Chapter 4

Geologic Setting

Martin C. Larsen

The Snake/Salt River Basin comprises approximately 5,500 square miles (16.80 million acres) in western Wyoming and extends into southeastern Idaho. In Wyoming, the Snake/Salt River Basin encompasses nearly all of Teton County and portions of Lincoln, Sublette, and Fremont counties. The basin is bounded by the Overthrust Belt to the west and south, the Green River Basin to the southeast, the Wind River Range to the east-southeast, the Bighorn Basin to the east, and the Yellowstone River Drainage to the north. Of all Wyoming basins, the Snake/Salt River Basin has the most complex geology. The geologic settings for this drainage encompass:

- The Overthrust Belt, which includes three major mountain chains (Salt River, Wyoming, and Snake River Ranges) related to the Sevier Orogeny;
- Two structural basins (Jackson Hole and Hoback) and three mountain ranges (Gros Ventre, Teton, and Absaroka) associated with the Laramide Orogeny;
- Range-front normal faulting and two structural basins associated with the Basin and Range Province; and
- The Yellowstone Plateau, and the Absaroka Volcanic province.

An extensive set of figures, maps and plates are included in this report to depict the basin's complex geologic settings. **Plate 1** illustrates the bedrock geology of the Snake/Salt River Basin in Wyoming and a small portion of southeastern Idaho overlain on a base map that shows highway, township, state and county data. Inset maps present the elevations of the Precambrian basement and lineaments. **Appendix A** contains detailed descriptions of the geologic units shown in **plate 1**. Six cross-sections, **figures 4-1** through **4-6**, show typical subsurface structure in the Snake/Salt River Basin. Isopach maps of the major aquifers in the Snake/Salt River Basin are unavailable.

4.1 General geologic history

The correlation between the major structural and lithologic elements significantly influences the availability of groundwater within the Snake/Salt River Basin. The geologic history relevant to Snake/Salt River Basin groundwater resources begins with the nonconformable deposition of transgressive marine sediments onto underlying Precambrian basement rocks. From that time forward, a general geologic history that describes the development of the stratigraphic, structural, and volcanic elements the Snake/Salt River Basin is as follows:

1. Paleozoic strata in the Snake/Salt River Basin were deposited in numerous marine and nonmarine environments related to periodic transgressive and regressive environments. Sandstone, shale, conglomerate, and limestone are the dominant lithologies, with less extensive dolomite. Deposition in the Paleozoic Era was broken by long periods of erosion, as indicated by several regional unconformities in the geologic record.

2. The Mesozic Era was a time of shallow seas with deposition of interbedded layers (in decreasing abundance) of sandstone, siltstone, shale, carbonates, and evaporites. An emergent transition to terrestrial environments during the Late Triassic and Early Jurassic epochs deposited marginal marine, eolian, fluvial, and paludal sandstone and shale.

3. Sevier and Laramide deformation affected the Southwest Cordillera between earliest Cretaceous and Early Eocene time (approximately 140 - 35 million years ago). The Sevier Orogeny is defined by "thin-skinned" deformation, characterized by shallow thrusts faults. Parallel north-south trending Sevier-aged faults in the Overthrust Belt are generally younger to the east. Laramide deformation was a period of intense folding and faulting with large-scale reverse and thrust faults and asymmetric folds. The "thick-skinned" deformation of the Laramide Orogeny included Precambrian basement-cored mountain ranges and uplifts that surrounded and partitioned the Snake/Salt River Basin structural basins. During

the Middle Eocene, massive eruptions related to the Absaroka Volcanic Province emplaced rhyolitic and basaltic volcanic material along the northern side of the Snake/Salt River Basin.

4. Late Tertiary Basin and Range normal faulting, coupled with volcanic activity from the Yellowstone hotspot, has overprinted many of the Sevier and Laramide geologic relationships. Uplift during the past five million years resulted in erosion of Tertiary strata, stripping the Laramide and Sevier structures, and shaping the present day landscape of the Snake/Salt River Basin. Tertiary-age rocks include volcanic deposits and an assortment of sedimentary units, including conglomerates, sandstone, limestone, and mudstone. Some of the Tertiary volcanics include andesitic flows, breccias, and porphyries that resemble breccias of the Yellowstone and the Absaroka volcanic regions.

5. The youngest units in the Snake/Salt River Basin are unconsolidated Quaternary alluvial, colluvial, lacustrine, and glacial deposits of varying thicknesses. These deposits, some several hundreds of feet thick, consist of interbedded mixtures of clay, silt, sand and gravel, landslide deposits, glacial deposits, and lacustrine sediments. Quaternary glacial deposits correlate to the advance and retreat of the Bear Lake and Pinedale glaciations (15,000 years before present).

4.2 Structural geology

The Snake/Salt River Basin encompasses three characteristic structural provinces: 1) the continental shelf deposits, which includes the Teton and Gros Ventre ranges; 2) west of the shelf zone, structurally deformed passive margin Paleozoic and Mesozoic units that include the Wyoming, Salt and Snake River ranges (i.e., the Overthrust Belt); and 3) the volcanism of the Yellowstone Plateau and Absaroka Province. The dominant structural features that form the backbone of the Teton and Gros Ventre ranges consist of basement core, broad, asymmetrical anticlines, northeast dipping thrust faults, and parallel folds. The initial stages of forming Teton and Gros Ventre structures were concurrent with the early phases of the Laramide deformation. These major structures controlled the character and trend of the later, Snake, and Salt River structures in Wyoming. The structural architecture of the Salt River, and Snake River Ranges are also the result of the Sevier "thin-skinned" deformation. The Overthrust Belt located in southwestern Wyoming and neighboring areas of Idaho and Utah, is a north-south trending, elongate fold and thrust belt that encompasses structurally deformed Paleozoic and Mesozoic units. The complex structural deformation in this region includes folding, imbricated thrust faults, and reverses faulting. During the Sevier Orogeny, thrust sheets were pushed eastward, resulting in the parallel thrust faults with the younger thrust belts to the east.

Beginning in the Tertiary and continuing to the present day, some Laramide and Sevier structural features have been overprinted or transected by north-south tending, high-angle normal faults due to Neogene Basin and Range extension. Normal faults are coincident with north-northwest tending folds and thrust fault bounded uplifts that define a complex set of half-grabens. Holocene-age displacement is apparent on some of the normal faults.

The topography of the Snake/Salt River Basin is reflected by major structural features that uplifted, folded, faulted, and eroded Precambrian basement and the Phanerozoic sedimentary and volcanic deposits. The insert map in **plate 1** is a structural contour map of the Precambrian basement surface in the Snake/Salt River Basin that shows a general northwest-southeast lineament trend. The geologic cross-sections on **figures 4-2** through **4-7** show Precambrian basement rocks overlain by varying thicknesses of Phanerozoic formations, all deformed by large-scale folding and faulting.

