THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

A GEOLOGIC TOUR OF WYOMING FROM LARAMIE TO LANDER, JACKSON AND ROCK SPRINGS

by
Brainerd Mears, Jr., William P. Eckerle, Douglas R. Gilmer, Timothy L. Gubbels, Gary A. Huckleberry, Hollis J. Marriott, Kenneth J. Schmidt and Lyndon A. Yose

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Front Cover: Boars Tusk, the neck of a 1.2 million-year old volcano, dramatically exposed by erosion. This feature is composed of wyomingite, a rare high-potassium volcanic rock. The Boar's Tusk, north of Rock Springs, is one of many spectacular geologic features visited on this tour of Wyoming. (Photograph by Brainerd Mears, Jr.)

Back Cover: (Above) false-color Landsat mosaic of Wyoming from 570 miles high. (Compiled by U.S. Department of Agriculture Aerial Photography Field Office; color separations courtesy of Department of Geology and Geophysics, University of Wyoming, Laramie.) (Below) map showing locations of other guides to Wyoming geology available from the Geological Survey of Wyoming.

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Era	Period	Epoch	WIND RIVER RANGE AND BASIN	TETON, GROS VENTRE, ABSAROKA AND WASHAKIE MOUNTAINS	GREEN RIVER BASIN: NORTH AND WEST	GREEN RIVER BASIN: EAST AND SOUTH	RAWLINS UPLIFT AND GREAT DIVIDE BASIN	LARAMIE AND HANNA BASINS
CENOZOIC	QUATERNARY		Pleistocene and Holocene alluvium, colluvium, mass-movement deposits, glacial deposits, lake beds, eolian deposits, some volcanics					
CENOZOIC	TERTIARY	Pliocene		Pliocene rocks including Huckleberry Ridge Tuff				
CENOZOIC	TERTIARY	Miocene	Miocene rocks	Miocene rocks including volcanics and Camp Davis Formation	Miocene rocks	Browns Park Formation	Browns Park Formation and other Miocene rocks	Miocene rocks
CENOZOIC	TERTIARY	Oligocene	White River Formation	White River Formation	Conglomerate	Bishop Conglomerate	Bishop Conglomerate and White River Formation	White River Formation
CENOZOIC	TERTIARY	Eocene	Eocene rocks including Aycross, Tepee Trail and Wagon Bed Formations Wind River Formation Indian Meadows Formation	Aycross, Tepee Trail and Wagon Bed Formations; Absaroka Volcanic Supergroup variegated sequence	Bridger Formation Green River Formation Congl; Pass Peak Formation; Wasatch Formation	Bridger Formation Green River Formation Wasatch Formation	Bridger Formation; Wagon Bed Fm Green River Formation Wasatch Formation	Wagon Bed Formation Wind River Formation
CENOZOIC	TERTIARY	Paleocene	Fort Union Formation	Pinyon Conglomerate	Hoback Formation	Fort Union Formation	Fort Union Formation	Hanna Formation Ferris Formation
MESOZOIC	CRETACEOUS	Upper	Lance Formation Meeteetse Formation; Lewis Shale Mesaverde Formation Cody Shale: Steele Shale, Niobrara Formation Frontier Formation	Harebell Formation Meeteetse Formation Mesaverde Formation Sohare sequence Bacon Ridge Sandstone Cody Shale Frontier Formation	Adaville Formation Hilliard or Baxter Shale Frontier Formation	Lance Formation Fox Hills Sandstone Lewis Shale Mesaverde Group or Formation Baxter Shale Frontier Formation	Lance Formation Fox Hills Sandstone Lewis Shale Mesaverde Group or Formation Cody Shale: Steele Shale, Niobrara Formation Frontier Formation	Medicine Bow Formation Fox Hills Sandstone Lewis Shale Mesaverde Group or Formation Steele Shale Niobrara Formation Frontier Formation
MESOZOIC	CRETACEOUS	Lower	Mowry Shale Thermopolis Shale Cloverly Formation	Mowry Shale Thermopolis Shale Cloverly Formation	Aspen Shale Bear River Formation Gannett Group	Mowry Shale Thermopolis Shale Undivided	Mowry Shale Thermopolis Shale Cloverly Formation	Mowry Shale Thermopolis Shale Cloverly Formation
MESOZOIC	JURASSIC	Upper	Morrison Formation Sundance Formation	Morrison Formation Sundance Formation	Stump Sandstone Preuss Sandstone	Curtis Formation Entrado Sandstone	Morrison Formation Sundance Formation	Morrison Formation Sundance Formation
MESOZOIC	JURASSIC	Middle	Gypsum Spring Formation	Gypsum Spring Formation	Twin Creek Limestone Gypsum Spring Fm	Carmel Formation		
MESOZOIC	JURASSIC	Lower	Nugget Sandstone	Nugget Sandstone	Nugget Sandstone	Nugget Sandstone	Nugget Sandstone	
MESOZOIC	TRIASSIC		Chugwater Formation: Popo Agie Member, Crow Mountain Sandstone, Alcova Limestone, Red Peak Member Dinwoody Formation	Chugwater Formation: Popo Agie Member, Crow Mountain Sandstone, Alcova Limestone, Red Peak Member Dinwoody Formation	Ankareh Formation Thaynes Limestone Woodside Formation Dinwoody Formation	Ankareh Formation Thaynes Limestone Woodside Formation Dinwoody Formation	Chugwater Formation: Popo Agie Member, Crow Mountain Sandstone, Alcova Limestone, Red Peak Member Goose Egg Formation	Jelm Formation Chugwater Formation (part) Goose Egg Formation
PALEOZOIC	PERMIAN		Phosphoria Formation; Goose Egg Formation	Phosphoria Formation	Phosphoria Formation	Phosphoria Formation	Goose Egg Formation	Goose Egg Formation: Forelle Limestone, Satanka Shale Casper Formation
PALEOZOIC	PENNSYLVANIAN		Tensleep Sandstone Amsden Formation	Tensleep Sandstone Amsden Formation	Tensleep Sandstone Amsden Formation	Weber Sandstone Amsden Formation	Tensleep Sandstone Amsden Formation	Casper Formation Fountain Formation
PALEOZOIC	MISSISSIPPIAN		Madison Limestone	Madison Limestone	Madison Limestone	Madison Limestone	Madison Limestone	Madison Limestone
PALEOZOIC	DEVONIAN		Darby Formation	Darby Formation	Darby Formation	Darby Formation		
PALEOZOIC	SILURIAN							
PALEOZOIC	ORDOVICIAN		Bighorn Dolomite	Bighorn Dolomite	Bighorn Dolomite	Bighorn Dolomite		
PALEOZOIC	CAMBRIAN	Upper	Gallatin Limestone	Gallatin Limestone	Gallatin Limestone	Gallatin Limestone	Cambrian rocks	
PALEOZOIC	CAMBRIAN	Middle	Gros Ventre Formation Flathead Sandstone	Gros Ventre Formation Flathead Sandstone	Gros Ventre Formation Flathead Sandstone	Gros Ventre Formation Flathead Sandstone	Cambrian rocks Flathead Sandstone	
PALEOZOIC	CAMBRIAN	Lower						
PRECAMBRIAN			Igneous and metamorphic rocks					

Modified from Love and Christiansen (1980) and Stratigraphic Nomenclature Committee, Wyoming Geological Association (1969).

Introduction

Welcome to Wyoming. The name, derived from a Delaware Indian word, is roughly translated, *at the big plains* or *land between the mountains*. Our tour route (like the Oregon Trail, Union Pacific Railroad and U.S. Interstate 80) traverses the heart of the State, the Wyoming basin province, with views of, and some penetrations into, the encircling mountains.

The style of this guide to Wyoming geology lies between very detailed geologic road logs (*at 7.6 miles, outcrop of Frontier Formation behind sagebrush to the left*) and very generalized descriptions for non-geologists (*the surrounding hills are granite, a rock that crystallized from molten material in the bowels of the Earth*). The intended audience is broad, ranging from laymen familiar with elementary geologic concepts to professional geologists. For this and other geologic excursions in the State we recommend the *Geologic map of Wyoming* (scale 1:500,000) (Love and Christiansen, 1985) and the *Wyoming geologic highway map* (scale 1:1,000,000) (Christiansen, 1986). In the interest of readability, the authors have not attempted to cite references in every case. Cited references and additional reference materials are listed at the end of this guide.

The tour is divided into segments, and maps showing the routes of those segments are gathered together in the center of the book (p. 25 through 29). Facing this page is a compilation of stratigraphic columns for the areas visited on the tour. (Many but not all of the units shown will be observed during the tour. Some are in the general area traveled, but off the route, and others are not exposed at the surface in some areas.)

A brief summary of Wyoming's geologic history, with emphasis on Quaternary events, precedes the tour descriptions, and each trip segment is introduced by a general statement. The compilation is a cooperative effort by members of the 1984 University of Wyoming geomorphology seminar. It was based on a three-day field trip conducted by Brainerd Mears, Jr. that featured a tour of Jackson Hole led by J. David Love.

Synopsis of Wyoming's geologic history

Brainerd Mears, Jr.

Precambrian

The earliest and longest record of Wyoming's geological history is preserved in complex metamorphic and igneous Precambrian rocks, which have been radiometrically dated from about 1.4 billion years old to more than 3.2 billion years old. After a long and complicated history, these rocks of the *basement complex* were planated to a surface of low relief, across which Paleozoic and Mesozoic rocks were deposited. Today, Precambrian rocks are found in the uplifted cores of many mountain ranges in Wyoming, where they have been exposed by prolonged Cenozoic erosion.

Paleozoic and Mesozoic

Throughout its Paleozoic and most of its Mesozoic history, the Wyoming region was part of the relatively stable continental platform (or craton) that lay east of the broad, subsiding Cordilleran geosyncline. As stratigraphers tell us, *the seas came in and the seas went out* across the region, depositing a generally westward-thickening sequence of marine and nonmarine rocks.

By Late Cretaceous time, the Sevier orogeny, which had commenced far to the west in the geosyncline, had migrated eastward to westernmost Wyoming. In this style of mountain building, the geosynclinal rocks were folded and displaced eastward along low-angle thrust faults, creating great imbricate slabs **(Figure 1A)**. Toward the continental interior, thick deposits of sediments, eroded from the mountains, were deposited on the gently subsiding platform to form a broad piedmont plain, mantled by peat-forming (coal) swamps and forests grading to a shoreline of shifting seas.

Latest Cretaceous through Tertiary

For interpretations in the following summary of Wyoming's geologic and paleogeographic history from latest Mesozoic through Tertiary time, I am indebted to D.L. Blackstone, Jr., J.D. Love and the late S.H. Knight.

The State's existing pattern of mountains and broad basins began to develop in latest Cretaceous time, during the initial phases of the Laramide orogeny **(Figure 1B)**. The continental platform in Wyoming east of the thrust belt was strongly deformed by the rise of broad anticlinal mountains riding up along reverse faults, some of which may have reached the base of the Earth's crust at the Mohorovicic Discontinuity (Moho). The structural uplift of the mountains may have been 20,000 feet above sea level, but the mountains probably never reached such heights because they were eroded as they rose. Erosion stripped off the sedimentary rock cover, exposing the Precambrian crystalline cores. The resultant debris was shed into broad basins, whose subsidence below sea level may have equaled the upward displacement of the mountains.

During Eocene time, the basins filled with sediments and the crystalline rocks of the mountains were partially planated. A surface of low relief graded from the mountains across the basin floors **(Figure 1C)**. In late Eocene time, streams rejuvenated, excavating soft rocks in the basins and establishing a topography that in many ways resembled the present **(Figure 1D)**.

During most of the Eocene, the region was near sea level and evidence from vertebrate paleontology and paleobotany indicates that the climate was tropical to subtropical. Palms, fig trees, cypress and magnolias grew in Wyoming and primitive mammals flourished. To the west, flamingos and crocodiles occupied the broad lake in which Eocene Green River Formation sediments were deposited. This ancient lake is referred to as Lake Gosiute.

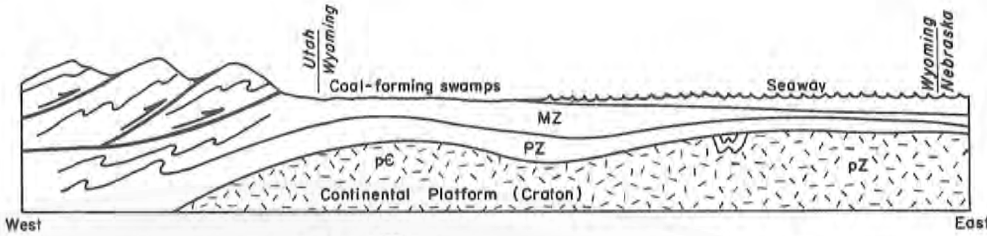
The subsequent history of the region in Oligocene, Miocene and into Pliocene times involved broad regional uplift, with normal faulting replacing Laramide-style thrusting **(Figure 1E)**. As the intermontane basin floors rose to near their present elevations of over a mile above sea level, they were filled with deposits that were in part derived from eroding uplands but greatly supplemented by vast clouds of volcanic ash drifting in from eruptive centers to the west and southwest. During post-Laramide times, the climate "deteriorated" (I would say became drier, cooler and more invigorating). Paleobotanical and vertebrate paleontologic remains record the development of grasslands populated by grazing animals.

Quaternary

In Pliocene or perhaps Late Miocene time, the dominant pattern of basin filling ended. The elevated late Tertiary landscape of low relief, which graded from planation surfaces on the more re-

Utah to Nebraska

A. Late Cretaceous: Sevier Orogeny advancing eastward.



Southeast Wyoming

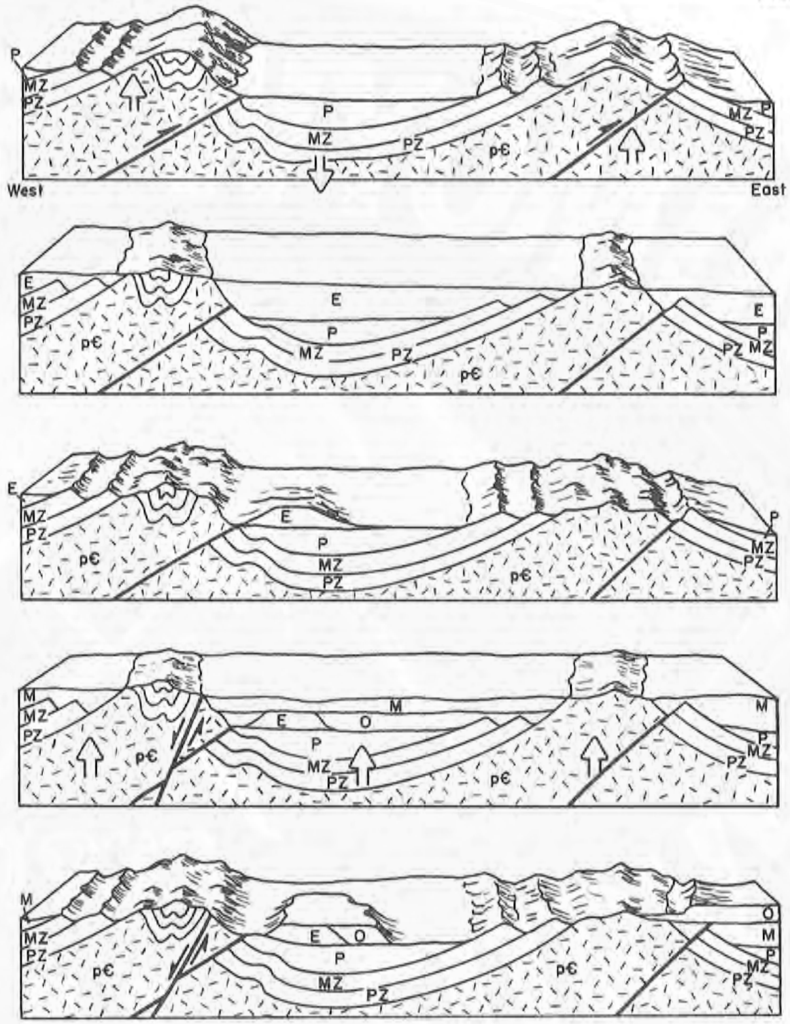
B. Latest Cretaceous and Paleocene: Laramide orogeny deforms craton, mountains rise and basins subside.

C. Middle Eocene: erosion of mountains, deposition in basins and possible origin of high-level surface planated on mountains.

D. Late Eocene: stream rejuvenation and basin excavation.

E. Oligocene to Late Miocene - Early Pliocene: basin filling, epeirogenic uplift and normal faulting.

F. Pliocene and Quaternary: stream rejuvenation and basin excavation.



EXPLANATION

M	*Miocene*	PZ	*Paleozoic*
O	*Oligocene*	pЄ	*Precambrian*
E	*Eocene*		*Fault, arrow indicates direction of movement.*
P	*Paleocene*		
MZ	*Mesozoic*		*Tectonic uplift or subsidence*

Figure 1. Generalized Late Cretaceous and Cenozoic structural evolution of Wyoming.

sistant rocks of the mountains across softer rocks of the filled basins, was progressively eroded. Basin-fill sediments were excavated by rejuvenated streams as the present landscape of broad basins flanked by mountain fronts was etched out **(Figure 1F)**. Streams issuing from the mountains deposited cobbles and gravel along their courses through the basins. Softer interstream deposits and older sedimentary rocks eroded more rapidly than the resistent gravel-armored channel deposits, producing topographic reversals. Thus, abandoned river floodplains now form elongate mesa-like benches and step-like terraces above present stream levels.

Whether the late Cenozoic stream rejuvenation resulted from pulses of epeirogenic uplift, or from climatic changes or a combination of both is debated. In any case, this ongoing episode was accompanied by the glacial and interglacial events of the Pleistocene and Holocene. Continental glaciers, the great ice sheets that extended across much of Canada and well into the northern United States during the Pleistocene, never reached Wyoming. Here the record is of valley glaciers, tongues of ice that originated high in the mountains, advanced down valleys and in places extended a few miles beyond the mountain fronts.

***Alpine glaciation*:** We live in a mild phase of an Ice Age. Today, small glaciers exist among the higher peaks of Wyoming (some 30 glaciers in the Wind River Range alone). These glaciers probably were born during the Neoglacial, or Little Ice Age, of the last 4,000 years, which followed the maximum warming trend that ended the Pleistocene (Altithermal episode). In the alpine zone of the high country, intense frost action creates abundant periglacial features such as the frost-rived blocks of *felsenmeer* (German for *sea of rock*) on mountain peaks.

During the Pleistocene **(Figure 2)** glaciers moved down valleys, scouring them into great U-shaped troughs such as Dinwoody canyon, which heads near Gannett Peak in the Wind River Range. These glaciers reached several miles onto the plains adjacent to the Wind River Range and into Jackson Hole of the Teton country. When the glaciers melted, they left great looping moraines that impounded our largest scenic lakes, such as Fremont Lake and Bull Lake along the Wind River Range and Jackson and Jenny Lakes adjacent to the Teton Mountains.

The Pleistocene glacial history of Wyoming has been extensively studied, notably by K.L. Pierce and G.M. Richmond of the U.S. Geological Survey and Eliot Blackwelder of the U.S. Geological Survey and Stanford University. Well-preserved moraines along the Wind River Range provided much of the evidence for Blackwelder's (1915) proposal that there were two late Pleistocene alpine glacial episodes. The younger of these he called *Pinedale*, from the locality near that town where Fremont Lake is impounded by moraines. Pinedale moraines have a relatively youthful appearance, marked by a strong knob-and-basin topography, and they generally lie just inside a more subdued morainal topography that is better drained by integrated streams. These more subdued moraines, with more gently sloped knobs and more filled basins, record an earlier glacial advance that Blackwelder called *Bull Lake* from well-developed examples around that lake on the north flank of the Wind River Range. Blackwelder (1915) and Richmond (1965) consider the Pinedale to be a late Wisconsin event and the Bull Lake to be early Wisconsin. Pierce and others (1976), with whom I agree, consider the Pinedale as Wisconsin in age and the Bull Lake event as Illinoian with an intervening interglacial episode.

