Sandstone. Pipiringos (1968) used the term Jelm Formation for rocks in south-central Wyoming between the underlying Alcova Limestone and the overlying Popo Agie Formation instead of the Crow Mountain Sandstone, but did not recognize the Jelm in the Lander area. For this map and report, what has been called Jelm Formation is included with (or is equivalent to) the Crow Mountain Sandstone.

Popo Agie Formation and Crow Mountain Sandstone undivided (₸pc)

Popo Agie Formation (₸p) (Upper Triassic)—Pipringos (1968) divided the Popo Agie into two members, the upper Lyons Valley Member and the lower Brynt Draw Member. These members can be distinguished along the flank and flank folds of the Wind River Range but are indistinguishable east of Beaver Creek (Pipringos, 1968). Because these members are comparatively thin, they are mapped as one unit approximately 100 feet (30 m) thick and are described below as they appear at Dallas anticline.

The Lyons Valley Member of the Popo Agie Formation consists of purple and ocher siltstone, analcime-rich claystone, and analcimolite (Pipiringos, 1968). The Lyons Valley Member gradationally contacts the Brynt Draw Member. This contact may present itself as a break in slope where the more competent strata of the underlying Brynt Draw Member give way to the softer strata of the Lyons Valley Member (Pipringos, 1968).

The Brynt Draw Member of the Popo Agie Formation consists of approximately 20 feet (m) of pale-red to purplish-red, calcareous, silty claystone and locally reddish-gray to grayish-yellow, calcareous, silty sandstone. The uppermost part consists of dolomitic (?) siltstone containing lime-cemented siltstone pebbles (Pipringos, 1968).

Crow Mountain Sandstone (₸cm) (Upper Triassic)—The Crow Mountain Sandstone is a hematite-stained (Brocka, 2007), reddish-brown, very fine to fine-grained, limey, argillaceous, thin-bedded to massive sandstone, interbedded with reddish-brown, fissile, slightly calcareous shale and sandy siltstone. Thickness of the Crow Mountain is approximately 189 feet (58 m) thick (Rohrer, 1973).

Unconformity(Rohrer, 1973)

Alcova Limestone (TRa) (Lower Triassic)—The Alcova limestone is a pinkish to grayish-white, hard, finely crystalline (Love, 1957), thinly laminated, resistant limestone that forms ledges and small dip slopes (Rohrer, 1973). On the Lander 1:100,000-scale Quadrangle geologic map, the Alcova may be depicted as a line where it is thin and does not form a mappable dip slope. In NE¼ sec. 20 and SE¼ sec. 28, T. 33 N., R. 100 W., because of the dip, very thin Alcova is mapped as a line overlain by Crow Mountain Sandstone and Popo Agie Formation undivided (TRpc) but farther down dip the same Alcova forms a wider, mappable dip slope overlain by the normal sequence of Crow Mountain and Popo Agie. The result is a map showing what appears to be a repeated section of Alcova and Crow Mountain/Popo Agie. Thickness of the Alcova varies from 3.5 feet (1.1 m) (Rohrer, 1973) to 10 feet (3 m) or more (Abercrombie, 1989).

Red Peak Formation (TRr) (Lower Triassic)—The Red Peak Formation is composed of hematite-stained, red to reddish-brown, commonly calcareous, thin to thick-bedded, interbedded and intergradational siltstone, sandstone, and shale. The lower part of the unit commonly contains more shale and siltstone than the part above. Minor landslides occur locally along bedding planes in lower part (Rohrer, 1973). Thickness varies from 800 to 1,000 feet (240 to 300 m) (Love, 1957).

Dinwoody Formation (TRd) (Lower Triassic)—The Dinwoody Formation is made up of gray to greenish-gray, fine-grained, sandy, dolomitic siltstone, silty greenish-gray shale, and thin, slabby sandstone. The Dinwoody is thin-bedded with ripple marks and readily weathers to a yellowish-gray or yellowish-brown (Paull and Paull, 1993). Sandstone beds weather into characteristic hard slabs with brown-stained fractures and bedding surfaces (Love, 1957). The base of the formation locally contains small dolomite pebbles (Rohrer, 1973). Along the southwestern margin of the Wind River Basin, some lenticular anhydrite and gypsum beds are present (Love, 1957). Reported thickness ranges from 40 feet (12 m) (Rohrer, 1973) to 60 feet (18 m) (Abercrombie, 1989).

Red Peak and Dinwoody formations undivided (TRrd)

Unconformity(Rohrer, 1973); **discomformity** (Paull and Paull, 1993)

PALEOZOIC UNITS

Phosphoria and Park City formations undivided (Pp) (Permian)—In some areas along the flank of the Wind River Range, these two formations are subdivided and mapped as three separate units composed of different members of each formation. Each member of the Phosphoria and Park City formations, with the exception of the Grandeur Member of the Park City, were not thick enough to map separately at the 1:100,000 scale.

Ervay Member of the Park City Formation and the Tosi Chert and Retort Phosphatic Shale members of the Phosphoria Formation (Ppr)—These members are mapped as one unit, about 100 feet (30 m) thick (Rohrer, 1973).