The major structural elements of the Snake/Salt River Basin (**fig. 4-1**) comprise:

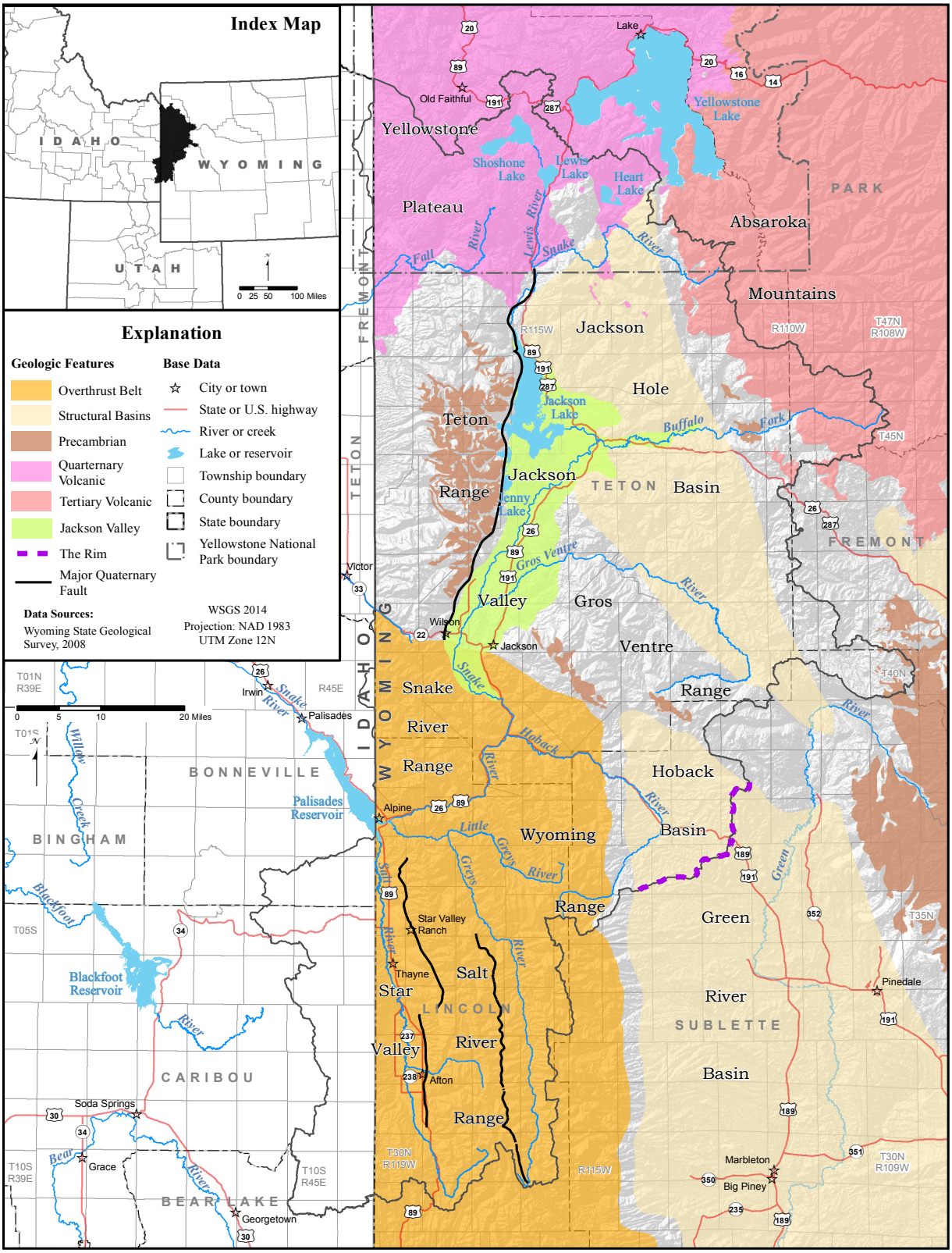
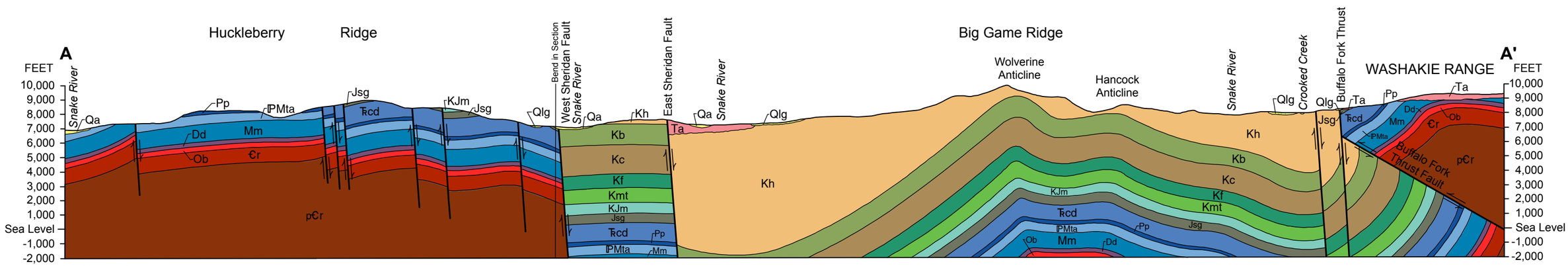


Figure 4-1. Geologic features, Snake/Salt River Basin.

Cross Section A - A'



No Vertical Exaggeration

Index Map and Line of Section

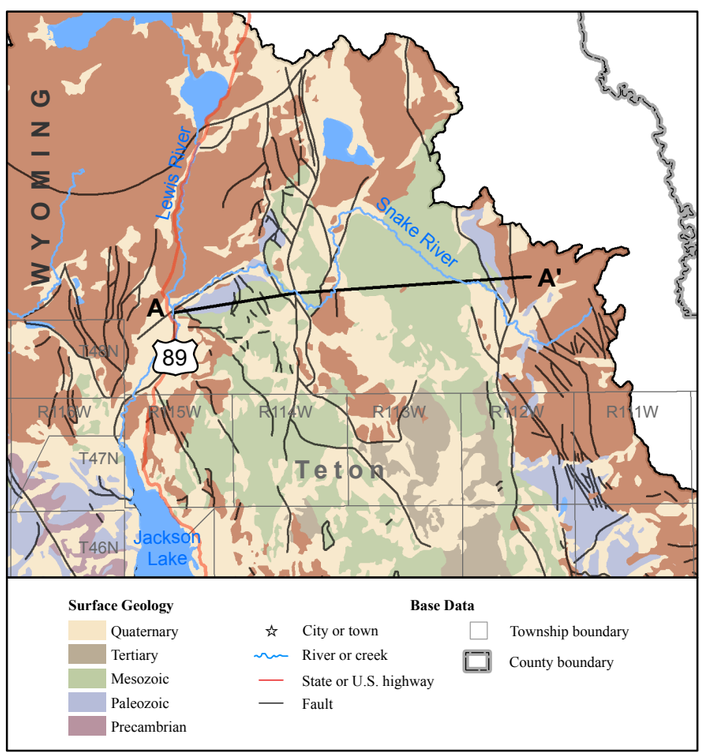


Figure 4-2. Geologic cross section A-A'.

Geologic Units

CENOZOIC

Quaternary

- Qa — Alluvium and terrace deposits
- Qlg — Landslide and glacial deposits

Tertiary

- Ta — Absaroka Volcanic Supergroup

MESOZOIC

Cretaceous

- Kh — Harebell Formation
- Kb — Bacon Ridge Sandstone
- Kc — Cody Shale
- Kf — Frontier Formation
- Kmt — Mowry and Thermopolis Shales

MESOZOIC (cont.)

Cretaceous-Jurassic

- KJm — Cloverly and Morrison Formations

Jurassic

- Jsg — Sundance and Gypsum Spring Formations

Triassic

- Ꞧcd — Chugwater and Dinwoody Formations

PALEOZOIC

Permian

- Pp — Phosphoria Formation

Pennsylvanian-Mississippian

- IPMta — Tensleep Sandstone and Amsden Formation

PALEOZOIC (cont.)