Interpretation of a Pre-Bull Lake glaciation, which Blackwelder (1915) called *Buffalo* from deposits near the Buffalo Fork of the Snake River, is based largely on tills (unstratified glacial deposits) that lack topographic

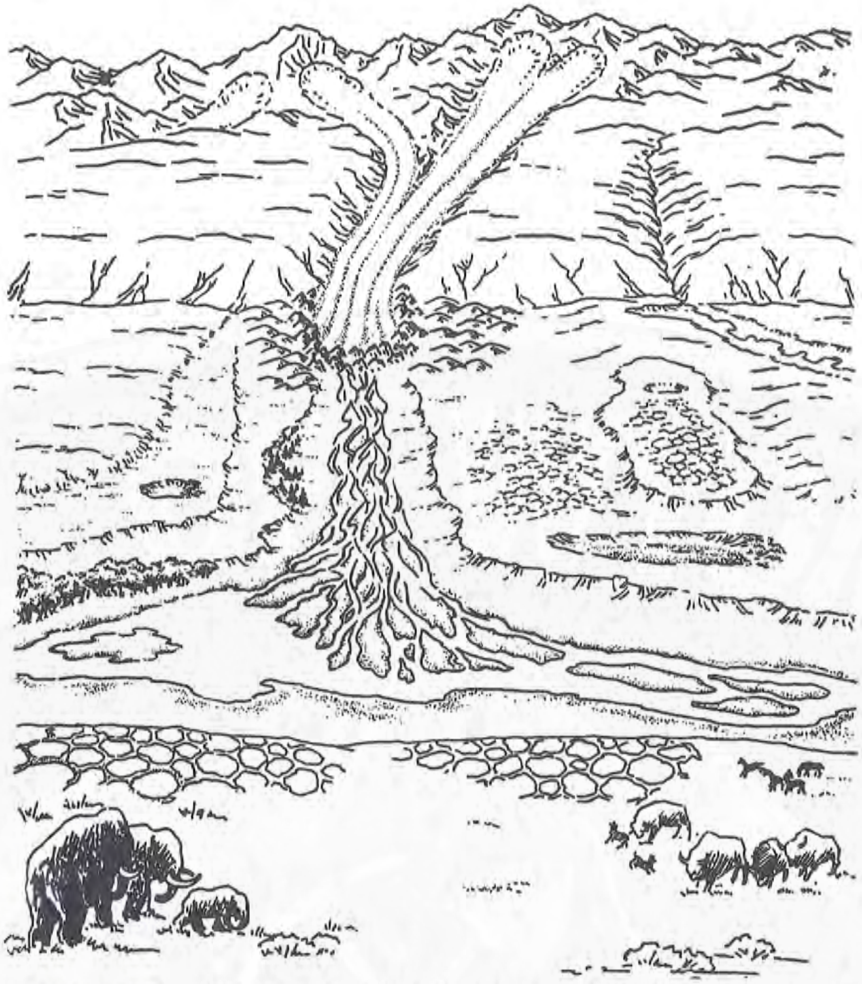


Figure 2. Wyoming panorama as inferred for Pleistocene late Pinedale glacial time about 18,000 years ago. Glaciers extended onto the margins of the windswept basin floors, which were mainly underlain by permanently frozen ground containing active ice- and sand-wedge polygons. A shrub grassland supported a diverse fauna including such tundra dwellers as mammoths, musk ox and collared lemmings as well as many other vertebrate animals. (Drawing by Anne C. Mears.)

expression as moraines. The term Buffalo is, however, no longer used because pre-Bull Lake glaciation is very complex and involves several glacial episodes, the earliest of which Love and Love (1983) think is probably Pliocene.

Periglacial developments on basin floors: During times when valley glaciers advanced several miles beyond the mountain fronts, the unglaciated basin floors were periglacial steppe (shrub grasslands underlain by permafrost). Average yearly temperatures were about 20°F colder than the present.

Until recently, most Pleistocene paleoclimatic interpretations were based on studies of glacial deposits and landforms. But what were the accompanying conditions on Wyoming's unglaciated piedmonts and intermontane basins? The Pleistocene in Wyoming may have present-day analogues in Alaska. There, many plains are patterned by tundra polygons as much as 100 feet in diameter, delineated by ice- and sand-filled wedges. The wedges result from intense freezing of the permanently frozen ground (permafrost) that produces repeated thin contraction cracks. Some are filled with ice from frost, snow and melt water; others, in drier areas, are directly filled with wind-blown sand. Repeated over many years, this process creates penetrating ice or sand wedges, against which the host materials are deformed. Commonly, the ground is bent upward against the wedges, but in some cases it bends downward. Where the permafrost thaws, as from climatic warming, the spaces left by melting ice wedges may be filled from above by sediments, thus preserving casts of the former ice masses. In the Wyoming basin floors, approximately 75 sites of multiple ice-wedge casts have been discovered. They form polygonal networks as much as 30 feet in diameter and are commonly covered by younger deposits. The wedges have mainly been found in artificial excavations like the Rawlins sanitary landfill site visited on this tour.

Today, Wyoming has the highest annual average wind velocity in the United States (except for Alaska), which is why experimental giant wind-driven turbines were set up near the town of Medicine Bow. Geologic evidence provided by wind-deflation basins such as the Big Hollow west of Laramie (**Route map A**), and by extensive sand dune belts such as the 60-mile-long Killpecker dune field in west-central Wyoming, suggest long-continued wind action during warmer arid times (such as the Altithermal) and also during the Pleistocene. The many periglacial sand-wedge relics also indicate windy and relatively arid Pleistocene climates.

Laramie to Walcott Junction

William P. Eckerle

General description

The Laramie Basin is a broad structural and topographic basin flanked on the west by the Medicine Bow Mountains and on the east by the Laramie Range (**Route map A** and **Figure 3A**). Before the Laramide orogeny, the region had low relief developed across a moderately thick sequence of marine and terrestrial sediments on the continental platform. Laramide anticlinal upwarping and reverse faulting produced the Laramie Range and Medicine Bow Mountains as well as the intervening broad syncline of the Laramie Basin.

During the Tertiary, terrigenous sediments filled the basin. Subsequent erosion excavated a great thickness of sediment from the basin, exposing the Precambrian cores of the adjacent mountains as the present topography developed.

The resistant Pennsylvanian-Permian Casper Formation, a sequence of interbedded sandstones and limestones, forms the dip slope on the west flank of the Laramie Range (**Figure 3B**). The Casper Formation is a major aquifer along the eastern margin of the basin. The Laramie area is underlain, from east to west, by the west-dipping Permian Satanka Shale and Forelle Limestone and the Triassic Chugwater Formation (**Figure 3B**).

The route (Route map A)

From Laramie, drive north on U.S. Highway 30/287. The route generally parallels the Big Laramie River for approximately 25 miles. This river heads in the uplifted area of northern Colorado, southwest of the Laramie Basin, and flows northward to a point 25 miles north of Bosler, Wyoming. There it takes an eastward course and flows through a deep canyon incised into the Precambrian basement complex of the Laramie Range. This odd behavior (for a river) is a result of superposition from overlapping Tertiary basin fill. Sediments once filled the basin and covered the mountain range. The river established its path over the buried mountains and then eroded its way down as the sedimentary cover was excavated. Several other rivers in Wyoming have apparently incised channels through mountain ranges in this manner.

Gravel-capped benches and terraces developed during Pleistocene excavation of the basin are evident. Other Quater-

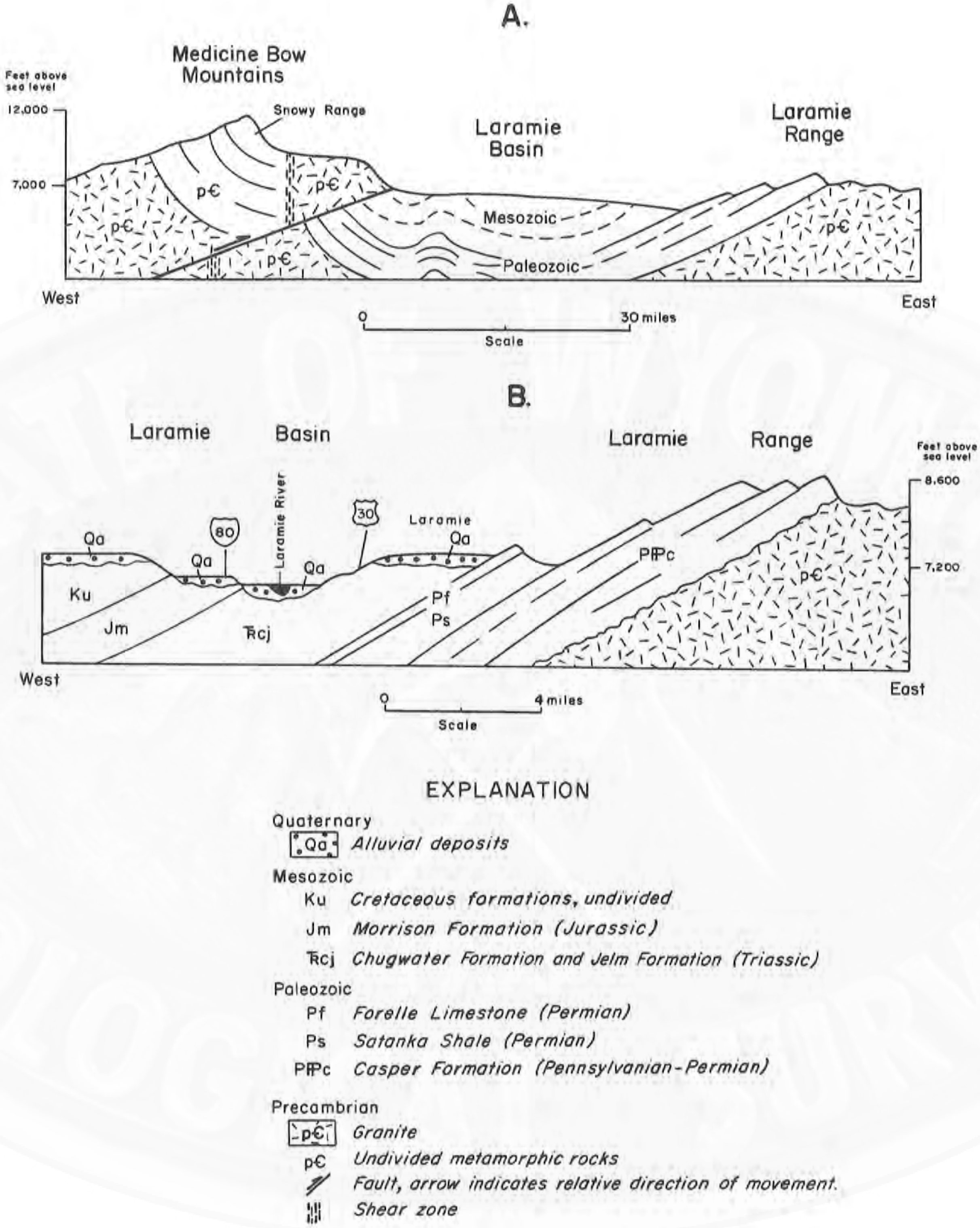


Figure 3. Schematic cross sections showing (A) Laramie Basin and adjacent ranges and (B) the town of Laramie and surrounding area. Most of the town of Laramie is built on alluvial deposits of the Laramie River (Qa) or on Permian-Triassic sedimentary rocks.

nary erosion involved eolian deflation that produced basins ranging in size from the Big Hollow (nine by three miles wide and 150 feet deep) west of Laramie to numerous smaller blowouts observable from the highway route. These appear as depressions that drain only internally and frequently include intermittently filled ponds.

U.S. Highway 30 crosses Triassic Chugwater Formation redbeds (some stratigraphers divide this unit into several formations and elevate the Chugwater to group status) from the Laramie city limits to the Diamond Horseshoe Restaurant (about 1.5 miles north of town). The highway then traverses Quaternary gypsite deposits in the valley that extend to the base of a gravel-capped bench occupied by the O.K. Corral. Gypsite is an earthy variety of gypsum occurring above gypsum strata. Ahead, the route crosses several gravel-capped surfaces underlain by the Wall Creek Sandstone Member of the Cretaceous Frontier Formation and light colored shale and soft limestone of the Cretaceous Niobrara Formation.

The road crosses Big Laramie River near the junction with Wyoming Highway 34 to Wheatland. The mostly abandoned town of Bosler is just ahead. The Cretaceous Steele Shale is encountered near Bosler, and it continues at the ground surface until it is replaced by Eocene Wind River Formation on the approach to the Union Pacific Railroad siding at Lookout.

The contact of the gray Lewis Shale occurs three miles north of Lookout Siding and from there progressively older Cretaceous bedrock is crossed. About 15 miles beyond Bosler, the pine-covered ridge above the Union Pacific railroad tracks is the Pine Ridge Sandstone of the upper Mesaverde Group. Underlying Steele Shale is exposed along the valley of Rock Creek. Rock Creek, which heads in the Medicine Bow Mountains to the southwest, has several fluvial terraces capped by coarse cobbles and boulders that probably reflect episodes of Pleistocene glacial outwash.

For ten miles beyond the town of Rock River, the highway traverses Steele Shale. The Laramie Range and Laramie Peak (elevation 10,272 feet) are prominent in the skyline to the northeast.

Whitish chalks of the Niobrara Formation are exposed in road cuts about ten miles north of Rock River. The highway continues along the strike of the south-dipping Frontier Formation, past a cabin built of dinosaur bones that were collected at Como Bluffs (**Figure 4**). A Point of Interest sign describes the *Dinosaur Graveyard* at Como Bluffs and the cabin is on the right near the highway just past a group of private buildings. The Morrison Formation, which crops out on the north side of Como Bluffs, provided great quantities of dinosaur bones. During the late nineteenth century it was an important collection site of the famous paleontologist O.C. Marsh from Yale University. To the south is a hogback of resistant Wall Creek sandstone in the Frontier Formation, which in turn overlies the silver-gray Mowry Shale along the highway.

Como Bluffs is an eroded southeast-plunging anticline with a high-angle reverse fault on the northwestern flank (**Figure 5**). The steep face of the bluffs is not visible from the dinosaur-bone cabin area. Viewed down the road, from the southwest, the bluffs form hogbacks capped by the south-dipping Muddy Sandstone (a sandstone unit that in some parts of Wyoming replaces the upper part of the Thermopolis Shale) and the conglomeratic sandstones of the Cloverly Formation. The Como Bluffs axis marks the geomorphic boundary between the Laramie Basin to the south and Shirley Basin to the north.

Figure 4. (Above) cabin at Como Bluffs with walls made of fossilized dinosaur bones. (Left) a one-foot-wide vertebrae bone on the southeast corner of the cabin. (Photographs by Sheila Roberts.)

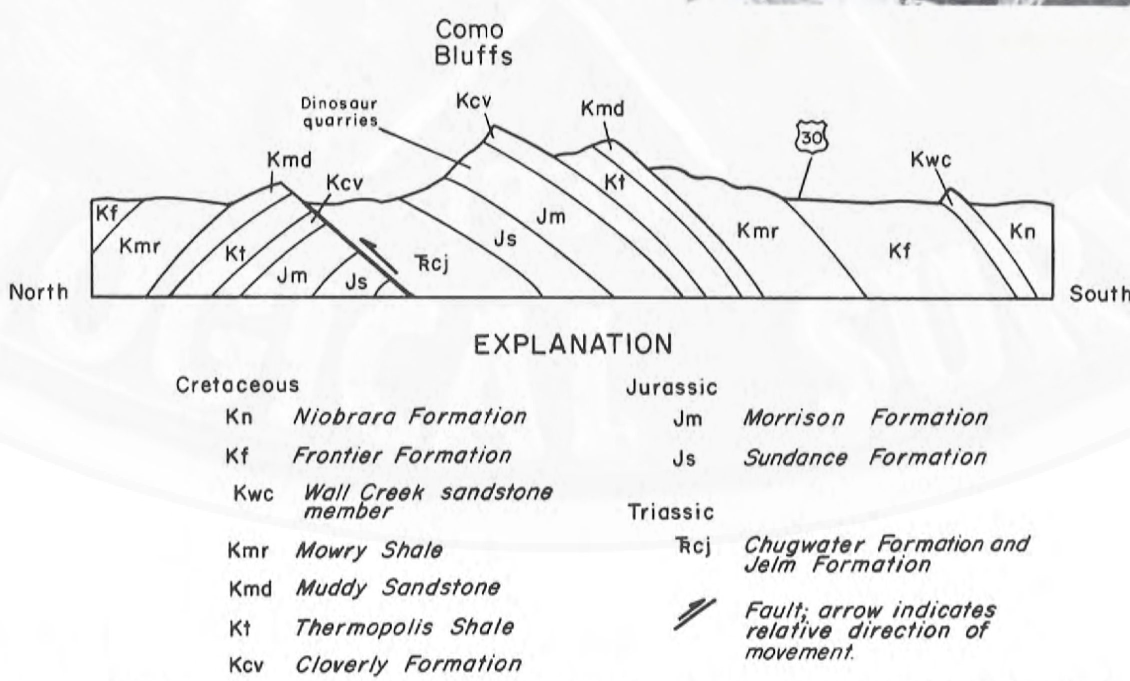


Figure 5. Como Bluffs cross section (from data in Dunbar, 1942). Maximum vertical relief is about 400 feet; horizontal distance is approximately four miles.

In the distance, approximately 20 miles southwest of Como Bluffs, Elk Mountain (**Figure 6A**) forms a prominent anticlinal uplift whose crystalline Precambrian core of granite and gneiss has been thrust eastward over east-dipping Cretaceous Steele Shale (**Figure 6B**). The steep eastern escarpment is developed on Precambrian rocks of the hanging wall of the fault. The western slope contains west-dipping Paleozoic rocks including the Madison Limestone, Amsden Formation and Casper Formation (they become prominent as the route continues to Walcott Junction).

At the plunging nose of the Como Bluffs anticline, the highway crosses silver-gray Mowry Shale, poorly exposed Frontier and Niobrara Formations and the Steele Shale near the Medicine Bow River. The Steele Shale forms a broad lowland for approximately seven miles.

Flat Top anticline is on the skyline to the north as you approach the town of Medicine Bow. This structure is capped by Casper Formation sandstone. During dry periods, heavy alkali deposits form around small ponds and along the Medicine Bow River.

The historic Virginian Hotel is the small town of Medicine Bow's major landmark. A road across the highway from the hotel leads to large experimental wind turbines that can be seen to the southwest from the road approaching Medicine Bow.

Traveling west from Medicine Bow, the route crosses the Hanna Basin. This basin is unique because of its great structural depth compared to its relatively small area. It is filled with as much as 35,000 feet of Paleozoic, Mesozoic and Paleocene rocks.

Four miles west of Medicine Bow, the road ascends a small hill and crosses into Mesaverde Group, Lewis Shale and Medicine Bow Formation rocks. Small ridges and knobs of sandstone dot the ground surface. The contacts between these units are somewhat obscure. As the highway approaches the nose of the Simpson Ridge anticline, a timber-covered ridge on the skyline to the southwest, it crosses the Tertiary-Cretaceous Ferris Formation and the Paleocene Hanna Formation. Approximately nine miles west of Medicine Bow, the highway crosses Mesaverde Formation in the north-plunging nose of the Simpson Ridge anticline (also known as the Saddleback Hills).

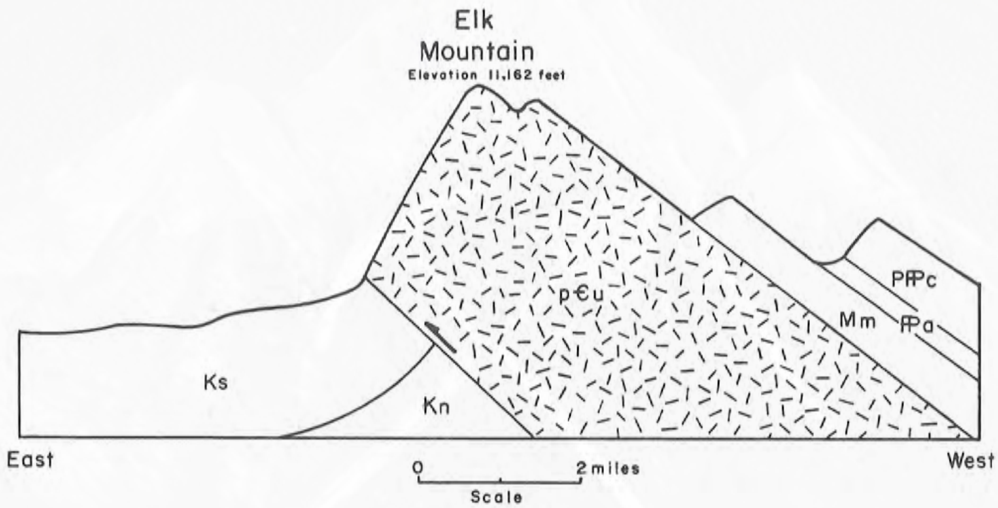
Beyond Simpson Ridge, the highway traverses the Ferris Formation for approximately four miles and passes into the Hanna Formation approaching the axis of the Hanna syncline. This syncline trends northeast and is broken by a series of normal faults. The Hanna and Ferris Formations are two of Wyoming's major coal-bearing formations.

About 18 miles beyond Medicine Bow, the town of Hanna and the open pit workings of the Hanna coal field appear on the north (right). Pass the junction where Wyoming Highway 72 leads north (right) to Hanna or south (left) to Elk Mountain. The highway traverses Hanna Formation for approximately seven miles west of the junction and then Ferris Formation for the next four miles.

The prominent feature to the southwest is the northwest-trending Pass Creek anticline, whose core of resistant Mesaverde sandstone is faulted against the Lewis Shale. As the route crosses the anticline 11 miles beyond the Hanna junction, roadcuts through the Lewis Shale display several normal faults marked by shale abutting against sandstone (**Figure 7**). Beyond the Pass Creek anticline, the northwest-trending Walcott syncline contains some overturned beds of Lewis Shale and Medicine Bow Formation. Roadcuts and exposures on the hills to the right show the changes in dip.

Down the highway about 1.5 miles, a cut on the south (left) side of the road exposes a shallow mass movement in sandstone of the Lewis Shale. Here a gently dipping sheared zone of fragmented sand-

A



B

EXPLANATION

Mesozoic

Ks *Steele Shale (Cretaceous)*

Kn *Niobrara Formation (Cretaceous)*

Fault; arrow indicates relative direction of movement.

Paleozoic

PPPc *Casper Formation (Pennsylvanian-Permian)*

PPa *Amsden Formation (Pennsylvanian)*

Mm *Madison Limestone (Mississippian)*

Precambrian

p€u *Undivided*

Figure 6. Elk Mountain: (A) view west from U.S. Highway 30 just southeast of Como Bluffs (photograph by Sheila Roberts); (B) schematic cross section (after Beckwith, 1941).

stone truncates steeply dipping sandstones that form a hogback outcrop on both sides of the road. The shear is overlain by a displaced slab (**Figure 8**). This feature may be a periglacial slab glide.

Approaching Walcott Junction, the highway crosses concealed Miocene Browns Park Formation sandstones that unconformably overlie the Cretaceous Medicine Bow Formation in the southwestern end of the Walcott syncline.