Ervay Member of the Park City Formation—The Ervay Member is composed of a resistant, light-gray weathering, argillaceous dolomite containing scattered chert lenses, most common in the lower part. This unit forms large dip slopes along the flank of the Wind River Range and is 35 to 40 feet (11 to 12 m) thick (Rohrer, 1973).

Tosi Chert Member of the Phosphoria Formation—The main body of the Tosi Chert Member is composed of beds of gray to greenish-gray nodular chert where thin interbeds of shale are common (Ahlstrand and Peterson, 1978). The lower part of the member is often shaley or interbedded with dark shale. Argillaceous partings and thin cherty glauconitic phosphorite layers are also present (Rohrer, 1973). The reported thickness is approximately 15 feet (4.6 m) (Rohrer, 1973).

Retort Phosphatic Shale Member of the Phosphoria Formation—The upper part of the Retort is composed of an interval of phosphorite and phosphatic shale (Ahlstrand and Peterson, 1978). Below this, the main part of the Retort is composed of dark-gray to brownish-black shale and dark-gray to black, argillaceous dolomite. Basal beds contain quartz silt and sand as well as phosphatic pellets, oolites, pisolites, and intraclasts, overlain by a second interval of phosphatic shale and pellital phosphorite containing minor amounts of silt- or sand-sized quartz. Rohrer (1973) reported a thickness of approximately 45 feet (14 m).

Franson Member of the Park City Formation and Mead Peak Phosphatic Shale Member of the Phosphoria Formation (Ppm)—These members are mapped as one unit approximately 165 feet (50 m) thick.

Franson Member of the Park City Formation—Description of this unit is from Rohrer (1973). The upper part of the Franson Member consists of moderately resistant, argillaceous, light gray weathering dolomite that locally forms small ledges and contains interbeds of siltstone and locally nodular chert. The rest of the unit is gray to light gray weathering, slope-forming, dolomitic claystone and siltstone containing interbedded argillaceous dolomite, dolomitic sandstone, and thin- to thick-bedded nodular chert underlain by light-gray weathering, resistant, ledge-forming, thick-bedded, fossiliferous dolomite and dolomitic limestone. Rohrer (1973) reported a thickness of 155 feet (47 m) for this member.

Meade Peak Phosphatic Shale Member of the Phosphoria Formation—The upper part of the Meade Peak Phosphatic Shale Member is limey and dolomitic shale that weathers light-gray to light greenish gray and contains interbedded fossiliferous dolomite. Nodular chert can be found at the unit's top. The lower unit is grayish-black (weathers bluish dark gray to gray), interbedded, fossiliferous, limy, oolitic to pelletal and bioclastic (Ahlstrand and Peterson, 1978, p. 91) phosphate rock containing interbedded phosphatic shale. Rohrer (1973) reported a thickness of about 10 feet (3 m), but also noted that the thickness of this unit is variable.

Grandeur Member of the Park City Formation (Ppg)—The Grandeur Member consists of light-gray to brownish-gray, sandy, argillaceous, fossiliferous, dolomitic limestone and limy dolomite with interbeds of sandstone, minor shale, and claystone. Carbonate rocks generally contain small irregular lenses or nodules of chert. Locally this chert can form a thick bed (Rohrer, 1973). Thickness of the Grandeur varies from 30 to 50 feet (9 to 15 m) (Rohrer, 1973).

Unconformity(Rohrer, 1973)

Tensleep Sandstone and Amsden Formation undivided (ⲢMta)

Tensleep Sandstone (ⲢPt) (Upper and Middle Pennsylvanian)—The Tensleep Sandstone is composed of gray to buff to brown, cross-bedded, fine- to medium-grained, calcareous, cliff-forming sandstone (Brocka, 2007); thin beds of quartzite and chert are common (Bayley, 1965a). The Tensleep is locally silicified at the top (Rohrer, 1973). The basal portion may include few thin beds of limestone or dolomite (Keefer and Van Lieu, 1966). Thickness is approximately 400 feet (120 m).

Amsden Formation (ⲢMa) [(Middle and Lower Pennsylvanian and Upper Mississippian (?)]—The upper part of the Amsden is a variable sequence of red and green shales and sandy shales sometimes containing hematite nodules (Keefer and Van Lieu, 1966) and white, light-gray, red, and purple hard, cherty and sandy dolomites interbedded with red and green shale, limestone, and sandstone (Agatston, 1957) ranging in thickness from 80 feet (24 m) (Keefer and Van Lieu, 1966) to 200 feet (61 m) (Agatston, 1957). At the base of the Amsden is the Darwin Sandstone Member [Lower Pennsylvanian or Upper Mississippian (?)], 0 to 170 feet (52 m) thick (Agatston, 1957). The Darwin consists of red, gray, and white fine- to medium-grained, cross-bedded to massive, cliff-forming sandstone. In outcrop, appearance is similar to the Tensleep Sandstone (Keefer and Van Lieu, 1966). The Darwin thins to the south and is absent or poorly represented south of the Little Popo Agie River (Keefer and Van Lieu, 1966). Farther south and east, a 15- to 30-foot (4.6 to 9.1 m)-thick, non-resistant, thinly bedded sandstone is present at the base of the Amsden Formation that forms a much less distinct unit than the Darwin Sandstone member to the north (Keefer and Van Lieu, 1966). The thickness of the entire Amsden Formation is highly variable, ranging from 120 to 400 feet (37 to 120 m) thick (Keefer and Van Lieu, 1966).