Mississippian

- Mm — Madison Limestone

Devonian

- Dd — Darby Formation

Ordovician

- Ob — Bighorn Dolomite

Cambrian

- Є̶r — Cambrian rocks

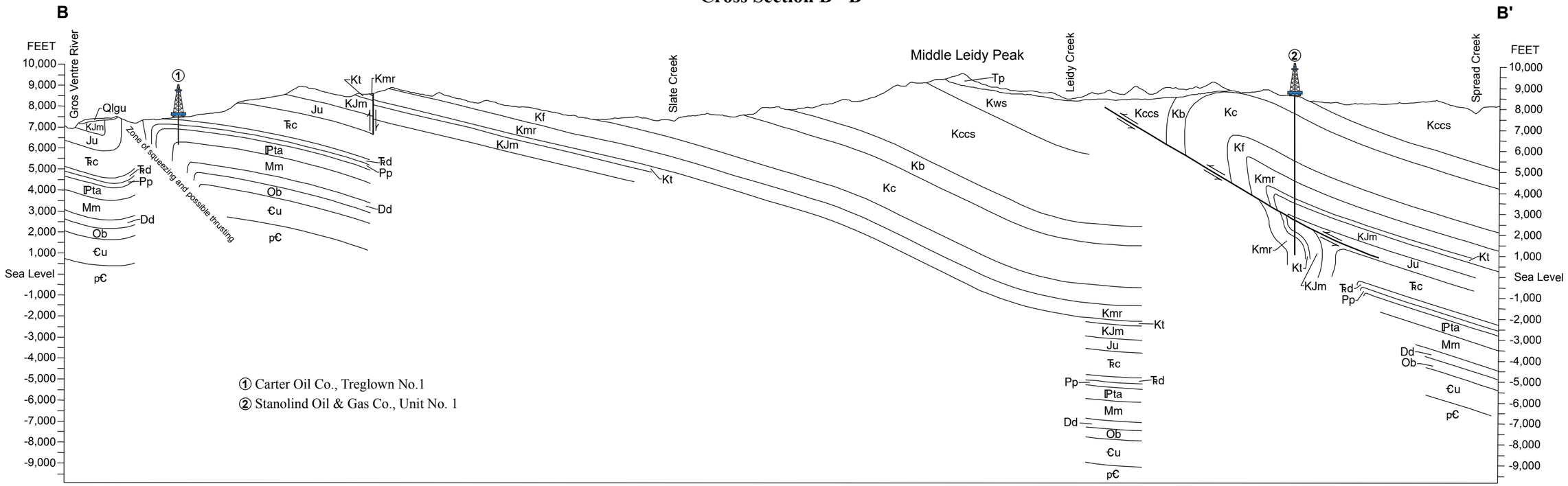
PRECAMBRIAN

- p̶Є̶r — Precambrian rocks

Fault

Love, J.D., and Keefer, W.R., 1975, Geology of sedimentary rocks in southern Yellowstone National Park, Wyoming: U.S. Geological Survey, Professional Paper 729-D, scale 1:62,500.

Cross Section B - B'



No Vertical Exaggeration

Index Map and Line of Section

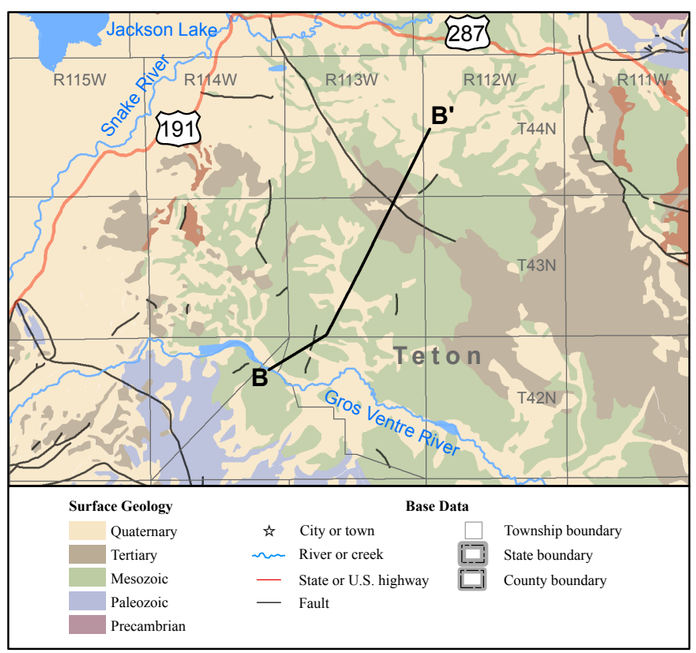


Figure 4-3. Geologic cross section B-B'.

Geologic Units

CENOZOIC

Quaternary

Qal – Alluvium

Qlsd – Landslide debris

Qlgu – Landslide and glacial debris

Tertiary

Tp – Pinyon Conglomerate and greenish-gray and brown sandstone and shale sequence undivided

MESOZOIC

Cretaceous

Kws – White sandstone sequence

Kccs – Lenticular sandstone and shale sequence and coaly sequence, undivided

Kb – Bacon Ridge Sandstone

Kc – Cody Shale

MESOZOIC (cont.)

Cretaceous (cont.)

Kf – Frontier Formation

Kmr – Mowry Shale

Kt – Thermopolis shale and Muddy sandstone

Cretaceous-Jurassic

KJm – Cloverly and Morrison Formations

Jurassic

Ju –Jurassic rocks undivided

Triassic

Ꞧc – Chugwater Formation

Ꞧd – Dinwoody Formation

PALEOZOIC

Permian

Pp – Phosphoria Formation

PALEOZOIC (cont.)

Pennsylvanian-Mississippian

IPta – Tensleep and Amsden Formations

Mississippian

Mm – Madison Limestone

Devonian

Dd – Darby Formation

Ordovician

Ob – Bighorn Dolomite

Cambrian

Ꞓu – Cambrian rocks undivided

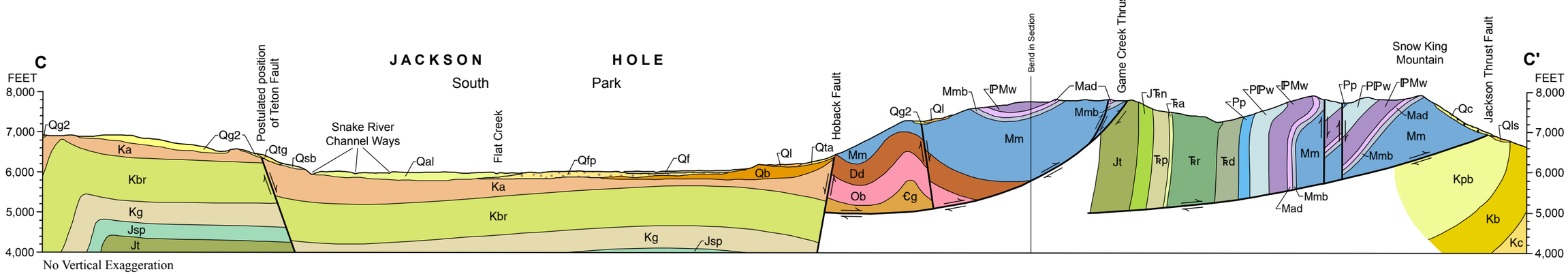
PRECAMBRIAN

p€ – Precambrian igneous and metamorphic rocks

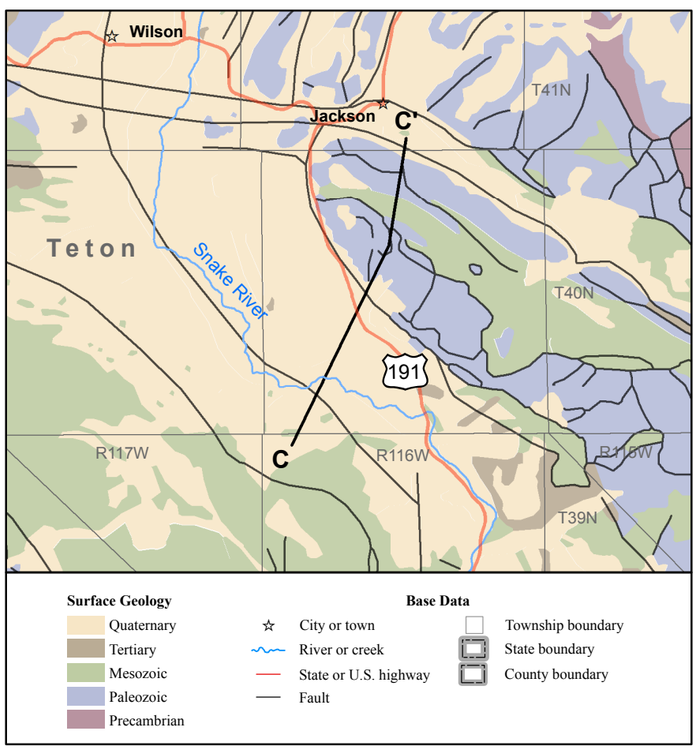
Fault

Love, J.D., Keefer, W.R., Duncan, D.C., Bergquist, H.R., and Hose, R.K., 1951, Geologic map of the Spread Creek-Gros Ventre River area, Teton County, Wyoming: U.S. Geological Survey, Oil and Gas Investigations Map OM-118, scale 1:48,000.