Figure 7. Roadcut in the core of the Pass Creek anticline, on the north side of U.S. Highway 287/30, eleven miles west of Hanna, Wyoming. The cut exposes normal faults in Lewis Shale, defined by offset of sandstone and shale beds. (Photograph by Sheila Roberts.)

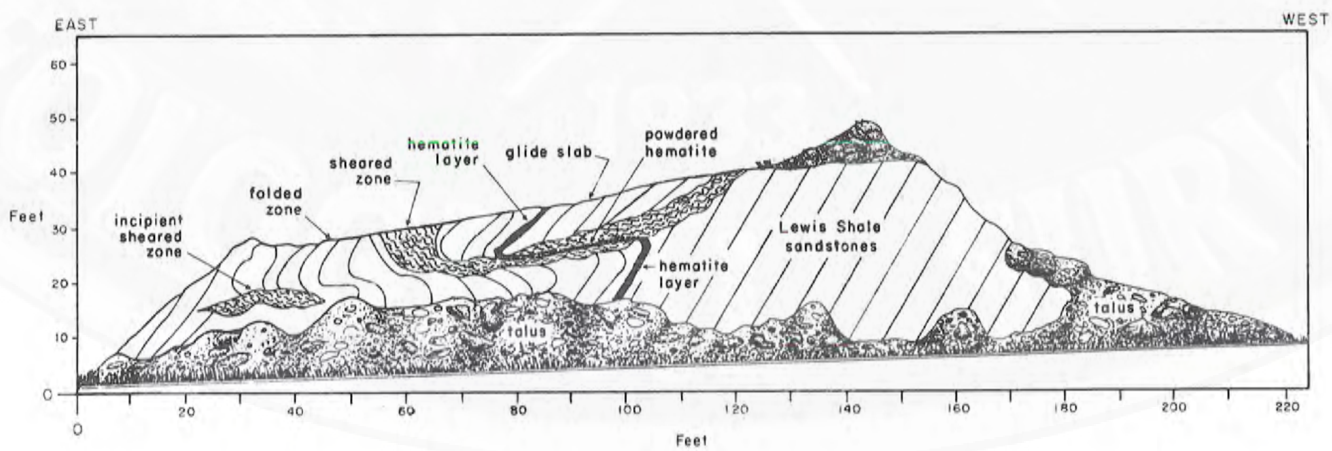


Figure 8. Diagrammatic sketch of mass movement of possible Pleistocene periglacial origin, exposed in a roadcut near Walcott Junction. A shear zone separates steeply dipping sandstones below from a slab of displaced rock above. The upper slab slid along a zone of sandstone chips that might have developed in the zone of seasonal freeze-thaw above permanently frozen ground. A thin band of pulverized brown sand marks the displacement of a hematitic layer in the dipping rock strata. At the toe of the shear the rocks are folded.

Walcott Junction to Muddy Gap

Lyndon A. Yose

General description

From Walcott Junction to Muddy Gap, many of the major aspects of Wyoming's geological history are displayed. Precambrian to Late Cretaceous rocks are exposed in Laramide structures that are, in places, unconformably overlain by Tertiary sandstones. The Rawlins Hills, although relatively unimpressive, have the basic elements of Wyoming's major mountain ranges: a Precambrian core flanked by dipping Paleozoic and Mesozoic rocks along the east side and a high-angle reverse fault along the west side.

North of the Rawlins Hills the route descends into a broad basin, Separation Flats. This basin is the result of major eolian deflation of Cretaceous shales during Quaternary time and, like the smaller blowouts seen around Laramie, it lacks external drainage.

Muddy Gap provides a route through the south flank of a major Laramide uplift, most of which has since sunk into a later Tertiary graben.

The route (Route map B)

At Walcott Junction, enter Interstate 80 and drive west into the east end of the Fort Steele anticline. The Fort Steele anticline is flanked by the resistant sandstone units of the Cretaceous Mesaverde Group. These are especially evident in the prominent ledgy hills to the north (right).

Interstate 80 proceeds west on the Cretaceous Steele Shale, passing the turnoff to the site of old Fort Steele seven miles beyond Walcott Junction. About five miles beyond the Fort Steele exit, Grenville Dome is exposed just south of the highway. Grenville Dome **(Figure 9)** is flanked by Cretaceous Frontier Formation and is cored by Cretaceous Mowry Shale. The north flank, which parallels Interstate 80, is broken by a series of north-trending normal faults in the Frontier Formation. The dome's structural axis parallels Interstate 80 to approximately 1.5 miles west of Sinclair.

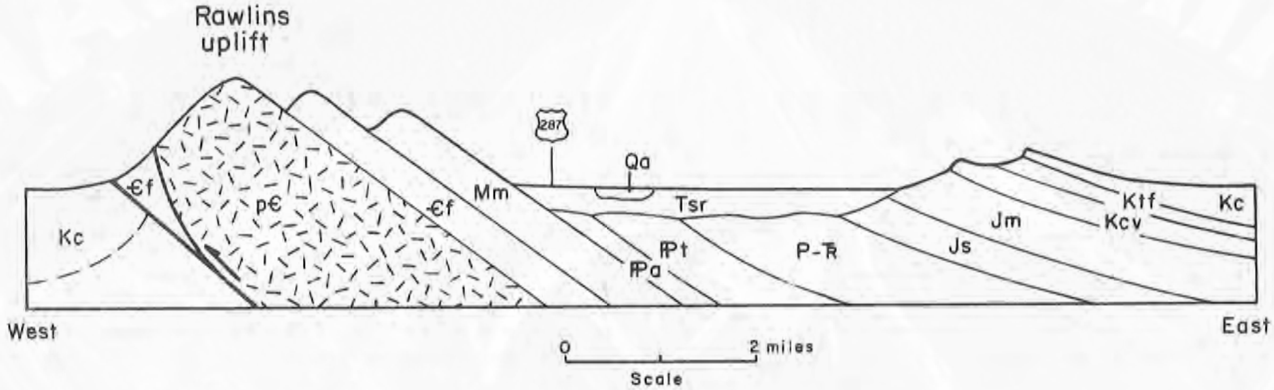
At Sinclair you may want to turn

Figure 9. Aerial view of Grenville Dome, a Laramide structure at the southeast tip of the Rawlins uplift. Resistant rocks forming ridges on the flanks of the dome are Frontier Formation sandstones. The circular core is composed of Mowry Shale. (Photograph courtesy of R.W. Marrs.)

north for a side trip to Seminoe State Park. Hausel and Jones (1984) provide a road log of that route, describing well-exposed Upper Cretaceous through Precambrian rocks, Laramide structures and modern sand dunes.

Westward, Interstate 80 enters the east flank of the Rawlins uplift, where the deformed rocks are unconformably overlain by a veneer of soft, tan Miocene sandstones. The Rawlins uplift, a Laramide structure, is cored by Precambrian rocks and is asymmetric to the west **(Figure 10)**. Rawlins is the site of the old State prison, which is now a museum.

On the east side of Rawlins, take Interstate 80 bypass and turn north to U.S. Highway 287. Miocene rocks are exposed in roadcuts. As Highway 287 rises onto the first hill, turn right to the Rawlins city dump. Drive about 1.5 miles to the dump and then follow the dump road to the sanitary landfill unloading area. Turn north (left) into the large excavated channel. Here, the walls of the landfill excavations expose excellent ice-wedge casts cutting Quaternary cobble gravels that are sharply upturned against the wedges **(Figure 11)**. The wedge fills contain a few large clasts within a sandy matrix that is devoid of internal fabric. The mantle



EXPLANATION

Quaternary
- Qa — *Alluvial deposits*

Tertiary
- Tsr — *Split Rock Formation (Miocene)*

Cretaceous
- Kc — *Cody Shale*
- Ktf — *Thermopolis Shale to Frontier Formation*
- Kcv — *Cloverly Formation*

Jurassic
- Jm — *Morrison Formation*
- Js — *Sundance Formation*

Permo-Triassic
- P-TR — *Goose Egg Formation (Permian-Triassic) and Chugwater Formation (Triassic)*

Pennsylvanian
- IPt — *Tensleep Sandstone*
- IPa — *Amsden Formation*

Mississippian
- Mm — *Madison Limestone*

Cambrian
- €f — *Flathead Sandstone*

- p€ — *Precambrian, undivided*
- *Fault; arrow indicates relative direction of movement.*

Figure 10. Schematic cross section of Rawlins uplift (after Barlow, 1953). Maximum topographic relief on the uplift is about 800 feet.

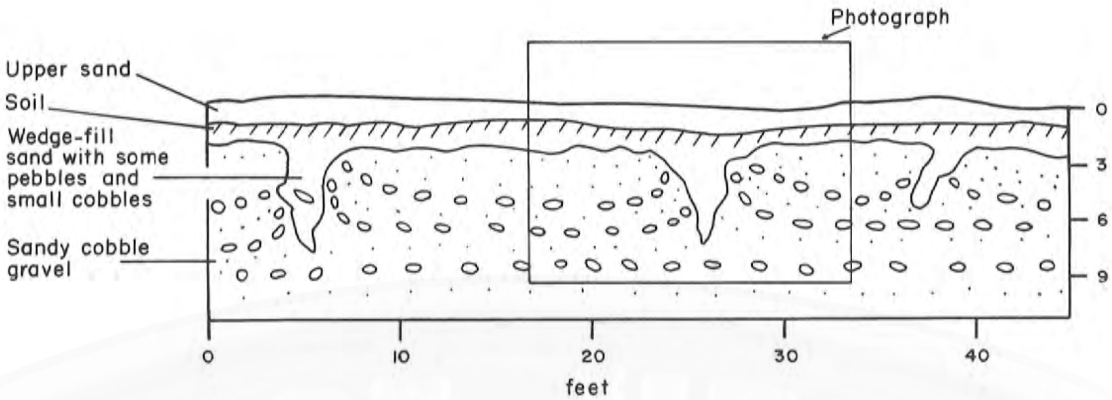


Figure 11. Ice-wedge casts cutting Pleistocene gravels at the Rawlins sanitary landfill: (above) cross section of a part of the cut wall of the landfill; (right) photograph of an ice wedge, located by black-line box on cross section. (Photograph by Brainerd Mears, Jr.)

providing the wedge fill has a moderately strong surface soil of probable late-Wisconsin or older development. Retrace your route back to Highway 287 and turn north (right).

Northward from the landfill road, Highway 287 crosses Tertiary sediments that unconformably overlap older rocks dipping eastward off the Rawlins uplift. West (left) of the highway, Precambrian rocks in the core of the uplift are occasionally visible. The prominent reddish brown strata on the flank of the uplift are Cambrian Flathead Sandstone. Mississippian Madison Limestone and some Pennsylvanian rocks are also prominent. To the east, the upper part of the flanking sequence includes Triassic through Cretaceous formations dipping gently eastward.

At the north end of the uplift, Highway 287 leaves the unconformable Miocene overlap. About 13 miles from Rawlins, the descent into Separation Flats crosses Bell Springs fault (**Figure 12**). East of the fault, a well-exposed sequence of the Chugwater Formation, Nugget Sandstone and Sundance, Morrison and Clo-

Figure 12. View northwest across Bell Springs fault. The nearest cliff (on the right) exposes Permian-Triassic and younger Mesozoic rocks on the upthrown side of the fault. In center left is part of Separation Flats (low area) flanked by Mesaverde Ridge. Snow-covered Whiskey Peak and Green Mountain are on the distant skyline. (Photograph by Sheila Roberts.)

verly Formations is exposed along a high and impressive fault-line scarp. On the west side of the fault, west-dipping strata of the Cloverly Formation abut the basal Permian-Triassic redbeds.

From Bell Springs fault to Lamont, the route crosses Separation Flats. Here Quaternary deposits unconformably overlie a series of three mostly beveled and concealed anticlines and associated synclines. The southernmost, Bell Springs anticline, parallels the Bell Springs fault to the southwest, then diverges southward along the western flank of the Rawlins uplift. North from the Bell Springs anticline are the O'Brien Springs and Mahoney anticlines, both of which trend west. Mesaverde Formation and other Upper Cretaceous rocks form the cliffs that rim the flats on the west (left).

The Quaternary deposits, dominantly windblown sand, form a broad area of dunes stabilized by vegetation of rabbit brush and greasewood. Playa lakes (intermittent lakes that dry up in the summer) occur in some of the deflation hollows in this area. To the north and east, active dunes are visible as light colored stripes along the base of the Ferris mountain front.

About a mile north of Lamont, as the highway approaches Muddy Gap, the Mesaverde Formation dips northward, in the north limb of the Mahoney anticline, into a syncline along the front of the Ferris Mountains. The northern limb of this syncline rises steeply along the mountain front to form impressive hogbacks and flatirons on steeply south-dipping strata of Paleozoic through Mesozoic age. Gravel-capped Quaternary benches and terraces are prominent on the right along the base of the mountain front. On the east side of the highway near Muddy Gap, a steep hogback of the Early Cretaceous Muddy Sandstone displays a prominent rectangular joint pattern **(Figure 13)**.

The flanking hogbacks and flatirons suggest the front of a major mountain range, comparable to the Wind River Range or Bighorn Mountains. Instead, the road passes through the steep-sided Muddy Gap and crosses the south-bounding fault of the Sweetwater graben into an area of low topographic relief filled with Tertiary sediments. The sediments partially bury the collapsed core of a former mountain range **(Figure 14)**.

Figure 13. Muddy Sandstone ridges (hogbacks) at Muddy Gap. Prominent rectangular joint patterns are highlighted by vegetation. (Photograph by Sheila Roberts.)

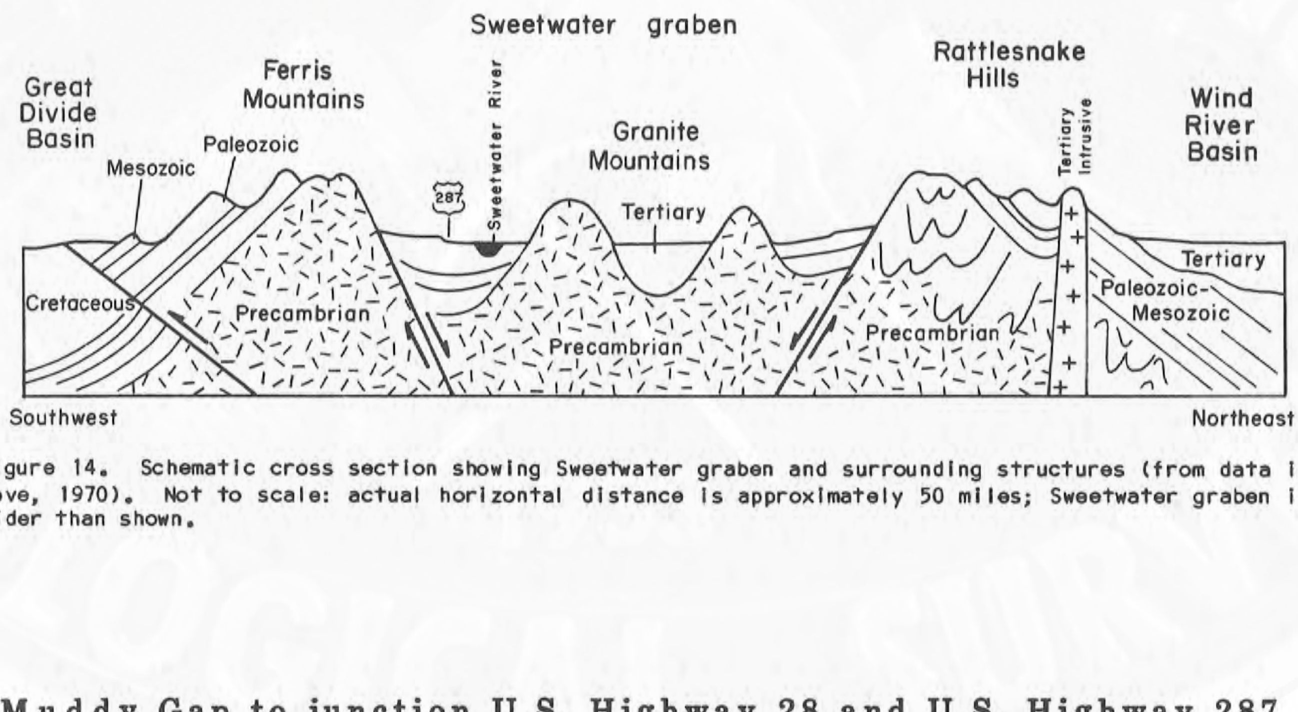


Figure 14. Schematic cross section showing Sweetwater graben and surrounding structures (from data in Love, 1970). Not to scale: actual horizontal distance is approximately 50 miles; Sweetwater graben is wider than shown.

Muddy Gap to junction U.S. Highway 28 and U.S. Highway 287

Kenneth J. Schmidt

General description

In the graben north of Muddy Gap, the rounded granite exfoliation domes of the Granite Mountains come into view. Although pink to gray Precambrian granite prevails in the area of the domes, Precambrian metasediments, granite gneiss and mafic dikes are also present to the north and west. The range originated during the Laramide orogeny of latest Cretaceous through Eocene time, contemporaneous with the rise of the Wind River Range to the west (Love, 1970). Early to Middle Eocene boulders, the Crooks Gap Conglomerate exposed in Green Mountain to the south, were shed from the uplifted block. In Miocene time, the Sweetwater graben subsided and was filled by the Split Rock Formation, wind- and water-deposited sandstone, leaving only the top of the Granite Mountains unburied **(Figure 14)**. This formation floors the valley of the Sweetwater graben and is crossed by U.S. Highway 287 from just north of Muddy Gap to Beaver Rim. Subsequent Miocene to Pliocene deposits buried all but the highest peaks.

Late Pliocene and Pleistocene regional uplift caused Tertiary sedimentary rocks to be stripped from most intermontane basins of the Wyoming region; however, Tertiary deposits were largely preserved in the subsiding Sweetwater graben. Only the upper 1,000 feet of the exhumed granite domes are exposed. The domes display typical granitic exfoliation jointing, roughly conforming to the shape of the outcrops **(Figure 15)**.

The route (Route map B)

Just north of Muddy Gap, at the junction with Wyoming Highway 220, turn west (left) toward Lander on U.S. Highway 287.

Split Rock

About eight miles past the junction is the turnoff to the Split Rock Historical Site. It has interesting exhibits, but the split in Split Rock is not visible from that location. To observe Split Rock, drive about three miles farther on Highway 287 to the historical marker.

Split Rock, a landmark of the Oregon Trail, is visible to the east from the historical marker **(Figure 16)**. It is an exfoliation dome of Precambrian granitic rock cut by a mafic dike that has weathered out to form the split in the rock.

About 11 miles beyond the Split Rock monument, enter Jeffrey City, a uranium boom town built in the 1950s that is now (1986) largely a ghost town.

Figure 15. Precambrian granite at the south edge of the Granite Mountains. Note exfoliation jointing parallel to the outcrop surface and vertical jointing. (Photograph by Sheila Roberts.)

Figure 16. Because of its distinctive notched summit, Split Rock became a major landmark for emigrants on the Oregon-Morman-California Trail and for Pony Express riders. Located on the Sweetwater River in central Wyoming, Split Rock is visible for more than 50 miles along the historic pioneer trails. (Dark horizontal band in the center of the photograph is a cloud shadow.) (Photograph courtesy of Wyoming Travel Commission.)

Ice Slough

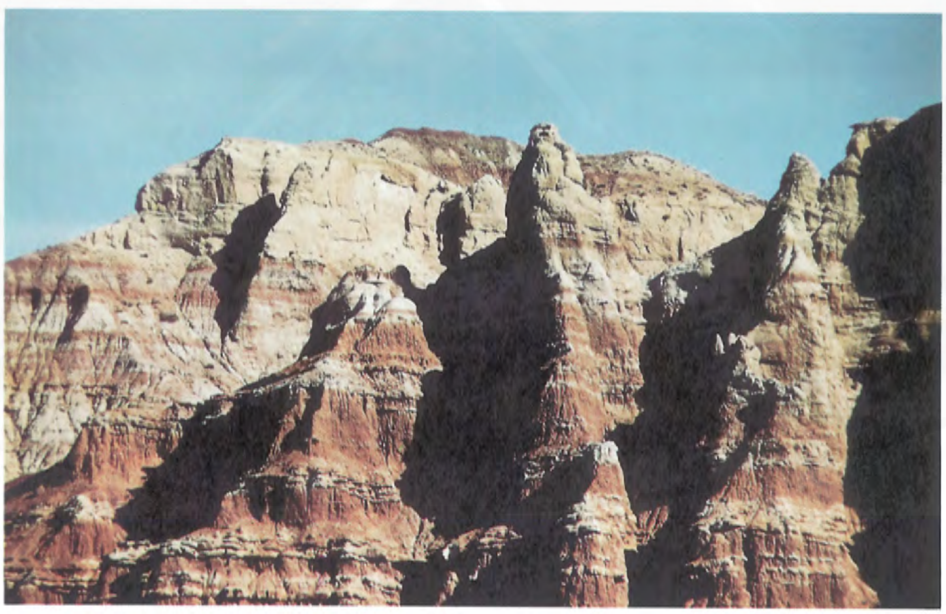
About ten miles beyond Jeffrey City, U.S. Highway 287 crosses Ice Slough where ice, insulated by peat deposits, could be collected until late July by travelers on the Oregon Trail **(Figure 17)**.