Unconformity

Madison Limestone, Darby Formation, and Bighorn Dolomite undivided (MDO)—Used only on Cross section A-A′ (see map).

Madison Limestone and Darby Formation undivided (MD)

Madison Limestone: (Upper and Lower Mississippian)—The Madison Limestone is often divided into informal upper and lower members. Combined thickness of both members ranges from 235 feet (71.6 m) (Keefer and Van Lieu, 1966) to 600 feet (180 m) (Bayley, 1965a).

The upper member consists mainly of thin to massive and irregularly bedded gray, tan, and yellowish-tan dolomite and limestone. Thin beds of red siltstone and shale are locally present. Keefer and Van Lieu (1966) noted that the distribution of the upper member is limited to a yet undefined extent by post-Madison erosion.

The lower member consists of bluish-gray to gray, massive to thin-bedded crystalline limestone and dolomitic limestone with abundant cherty layers (Brocka, 2007) and nodules (Keefer and Van Lieu, 1966). The limestone is often mottled by irregular inclusions of tan granular limestone or dolomite. The lower strata also contain masses of angular brecciated limestone in a red earthy matrix which leads to conspicuous red staining on many outcrops. The basal part of the lower member often contains thin beds of buff, granular, dolomitic limestone, similar to the upper parts of the Darby Formation.

Unconformity (Keefer and Van Lieu, 1966)

Darby Formation (Devonian)—This poorly exposed unit is present along the eastern flank of the Wind River Range but is thickest on the northwest end of the range thinning progressively to the south and east. The wedge-edge of the formation is within the Lander 30′ x 60′ Quadrangle. In Sinks Canyon the Darby consists of tan, crystalline dolomite, imbedded with large fragments of white, medium- to coarse-grained quartzitic sandstone and is only 20 feet (6 m) thick (Keefer and Van Lieu, 1966). The formation is not present south or east of this occurrence, but where it does occur on the quadrangle it is mapped together with the Madison Limestone.

Unconformity (Keefer and Van Lieu, 1966)

Ordovician and Cambrian rocks undivided (O€)

Bighorn Dolomite (Ob) (Upper and Middle Ordovician)—The Bighorn Dolomite thins to the east from the Wind River Mountains and is absent in approximately the eastern half of the Lander 30′ x 60′ Quadrangle (Keefer and Van Lieu, 1966). It is subdivided into upper and lower named members and an unnamed middle member; total thickness is from 0 to approximately 200 feet (61 m). The Leigh Dolomite Member at the top of the formation is white, gray and pink, dense, thin-bedded to platy dolomite that weathers chalky white. It forms a conspicuous white recessed band along cliff faces. Beds of massive dolomite similar to those of the middle unnamed member are found in the upper part of the Leigh Dolomite at many localities (Keefer and Van Lieu, 1966). The unnamed middle member is composed of a buff to light-gray, hard, uniform, granular, cliff-forming dolomite (Keefer and Van Lieu, 1966). The surface weathers to a distinctive pitted or "fretwork" pattern (Gower, 1978). The Lander Sandstone Member at the base of the Bighorn appears only locally along the flank of the Wind River Range. This member is a gray to tan, and in part red, lenticular, fine- to coarse-grained, dolomitic quartz sandstone or sandy dolomite (Ross, 1957) about 2 feet (0.6 m) thick (Brocka, 2007).

Unconformity

Cambrian rocks undivided (€u)—Includes the Gallatin and Gros Ventre formations and the Flathead Sandstone.

Gallatin and Gros Ventre formations undivided (€gg)

Gallatin Formation (€g) (Upper Cambrian)—Two named members of the Gallatin Formation are mapped as one unit, which varies from 209 to 365 feet (63.7 to 111 m) thick

(Keefer and Van Lieu, 1966). The Open Door Limestone Member, the upper unit of the Gallatin, is soft greenish-gray shale overlain by hard, thinly bedded to massive, cliff-forming limestone with a few beds of flat-pebble conglomerate (Keefer and Van Lieu, 1966). Limestone is micritic with microbial laminations (Brocka, 2007). The uppermost part of this unit is often mottled with small tan irregular masses of granular limestone. Exposures may have a reddish stain due to red earth-filled cavities in the upper parts. The Du Noir Member, the lower unit of the Gallatin, is gray, resistant, cliff-forming, thinly bedded, glauconitic and oolitic limestone. The upper part of the Du Noir often contains flat-pebble limestone conglomerates (Shaw, 1957). Shaw (1957) noted that exposures at Conant Creek are composed of brown limestone, overlain by brown calcareous sandstone (sandy limestone) and flat-pebble limestone conglomerate. The Du Noir Member is 75 to 100 feet (23 to 30 m) thick (Shaw, 1957).