Cross Section C - C'



Index Map and Line of Section



Geologic Units

CENOZOIC

Quaternary

- Qal — Alluvium
- Qfp — Floodplain deposits
- Qtg — Terrace deposits undifferentiated
- Qc — Colluvium
- Qls — Landslide debris
- Qta — Talus
- Qf — Alluvial fan deposits
- Qsb — Slump block
- Ql — Loess
- Qg2 — Glacial deposits and related outwash gravels
- Qb — Lithified talus breccia

MESOZOIC

Cretaceous

- Kpb — Post-Bacon Ridge rocks
- Kb — Bacon Ridge Sandstone
- Kc — Cody Shale

MESOZOIC (cont.)

Cretaceous (cont.)

- Ka — Aspen Shale
- Kbr — Bear River Formation
- Kg — Gannett Group

Jurassic

- Jsp — Stump and Preuss Sandstones
- Jt — Twin Creek Limestone

Jurassic-Triassic

- JŦn — Nugget Sandstone

Triassic

- Ŧp — Popo Agie Member (Chugwater Formation)
- Ŧa — Alcova Limestone Member (Chugwater Formation)
- Ŧr — Red Peak Member (Chugwater Formation)
- Ŧd — Dinwoody Formation

PALEOZOIC

Permian

- Pp — Phosphoria Formation

PALEOZOIC (cont.)

Permian-Pennsylvanian

- PIPw — Wells Formation upper unit

Pennsylvanian-Mississippian

- IPMw — Wells Formation lower unit

Mississippian

- Mad — Darwin Sandstone Member (Amsden Formation)
- Mmb — Bull Ridge Member (Madison Limestone)
- Mm — Main body Madison Limestone

Devonian

- Dd — Darby Formation

Ordovician

- Ob — Bighorn Dolomite

Cambrian

- Ꞓg — Gallatin Limestone

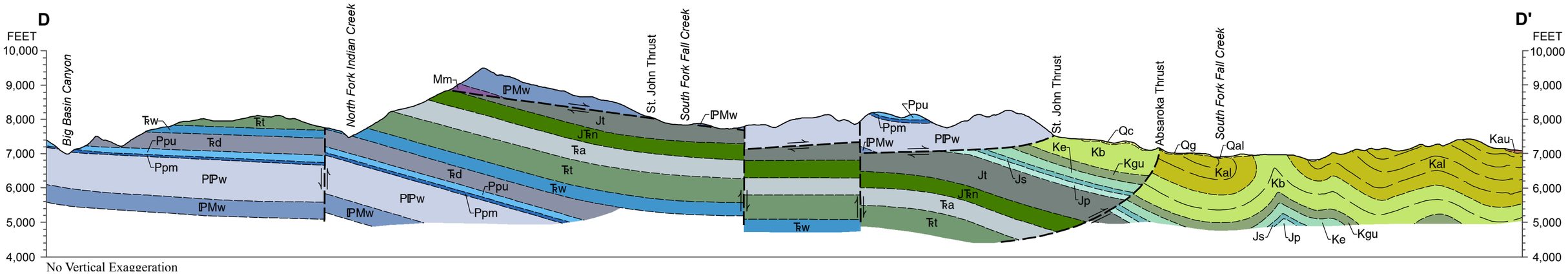
Fault

Figure 4-4. Geologic cross section C-C'.

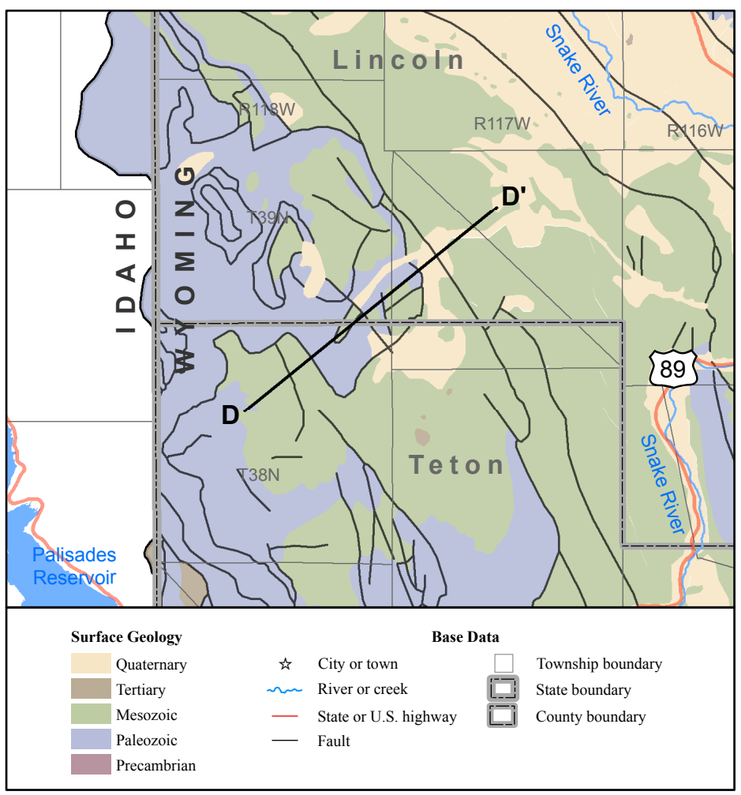
Love, J.D., and Albee, H.F., 1972, Geologic map of the Jackson quadrangle, Teton County, Wyoming: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-769-A, scale 1:24,000.

4-41

Cross Section D - D'



Index Map and Line of Section



Geologic Units

CENOZOIC

Quaternary

- Qal — Alluvium
- Qc — Colluvium
- Qg — Glacial deposits

MESOZOIC

Cretaceous

- Kau — Upper Aspen Formation
- Kal — Lower Aspen Formation
- Kb — Bear River Formation
- Kgu — Gannett Group
- Ke — Ephraim Conglomerate

MESOZOIC (cont.)

Jurassic

- Js — Stump Sandstone
- Jp — Preuss Formation
- Jt — Twin Creek Limestone

Jurassic-Triassic

- JŦn — Nugget Sandstone

Triassic

- Ŧa — Ankareh Formation
- Ŧt — Thaynes Formation
- Ŧw — Woodside Formation
- Ŧd — Dinwoody Formation

PALEOZOIC

Permian

- Ppu — Phosphoria Formation
- Ppm — Mead Peak Member (Phosphoria Formation)

Permian-Pennsylvanian

- PIPw — Upper Wells Formation

Pennsylvanian-Mississippian

- IPMw — Lower Wells Formation

Mississippian

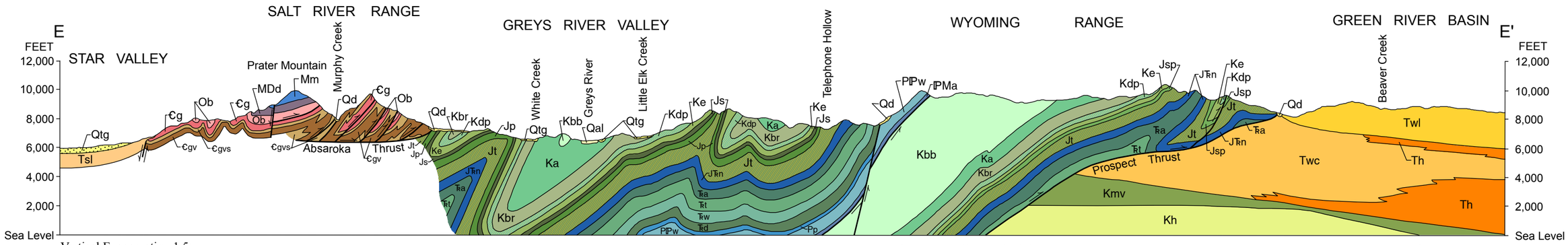
- Mm — Mission Canyon Limestone

Fault

Figure 4-5. Geologic cross section D-D'.