Beaver Rim

Westward, the highway traverses the Miocene Split Rock Formation, for about 16 miles, to the crest of Beaver Rim. Beaver Rim provides a panorama of the Wind River Basin, bounded on the north by the Owl Creek and Absaroka Mountains and on the south by the Wind River Range. Below the crest, outcrops of the Tertiary Split Rock, White River, Wagon Bed and Wind River Formations form the face of the scarp to the north. Soft tan sandstones of the Split Rock Formation along the cliff rim are successively underlain by white, tuffaceous siltstone of Oligocene White River Formation (forming conspicuous hoodoos) **(Figure 18)**; Eocene Wagon Bed Formation, composed of pyroclastic debris (material

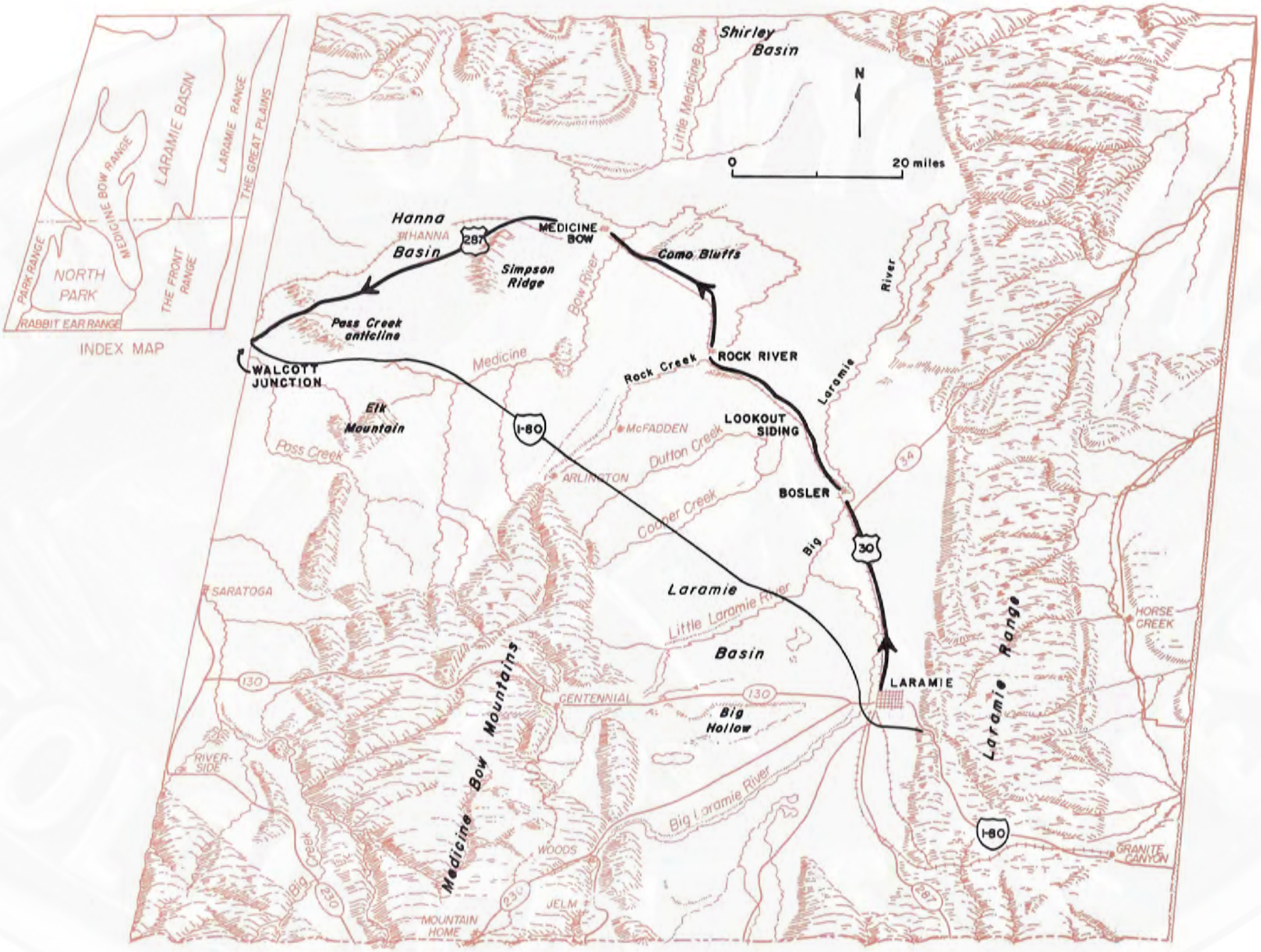
Plate 1

1A. View of Red Canyon, looking north from Wyoming Highway 28 (described on p. 33). (Photograph by Brainerd Mears, Jr.)

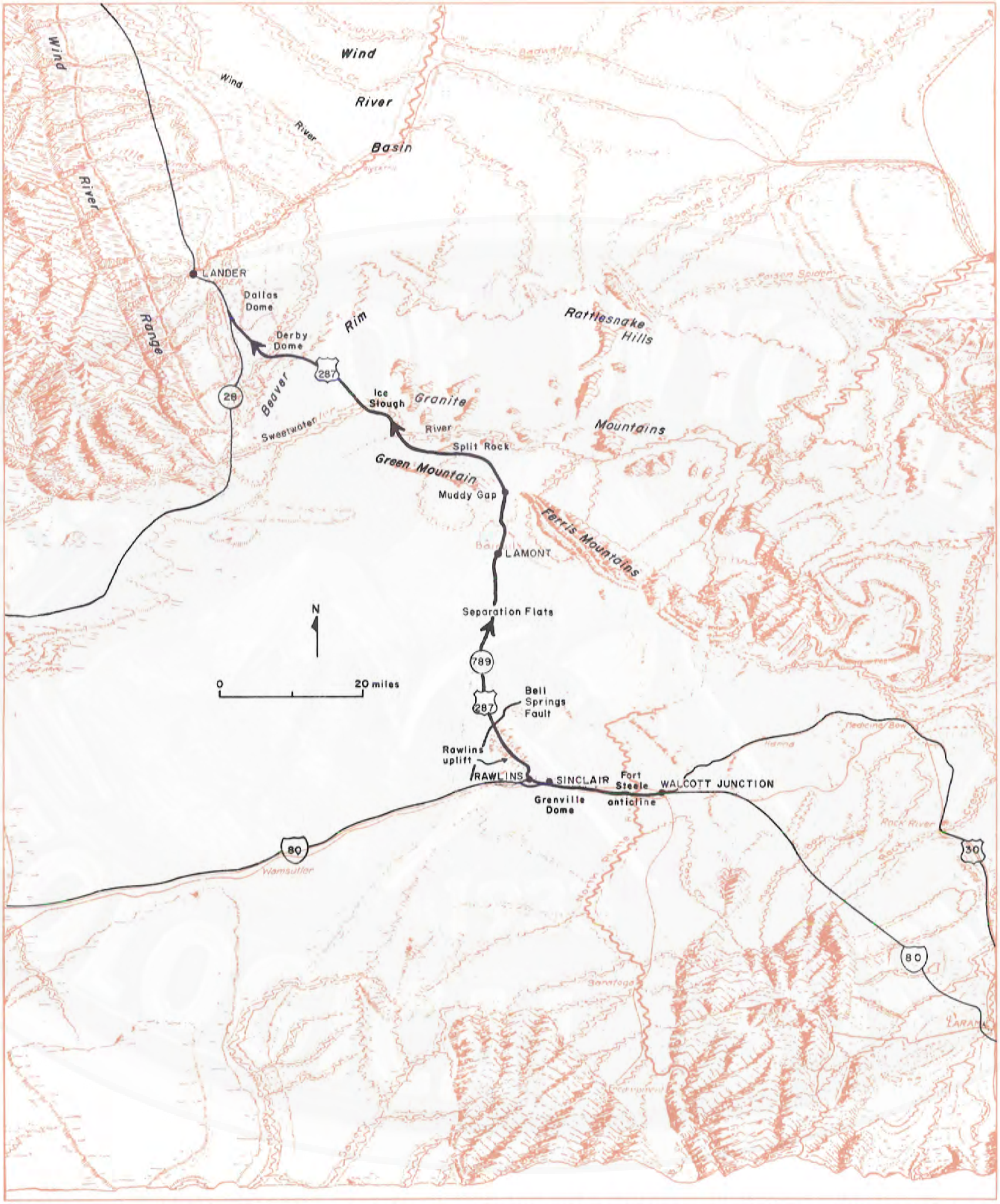


1B. Wind River Formation badlands near Dubois, Wyoming. (Photograph courtesy of Wyoming Travel Commission.)

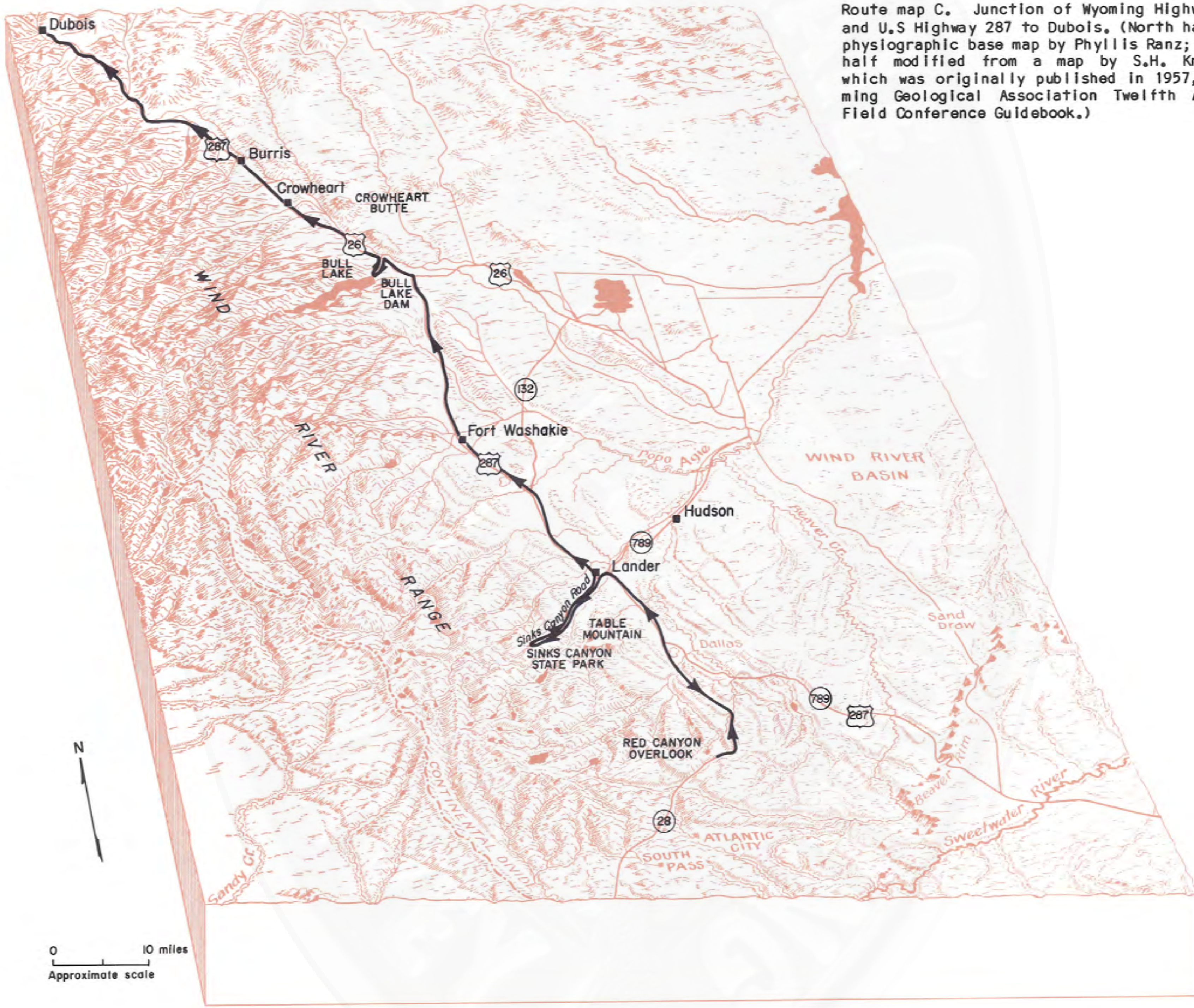
Route maps A through E



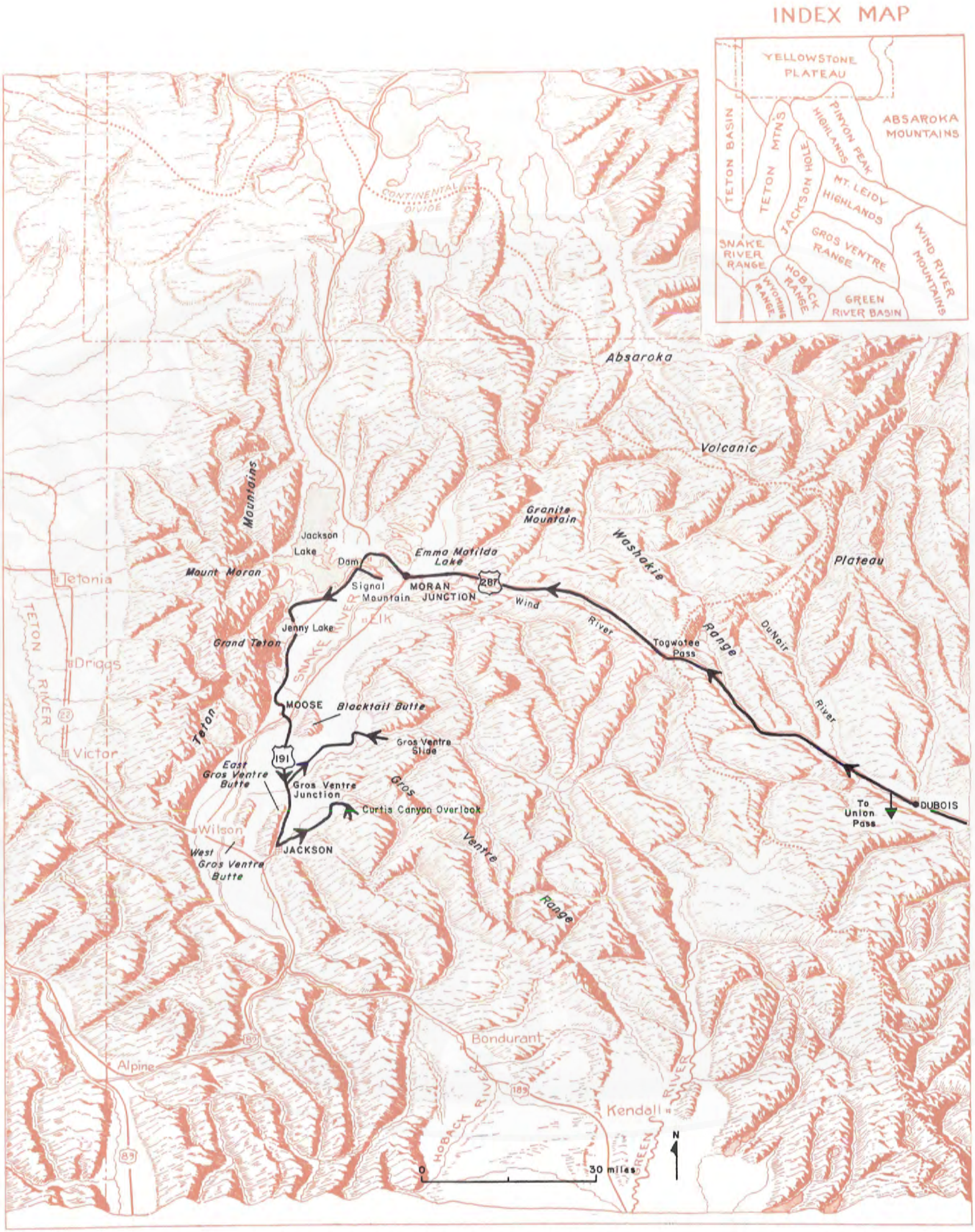
Route map A. Laramie to Walcott Junction. (Physiographic base map by S.H. Knight, originally published in 1953, Wyoming Geological Association Eighth Annual Field Conference Guidebook.)



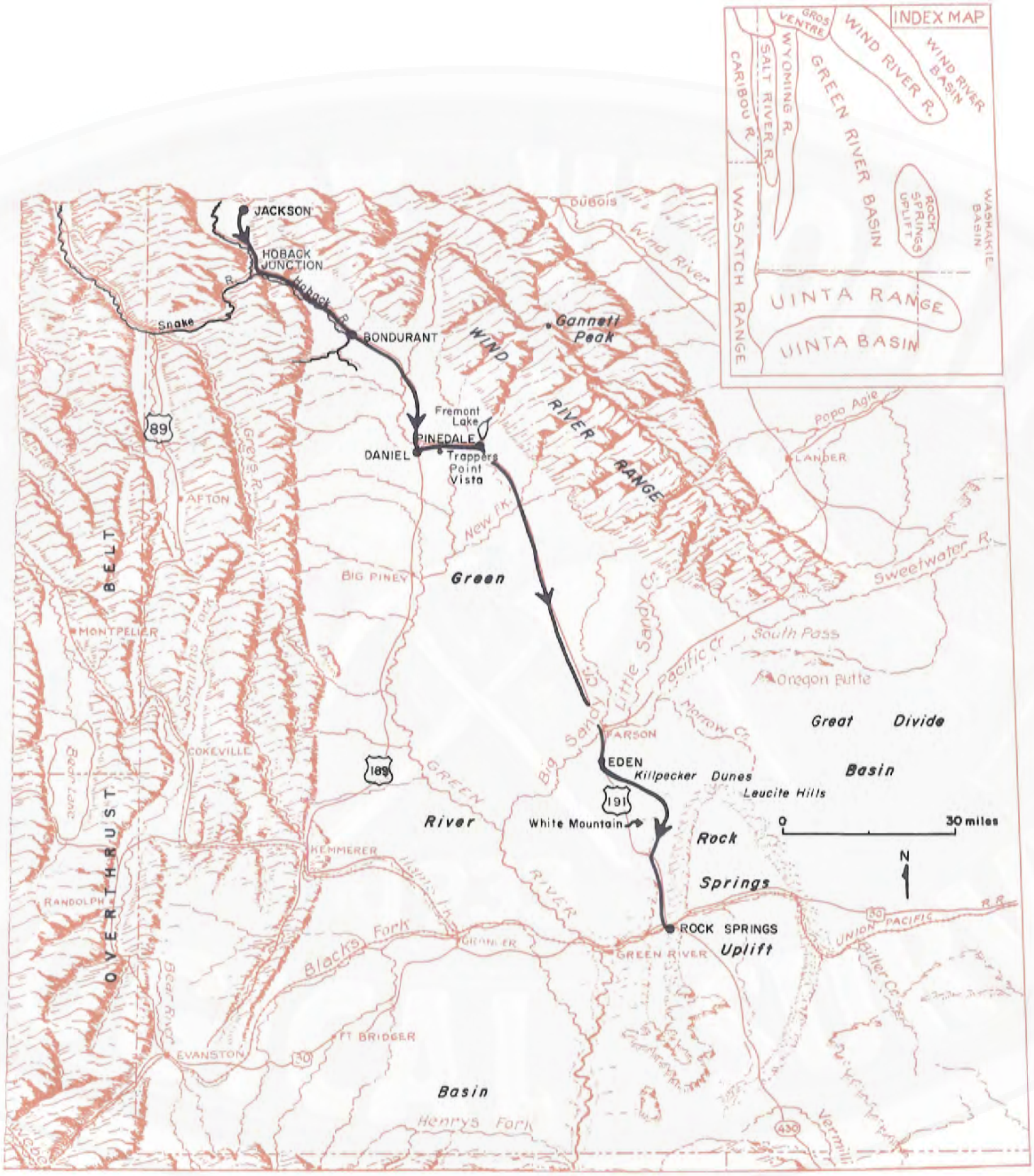
Route map B. Walcott Junction to Junction U.S. Highway 287 and Wyoming Highway 28. (Physiographic base map by S.H. Knight, originally published in 1951, Wyoming Geological Association Sixth Annual Field Conference Guidebook.)



Route map C. Junction of Wyoming Highway 28 and U.S Highway 287 to Dubois. (North half of physiographic base map by Phyllis Ranz; south half modified from a map by S.H. Knight, which was originally published in 1957, Wyoming Geological Association Twelfth Annual Field Conference Guidebook.)



Route map D. Southwest of Dubois to Jackson. (Physiographic base map by S.H. Knight, originally published in 1956, Wyoming Geological Association Eleventh Annual Field Conference Guidebook.)



Route map E. Jackson to Rock Springs. (Physiographic base map by S.H. Knight, originally published in 1955, Wyoming Geological Association Tenth Annual Field Conference Guidebook.)

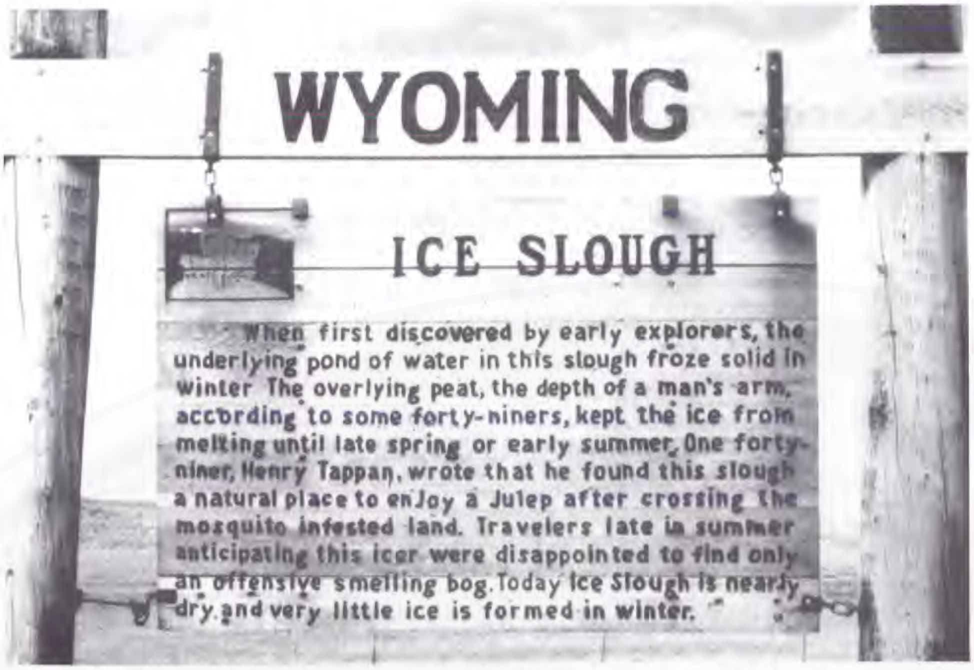


Figure 17. Sign describing Ice Slough. (Photograph by Douglas Gilmer.)