Gros Ventre Formation (Ꞓgv) (Upper and Middle Cambrian)—The Gros Ventre Formation is composed of three members, readily distinguishable along the eastern flank of the Wind River Range. However, to the east and south, distinctions are more ambiguous due to lateral facies changes in the middle member. Eastern exposures may be green, sandy or silty, glauconitic shales containing some weak sandstone, glauconitic sandstone, and limestone, while southern exposures may consists of red, fine-grained sandstone, siltstone, and thin shales (Keefer and Van Lieu, 1966). The Gros Ventre readily forms slopes with very little exposure (Shaw, 1957). All three members are mapped on the Lander 1:100,000-scale Quadrangle as one unit with a total thickness ranging from 300 feet (91 m) (Bayley, 1965) to 700 feet (210 m) (Brocka, 2007).

The upper unit of the Gros Ventre is the Park Shale Member, a soft, greenish-gray, sandy or silty, glauconitic shale with thin-bedded intraformational limestone that increases in abundance near the top. Flat-pebble limestone conglomerates in a dense granular limestone matrix are common in the upper part. Shaw (1957) reported a thickness of 400 feet (120 m) for the Park Shale.

The middle of the Gros Ventre Formation is the Death Canyon Limestone Member, a dark-gray and tan, hard, thin-bedded, cliff-forming limestone commonly mottled by inclusions of irregularly shaped tan granular limestone or dolomite masses. The Death Canyon grades laterally east and south of the outcrops on the flank of the Wind River Range where, between Winkleman Dome and Beaver Creek into shale and was not distinguished from the Wolsey and Park shale members above and below (Shaw, 1957; Keefer and Van Lieu, 1966). However, Keefer and Van Lieu (1966) suggested that "beds of gray glauconitic flat-pebble limestone conglomerate, possibly equivalent to part of the Death Canyon Limestone Member, are present in the middle of the formation."

At the bottom of the Gros Ventre Formation, the Wolsey Shale Member consists mainly of soft, dark-green, fissile, slope-forming, glauconitic shale. The lower part tends to be sandy; this sandy component increases to the south until the entire unit grades into the thickened Flathead Sandstone. The Wolsey Shale is 175 to 200 feet (53 to 61 m) thick (Shaw, 1957).

Flathead Sandstone (Ꞓf) (Middle Cambrian)—The upper section of the Flathead Sandstone is composed of reddish-gray to reddish-brown, hard, ledge-forming, fine- to coarse-grained orthoquartzite that grades into interbedded fine-grained sandstone, siltstone, and shale (Hausel, 1991). The upper part is underlain by brownish to reddish-maroon, coarse- to medium-grained, cross-stratified sandstone containing minor amounts of arkose and shale. The lower section has a number of cements including quartz overgrowths, calcite, hematite, and limonite (Brocka, 2007). Basal beds commonly consist of shale, arkose, and conglomerate (Keefer and Van Lieu, 1966). Shaw (1957) noted the tendency for the Flathead Sandstone to both redden and thicken to the south and east of the Wind River Range. Thickness of the Flathead is 200 to 350 feet (61 to 110 m) (Keefer and Van Lieu, 1966).

Unconformity

PRECAMBRIAN UNITS

Proterozoic rocks

Diabase dikes (Yd)—Older Precambrian rocks are cut by dark-gray to black, fine- to medium-grained mafic dikes. These are laterally continuous and generally strike in a northeasterly direction. Dikes in the southwest corner of the map area have been dated at ~2,060 Ma (mega-annum or millions of years before present); thickness from 10 to 200 feet (3 to 60 m) (Hausel, 1991).

Archean rocks

Fine-grained quartz monzonite (Afq) (Archean?)—Gray, fine-grained, equigranular quartz monzonite, consists principally of biotite, quartz, microcline, and oligoclase.

Bears Ear Pluton—The Bears Ear Pluton was first named by Naylor and others (1970) and was dated at 2545±30 Ma by Stuckless and others (1985). The Bears Ear Pluton includes both the biotite quartz monzonite and porphyritic quartz monzonite of Pearson and others (1973). However, Pearson and others (1973) interpreted these rocks to be a late phase of the greater Louis Lake batholith. Pearson and others (1971) noted crosscutting relationships between the biotite and porphyritic quartz monzonite and its apparent intrusion into the quartz diorite of the Louis Lake batholith. Similarly, Naylor and others (1970) thought that the porphyritic quartz monzonite represented a separate pluton. Pearson and others (1971) alternatively referred to the biotite and porphyritic quartz monzonite phase as the Popo Agie batholith.

Biotite quartz monzonite of the Bears Ear Pluton (Aqm)— Biotite quartz monzonite of the Bears Ear Pluton forms irregular bodies of leucocratic rock that are texturally heterogeneous, ranging from pegmatite to alaskite to fine- and medium-grained biotite quartz monzonite that form anastomosing dikes and veins. Contacts around this unit are very generalized and illustrate areas where this rock type is particularly abundant relative to adjacent areas (Pearson and others, 1973). The biotite quartz monzonite is dated at 2,545±30 Ma (Stuckless and others, 1985).

Porphyritic quartz monzonite of the Bears Ear Pluton (Apq)—The Porphyritic quartz monzonite of the Bears Ear Pluton exhibits gradational contacts with the quartz diorite of the Louis Lake Batholith. Pearson and others (1973) suggested that the porphyritic quartz monzonite represents either a later portion of the Louis Lake Batholith or a separate event, i.e. the "Popo Agie Batholith" or "Bears Ear Pluton."