Love, J.D., and Keefer, W.R., 1975, Geology of sedimentary rocks in southern Yellowstone National Park, Wyoming: U.S. Geological Survey, Professional Paper 729-D, scale 1:62,500.

Cross Section E - E'



Vertical Exaggeration 1.5x

Love, J.D., and Keefer, W.R., 1975, Geology of sedimentary rocks in southern Yellowstone National Park, Wyoming: U.S. Geological Survey, Professional Paper 729-D, scale 1:62,500.

Index Map and Line of Section

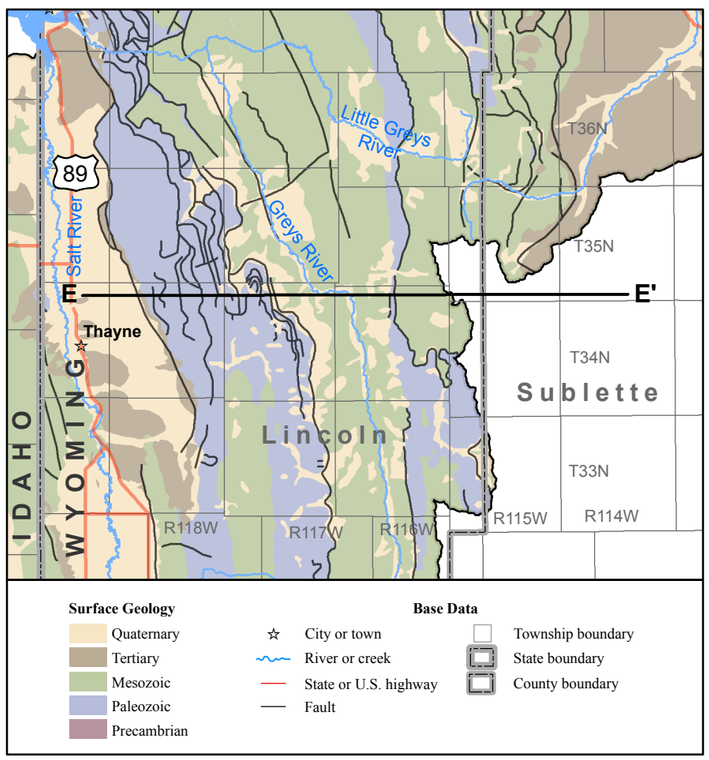


Figure 4-6. Geologic cross section E-E'.

Geologic Units

CENOZOIC

Quaternary

- Qal — Floodplain and alluvial fan deposits
- Qd — Rock debris and colluvium
- Qtg — Terrace gravels and older alluvium

Tertiary

- Tsl — Salt Lake Formation
- Twl — La Barge Member (Wasatch Formation)
- Twc — Chappo Member (Wasatch Formation)
- Th — Hoback Formation

MESOZOIC

Cretaceous

- Kbb — Blind Bull Formation
- Kmv — Mesaverde Sandstone
- Kh — Hillard Shale
- Ka — Aspen Formation
- Kbr — Bear River Formation

MESOZOIC (cont.)

Cretaceous (cont.)

- Kdp — Gannett Group from top to base of Peterson
- Ke — Ephraim Conglomerate

Jurassic

- Js — Stump Sandstone
- Jp — Preuss Redbeds
- Jsp — Stump Sandstone and Preuss Redbeds
- Jt — Twin Creek Limestone

Jurassic-Triassic

- JTRn — Nugget Sandstone

Triassic

- TRa — Ankareh Redbeds
- TRt — Thaynes Limestone
- TRw — Woodside Redbeds
- TRd — Dinwoody Formation

PALEOZOIC

Permian

- Pp — Phosphoria Formation

Permian-Pennsylvanian

- PIPw — Wells Formation

Pennsylvanian-Mississippian

- IPMa — Amsden Formation

Mississippian

- Mm — Madison Limestone

Mississippian-Devonian

- MDd — Darby Formation

Ordovician

- Ob — Bighorn Dolomite

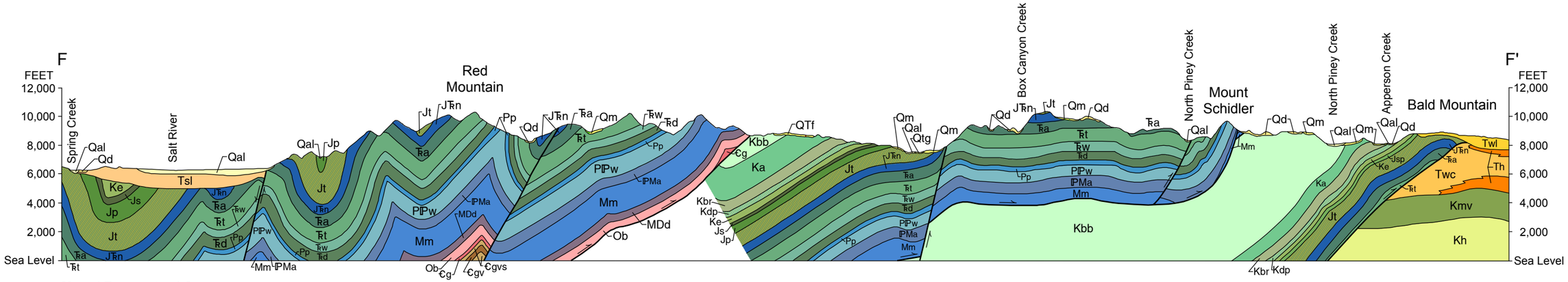
Cambrian

- Ꞓg — Gallatin Limestone
- Ꞓgvs — Gros Ventre Shale
- Ꞓgv — Gros Ventre Formation middle limestone member

Fault

4-43

Cross Section F - F'



Vertical Exaggeration 1.5x

Love, J.D., and Keefer, W.R., 1975, Geology of sedimentary rocks in southern Yellowstone National Park, Wyoming: U.S. Geological Survey, Professional Paper 729-D, scale 1:62,500.