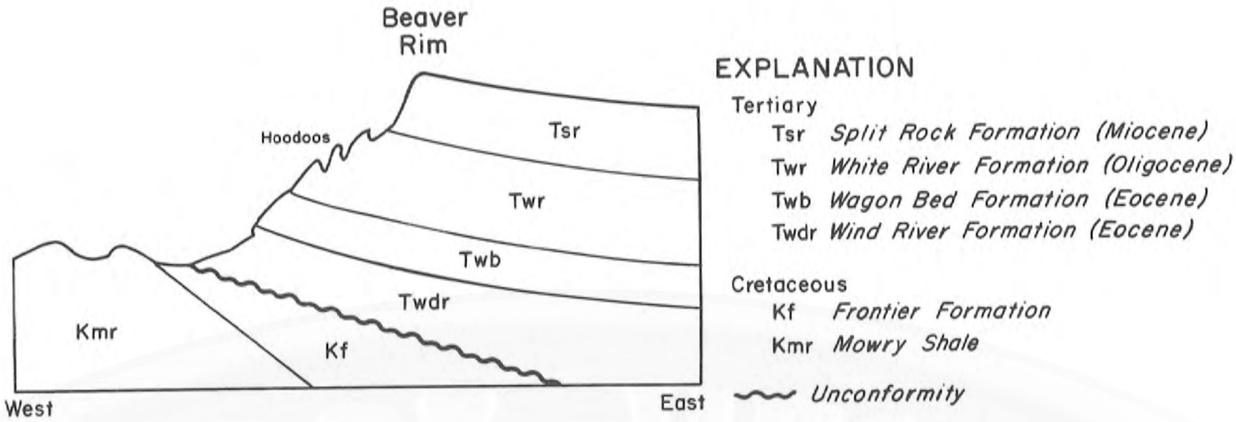
derived from volcanic explosions) eroded from the Absaroka Range; and red Eocene Wind River Formation. These near-horizontal units unconformably overlie the north-dipping Upper Cretaceous Frontier Formation and the steely gray, siliceous, relatively resistant Lower Cretaceous Mowry Shale. The unconformity represents an erosion surface of considerable relief. Tertiary rocks once filled the Wind River Basin, but were excavated during a late Pliocene through Quaternary episode of stream rejuvenation. During this time, the Wind River deepened its basin more than the Sweetwater River and produced the retreating scarp at Beaver Rim.

About a mile before the road descends Beaver Rim, the old unmaintained highway forks off to the right, providing an alternate route for 10 miles. Because of its poor condition, the road is recommended only for the adventurous. It offers close-up views of the hoodoos and safer places to park and look at the rocks. The old highway eventually dead-ends at a ruined bridge, but a dirt road that forks off to the left a short distance before that dead end provides a connection to the new highway.

Descending from the top of Beaver Rim, the route cuts down the section, crossing the near-horizontal sequence of Tertiary rocks, and the underlying Cretaceous west-dipping Mowry Shale (steely gray) and Frontier Formation shales in the valley bottom. The road then rises as it crosses prominent ledges of Wall Creek sandstone to a surface on the Cretaceous Cody Shale.

On both sides of the road where it descends into the eroded core of Derby Dome, west-dipping strata ranging from Cretaceous Frontier Formation to the Red Peak Member of the Triassic Chugwater Formation are well exposed. A dramatic outcrop of red Chugwater on the right displays the fold axis.

Beyond Derby Dome, the road follows a synclinal valley, floored by Cody Shale and bounded on the right by the sharply folded and faulted anticlinal structure trending north along the east side of the Wind River Range from Derby Dome through Dallas Dome and beyond. Dallas Dome is the site of Wyoming's first oil field; the discovery well was drilled in 1883 near an oil seep reported by Captain Benjamin Bonneville in 1827 (**Figure 19**). The left side of the synclinal valley is bounded by northeast-dipping Frontier Formation along the flank of the Wind River mountains. Continue to the junction with State Highway 28.



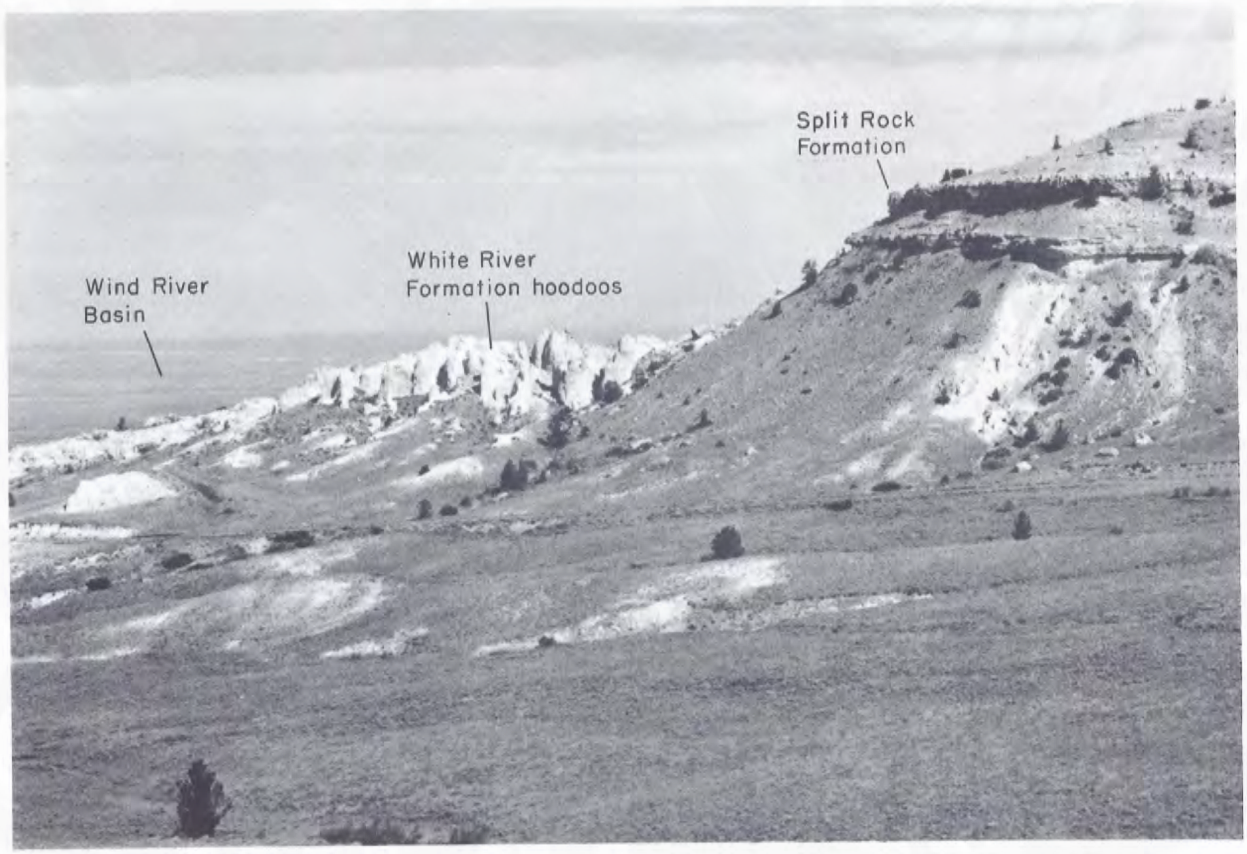


Figure 18. (Above) a schematic cross section of Beaver Rim (after Van Houten, 1957). The rim scarp is approximately 800 to 900 feet high. Note the southward dip of the Tertiary strata away from the Wind River Basin. This is probably the result of tectonic rebound when the basin was re-excavated during late Cenozoic time. (Below) view of Beaver Rim from the old highway (alternate route described in text), showing hoodoos in the Oligocene White River Formation. The bizarre conical shapes of the hoodoo outcrops formed by differential erosion of these near-horizontal strata, probably influenced by joint patterns in the rock. (Photograph by Sheila Roberts.)

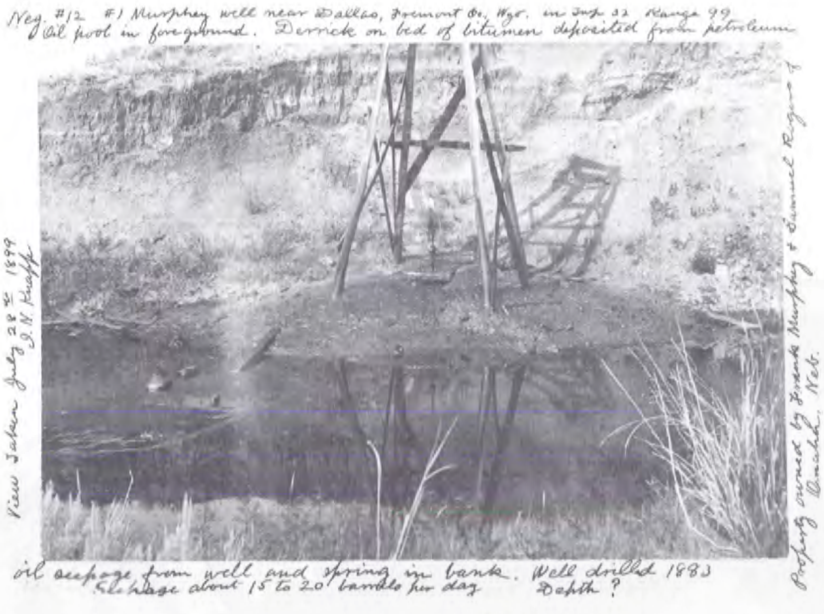


Figure 19. (Above) historical photograph of No. 1 Murphy well, near Dallas, Fremont County. This well was drilled in 1883 in Wyoming's first oil field. (Photograph by I.N. Knapp, 1899, courtesy of J.D. Love.) (Right) recent photo of the same well site in 1984. (Photograph by G.B. Glass.)

Red Canyon to junction of U.S. Highway 287 and Wyoming Highway 26

Timothy L. Gubbels

General description

This part of the route parallels the western edge of the Wind River Basin and the eastern and southern flank of the Wind River Range. The Wind River Range was uplifted during the Laramide orogeny along a reverse fault that bounds the range on the southwest **(Figure 20).** During uplift, the strata on the north flank were tilted to the northeast. As the mountains were uplifted, the Wind

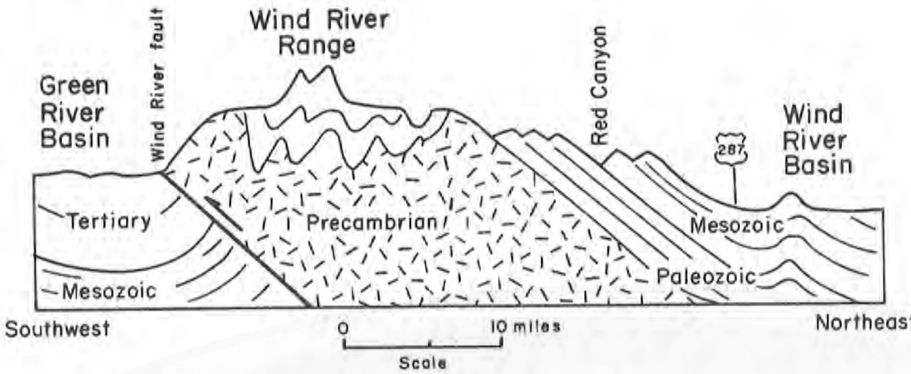


Figure 20. Schematic cross section of the Wind River Range. Gannett Peak (elevation 13,804 feet), in the Precambrian core of the range, is the highest point in Wyoming. In this cross section, the Green River Basin is at about 7,200 feet above sea level and U.S. Highway 287 in the Wind River Basin is at 5,500 feet.

River Basin was downwarped so that the total structural relief between the ridge crest and the basement below the basin floor is 30,000 feet. Subsequent erosion by the Wind River and its tributaries removed much sedimentary basin fill, incised deep canyons on both flanks and sculptured the hogbacks.

The route (Route map C)

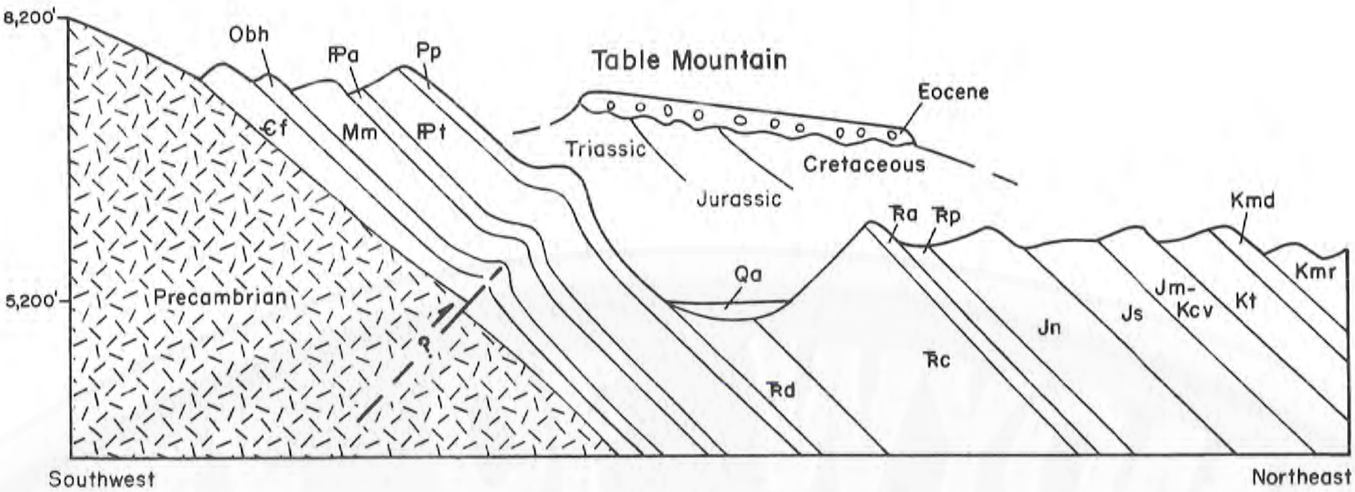
Turn left on State Highway 28 and drive about ten miles for a magnificent view of Red Canyon (**Plate 1A**, p. 21, and **Figure 21**). Turn north (right) into the scenic-area parking lot. To the west is the flank of the Wind River Range, a major Laramide structure. Strata on the flank are upwarped and eroded to form prominent hogbacks. Northwest from the vista point, the dip slope on the left is underlain by Permian Phosphoria Formation. Stratigraphically above (but topographically below) the Phosphoria is Triassic Dinwoody Formation, a shale unit whose less resistant nature is responsible for the extensive strike valley. To the right, the Red Peak Member of the Chugwater Formation, composed of red sandstones, siltstones and silty shales, forms the broad reddish slope rising from the valley floor to an impressive scarp. It is capped by light gray, ledge-forming Alcova Limestone. Set back above this ledge is the conglomerate-bearing Triassic Popo Agie Member (pronounced Po-POH-zuh).

In the distance to the northwest, Table Mountain slopes gently northeastward. It is a planated, gravel-capped surface that truncates steeply dipping Triassic through Cretaceous beds. Interpreted as a pediment, the Table Mountain surface represents a previous valley floor that was isolated as a mesa during excavation of the Wind River Basin.

If you wish to continue on Highway 28, the famous gold mining district of South Pass lies just ahead. A tour guide by Hausel (1984) describes that area.

Retrace the route to the junction, turn north (left) and follow Highway 287 to Lander. Progressively younger rocks are exposed along the route. The Nugget Sandstone (Triassic-Jurassic), a pink to creamy colored, crossbedded, fine-grained, largely eolian sandstone is a competent, well-indurated unit that forms a cliff (**Figure 22**). Farther north, the highway passes through the Jurassic Sundance Formation and variegated beds of the Morrison Formation. Beyond this, the northeast-dipping Cretaceous Frontier Formation is visible with the silvery Mowry Shale below it. Near Lander the road traverses Cody Shale. *(About ten miles east of Lander on Highway 789 is the small town of Hudson, where two restaurants are noted for their steaks and seafood. Highly recommended.)*

In Lander, turn southwest (left) onto Fifth Street at the Safeway store. At the end of Fifth Street, turn right onto Wyoming Highway 131 (Fremont Street) and the Sinks Canyon Road, which follows the Popo Agie River (where a good campsite is located in the State Park). Southwest of Lander, the river has incised a deep gorge exposing northeast-dipping



EXPLANATION

Quaternary

Qa	*Alluvial deposits*

Cretaceous

Kmr	*Mowry Shale*
Kmd	*Muddy Sandstone*
Kt	*Thermopolis Shale*
Kcv	*Cloverly Formation*

Jurassic

Jm	*Morrison Formation*
Js	*Sundance Formation*
Jn	*Nugget Sandstone (base is Triassic)*

Triassic

TRp	*PopoAgie Member, Chugwater Formation*
TRa	*Alcova Limestone and Crow Mountain Sandstone, Chugwater Formation*
TRc	*Red Peak Member, Chugwater Formation*
TRd	*Dinwoody Formation*

Permian

Pp	*Phosphoria Formation*

Pennsylvanian

IPt	*Tensleep Sandstone*
IPa	*Amsden Formation*

Mississippian

Mm	*Madison Limestone*

Ordovician

Obh	*Bighorn Dolomite*

Cambrian

€f	*Flathead Sandstone and other Cambrian rocks*

Fault; arrow indicates direction of movement; inferred where dashed.

Figure 21. Schematic cross section of the southeast flank of the Wind River Range and western Wind River Basin, looking northwest from the head of Red Canyon. Section is about 11 miles across, and vertical relief at the surface is about 3,000 feet. Elevations are in feet above mean sea level.

Figure 22. Nugget Sandstone outcrop along Wyoming Highway 28, northeast of Red Canyon. Large-scale, probable eolian cross-bedding is well exposed in the rocks. (Photograph by Sheila Roberts.)

Paleozoic strata of the Tensleep Sandstone, Amsden Formation and Madison Limestone. Stop at the Visitors' Center and walk to the spot where the river crosses onto the Madison Limestone and disappears into the Sinks of the Popo Agie River (**Figure 23**). The river flows underground for about 600 feet to the "Rise" and then reemerges to continue its course down the canyon. (Abundant trout, some as long as two feet, live here enjoying the peaceful security provided by the *No Fishing* signs.) Less than a mile up the road is a campground and a nature trail that emphasizes the botany and geology of the canyon. Retrace the route to Lander, turn left onto Fifth Street and left again onto West Main Street (Highway 287).

Ten miles northwest of Lander, U.S. Highway 287 passes through Fort Washakie, headquarters of the Indian Agency for the Wind River Indian Reservation. Moraines of the Bull Lake and Pinedale glaciations can be seen along the flank of the Wind River Range in the distance to the west.

The road follows the Cody Shale strike valley from Lander beyond Washakie to Winkleman Dome, which is dotted

Figure 23. The Sinks of the Popo Agie River west of Lander, Wyoming. At this spot the river disappears into a solution cavern in the Madison Limestone and flows underground for 600 feet. (Photograph courtesy of Wyoming Recreation Commission.)

with oil pump jacks. It is at the north end of Sage Creek anticline, one of the series of oil-bearing anticlines, like Dallas and Derby Domes, which parallel the northwest flank of the Wind River Range. At Winkleman Dome the highway crosses a gravel-capped Pleistocene surface that has been correlated with pre-Winsonsin glacial/interglacial episodes in the Wind River Range. Gravels were brought from the Absaroka Range by the ancestral Wind River, which flowed southward (parallel to the highway). Since that Pleistocene episode, the river course changed to eastward, and at Winkleman Dome it has cut down 500 feet to its present level

On the approach to the descent toward the Wind River, view near-horizontal tan sandstones. These rocks are mountainward facies of the Eocene Wind River Formation that unconformably overlie the older folded strata.

Turn west (left) toward Dubois at the junction of Highways 26 and 287, 17 miles north of Washakie. Just beyond the junction, a high gravel-capped bench about 500 feet above the Wind River is interpreted as a pre-Bull Lake outwash surface, and a low terrace along the river is interpreted as a Pinedale surface.

Near Bull Lake, the highway rises through exposures of till in the outermost moraine of the Pinedale glaciation. Note the relatively fresh character of the till, the immature zonal character of the soil and the irregular hummocky and bouldery nature of the moraine. The canyon of Bull Lake is to the west.

Approximately one mile past the outer limit of the Pinedale moraines (2.5 miles past the junction of Highways 26 and 287), turn southwest (left) on Bull Lake Road (unpaved) and proceed about two miles to Bull Lake Dam.