Quartz diorite of the Louis Lake Batholith (Aqd)— Quartz diorite of the Louis Lake Batholith is dated at 2,630±2 Ma (Frost and others, 1998) and intrudes the South Pass supracrustal sequence. It is dominated by massive, undeformed, gray, even-grained, weakly porphyritic biotite-hornblende quartz diorite. The batholith locally includes granodiorite (Pearson and others, 1973) and contains small, widely spaced disk-shaped clots of amphibolite (Hausel, 1988). Weak magmatic flow foliation is found locally within the Louis Lake Batholith (Frost and others, 2006). Penetrative high-temperature deformation, accompanied by near-vertical elongation lineations, occurs along the southern border of the batholith near South Pass (Schmitz and Snoke, 2005).

Miners Delight Formation—The Miners Delight Formation is composed of a group of diversified lithologies dominated by metagreywacke; it hosts numerous shear zones and epigenic vein gold deposits. The formation's age is approximately 2.8 Ga (giga-annum or billions of years before present), but relative ages of the subunits are unknown. [Note: the CORRELATION OF MAP UNITS on the map sheet is not intended to show age relationships]. The total thickness of the Miners Delight Formation has not been determined, but is greater than 5,000 feet (2,000 m) and possibly as much as 20,000 feet (6,000 m) (Hausel, 1991). The formation is subdivided into several mappable units based on dominant lithologies.

Metagreywacke (Amg)—Feldspathic and biotitic metagreywacke interbedded with mica schist; greywacke is fine-grained, bedded, proximal and distal turbidite with bedding-parallel foliation; rocks are only slightly metamorphosed.

Graphitic schist (Ams)—Black, iron-stained schist; commonly sheared; locally contains quartz stringers, veins, and gold mineralization.

Mafic amphibolite (Amo)—Black hornblendic amphibolite with fine- and medium-grained texture; includes metamorphosed gabbro dikes and sills and basalt flows; locally hosts auriferous shear zones.

Mixed member (Amm)—Mixed unit of fine-grained mafic metavolcanics, metagreywacke, tremolite-actinolite schist, and chlorite schist, with local interbeds of metaconglomerate.

Metachert (Amc)—Hard, banded, massive, dark-gray to black interlayered "cherty" metagreywacke, locally mylonitic to ultramylonitic in texture.

Metadacite (Amd)—Black metadacite porphyry flows and sills (?) with plagioclase phenocrysts (porphyroblasts) aligned in a trachytic texture.

Meta-andesite (Ama)—Ellipsoidal and nonellipsoidal meta-andesite flows.

Round Top Mountain Greenstone (Arm) (Archean)—The Round Top Mountain Greenstone is dominantly greenstone, greenschist and mafic-amphibolite. Ellipsoidal (pillow) metabasalt structures are preserved on Roundtop Mountain. The unit also includes lesser metagreywacke, metatuff, chlorite-schist, and actinolite-schist (Hausel, 1991; Bayley and others, 1973).

Goldman Meadows Formation (Agm)—The Goldman Meadows Formation consists of two members, iron formation and schist, that are combined in this map. The iron formation member consists of black to dark-gray, hard, dense and laminated alternating layers of magnetite and metachert with varying amounts of amphibole. The schist member principally consists of porphyroblastic pelitic schist, thin quartzites, and massive to schistose amphibolites (Hausel, 1991).

Diamond Springs Formation (Ads)—The Diamond Springs Formation is made up of green to gray to black, metabasalt, metagabbro, and serpentinite; it is dominated by serpentinite, tremolite-talc-chlorite schist, and mafic amphibolite (Hausel, 1991).

Gneissic granite and orthogneiss (Ago)— Gneissic granite and orthogneiss comprises fine- to coarse-grained, sometimes veined and banded, granodiorite, granite, and tonalite gneiss, orthogneiss, and red granite (Langstaff, 1994). The granitic gneiss and orthogneiss crops out in the Tin Cup Mountain area in the eastern part of the map.

Archean gneisses undifferentiated (Agu)—In the southern part of the Lander 1:100,000-scale quadrangle, undifferentiated gneiss is similar to the undifferentiated Archean granitic gneiss in the central Granite Mountains to the northeast. It is dominantly pink, varying to tan and gray, and is generally coarsely foliated and coarse-grained, varying locally to fine-grained migmatite, with some localized areas that are extremely contorted. The gneiss includes granitic gneiss accompanied by small amounts of amphibolite gneiss, biotite schist, chlorite schist, and sillimanite schist. The gneiss is cross-cut by aplite, pegmatite, mafic dikes, and small ultramafic intrusions.

Unnamed metasedimentary group (As)—An unnamed metasedimentary group crops out only in small area in the extreme south-central part of quadrangle.

Gneiss (Agn)—In the southwestern part of the map area, gneisses associated with the South Pass Greenstone Belt are mainly felsic gneiss and granitic migmatite interlayered with supracrustal rocks and intruded by granodiorite. This gneiss encloses concordant amphibolite, tonolite gneiss, and ultramafic enclaves, and exhibits common augen and migmatitic textures as described by Hausel (1991).

REFERENCES CITED AND SOURCES OF GEOLOGIC DATA

(Numbers refer to Figure 2, INDEX TO SOURCES OF GEOLOGIC MAPPING)
[Note: some * references are not cited specifically in this report, but were consulted.]