Index Map and Line of Section

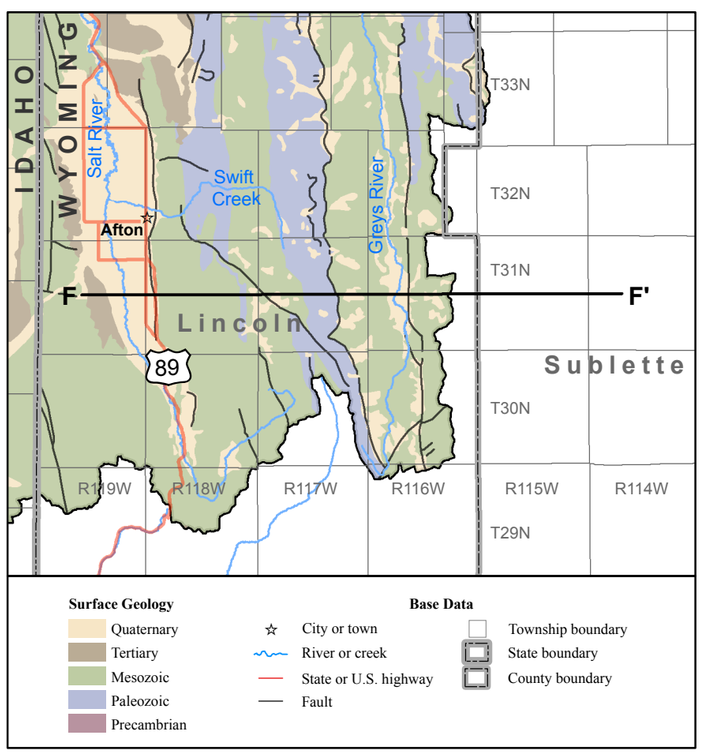


Figure 4-7. Geologic cross section F-F'.

Geologic Units

CENOZOIC

Quaternary

- Qal — Floodplain and alluvial fan deposits
- Qd — Rock debris and colluvium
- Qtg — Terrace gravels and older alluvium
- Qm — Glacial till and moraine

QUATERNARY-CENOZOIC

Quaternary-Tertiary

- QTf — Fanglomerate or till

CENOZOIC

Tertiary

- Tsl — Salt Lake Formation
- Twl — La Barge Member (Wasatch Formation)
- Twc — Chappo Member (Wasatch Formation)
- Th — Hoback Formation

MESOZOIC

Cretaceous

- Kbb — Blind Bull Formation
- Kmv — Mesaverde Sandstone

MESOZOIC (cont.)

Cretaceous (cont.)

- Kh — Hillard Shale
- Ka — Aspen Formation
- Kbr — Bear River Formation
- Kdp — Gannett Group from top to base of Peterson
- Ke — Ephraim Conglomerate

Jurassic

- Js — Stump Sandstone
- Jp — Preuss Redbeds
- Jsp — Stump Sandstone and Preuss Redbeds
- Jt — Twin Creek Limestone

Jurassic-Triassic

- JTRn — Nugget Sandstone

Triassic

- TRa — Ankareh Redbeds
- TRt — Thaynes Limestone
- TRw — Woodside Redbeds
- TRd — Dinwoody Formation

PALEOZOIC

Permian

- Pp — Phosphoria Formation

Permian-Pennsylvanian

- PIPw — Wells Formation

Pennsylvanian-Mississippian

- IPMa — Amsden Formation

Mississippian

- Mm — Madison Limestone

Mississippian-Devonian

- MDd — Darby Formation

Ordovician

- Ob — Bighorn Dolomite

Cambrian

- Ꞓg — Gallatin Limestone
- Ꞓgvs — Gros Ventre Shale
- Ꞓgv — Gros Ventre middle limestone member

Fault

4-44

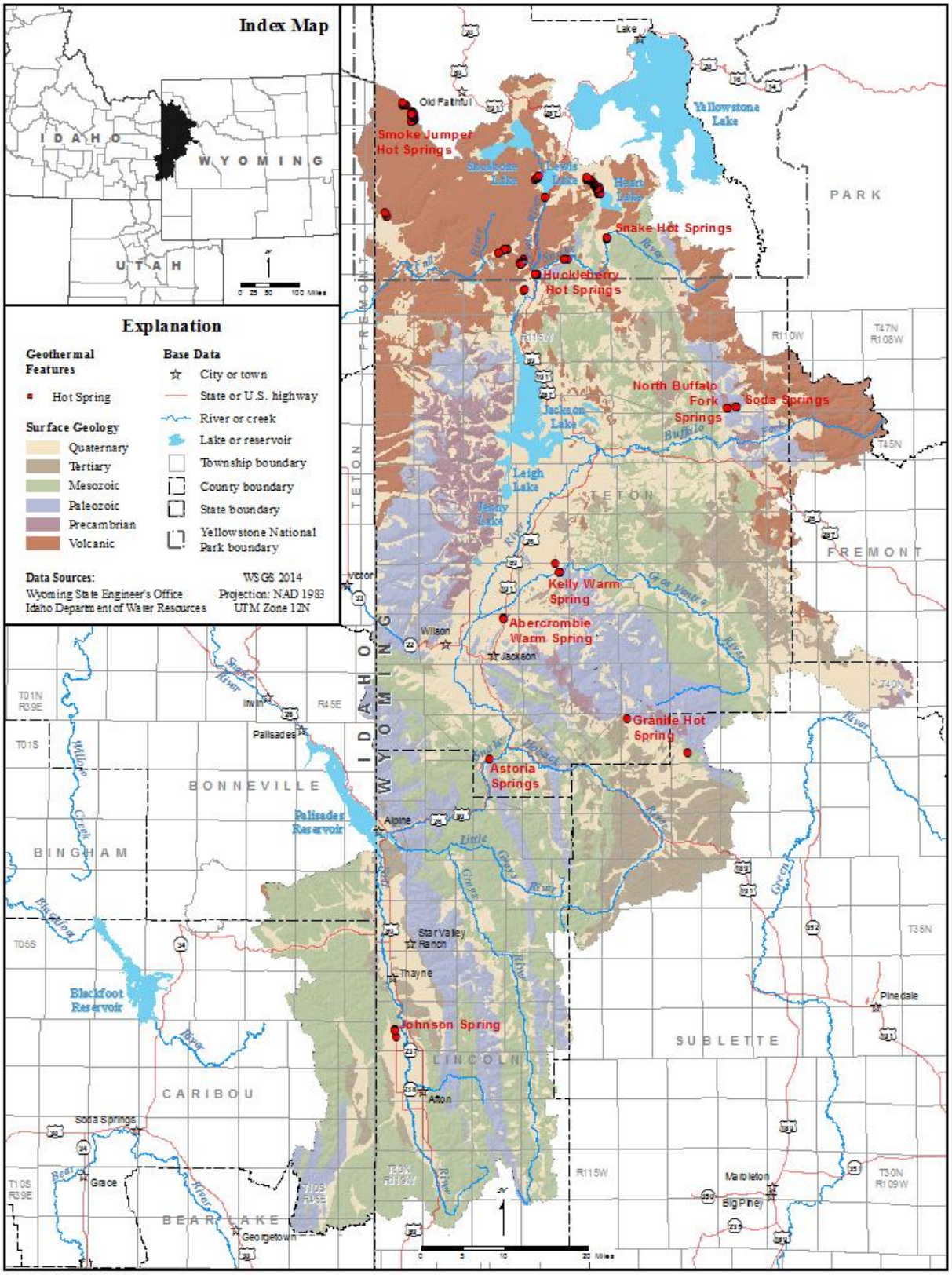


Figure 4-8. Geothermal features, Snake/Salt River Basin.

- Multiple phases of folding and faulting that involved Precambrian basement rocks.
- Folding and faulting of the Overthrust Belt during the Sevier Orogeny.
- Extension of the Basin and Range Province.
- Volcanism that created the Yellowstone Plateau and the Absaroka Range.
- Uplifted mountain ranges that surround and separate the basins, including the Gros Ventre, Teton, Wyoming, Salt River and Snake River mountains. Subsidence of structural basins including Jackson Hole, Hoback Basin, and Star Valley.

4.3 Geologic units in the Snake/Salt River Basin

Geologic units within the Snake/Salt River Basin vary widely in lithology and distribution, and range in age from Precambrian crystalline rocks to recent alluvial and terrace deposits. The legend on **plate 1** identifies the geologic units present in Snake/Salt River Basin; the individual geologic units are described in **appendix A**. The distribution of geologic units throughout the basin reflects several periods of deposition, uplift, faulting, folding, erosion, volcanism, and reworking/re-deposition of older units as younger units.