Bull Lake Road to Moran Junction

Gary A. Huckleberry

General Description

Bull Lake, impounded by moraines, is a classical site where major aspects of Wyoming's glacial history have been studied. From that area, the route along the Wind River crosses several dissected, gravel-capped Quaternary bench surfaces and two hummocky sites of end moraines on the way to the town of Dubois, near the northwest end of the Wind River Basin. Paleozoic and Mesozoic strata dip off the flank of the Wind River Range to the left, and extend to the skyline, where peaks of Precambrian rock are occasionally visible. Across the river to the right, colorful badlands characterize the near-horizontal Eocene rocks in the dissected basin floor. Beyond, the Laramide Owl Creek Mountains rise to the skyline and, as the basin progressively narrows, the distant pinnacles are developed on rocks associated with the Absaroka Volcanic Plateau. A few miles beyond Dubois, the route begins its ascent to Togwotee (pronounced TOH-ga-tee) Pass, from which it descends into Jackson Hole.

The route (Route maps C and D)

A series of Pinedale lateral and recessional moraines (**Figure 24**) partly dam the northeast-trending glacial valley that is occupied by Bull Lake. To the north (partially depicted in **Figure 25**) is a large exposure of Pinedale till composed of boulders and cobbles in a sandy matrix. Although the water level was raised by the man-made dam, massive exposures of till still stand above lake level.

Eliot Blackwelder, who pioneered the study of Quaternary stratigraphy around Bull Lake, selected it as the type locality for the Bull Lake glaciation of

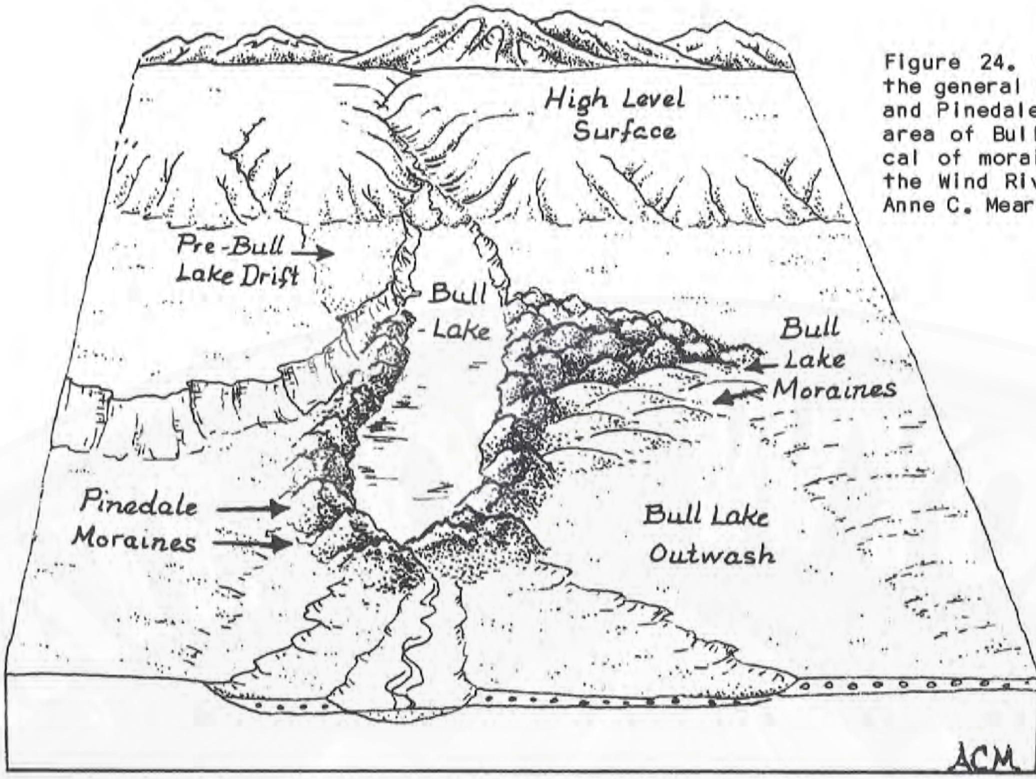


Figure 24. Block diagram showing the general relations of Bull Lake and Pinedale moraines at the type area of Bull Lake, which is typical of morainal sites adjacent to the Wind River Range. (Drawing by Anne C. Mears.)

Figure 25. Bouldery Pinedale till and moraines exposed in a gravel pit at Bull Lake Dam. The cut is about 40 feet high. Tree-covered moraine rises to the skyline in the background. (Photograph by Sheila Roberts.)

the Rocky Mountain region (Blackwelder, 1915). Blackwelder recognized at least two separate glaciations, as evidenced by moraines with distinct topography. The older, more subdued moraines are associated with the Bull Lake glaciation, which he correlated with the early Wisconsin glaciation of the mid-continent. The younger moraines have well-developed knob and basin topography and are Pinedale moraines, which Blackwelder correlated with the late-Wisconsin continental glaciation.

Pinedale moraines display well-developed knob and basin topography, and contain many boulders at the surface. Boulders on Pinedale moraines are minimally weathered, unlike boulders of similar lithology on Bull Lake moraines that have thick weathering rinds, pitted surfaces and deep frost cracks. Here, the Pinedale till is sandy, with relatively weak soil development.

Later work by Gerald Richmond (1965), in the Bull Lake area, resulted in modification of Blackwelder's glacial sequence. Based on several exposures of till separated by soils **(Figure 26)**, Richmond proposed that the Quaternary stratigraphy around Bull Lake indicates five Pleistocene glaciations: three pre-Bull Lake, one Bull Lake and one Pinedale. The three pre-Bull Lake glaciations, from oldest to youngest, are the Washakie Point, Cedar Ridge and Sacagawea Ridge. The type locality for the Washakie Point and Cedar Ridge glaciations are along Bull Lake, whereas that of the Sacagawea Ridge occurs at Dinwoody Lake, several miles to the northwest. Richmond also recognized two pulses of Bull Lake glaciation and three of Pinedale glaciation, based on the presence of weakly developed intervening soils.

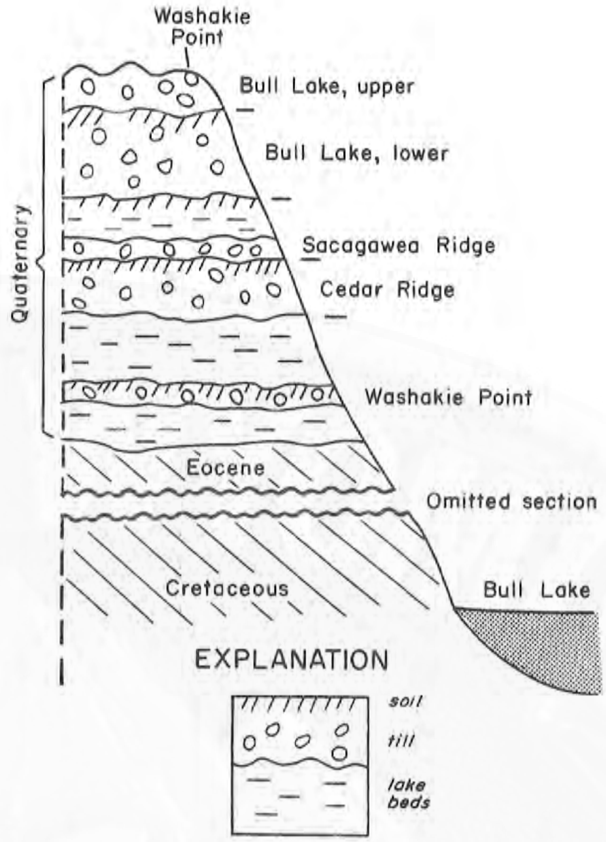


Figure 26. Schematic representation (after Richmond, 1976) of Pleistocene deposits at Washakie Point, along the north shore of Bull Lake. The cliff rises 1,050 feet above the lake; Pleistocene sediments at the top are 270 feet thick.

Return to U.S. Highway 287, turn west (left), and ascend onto Bull Lake-age outwash terraces. These terraces are 80 to 200 feet above present stream level. To the south (left) is a broad, relatively smooth moraine of Bull Lake age with less abundant surface boulders than Pinedale moraines. Pinedale glaciers extended over the older till and through a valley cut into Bull Lake deposits.

About five miles beyond the turnoff to Bull Lake, U.S. Highway 287 passes a point of interest. The sign describes the origin of the name Crowheart Butte, the prominent butte north of the highway **(Figure 27)**. It is capped by a channel sandstone in the Eocene Wind River Formation.

U.S. Highway 287 follows the fertile, irrigated valley of the Wind River into the northwest corner of the Wind River Basin. Approximately 17 miles beyond the Crowheart Butte point of interest, the road ascends moraines associated with the glaciation of Dinwoody Canyon to the southwest.

About two miles farther (12 miles beyond the Crowheart Post Office), where the road descends from the moraines, pull off into an unmarked parking strip along the right side of the road for an extensive panorama of colorful and complex geology. A knob of Pinedale till just beyond the fence provides the best view. The Wind River Range is to the west and southwest. In places on the skyline, the Precambrian core of the range is visible above Madison Limestone. Paleozoic bedrock (Madison Limestone, Amsden Formation and Tensleep Sandstone) dips off the range toward the northeast. The lower dip slopes (below lower tree line) are Phosphoria and Chugwater Formations and Nugget Sandstone. In the foreground are the Dinwoody moraines.

To the northwest, brightly variegated, horizontally bedded Wind River Formation (Eocene) badlands unconformably overlie Cretaceous and older rocks (**Figure 28**). The unconformable relations indicate that Laramide deformation ended here before Eocene time.

To the north, across the Wind River, a series of northwest-trending thrust faults are part of the Wind Ridge thrust system (Love, 1939). Frontier (Cretaceous) and Indian Meadows (Eocene) Formations are thrust over flat-lying Wind River Formation. On the skyline farther east, several large Paleozoic blocks, chiefly Bighorn Dolomite and Madison Limestone, are surrounded by Cretaceous and Tertiary units. Whether the blocks are isolated erosional remnants of a

Figure 27. Crowheart Butte. (Photograph by Sheila Roberts.)

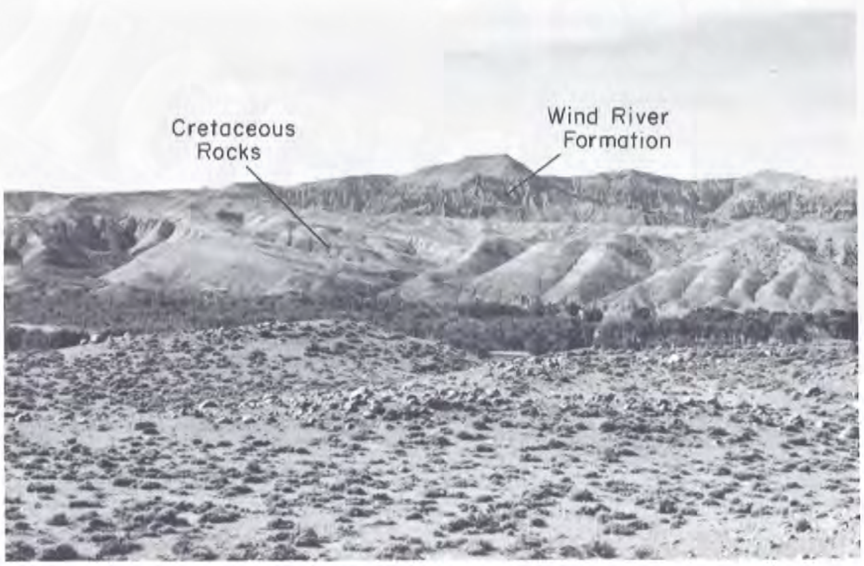


Figure 28. Horizontally bedded Eocene Wind River Formation overlies dipping Cretaceous strata. (Photograph by Sheila Roberts.)

once more continuous thrust sheet or gravitational slide masses that moved across an Eocene landscape from the Washakie Range to the north is still debated.

Continue on U.S. Highway 287 toward Dubois. Colorful sedimentary-rock units (Sundance, Morrison and Cloverly Formations and the Thermopolis Shale) are exposed across the Wind River to the north-northeast. The redder and more resistant units include the Chugwater Formation and the Nugget Sandstone. Farther along the highway, the candy-striped sediments in the badland topography to the right are Wind River Formation (**Plate 1B**, p. 21).

In Dubois, stay on U.S. Highway 287 (**Route map D**). Just past Dubois, observe colorful Wind River Formation badlands to the north (right) and northwest-dipping redbeds of Chugwater strata to the south (left). About seven miles beyond Dubois, the road passes a cliff of steeply dipping Tensleep Sandstone and Phosphoria Formation on the north (right) and then crosses the river. On the skyline to the front, the distant cliffs are volcanic breccias, conglomerates and tuffs in the Wiggins Formation, the youngest member of the Absaroka Volcanic Supergroup (**Figure 29**).

The Absaroka Volcanic Plateau extends northward from the vicinity of Togwotee Pass to the Montana-Wyoming border. Unlike other mountain ranges in Wyoming, the Absaroka mountains are aggradational, formed by the piling up of volcanic rocks during repeated eruptions. Eocene Absaroka volcanism was violent and geologically rapid (less than ten million years). Several formations have been recognized in the Absaroka Volcanic Supergroup (Love, 1939; Love and Christiansen, 1985). Since its deposition, the Absaroka Range has been extensively eroded and glaciated to produce rugged and spectacular topography.

The road crosses a bridge over the Wind River just beyond the Union Pass historical marker. The marker commemorates the passage of a party of John Jacob Astor's "Astorians" through this country in 1811. Beyond the river cross-

Figure 29. Breccia Cliffs in the Wiggins Formation of the upper Absaroka Volcanic Supergroup (Photograph courtesy of Wyoming Travel Commission.)

ing, the highway begins a 22-mile ascent to Togwotee Pass, rising some 2,250 feet, mainly across claystones and siltstones of a facies of the Wind River Formation whose drab colors contrast markedly with the colorful variegated deposits previously seen along the route. Approximately two miles beyond the turnoff (south) to Union Pass road, near the beginning of the ascent, the highway cuts through a Pinedale moraine deposited at the junction of two alpine glaciers that emerged from the Wind River and DuNoir River valleys during the Pleistocene.

Farther along the route, the hummocky topography across the river to the left is a complex mass of glacial and landslide deposits. In places, roadcuts expose the drab colored facies of the Wind River Formation. On entering the generally timbered zone of higher precipitation, the highway crosses extensive landslide (slump and flow) deposits derived from the clay-rich and unstable Eocene Aycross Formation, of the middle Absaroka Volcanic Supergroup. Recent mass movements are attested by patched and diverted segments of the highway. In places, near-vertical cliffs of the Wiggins Formation are visible at the skyline to the north. About 20 miles beyond the river crossing, near the end of the ascent to the Continental Divide at Togwotee Pass, Pleistocene lava flows capped with a small mass of red scoria are visible in Lava Mountain, forming the skyline to the left front. At Togwotee Pass, greenish, low rounded hills to the south and west are carved into the Aycross Formation. To the northeast are horizontally layered gray and white volcanics of the Absaroka Range. Togwotee Pass is situated along the continental divide at an elevation of 9,544 feet.

U.S. Highway 287 descends from Togwotee Pass into Jackson Hole. About six miles beyond the pass, steeply dipping Paleozoic rocks to the north (Madison Limestone) are exposed by erosion that removed the former cover of Absaroka volcaniclastic rocks. Paleozoic rocks here are thrust southward onto Cretaceous rocks along the Buffalo Fork thrust. Quaternary normal faulting created scarps that cut glacial debris.

About nine miles beyond the Continental Divide, the Togwotee scenic overlook provides an excellent panorama of the Teton Mountains-Jackson Hole area to the west. Beyond the scenic overlook towards Moran Junction, where the highway cuts steep slopes of unstable latest Cretaceous Harebell Formation (interbedded quartzite conglomerate, sandstone and claystone), road damage caused by landslides is common.

The Teton Mountains and Jackson Hole region

Douglas R. Gilmer

General description

The abruptness with which the Teton Mountains rise above Jackson Hole is accentuated by the absence of foothills along the base of the range (**Figures 30 and 31**). The dramatic contrast between the highest peak, the Grand Teton, at 13,766 feet above sea level, and the nearby floor of Jackson Hole, at 6,750 feet above sea level, also adds to the grandeur. The Tetons are the youngest mountain range in the Rocky Mountains and are among the most spectacular. The following discussion of the Teton-Jackson Hole region is largely based on a personally conducted tour by J.D. Love. For more detailed discussions, see *Road log, Jackson to Dinwoody and return* (Love and Love, 1983) and *Creation of the Teton landscape* (Love and Reed, 1971).

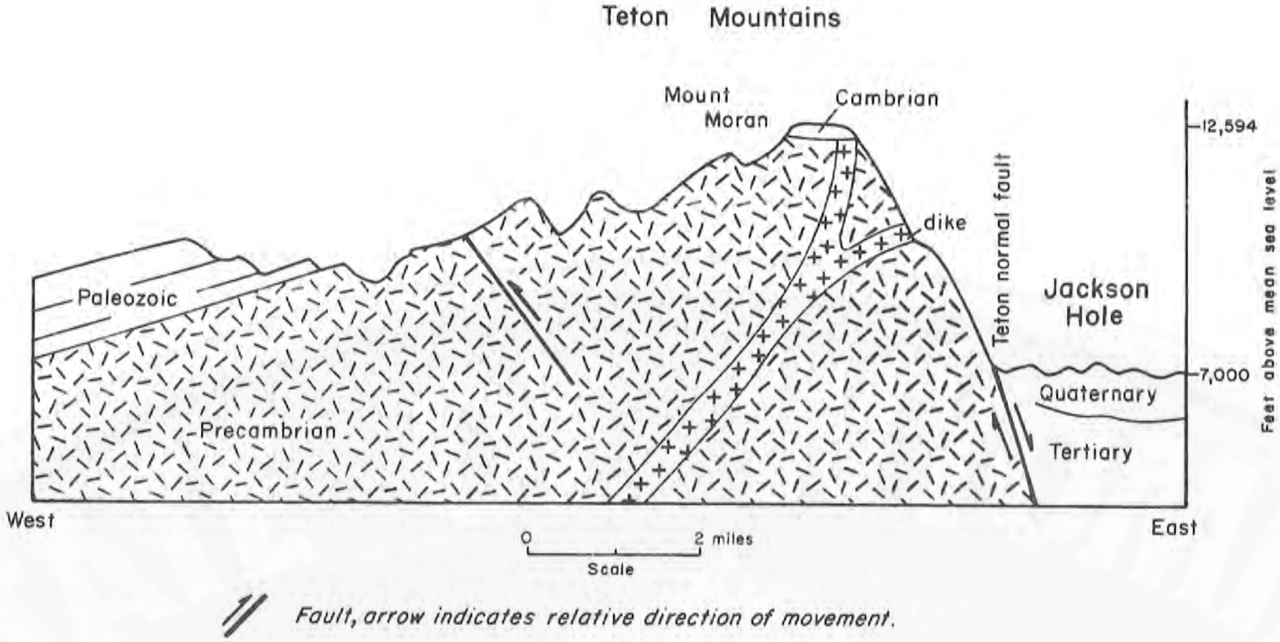


Figure 30. Schematic cross section of the Teton Mountains through Mount Moran (after Edmunds, 1951). The patch of Cambrian rocks on the mountain top suggests a vertical displacement of about four miles from the same strata in the downthrown block deep beneath the floor of Jackson Hole.

Tectonic history

The Teton region experienced two major episodes of tectonism. Between 80 and 65 million years ago, in Laramide time, the ancestral Teton/Gros Ventre uplift produced a southwest-trending arch. About nine million years ago this ancient arch was broken by the north-trending Teton normal fault zone (Figure 30) and the existing Teton range was initiated. Differential movement along this zone of high-angle normal faults is between 25,000 and 30,000 feet in the area of maximum slip. Continued movement is indicated by fault scarps that offset Pleistocene and Holocene deposits along the mountain front.

Glacial history

The Teton fault block has been strongly glaciated to create many cirques, aretes and U-shaped troughs. At least four glacial episodes affected the area. The oldest, referred to as the *ghost glaciation*, was pre-Pleistocene and is so named because only a few isolated tills substantiate its existence. One such till at Signal Mountain underlies the 1.9-million year old Huckleberry Ridge Tuff. Elsewhere, scattered erratics and deposits high above valley bottoms are also attributed to this episode. During the second major glacial episode, Jackson Hole was filled by ice 2,000 to 3,000 feet thick. Scattered remnants of till (such as that capping Signal Mountain) and large-scale grooves along the flanks of the mountains are the main evidence of this glaciation. Most of the deposits from this episode were obliterated by subsequent glaciations. The ensuing *Bull Lake* glacial episode, whose ice occupied much of the area, was followed by the *Pinedale* glaciation. Much of the Bull Lake record was buried or reworked. With a few exceptions, the prominent glacial landforms in Jackson Hole--moraines and moraine-dammed lakes, kettles and extensive outwash plains--are the result of Pinedale glaciation.