1. Abercrombie, S., 1989, Structural analysis of the Sheep Mountain - Beaver Creek thrust area, Fremont County, Wyoming: M.S. thesis, Baylor University, Waco, Texas, 71 p., plate 1 scale 1:24,000.

Agatston, R.S., 1957, Pennsylvanian of the Wind River Basin: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 29-33.

Ahlstrand, D.C., and Peterson, J.A., 1978, Permian carbonate facies, Wind River Basin, Wyoming: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 89-99.

Bauer, C.M., 1934, Wind River Basin [Wyoming]: Geological Society of America Bulletin, v. 45, no. 4, pt. 1, p. 665-696.

* Bayley, R.W., 1963, A preliminary report on the Precambrian iron deposits near Atlantic City, Wyoming: U.S. Geological Survey Bulletin 1142-C, p. C1-C23, plate 1 scale 1:6,000.

2. Bayley, R.W., 1965a, Geologic map of the Miners Delight Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-460, scale 1:24,000.

3. Bayley, R.W., 1965b, Geologic map of the Louis Lake Quadrangle, Fremont County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-461, scale 1:24,000.

Bayley, R.W., Proctor, P.D., and Condie, K.C., 1973, Geology of the South Pass area, Fremont County, Wyoming: U.S. Geological Survey Professional Paper 793, 39 p.

4. Bell, W.G., 1955, The geology of the southeastern flank of the Wind River Mountains, Fremont County, Wyoming: Ph.D. dissertation, University of Wyoming, Laramie, 204 p., map scale 1:96,000.

5. Brocka, C.G., 2007, Laramide stress conditions and deformation mechanisms during the formation of Derby and Dallas domes, Weiser Pass Quadrangle, Wind River Mountains, Wyoming: M.S. thesis, University of Missouri, Columbia, 174 p., plate 1 scale 1:24,000.

Burk, C.A., 1957, Stratigraphic summary of the nonmarine Upper Jurassic and Lower Cretaceous strata of Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 55-62.

Case J.C., Murray, W.B., and Piwoschuk, K.L., 1991, Preliminary map of landslides map on the Lander 1° x 2° Quadrangle, Wyoming: Wyoming State Geological Survey Open File Report (OFR) 91-2J, scale 1:250,000.

* Clements, J.W., 2008, Laramide stress conditions and deformation mechanisms during the formation of Hudson and Dallas Domes, Lander Quadrangle, Wind River Mountains, Lander, Wyoming: M.S. thesis, University of Missouri, Columbia, 120 p., map scale 1:24,000.

Cobban, W.A., 1957, Mowry and Frontier Formation in southern part of Wind River Basin, Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 67-70.

De Bruin, R.H., 2008, Oil and gas map of Wyoming: Wyoming State Geological Survey Map Series (MS) 53, scale 1:500,000, 1 sheet, color.

Frost, C.D., Frost B.R., Chamberlain, K.R., and Hulsebosch, T.P., 1998, The late Archean history of the Wyoming province as recorded by granitic magmatism in the Wind River Range, Wyoming: Precambrian Research, v. 89, p. 145-173.

Frost, C.D., Fruchey, B.L., Chamberlain, K.R., and Frost, B.R., 2006, Archean crustal growth by lateral accretion of juvenile supracrustal belts in the south-central Wyoming Province: Canadian Journal of Earth Sciences, v. 43, no.10, p.1533-1555.

Glass, G.B., and Roberts, J.T., 1978, Update on the Wind River Coal Basin: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 363-377.

Gower, M.A., 1978, Catalog of Paleozoic, Mesozoic and Cenozoic rock names for the Wind River Basin: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 39-45.

* Hares, C.J., 1946, Geologic map of the southern part of the Wind River basin and adjacent areas in central Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-60, scale 1:126,720.

Harris, R.E., 2004, Industrial minerals and construction materials map of Wyoming: Wyoming State Geological Survey Map Series (MS) 47, scale 1:500,000, 1 sheet, color.

Hausel, W.D., 1984, Tour guide to the geology and mining history of the South Pass gold mining district, Fremont County, Wyoming: Wyoming State Geological Survey Public Information Circular No. 23, map scale 1:24,000.

6. Hausel, W.D., 1988, Revised geologic map of the Louis Lake Quadrangle, Fremont County, Wyoming: Wyoming State Geological Survey Open File Report (OFR) 88-12, scale 1:24,000.

7. Hausel, W.D., 1991, Economic geology of the South Pass granite-greenstone belt, southern Wind River Range, western Wyoming: Wyoming State Geological Survey Report of Investigations 44, 129 p., plate 1 scale 1:48,000.

8. Hausel, W.D., 1992, Revised geologic map of the Miners Delight Quadrangle, Fremont County, Wyoming: Wyoming State Geological Survey Map Series (MS) 38, scale 1:24,000.

Hausel, W.D., 1998, Diamonds and mantle source rocks in the Wyoming craton, with a discussion of other U.S. occurrences: Wyoming State Geological Survey Report of Investigations 53, 93 p.