Precambrian basement rocks are exposed in the cores of the Tetons, Gros Ventre, and Absaroka mountains and are bounded by Paleozoic to Cenozoic sedimentary strata and volcanic material. The sedimentary succession of the Overthrust Belt, predominately the Wyoming, Salt, and Snake River ranges, can be divided into two main classifications: 1) a passive margin sequence ranging in age from Middle Cambrian to Late Jurassic that consists of carbonates and fine-grained clastic sedimentary strata, and 2) a clastic wedge ranging in age from Early Cretaceous to Late Tertiary strata comprised of marine and terrestrial clastic detritus. The passive margin deposits derived from successive transgressive-regressive sequences, and the clastic wedge resulted from material shedding off orogenic highlands to the west.

Volcanic material derived from the Absaroka Volcanic Province and Yellowstone hotspot that sculpted and formed the Absaroka Mountains and Yellowstone Plateau are composed primarily of basalt and rhyolite flows, tuffs, re-worked volcaniclastic material, and igneous intrusions.

Late Tertiary to Quaternary unconsolidated hydrogeologic units in the Snake/Salt River Basin include alluvial, fluvial, paludal, lacustrine and colluvial sediments; landslide deposits; glacial deposits; gravel pediment and fan deposits; and terrace gravels. The Quaternary-aged glacial deposits consist of poorly sorted clay, silt, sand, gravel. and boulders. Glacial deposits are present in the Overthrust Belt and Jackson Hole.

4.3.1 Teton Range (Smith, 1993)

The Teton Range, situated within the Middle Rocky Mountain physiographic province, is the youngest mountain range in the Rockies. The Neogene age Teton Range is superimposed over the northwest portion of the ancestral Gros Ventre Range. The Tetons are an upthrown, titled fault-block of Precambrian basement rocks and more than 5,000 feet of overlying Paleozoic sedimentary strata, including significant carbonates. The range has a vertical uplift of over 25,000 feet, inferred from the depth to basement, about 16,400 feet, underneath Jackson Hole. The Precambrian rocks exposed in the Teton Range consist predominantly of gneiss and schist, with intrusions of pegmatite granite. Exposures of metaconglomerates and metaquartzites also occur throughout the range.

The remarkable front of the Teton Range is a product of one of the most active normal faults in the Intermountain Seismic Belt (ISB) and the eastern extent of the Basin and Range Province. The Teton fault system originated as early as 5 to 13 million years ago and has been active ever since. Quaternary fault scarps, ranging from 9 to approximately 150 feet high, are exposed over 25 miles along the 33 mile length of the Teton fault. The youngest fault scarps offset Pinedale-age

(approximately 14,000 years) glacial deposits and younger alluvial and fluvial deposits.

4.3.2 Absaroka Mountains (Sundell, 1993)

The Absaroka Range is a remnant of thick volcanic and volcanic-derived accumulations erupted along a belt of andesitic stratovolcanoes. Today, the remaining deposits cover approximately 9,000 square miles in northwestern Wyoming and southwestern Montana. In the Snake/Salt River Basin, the Absaroka Range is bordered by the Bighorn Basin to the east, the Beartooth Mountains to the northeast, the Yellowstone Plateau to the north-northwest, and the Gros Ventre Range to the south. Volcanism occurred between 53 to 35 million years ago (53-35 Ma). Volcanic materials superimpose Phanerozoic sedimentary strata in the shallow foreland topographic and Laramide structural basin. The Absaroka Volcanic Province signifies the largest Eocene volcanic field in the Rocky Mountains. The Absaroka volcanic suite is composed of andesite, dacite, breccia, tuff, and re-worked volcaniclastic material (conglomerates, sandstone, siltstone, and claystone), with a maximum, combined thickness of more than 6,000 feet.

Deformation of the Absaroka volcanic rocks occurred as a result of Laramide folding and faulting, intrusive igneous activity, slope processes, and post-volcanic extension and compaction.

Some of the largest landslides ever known in Earth's history consisted of transported reworked volcanic material from the Absaroka Volcanic Province.

4.3.3 Gros Ventre Range (Horberg and others, 1949)

The Gros Ventre Range is a northwest trending, Laramide uplift that consists of a Precambrian-age basement core underlying a generally continuous Paleozoic, Mesozoic, and Tertiary sedimentary section. The range is situated just west of the Wind River Range and south of the Absaroka Mountains and is bounded to the southwest by the northwest-striking Cache Creek thrust fault, consisting of a broad asymmetrical anticline with a steep and locally faulted southwest limb (**fig. 4-1**). The western portion of the range is bounded by the Jackson Hole valley and is transected by Tertiary faults. Older structures extend to the north beneath Jackson Hole and into the Teton fault block. The range is subdivided into two asymmetric uplifts, or blocks of basement core, separated by the Granite Creek syncline: the eastern Shoal Creek block and the western Skyline Trail block. Maximum displacement occurred along the southwestern margin of the Gros Ventre Range where offset in Precambrian basement rocks indicates the greatest relative uplift.

4.3.4 Wyoming Range (Ross, 1960)

The Wyoming Range is bounded by the Hoback Basin to the east, the Green River Basin to the South, and the Gros Ventre Range to the north (**fig. 4-1**). The range is structurally bounded to west with the Salt River Range by the Absaroka Thrust sheet. Exposed shale, sandstone, conglomerate, and limestone units range in age from Middle Cambrian to Tertiary. The Wyoming Range encompasses the Darby thrust system, the easternmost and youngest thrust system of the Overthrust Belt. The primary structural features of the Darby Thrust system are the Darby, Prospect, Jackson, and Hogsback thrust faults. Sections of the Darby Thrust sheet have been overprinted by Basin and Range normal faults, predominantly, by the Hoback fault. The Hoback fault is a Mid-Tertiary high angle fault that is superimposed on previously folded and faulted Sevier structures. East of the Hoback fault, a series of imbricated thrust faults are structurally bounded by the Cache Creek thrust fault.

4.3.5 Salt River Range (Lageson, 1979)

The Salt River Range is the structural culmination of the Absaroka-St. Johns thrust complex and encompasses a complex array of imbricated thrust faults and asymmetric folds associated with/related to the Overthrust Belt system. The range is bounded by the Star Valley to the west, the Wyoming Range to the east-northeast and the Green River Basin to the east (**fig. 4-1**). The

Grand Valley fault bounds the range along the western margin where Tertiary-age units are offset against Mesozoic and Paleozoic strata. The Tertiary-age Grand Valley fault, a basin and range bounding normal fault, runs along the western margin of the Salt River Range and along the eastern margin of Star Valley forming an 85 mile long fault complex. Rock units within the Salt River Range vary from Middle Cambrian to upper Cretaceous and consisting of shale, sandstone, conglomerate, and limestones.

A parallel series of faults associated with the Absaroka thrust system are the primary structural features of this range. The Absaroka thrust system, part of the Overthrust Belt, is a 150 mile thrust sheet extending from the Snake River Plain in eastern Idaho to Salt Lake City, Utah. In the Salt River Range, the Absaroka Thrust sheet is considered to be a large-scale duplex structure bounded on the north and south by steep lateral ramps in large footwall imbricated thrusts.

4.3.6 Snake River Range (Horberg, 1949)

The Snake River Range is the northern continuation of the Wyoming and Salt River ranges and is the northern arc of the Overthrust Belt. The range is bounded by the Teton Range to the north, Gros Ventre Range to the east, and the Caribou Range, located in southeastern Idaho, to the southwest. The Snake River Range encompasses westward-dipping thrust faults and parallel folds. Although the Snake River Range includes nine, imbricate sheets of the Absaroka system, which form an overlapping array, the Absaroka, Poison Creek, and St. John thrust faults are the primary structural features of the range. The Absaroka thrust can be traced over the entire length of the Overthrust Belt. The St. John overrides the Absaroka at the north end of the complex in the Snake River Range. Rock units within the Overthrust Belt of the Snake River Range vary from Middle Cambrian to Late Tertiary. Middle Cambrian to Late Triassic age units consists of carbonates and fine grained clastics and Early Cretaceous to Late Tertiary strata comprises of marine and nonmarine clastic detritus.