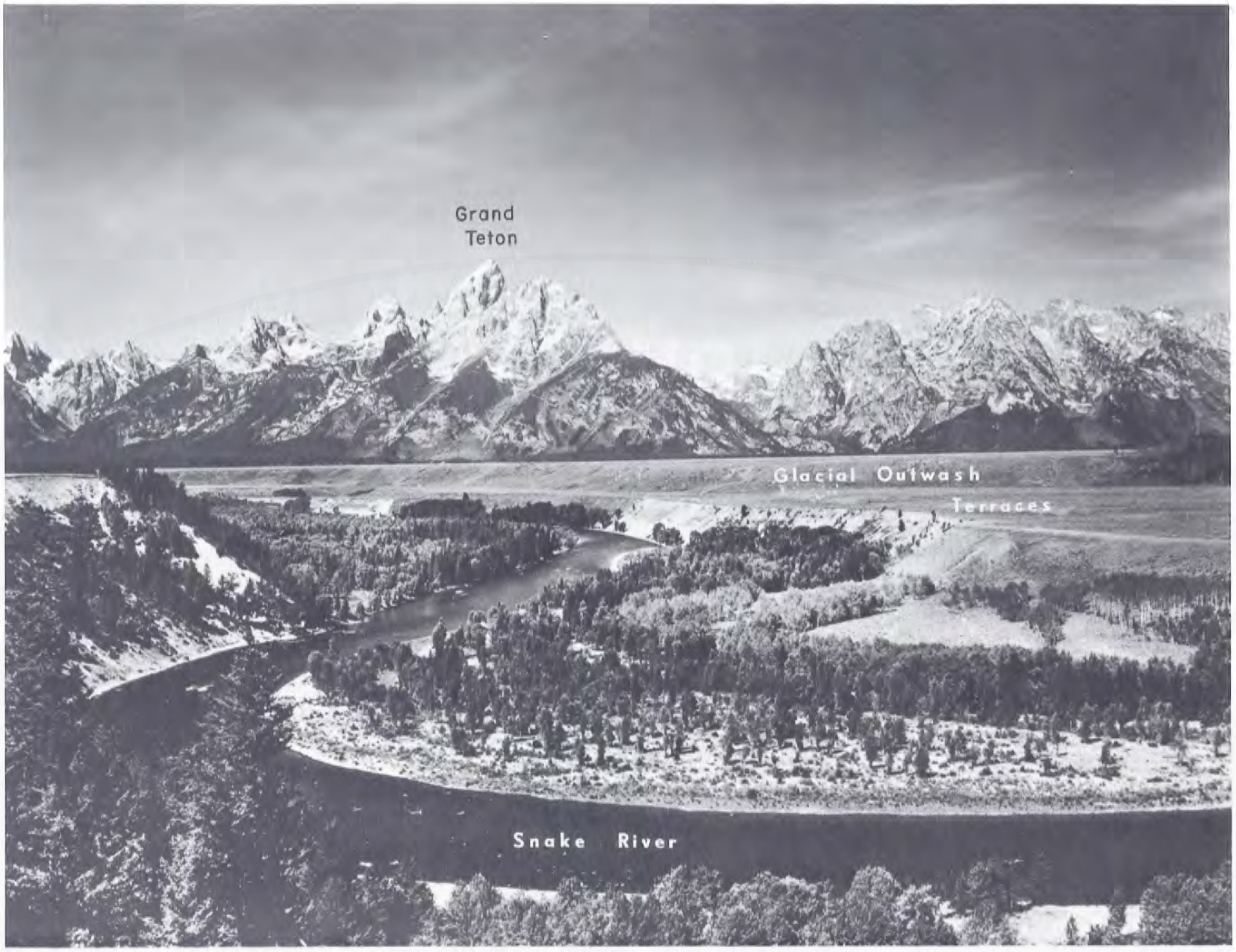


Figure 31. View from the Snake River Overlook (on U.S. Highway 191, east of our route), across terraces developed in Pinedale outwash, to the Teton front whose highest peak, Grand Teton, reaches 13,766 feet, about 6,700 feet higher than the elevation of the overlook. (Photograph courtesy of Wyoming Travel Commission.)

A distinctive phenomenon throughout Jackson Hole is the prevalence of tree cover on the moraines, whereas the outwash plains support only grass and sagebrush. According to Love (personal communication, 1984), the lack of vegetation on outwash deposits could reflect the removal of sand, silt and clay from the outwash deposits by flowing meltwater. Moraines retained the fine-grained fraction, and therefore developed a soil mantle that is conducive to tree growth.

The route (Route map D)

U.S. Highway 287 follows the Buffalo Fork westward down from Togwotee Pass and enters Jackson Hole at its north end near Moran Junction. Turn north at Moran Junction and follow Highway 287 to Jackson Lake Junction, then turn west onto Teton Park Road. One mile from the junction, the road crosses the Snake River on the Jackson Lake Dam.

Jackson Lake Dam was built partly on the Huckleberry Ridge Tuff, a porous volcanic rock, and partly on unconsolidated lake bed, glacial and alluvial sediments. On the dam's embankment, these sediments have been drilled to a depth of 635 feet without encountering bedrock of any kind. The embankment fill and the unconsolidated foundation sediments were saturated by water as the lake level rose. Under these conditions, in the event of a moderate to strong earthquake (the area is seismically active), the saturated embankment fill and the foundation beneath the north embankment could liquify, collapsing the dam and releasing millions of gallons of water into Jackson Hole with potentially catastrophic results (Glass and others, 1976; Bureau of Reclamation, 1984).

Several solutions to this problem were recently proposed (Bureau of Reclamation, 1984). One of these was to lower Jackson Lake to the former level of the natural moraine-dammed lake, which would remove the hazard but leave a temporarily unsightly mudflat around the lake and eliminate the water-storage and flood-control uses of the dam. This proposal would also leave present lakefront property well back from the water's edge.

The option chosen by the Bureau of Reclamation (1984) calls for spending an estimated $82 million to repair and modify portions of the dam. This plan centers around the installation of compaction piles to increase the density of embankment and foundation materials and reduce the potential for liquefaction. It is an expensive remedy and its effectiveness in the event of a major earthquake is unproven. However, the possible collapse of the dam is of immediate concern and the proposed construction is under way (1986).

About 2.5 miles south of the dam, turn east (left) from Teton Park Road and ascend Signal Mountain.

Near the summit, the Jackson Point Overlook provides a fine spot to photograph the Teton Mountains. Drive on to the very sharp bend in the road at the summit. This is the unmarked Emma Matilda Overlook. Park here, if there is room, or drive a short distance to the summit parking lot and walk back.

Emma Matilda Overlook

To the north, across the Snake River from the overlook, the Teton front fault dies out and is buried by rhyolitic lava flows from the Yellowstone caldera and the Pitchstone plateau in Yellowstone National Park. A little east of north from the overlook is Emma Matilda Lake, ponded behind Pinedale moraines. Farther east, Gravel Mountain is composed of gold-bearing quartzite gravels. They were transported from an uplift to the northwest. This gravel, the Pinyon Conglomerate, was deposited as large fans by uppermost Cretaceous and Paleocene rivers. Still farther east, Paleozoic sedimentary rocks of the Washakie Range are visible; the tremendous volcanic pile of the Absaroka Volcanic Plateau is in the background.

Signal Mountain summit

The road continues past Emma Matilda Overlook to the summit of Signal Mountain where an overlook affords a beautiful view to the east, south and west. To the south-southeast is the westward-building gravel fan of Spread Creek that testifies to recent westward tilting of the Jackson Hole block. At one time, when this block tilted eastward, the Snake River flowed south from Jackson Lake. Since then, the river has shifted eastward occupying three successive outlet channels through Pinedale moraines damming Jackson Lake before reaching its present location. The abandoned outlets and several braided stream channels in the Pinedale outwash plain, as well as many potholes, kettles and tree-covered moraines to the south are evident from the mountain summit.

In the south-central part of Jackson Hole, Blacktail Butte, East Gros Ventre Butte and West Gros Ventre Butte are block-faulted remnants of the ancestral Teton-Gros Ventre uplift.

Signal Mountain summit also offers an excellent view westward of the entire Teton range, rising steeply from the valley floor. The steep, straight east front of the range exhibits many triangular facets and stepped fault scarps. Cirques, U-shaped valleys, small glaciers and Pinedale-age moraines are prominent. Although not evident from this vantage point, the Teton range is an asymmetrically tilted block whose west slope is much gentler than the east slope **(Figure 30)**. The range is over 40 miles long but only one third as wide.

The highest, central part of the range is composed predominantly of Precambrian granite and gneiss intruded by many veins and dikes. At the northern and southern ends of the range, where uplift is less, Paleozoic and Mesozoic sedimentary rocks appear along the front. Peaks formed of these rock types display sedimentary bedding planes that contrast with the ragged slopes on the harder, more homogeneous granite and gneiss. Small faults and joint sets also modify the range front.

Jenny Lake

Descend Signal Mountain, turn south (left) onto Teton Park Road, and continue on the Jenny Lake Loop Road to an overlook directly across the lake from Cascade Canyon. This canyon is a classic U-shaped glacial valley leading down to moraine-dammed Jenny Lake. Note the numerous avalanche chutes on the mountainside above the lake.

Continuing south from Jenny Lake, Teton Park Road passes Timbered Island to the east (left), a forested Bull Lake moraine remnant. At Moose Junction, turn south (right) onto Highway 191. Drive to Gros Ventre Junction and turn east (left) onto the Gros Ventre Road. Follow the road past Kelly to the Gros Ventre River canyon.

Gros Ventre landslide

Approximately 2.5 miles into the Gros Ventre canyon is the site of the massive Gros Ventre landslide **(Figure 32)**. Triggered by an earthquake on the morning of June 23, 1925, a large mass of north-dipping Tensleep Sandstone detached from the south side of the Gros Ventre valley, slid down across the river, up onto the opposite valley wall, then settled back in the valley bottom **(Figure 33)**. The resulting natural dam was partially breached two years later, causing a flood that nearly obliterated the small town of Kelly just beyond the mouth of the canyon. The landslide scar is still prominent, and Slide Lake is backed up behind the unbreached part of the dam.

Curtis Canyon Overlook

Retrace the route back to U.S. Highway 191, turn south and drive to Jackson. In Jackson, drive south on Cache Street to Broadway (at the southwest side of the town square just beyond the antler archway). Turn left on Broadway and drive east to the split at the end of Broadway. Turn left on the gravel road that leads to the Elk Refuge. A little over a mile ahead, the road approaches and follows the east side of Millers Butte, a fault block containing Mississippian Madison Limestone and Mississippian-Pennsylvanian Amsden Formation. From there, the road crosses broad alluvial fan deposits. Follow signs to Curtis Canyon Campground. At the foot of the mountain, the dirt road rises up switchbacks for 1.2 miles to the Curtis Creek viewpoint (and nearby campground), which provides a panoramic view of the Tetons across Jackson Hole from the Gros Ventre Range. To the west,

Figure 32. Panoramic winter view of the Gros Ventre landslide (to left), and rock debris from the slide, which was washed down the valley when Slide Lake was breached (to right). (Photograph by Douglas Gilmer).

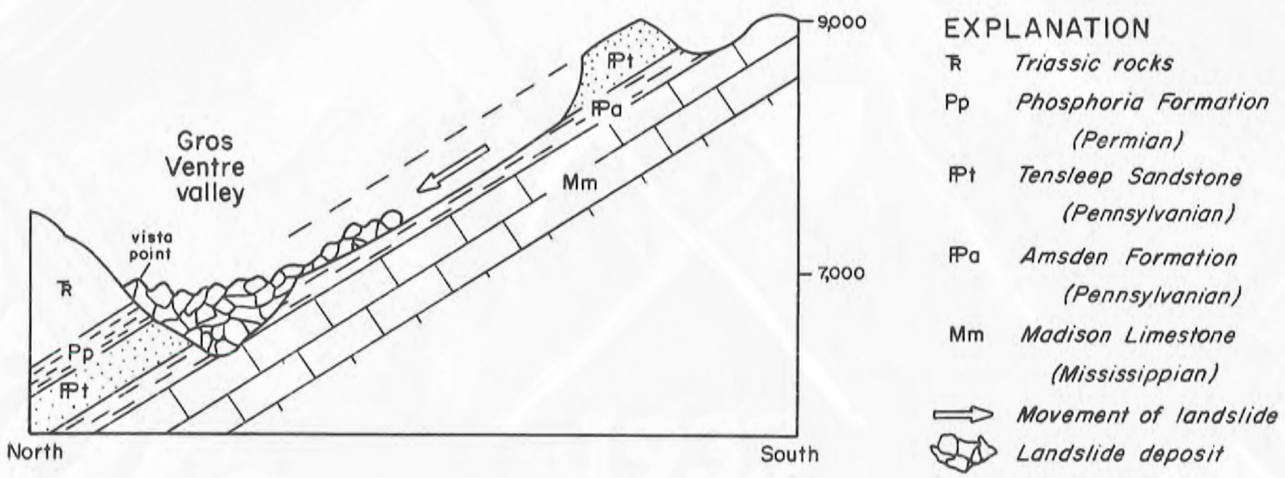


Figure 33. Schematic cross section of Gros Ventre landslide. Horizontal distance is approximately two miles. Elevations are in feet above mean sea level.

in the valley floor below the overlook, the cobble-capped streamlined hills may have been overridden and planated by pre-Bull Lake glacial ice.

The Curtis Canyon Campground, about one-quarter mile from the overlook, occupies a south-trending valley along the mountainside that has been interpreted as a giant glacial groove made by pre-Bull Lake ice. The campground is a fine place to spend the night and see a sunrise on the Tetons from the overlook. Retrace the route back to Jackson.

Jackson to Rock Springs

Hollis J. Marriott

General description

The Cache Creek fault trends westward through the southern part of Jackson. This fault separates the Precambrian-cored Gros Ventre Range from Snow King Mountain (marked by ski runs) at the south end of Jackson, in the Idaho-Wyoming overthrust belt. The route crosses parts of the overthrust belt mountains, the Green River Basin and the Rock Springs uplift. Ranges of the overthrust belt are the easternmost expression of the Sevier orogeny (briefly described in the earlier introductory geologic synopsis). Its style of deformation is well displayed along the route through Hoback Canyon. Here, folded Paleozoic and Mesozoic strata form great slabs bounded by low-angle thrust faults, and Precambrian basement rocks are notably absent. This structure contrasts markedly with the previously observed Laramide style of deformation, characterized by broad-backed, Precambrian-cored mountains (such as the Wind River Range) that are separated by wide intervening basins.

The route (Route map E)

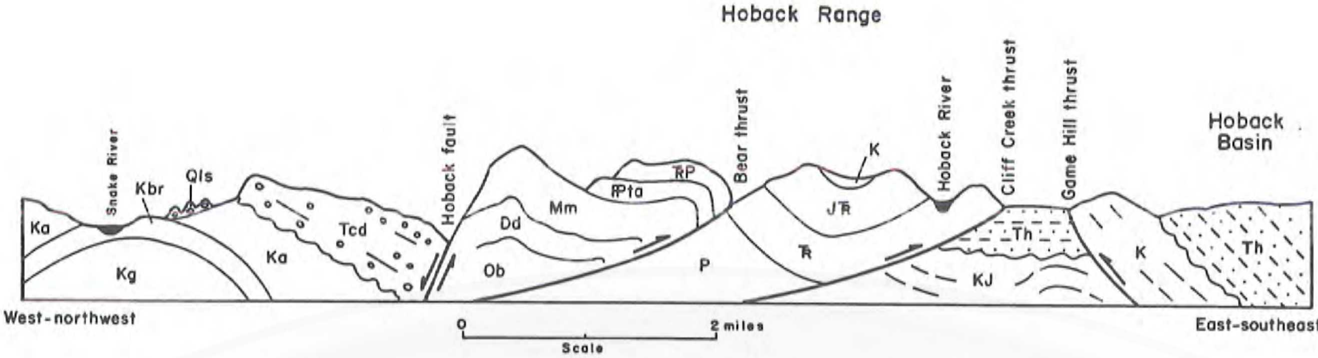
From Jackson, follow U.S. Highway 191 south along the Snake River. Approximately seven miles south of Jackson the valley narrows at the north end of the Snake River canyon. Rocks visible to the left include the Miocene Camp Davis Formation (conglomerates unconformably overlying gray Cretaceous Aspen Shale). The Aspen Shale tends to be unstable and evidence of slumping is visible on hillsides along the highway. At Hoback Junction, the Hoback River joins the Snake River, which drains into the Pacific Ocean via the Columbia River. Turn east at the junction and follow Highway 191/189.

From Hoback Junction to the entrance to Hoback Canyon, the road crosses the downthrown block of the Hoback (normal) fault (**Figures 34** and **35**). Rocks exposed along the route include Cretaceous shales and sandstones (Bear River Formation, Aspen Shale and Frontier Formation), overlain on the north (left) by cliffs of the Camp Davis Formation. Its coarse conglomerates were deposited along the Hoback fault during Miocene time.

The parking area on the north side of the road at the entrance to the steep-walled canyon is at the base of the Hoback fault scarp. A sulfur spring just below the turnout is probably related to the fault. Total fault displacement may be as much as 10,000 feet. The age and style of deformation suggest that the Hoback fault is related to Basin and Range events (Oligocene through Holocene extensional faulting), which occurred after Sevier activity had ceased.

Just east of the parking area, upthrown limestones and dolomites of the Devonian Darby Formation and Mississippian Madison Limestone form cliffs. Farther up the canyon, cliffs of the Pennsylvanian Tensleep Sandstone are overlain by slopes of dark Permian Phosphoria Formation shale. Outcrops of Triassic redbeds, the Woodside Formation shale are also visible.

In the canyon, the highway crosses several low-angle thrust faults of Sevier-style deformation (**Figure 34**). The Bear thrust can be seen across the river from a parking area about three miles east of the canyon mouth, where Tensleep Sandstone is thrust over steeply-dipping and folded Triassic redbeds.



EXPLANATION

Cenozoic
- Quaternary
  - Qls *Landslide deposit*
- Tertiary
  - Tcd *Camp Davis Formation (Miocene)*
  - Th *Hoback Formation (Paleocene)*

Mesozoic
- Cretaceous
  - Ka *Aspen Shale*
  - Kbr *Bear River Formation*
  - Kg *Gannett Formation*
  - K *Undivided*
- KJ *Cretaceous and Jurassic, undivided*
- JTR *Jurassic and Triassic, undivided*
- TR *Triassic, undivided*
- TRP *Triassic and Permian, undivided*

Paleozoic
- P *Permian, undivided*
- IPta *Tensleep Sandstone and Amsden Formation (Pennsylvanian)*
- Mm *Madison Limestone (Mississippian)*
- Dd *Darby Formation (Devonian)*
- Ob *Bighorn Dolomite (Ordovician)*

Fault; arrow indicates relative direction of movement.

Figure 34. Schematic cross section along U.S. Highway 191/189 from Hoback Junction through Hoback Canyon of the overthrust belt to Hoback Basin (based on data in Dorr and others, 1977).

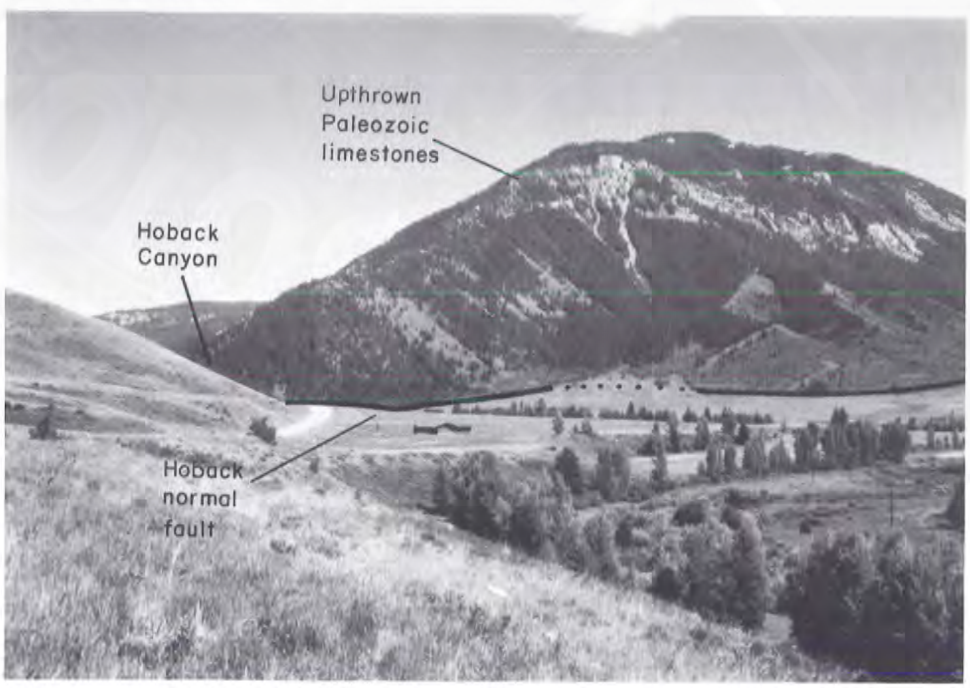


Figure 35. View eastward towards the entrance to Hoback Canyon. Paleozoic limestones are exposed in the upthrown block of the Hoback normal fault. (Photograph by Brainerd Mears, Jr.)

Looking northwest from the turnoff at Kozy Campground, the trace of the Cliff Creek thrust fault follows the base of Battle Mountain and is partially covered by a landslide in the Hoback Formation **(Figures 34 and 36)**.

Leaving Hoback Canyon, the highway passes from the overthrust belt into the relatively broad Hoback Basin, which contains Tertiary sediments derived from the Hoback and Gros Ventre uplifts. The yellow-tan cliffs are outcrops of resistant Pass Peak Sandstone (Eocene). Approximately 14 miles past Bondurant, the road crosses the Hoback rim, which separates the Hoback Basin to the northwest from the main part of the Green River Basin to the southeast. Beyond Hoback rim, drainage is into the Green River, and ultimately the Gulf of California via the Colorado River. Though the basins are distinct topographically, they are part of the same great synformal basin.

The road continues southeast along the south flanks of the Gros Ventre Mountains and Wind River Range. About two miles beyond Hoback rim, the route passes over glacial moraines of probable Bull Lake age. Here, ice of the Green River alpine glacier extended as much as five miles into the basin. At the junction just north of Daniel, stay left on Highway 191 that turns east to Pinedale. Approximately five miles east of the junction, turn south (right) on a dirt road to Trappers Point vista.

Trappers Point vista

Trappers Point overlooks the site of the the Upper Green River Rendezvous. Western fur trappers, traders and Indians held their annual meeting here five times between 1833 and 1839.