Hausel, W.D., and Sutherland, W.M., 2000, Gemstones and other unique minerals and rocks of Wyoming—A field guide for collectors: Wyoming State Geological Survey Bulletin 71, 268 p.

Hausel, W.D., and Sutherland, W.M., 2005, Geology of the Cedar Rim opal deposit, Granite Mountains, central Wyoming: Wyoming State Geological Survey Open File Report (OFR) 05-1, p. 11.

High, L.R., Jr., and Picard, M.D., 1969, Stratigraphic relations within upper Chugwater Group (Triassic), Wyoming: American Association of Petroleum Geologists Bulletin, v. 53, no. 5, p. 1091-1104.

Hogle, D.G., and Jones, R.W., 1991, Subsurface geology of Upper Cretaceous and lower Tertiary coal-bearing rocks, Wind River Basin, Wyoming: The Mountain Geologist, vol. 28, no. 2/3, p. 13-35. [Reprinted, 1992, as Wyoming State Geological Survey Reprint 53]

Johnson. J.F., and Sutherland, W.M., 2008, Preliminary geologic map of the Lander 30′ x 60′ Quadrangle, Fremont County, Wyoming: Wyoming State Geological Survey Open File Report (OFR) 08-2, scale 1:100,000.

Jones, N.R., Jones, R.W., Lucke, D.W., and Scott, J.E., 2009, Coal map of Wyoming: Wyoming State Geological Survey Map Series (MS) 92, scale 1:500,000, 1 sheet, color.

Keefer, W.R., 1965, Stratigraphy and geologic history of the uppermost Cretaceous, Paleocene, and lower Eocene rocks in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-A, 77 p.

9. Keefer, W.R., 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-D, p.D1-D35, 35 p., plate 1 scale 1:250,000.

Keefer, W.R., 1972, Frontier, Cody, and Mesaverde Formations in the Wind River and southern Bighorn Basin, Wyoming: U.S. Geological Survey Professional Paper 495-E, 23 p.

Keefer, W.R., and Rich, E.I., 1957, Stratigraphy of the Cody Shale and younger Cretaceous and Paleocene rocks in the western and southwestern parts of the Wind River Basin: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 71-78.

Keefer, W.R., and Van Lieu, J.A., 1966, Paleozoic formations in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-B, 60 p.

King, J.K., and Harris, R.E., 2002, Natural zeolites in Wyoming: Wyoming State Geological Survey Open File Report (OFR) 90-4.

Knapp, R.R., 1978, Depositional environments and diagenesis of the Nugget Sandstone: south-central Wyoming, northeast Utah, and northwest Colorado: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 131-138.

10. Langstaff, G.D., 1994, Geologic map of the Long Creek and Tin Cup Mountain area: Wyoming State Geological Survey Mineral Report (MR) MR 94-7, scale 1:24,000.

Love, J.D., 1957, Stratigraphy and correlation of Triassic rocks in central Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 39-45.

11. Love, J.D., 1970, Cenozoic geology of the Granite Mountains area, central Wyoming: U.S. Geological Survey, Professional Paper 495-C, 154 p., plate1 scale 1:126,300.

12. Love, J.D., Christiansen, A.C., and Jones, R.W., 1979, Preliminary geologic map of the Lander 1° x 2° Quadrangle, central Wyoming: U.S. Geological Survey Open-File Report 79-1301, scale 1:250,000.

13. McKay, E.J., 1948, Geology of Red Canyon Creek area, Fremont County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 68 p., map scale 1: 31,680.

Mullen, C., 1989, Dallas Field, *in* Wyoming oil and gas fields symposium: Bighorn and Wind River Basins: Wyoming Geological Association, p. 114-116.

Naylor, R.S., Steiger, R.H., and Wasserburg, G.J., 1970, U-Th-Pb and Rb-Sr systematics in 2,700 x 10^6 year old plutons: Geochimica Et Cosmochimia Acta, v. 34, p.1133-1159.

Paull, R.A., and Paull, R.K., 1993, Oil and gas and other resources of the Wind River Basin, Wyoming: Wyoming Geological Association Special Symposium, p. 31-47.

14. Pearson, R.C., Kiilsgaard, T.H., Patten, L.L., and Mattick, R.E., 1971, Mineral resources of the Popo Agie Primitive Area, Fremont and Sublette Counties, Wyoming: U.S. Geological Survey Bulletin 1353-B, 55 p., plate 1 scale 1:62,500.

15. Pearson, R.C., Patten, L.L., and Gaskill, D.L., 1973, Mineral resources of an area near the Popo Agie Primitive Area, Fremont County, Wyoming: U.S. Geological Survey Bulletin 1391-A, 18 p., plate 1 scale 1:63,360.

Peterson, J.A., 1957, Gypsum Spring and Sundance Formations, central Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 47-54.

Peterson, E.K., 1993, Wind River Indian Reservation coal resources, *in* Keefer, W.R., Metzger, W.J., and Godwin, L.H., editors, Oil and gas and other resources of the Wind River Basin, Wyoming: Wyoming Geological Association Special Symposium, p. 207-213.

Peterson, F., 1994, Sand dunes, sabkhas, streams, and shallow seas; Jurassic paleogeography in the southern part of the Western Interior basin, *in* Caputo, M.V., Peterson, J.A., and Franczyk, K.J., editors., Mesozoic systems of the Rocky Mountain region, U.S.A.: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 233-272.