4.3.7 Yellowstone Plateau (Smith, 1993)

The Yellowstone-Snake River Plain (YSRP), a 16 million-year old volcanic system that transects Nevada, Idaho, Montana, and Wyoming is one of the Earth's largest silicia-rich volcanic systems. The geology and hydrogeology is dominated by the Yellowstone hotspot. The Yellowstone-Snake River volcanic system in northwestern Wyoming is a large, silicic, Pleistocene-age volcanic field distinguished by three large calderas with a total eruptive volume of about 2,050 cubic miles. The Yellowstone Plateau, a relatively flat landscape with low, rolling mountains, accumulated from this volcanic material, rises approximately 8,200 feet high above mean sea level. The volcanic rocks from the Yellowstone area range in age from 0.6 to 16 million years old, with the oldest rocks outcropping in southwestern Idaho and northern Nevada. The Yellowstone-Snake River volcanic material within the Snake/Salt River Basin consists predominantly of rhyolite with scattered basalt flows and minor igneous intrusions.

4.3.8 Hoback Basin (Spearing, 1969)

During the early Tertiary, western Wyoming's overthrust region experienced numerous stages of uplift supplemented by synorogenic deposition of thick sediments into subsiding intermontane basins. The Hoback structural basin is a prime example of one of these sinking basins and the Hoback Formation, confined within the basin, exhibits one of these thick, early Tertiary deposits. The Hoback Basin covers approximately 315 square miles and is bounded by the Wyoming Range to the west, the Gros Ventre Range to the north north-east, and the Rim to the south (**fig. 4-1**). The Rim is a drainage divide at the northern boundary of the Green River Basin. The Hoback Formation ranges in age from Middle Paleocene to early Eocene. Structurally bounded along

the western portion of the basin, the Hoback Formation is overridden by the Jackson-Prospect thrust sheet along the Prospect fault and is folded along the Little Granite-Monument Ridge anticline. Along the western margin of the basin, the Hoback Formation has a moderate eastward dip of 40 degrees that decreases to 10 degrees at the eastern margin. On the eastern side of the basin, the units are structurally truncated by the Cache Creek Thrust fault and a small syncline along the southwestern flanks of the Gros Ventre Range. The Cache Creek thrust fault plane dips northeast, and its asymmetrical trace indicates a relativity low dip angle. The units dip towards the southwest along strike with the Cache Creek Thrust fault.
The Hoback Formation is characterized by three, major environments of deposition: thick sandstone facies; conglomerate facies; and thin, interbedded sandstone, shale, and limestone facies. The formation is wedge-shaped with the maximum basin subsidence and sedimentary axis located in the central and northern portions of the Hoback Basin. The formation is thickest (~16,000 feet) in the center of the basin and thins southward to approximately 2,500 feet where the southern boundary of the Hoback Basin meets the north end of the Green River Basin.

4.3.9 Jackson Hole (Smith, 1993)

Jackson Hole, a 44 mile long Laramide structural basin, occupies the hanging wall of the Teton fault and is covered by asymmetric, west dipping, Tertiary-Quaternary basin-fill stratigraphy. The valley is bounded by the Teton Range to the west and the Gros Ventre Range to the east (**fig. 4-1**). The Quaternary deposits in the valley consist of fluvial, alluvial, glacial, and volcaniclastic facies and are underlain by Tertiary fluvial, lacustrine, and volcaniclastic deposits. The glacial deposits in the valley provide evidence for two periods of Pleistocene glaciation known as the Bull Lake (100 to 150 thousand years ago) and the Pinedale (14 to 30 thousand years ago) periods. Several bedrock buttes, containing Paleozoic rocks, are exposed in the central and southern parts of the valley. Paleozoic units are also exposed on the eastern flank of the Teton Range.

4.3.10 Star Valley (Walker, 1965)

Star Valley consists of two half-grabens that resulted from extensional processes along the Grand Valley fault system during the Neogene. The valley is bounded by the Salt River Range to the east and the Gannett Hills in Idaho to the west. Sedimentary strata exposed along the front of the Salt River Range and Gannett Hills consist of Mesozoic age conglomerate, sandstone, limestone, and shale. Paleozoic limestone outcrops in a small butte located in the northern part of the valley. The elevation of the valley floor ranges from 6,000-7,000 feet and contains moderate slopes on the alluvial fans derived from the Salt River Range and Gannett Hills. The alluvial fans on the east side are steeper at their heads than the alluvial fans on the west side of the valley, indicating that the east side of the valley is remains structurally active along normal faults associated with the Grand Valley fault system.

Star Valley is divided into two basins because of the difference in sediment type and Quaternary displacement rates on different segments of the Grand Valley fault system. In the northern section of the valley, the Salt River Range front, geomorphic relations indicate a lower rate displacement along the Grand Valley fault than along the southern segment. The valley floor sediments in the northern section include older (early to late Pleistocene) alluvial fans and extensive Tertiary outcrops. In contrast, the southern section of the valley encompasses numerous fault scarps separating younger valley sediments from deformed Mesozoic and Paleozoic strata in the Salt River Range. Additionally, steep walled canyons, apparent range-front triangular facet spurs, and young, faulted range front alluvial fans indicate rapid basin subsidence. Pleistocene-age deposits in Star Valley consist of sand and gravel, which are the principal aquifers in the valley.

4.4 Geothermal resources

The geothermal resources of the Snake/Salt River Basin occur where groundwater exists at anomalously elevated temperatures relative to the average geothermal gradient. The hydrothermal

occurrences within the Snake/Salt River Basin are typically found at a depth that prohibits their beneficial use. Hydrothermal resources within the Snake/Salt River Basin are primarily suited to local, small-scale projects that utilize low-temperature waters for space-heating, de-icing, and recreational/therapeutic applications (e.g., Granite Hot Springs).

Generally, groundwater heats as it flows downdip into a structural basin in accord with the local geothermal gradient. Snake/Salt River Basin hydrothermal resources occur primarily where heated groundwater rises under artesian hydraulic pressures at velocities that preclude dissipation of the heat acquired at depth. This requires vigorous upward flow through permeable, up-folded strata or along faults, fracture systems, or wells. In general, the conditions that control hydrothermal resources occur only within the more productive Mesozoic and Paleozoic aquifers in the Snake/Salt River Basin. The locations of known and potential areas of hydrothermal resource development are shown on **figure 4-1**.

4.5 Mineral resources

Figures 5-4, **5-7**, **5-8**, and **5-9** show the distribution of petroleum operations and other active and historic mineral development locations within the Snake/Salt River Basin (**section 5.7.2**). Mineral development operations require the use of groundwater and may create potential avenues for groundwater contamination. Even in areas without mineral development, the presence of some naturally occurring minerals, such as those containing uranium, arsenic, and hydrocarbons, can, at significant concentrations, negatively impact groundwater quality.

Significant quantities of oil and gas have never been developed in the Snake/Salt River Basin.

Figure 5-7 shows abandoned coal, metal, uranium, phosphate, and sand and gravel mines in the Snake/Salt River Basin. Mapped coal, sand, and gravel mines are predominantly historic pit mines. A single, historic phosphate mine is located near Afton and a single uranium mine is located in the Absaroka Mountains near the Gros Ventre River. A historical metal mine is sited on the western flanks of the northern Teton Range. Currently, there is no active coal mining in the Snake/Salt River Basin. Sand, gravel, and limestone have been extensively mined within the Snake/Salt River Basin, and still are produced in some localities (**figs. 5-7** through **5-9**).