Picard, D.M., 1978, Stratigraphy of Triassic rocks in west-central Wyoming: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 101-130.

Pipiringos, G.N., 1968, Correlation and nomenclature of some Triassic and Jurassic rocks in south-central Wyoming: U.S. Geological Survey Professional Paper 594-D, 26 p.

Rieke, H.H., 1981, Geologic overview, coal, and coalbed methane resources of the Wind River Basin, Wyoming: TRW Energy Engineering Division, McLean, Virginia, U.S. Department of Energy Contract No. DE-AC21-78MCO8089, 159 p.

16. Rohrer, W.L., 1973, Geologic map of the phosphate reserve in the Lander area, Fremont County, Wyoming: U.S. Geological Survey Mineral Investigations Field Studies Map MF-305, scale 1:24,000.

Ross, R.J., Jr., 1957, Origin of Ordovician units exposed near the Wind River basin: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 17-19.

Schmitz, P.J., and Snoke, A.W., 2005, Emplacement of the Late Archean Louis Lake batholith during regional contraction, southern Wind River Mountains, Wyoming: Geological Society of America Abstracts with Programs, v. 37, no. 6, p. 42.

Shaw, A.B., 1957, Cambrian of the southwestern Wind River Basin, Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 9-16.

Skipp, W.L., 1957, Stratigraphy of the Thermopolis Shale and the Muddy Sandstone in the southwestern Wind River Basin: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 63-65.

* Soister, P.E., 1968, Stratigraphy of the Wind River Formation in south-central Wind River Basin, Wyoming; U.S. Geological Survey Professional Paper 594-A, 50 p.

Stuckless, J.S., Hedge, C.E., Worl, R.G., Simmons, K.R., Nkomo, I.T., and Wenner, D.B., 1985, Isotopic studies on the late Archean plutonic rocks of the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 96, p. 850-860.

Sutherland, W.M., and Hausel, W.D., 2003, Geologic map of the Rattlesnake Hills 30' x 60' Quadrangle, Natrona and Fremont Counties, Wyoming: Wyoming State Geological Survey, Map Series (MS) 61, scale 1:100,000.

Sutherland W.M., and Hausel, W.D., 2006, Geologic map of the South Pass 30′ x 60′ Quadrangle, Fremont and Sweetwater and Counties, Wyoming: Wyoming State Geological Survey Map Series (MS) 70, scale 1:100,000, and 34 p. pamphlet.

17. Thompson, R.M., Troyer, M.L., White, V.L., and Pipiringos, G.N., 1950 (Reprinted 1957), Geology of the Lander area, central Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-112, scale 1:63,360.

18. Thompson, R.M., and White, V.L., 1951, Geologic map of the Conant Creek-Muskrat Creek Area, Fremont County, Wyoming: U.S. Geological Survey Open File Report, map scale 1:48,000.

19. Thompson, R.M., and White, V.L., 1954, Geology of the Riverton area, central Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-127, scale 1:63,360.

* Troyer, M.L., 1951, Geology of the Lander (Hudson) and Plunkett Anticline and vicinity, Fremont County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 60 p., map scale 1:31,680.

Van Houten, F.B., 1957, Tertiary rocks of southwestern Wind River Basin area, central Wyoming: Wyoming Geological Association guidebook, 12th Annual Field Conference, p. 79-88.

20. Van Houten, F.B., 1964, Tertiary geology of the Beaver Rim area, Fremont and Natrona Counties, Wyoming: U.S. Geological Survey Bulletin 1164, 99 p., plate 2 scale 1:62,500.

* Van Houten, F.B., and Weitz, J.L., 1956, Geologic map of the eastern Beaver Divide-Gas Hills area, Fremont and Natrona Counties, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-180, scale 1:63,360.

Wittke, S.J., 2008, Preliminary surficial geologic map of the Lander 30′ x 60′ Quadrangle, Fremont County, Wyoming: Wyoming State Geological Survey Open File Report (OFR) 08-3, scale 1:100,000.

Wittke, S.J., 2009, Surficial geologic map of the Lander 30′ x 60′ Quadrangle, Fremont County, Wyoming: Wyoming State Geological Survey Map Series (MS) 88, scale 1:100,000.

Wood, H.E., II, 1934, Revision of the Hyrachyidae: American Museum of Natural History Bulletin, v. 67, art. 5, p. 181-295.

21. Unknown author and date, unpublished geologic mapping of the Blue Gulch 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

22. Unknown author and date, unpublished geologic mapping of the Campbell Ridge 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

23. Unknown author and date, unpublished geologic mapping of the Lander 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

24. Unknown author and date, unpublished geologic mapping of the Lander NW 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

25. Unknown author and date, unpublished geologic mapping of the Lander SE 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

26. Unknown author and date, unpublished geologic mapping of the Ray Lake 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

27. Unknown author and date, unpublished geologic mapping of the Wind River 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

28. Unknown author and date, unpublished geologic mapping of part of the Wolf Point 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.

29. Unknown author and date, unpublished geologic mapping of the Yellowstone Ranch 7.5′ Quadrangle, Fremont County, Wyoming: U.S. Geological Survey file map.