To the east, bordering the Green River Basin, the Wind River Range trends southeast for about 90 miles. The range is a typical Laramide structure, an eroded broad-backed anticline exposing Precambrian basement rocks. The uplift is bounded on the southwest by a high-angle reverse fault. Tertiary basin rocks are in contact with Precambrian rocks of the uplift **(Figure 20)**, and the Paleozoic and Mesozoic flatirons, hogbacks and strike valleys characteristic of the northeast flank of the range are absent.

The *Fremont surface* is a prominent plateau-like erosion surface below the high peaks that form the jagged skyline of the Wind River Range. Although not evident from this vista point, truncation of dipping sedimentary strata of Cambrian through Mesozoic age by this high-level erosion surface suggests that

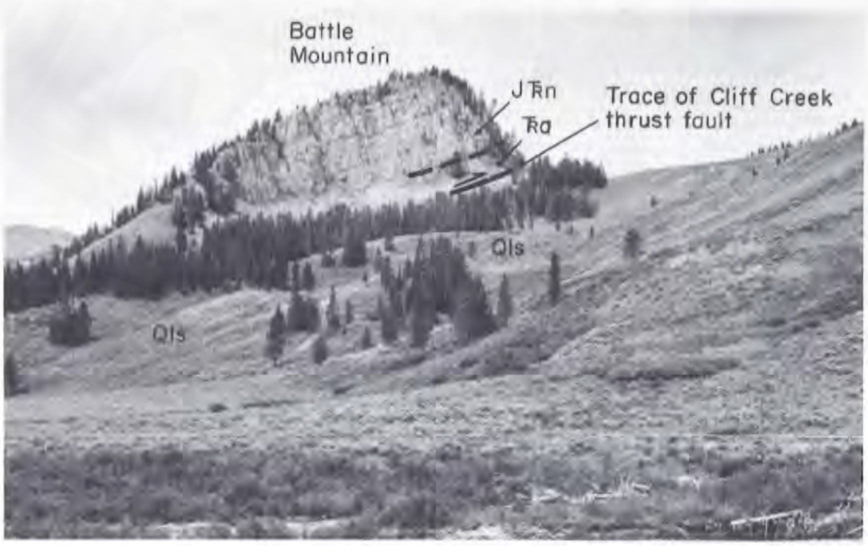


Figure 36. Cliff Creek thrust fault exposed at Battle Mountain in Hoback Canyon. Nugget Sandstone (J₸n) overlies Ankareh Formation (₸a) in the cliff. Quaternary landslide debris (Qls) covers much of the hillslope down to the Hoback River (foreground). (Photograph by Sheila Roberts.)

it is a post-Laramide erosional feature. It is probably a relict Pliocene cut-and-fill surface that extended from the crystalline rocks of the mountains across the filled basins. Subsequent erosion excavated much of the fill from the Green River Basin, establishing the present local relief.

To the west is an expansive view of the Green River Basin. The point sits on eroding Eocene Wasatch Formation. Meanders of the Green River are just west of these outcrops and the Green River Basin extends westward to the mountains of the overthrust belt on the horizon (**Figure 37**). Return to U.S. Highway 191 and drive east to Pinedale.

Pinedale

Near the southeast end of town, where the highway swings right, turn left on the road to Fremont Lake. The road climbs about 80 feet above the town onto a bench, a former outwash plain of Bull Lake age, and then continues across Bull Lake and Pinedale moraines (**Figure 38**). The older Bull Lake moraines have characteristically moderate relief, and weathering and erosion have modified most of the near-surface boulders. Near the lake, the road ascends the Pinedale moraine front into the steeper, rockier topography of the younger Pinedale deposits that encircle the south end of Fremont Lake.

Figure 37. View west from Trappers Point. Eocene Wasatch Formation forms the sparsely vegetated mounds in the foreground. The Green River meanders across the basin, and mountains of the overthrust belt are just visible 30 to 40 miles away on the skyline. (Photograph by Sheila Roberts.)

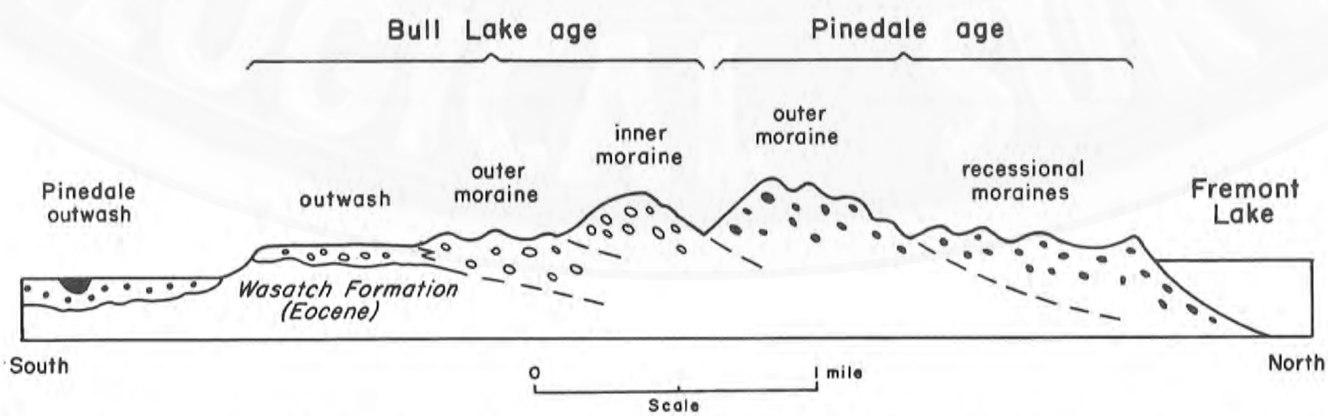


Figure 38. Glacial sequence from Pinedale to Fremont Lake (based on field excursions led by G.M. Richmond).

Fremont Lake vista

The lake occupies a deep glacier-scoured valley, dammed by Pinedale moraines including an outer terminal moraine and several recessional moraines.

Beyond the lake, the Fremont high-level surface and the high peaks of the Wind River mountains are prominent. The flat-topped hill to the southeast, in front of the main range and east of Fremont Lake, is Half Moon Mountain, a remnant of the Tertiary fill that once covered this area and lapped evenly onto the Fremont surface. Return to Pinedale and turn southeast (left) on U.S. Highway 191.

On leaving Pinedale, the route crosses outwash deposits in Quaternary terraces for about seven miles, then Wasatch Formation for the next 30 miles and then Green River Formation. Pass Farson (58 miles from Pinedale) and continue about four miles to Eden on Highway 191. In Eden note your mileage at the post office (to the right). Turn east (left) (no sign) off the main highway a little less than 3.5 miles south of Eden and cross a cattle guard to a paved, but extensively potholed, abandoned section of the highway. *(Note: Most of the next 30 miles of this tour follow dirt roads. The road to the top of White Mountain can be impassable. In wet or inclement weather it is wise to skip this section and continue to Rock Springs on Highway 191)*. Drive carefully southeast for about 2.2 miles, avoiding potholes in the unmaintained road, then turn east (left) on an unmarked dirt road that crosses Green River Formation (as well as some normally passable sandy areas). After about 6.5 miles, the road reaches the crest of White Mountain and turns south (right) for the descent. Park at the crest to observe the view eastward.

White Mountain overlook

White Mountain is underlain by west-dipping Green River Formation strata deposited in the Eocene Gosiute Lake. The Killpecker Creek valley east of the overlook is floored with Eocene Wasatch Formation. The Killpecker dune field **(Figure 39)** extends eastward for about 55 miles from the east margin of the Green River Basin, across White Mountain and the north end of the Rock Springs uplift into the Great Divide Basin. The dune field includes a variety of eolian features including sand dunes, silt and clay dunes, deflation hollows and salt plumes. The water table in the field is fairly high and intradunal ponds are common. Heavy-mineral assemblages suggest that the sand is derived from shore facies of sediments deposited in the Eocene Gosiute Lake (Ahlbrandt, 1973).

The elongate Killpecker dune belt has sharp north and south boundaries, probably reflecting eolian deposition by winds channeled through the notch in White Mountain, just north of the viewpoint (Ahlbrandt, 1973). A number of dune types are visible from White Mountain at the west end of the field. Dome dunes (no slip faces) occur where the wind is accelerated through the notch. Farther east (downwind) are transverse dunes (axes perpendicular to wind direction). Barchan dunes, near the edges of the field, are crescent-shaped dunes whose tails point downwind, and may represent sand-starved transverse dunes. Parabolic dunes (tails pointing upwind) are partially controlled by vegetation along the downwind margins of the active sand. Vegetationally stabilized dunes, forming wormy-looking topography around the active dune area, were probably active during the Altithermal episode, between 5,500 to 7,000 years ago, when mid-Holocene drought conditions resulted in more extensive free-blowing sand.

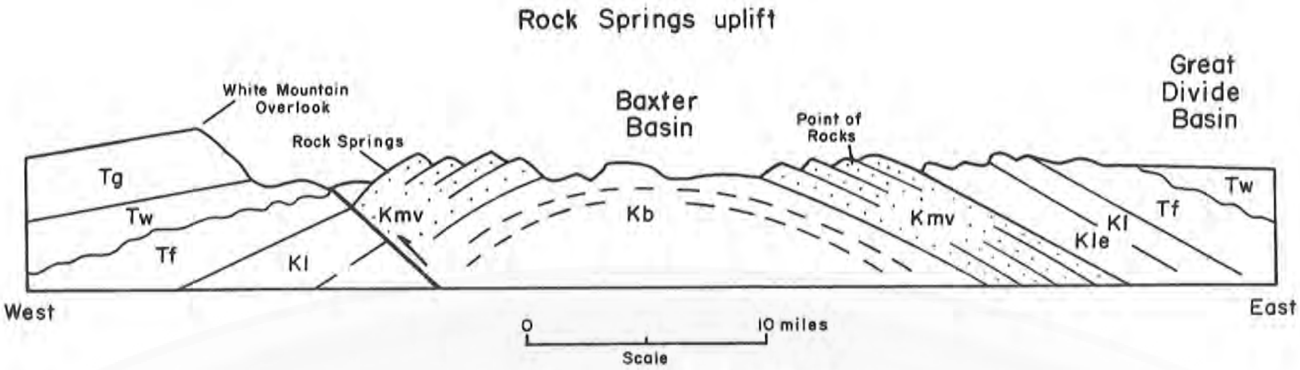
The rising slope of the Rock Springs uplift, along the east side of the valley, is underlain by Cretaceous rocks of the Mesaverde Group. The base of the Cretaceous slope approximates a fault along which the Mesaverde Group rocks were thrust over Paleocene rocks **(Figure 40)**.

Figure 39. View southward from White Mountain (at a point north of our route) across active dunes of the Killpecker field (foreground) and stabilized dunes (middle distance) to the Boars Tusk and the distant Rock Springs uplift. Note the person standing on the dune to the left, for a perspective on the scale of these dunes. (Photograph by Herb Pownall.)

The Rock Springs uplift was active into Eocene time. It is a typical Laramide broad-backed anticline, but of relatively limited height and extent. The oldest rocks exposed in the core are Cretaceous. Topographically, the uplift is a large breached anticline whose central portion is floored with Baxter (Cody) Shale rimmed by Mesaverde Group rocks.

The Leucite Hills, Pleistocene volcanic features, are visible to the east at the north end of the Rock Springs uplift. They include the prominent Boar's Tusk (**front cover photo** and **Figure 39**), a volcanic neck rising from the valley floor, and several lava-capped mesas, one of which, Steamboat Mountain, is capped by an eroded cinder cone. These mesas reflect topographic reversal (former valley floors that now stand high) where lava, flowing down valleys, formed resistant covers that protected the underlying sedimentary rocks from erosion that lowered the surrounding topography. The composition of the lava indicates a very deep magma source. Potassium-argon dates place the volcanism in the early Pleistocene, about 1.2 million years ago.

From the White Mountain vista point, continue southeast about six miles on the dirt road as it descends from the Green River Formation into a strike valley underlain by the Eocene Wasatch Formation. Due south of the Boar's Tusk, about one-half mile past a railroad crossing, bear south (right) and follow a well-graded (sometimes washboarded) dirt road, the Tri-Terri-



EXPLANATION

Tertiary		Cretaceous	
Tg	*Green River Formation (Eocene)*	Kl	*Lance Formation*
Tw	*Wasatch Formation (Eocene)*	Kle	*Lewis Shale*
Tf	*Fort Union Formation (Paleocene)*	Kmv	*Mesaverde Group*
		Kb	*Baxter Shale*
			Fault; arrow indicates direction of relative movement.

Figure 40. Schematic cross section from White Mountain across the Rock Springs uplift to the Great Divide Basin. White Mountain stands about 800 to 900 feet above the valley floor to the east.

tories Road. To the west (right) the Green River Formation is well-displayed along the east face of White Mountain. To the east (left) the valley is bounded by west-dipping sandstones of the Mesaverde Group, forming the west flank of the Rock Springs uplift. After about ten miles, the Tri-Territories road turns southwest and joins U.S. Highway 191. Turn left and drive south to Rock Springs, once a center for coal mining operations in the Mesaverde Group.

We hope this guide added interest to the well-exposed and varied geology across our State. Some of the following materials and readings should be helpful to those desiring more information.

Selected references and supplementary materials

Popular summaries

Blackstone, D.L., Jr., 1971, Traveler's guide to the geology of Wyoming: Geological Survey of Wyoming Bulletin 55, 90 p.

Love, J.D., and Reed, J.C., Jr., 1971, Creation of the Teton landscape: Grand Teton Natural History Association, 120 p.

Mears, Brainerd, Jr., 1972, Wyoming's glaciers, past and present: Wyoming Wildlife, v. 36, no. 4, p. 26-24.

Thomas, H.D., 1957, Geologic history and structure of Wyoming: Geological Survey of Wyoming Reprint 18, 11 p.

Wyoming Geological Association Guidebooks (road logs included)

1951, Southcentral Wyoming
1953, Laramie Basin and North Park, Wyoming and Colorado
1955, 1973, Green River Basin
1956, Jackson Hole area
1957, 1978, Wind River Basin
1977, Joint Wyoming-Montana-Utah Geological Associations Guidebook, Rocky Mountain thrust belt geology and resources
1980, The stratigraphy of Wyoming

Road logs

Hausel, W.D., 1984, Tour guide to the geology and mining history of the South Pass gold mining district, Fremont County, Wyoming: Geological Survey of Wyoming Public Information Circular 23, 1 sheet.

Hausel, W.D., and Jones, R.W., 1984, Self-guided tour of the geology of a portion of southeastern Wyoming: Geological Survey of Wyoming Public Information Circular 21, 44 p.

International Association for Quaternary Research, 1965, Guidebooks for Field Conference, VIIth Congress, v. 5, Field Conference E, Northern and Middle Rocky Mountains: International Association for Quaternary Research, 129 p.

Love, J.D., and Love, J.M., 1983, [Geologic] Road log, Jackson to Dinwoody and return: Geological Survey of Wyoming Public Information Circular 20, 33 p.

Spearing, D.R., and Steidtmann, J.R., 1977, Trip 1, Front of thrust belt to foreland: Wyoming Geological Association 29th Annual Field Conference Guidebook, p. 762-767.

Maps

Christiansen, R.D., compiler, 1986, Wyoming geologic highway map: Western Geographics, scale 1:1,000,000. [This map is also available from the Geological Survey of Wyoming.]

Geological Highway Map Committee, 1972, Geological highway map northern Rocky Mountain region, Idaho, Montana and Wyoming: American Association of Petroleum Geologists Map no. 5, scale 1 inch = approximately 30 miles. [This map is also available from the Geological Survey of Wyoming.]

Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000. [This map is also available from the Geological Survey of Wyoming.]

U.S. Geological Survey, 1968, Shaded relief map of Grand Teton National Park, scale 1:62,500. (Includes photographs, diagrams and a descriptive text by F.M. Fryxwell, J.D. Love, J.C. Reed, Jr., George Frison, C.H. McCurdy and Lloyd Loop on the reverse side.) [This map is also available from the Geological Survey of Wyoming.]

Wyoming highway map (issued annually): Wyoming State Highway Department, scale 1 inch=approximately 18 miles.

The U.S. Geological Survey has published 1:24,000-scale geologic maps for many of the areas discussed in this guide. A few of the maps that describe stops in the tour are listed below. These maps are available from the U.S. Geological Survey or the Geological Survey of Wyoming and the reader should consult one of these agencies for more complete listings of geological maps of Wyoming.

Murphy, J., and Richmond, G.M., 1965a, Bull Lake East Quadrangle: U.S. Geological Survey Geological Quadrangle Map GQ-431, scale 1:24,000.

Murphy, J., and Richmond, G.M., 1965b, Bull Lake West Quadrangle: U.S. Geological Survey Geological Quadrangle Map GQ-432, scale 1:24,000.

Reynolds, M.S., 1968, Muddy Gap Quadrangle: U.S. Geological Survey Geological Quadrangle Map GQ-771, scale 1:24,000.

Reynolds, M.W., 1971, Lamont Quadrangle: U.S. Geological Survey Geological Quadrangle Map GQ-912, scale 1:24,000.

Rohrer, W.L., 1966, Kissinger Lake Quadrangle: U.S. Geological Survey Geologic Quadrangle Map GQ-527, scale 1:24,000.

More technical articles and University of Wyoming theses

Ahlbrandt, T.S., 1973, Sand dunes, geomorphology and geology, Killpecker Creek area, northern Sweetwater County, Wyoming: Ph.D. dissertation, University of Wyoming, Laramie, 174 p.

Barlow, J.A., Jr., 1953, Geology of the Rawlins uplift, Carbon County, Wyoming: Ph.D. dissertation, University of Wyoming, Laramie, 179 p.

Beckwith, R.H., 1941, Structure of the Elk Mountain district, Carbon County, Wyoming: Geological Society of American Bulletin, v. 52, p. 1445-1486.

Blackstone, D.L., Jr., 1975, Late Cretaceous and Cenozoic history of Laramie Basin region, southeast Wyoming, *in* Cenozoic history of the southern Rocky Mountains: Geological Society of America Memoir 144, p. 249-279.

Blackwelder, Eliot, 1915, Post-Cretaceous history of the mountains of central western Wyoming: Journal of Geology, v. 23, no. 4, p. 307-340.

Bureau of Reclamation, 1984, Modification report, Jackson Lake safety of dams project, Minidoka Project, Idaho-Wyoming: U.S. Department of the Interior, 80 p.

Chadeayne, D.K., 1966, The geology of Pass Creek Ridge, Saint Marys and Cedar Ridge anticlines, Carbon County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 87 p.

Dorr, J.A., Jr., Spearing, D.R., and Steidtmann, J.R., 1977, Deformation and deposition between a foreland uplift and impinging thrust belt: Hoback Basin, Wyoming: Geological Society of America Special Paper 177, 82 p.

Dunbar, R.O., 1942, The geology of Como Bluffs anticline, Albany-Carbon Counties, Wyoming: M.S. thesis, University of Wyoming, Laramie, 40 p.

Edmunds, R.W., 1951, Structural geology and physiography of the northern end of the Teton Range, Wyoming: Augustana Library Publication no. 23, 82 p.

Gilliland, J.D., 1959, Geology of the Whiskey Mountain area, Fremont County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 93 p.

Glass, W.R., Keefer, T.N., and Rankl, J.G., 1976, Hydrologic effects of hypothetical earthquake-caused flood below Jackson Lake, northwestern Wyoming: U.S. Geological Survey Water Resources Investigations, Open File Report 76-77, 32 p.

Keefer, W.R., 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-D, 35 p.

Knight, S.H., 1953, Summary of the history of the Medicine Bow Mountains, Wyoming: Wyoming Geological Association 8th Annual Field Conference Guidebook, p. 65-76.

Kolm, K.E., 1982, Predicting the surface wind characteristics of southern Wyoming from remote sensing data and eolian geomorphology, *in* Marrs, R.W., and Kolm, K.E., editors, Interpretation of wind flow characteristics from eolian landforms: Geological Society of America Special Paper 192, p. 25-53.

Love, J.D., 1939, Geology along the southern margin of the Absaroka Range: Geological Society of America Special Paper 20, 134 p.

Love, J.D., 1960, Cenozoic sedimentation and crustal movement in Wyoming: American Journal of Science (Bradley Volume), v. 258A, p. 204-213.

Love, J.D., 1970, Cenozoic geology of the Granite Mountains area, central Wyoming: U.S. Geological Survey Professional Paper 495-C, 154 p., 10 plates.

Mears, B., Jr., 1974, The evolution of the Rocky Mountain glacial model, *in* Glacial geomorphology: State University of New York Publications, p. 11-40.

Mears, B., Jr., 1981, Periglacial wedges and the Late Pleistocene environment of Wyoming's intermontaine basins: Quaternary Research, v. 15, no. 3, p. 171-198.

Nissen, T.C., 1985, Field and laboratory studies of selected periglacial wedge-polygons in southern Wyoming: M.S. thesis, University of Wyoming, Laramie, 165 p.

Ogden, P.R., Jr., 1979, Geology, major element geochemistry and petrogenesis of Leucite Hills volcanic rocks, Wyoming: Ph.D. dissertation, University of Wyoming, Laramie, 137 p.

Pierce, K.L., Obradovich, J.D., and Friedman, I., 1976, Obsidian hydration and correlation of Bull Lake and Pinedale glaciations near West Yellowstone, Montana: Geological Society of America Bulletin v. 87, no. 5, p. 703-710.

Richmond, G.M., 1965, Glaciation of the Rocky Mountains, *in* Wright, H.E. and Frey, D.G., editors, Quaternary of the United States: Princeton University Press, Princeton, New Jersey, p. 217-230.

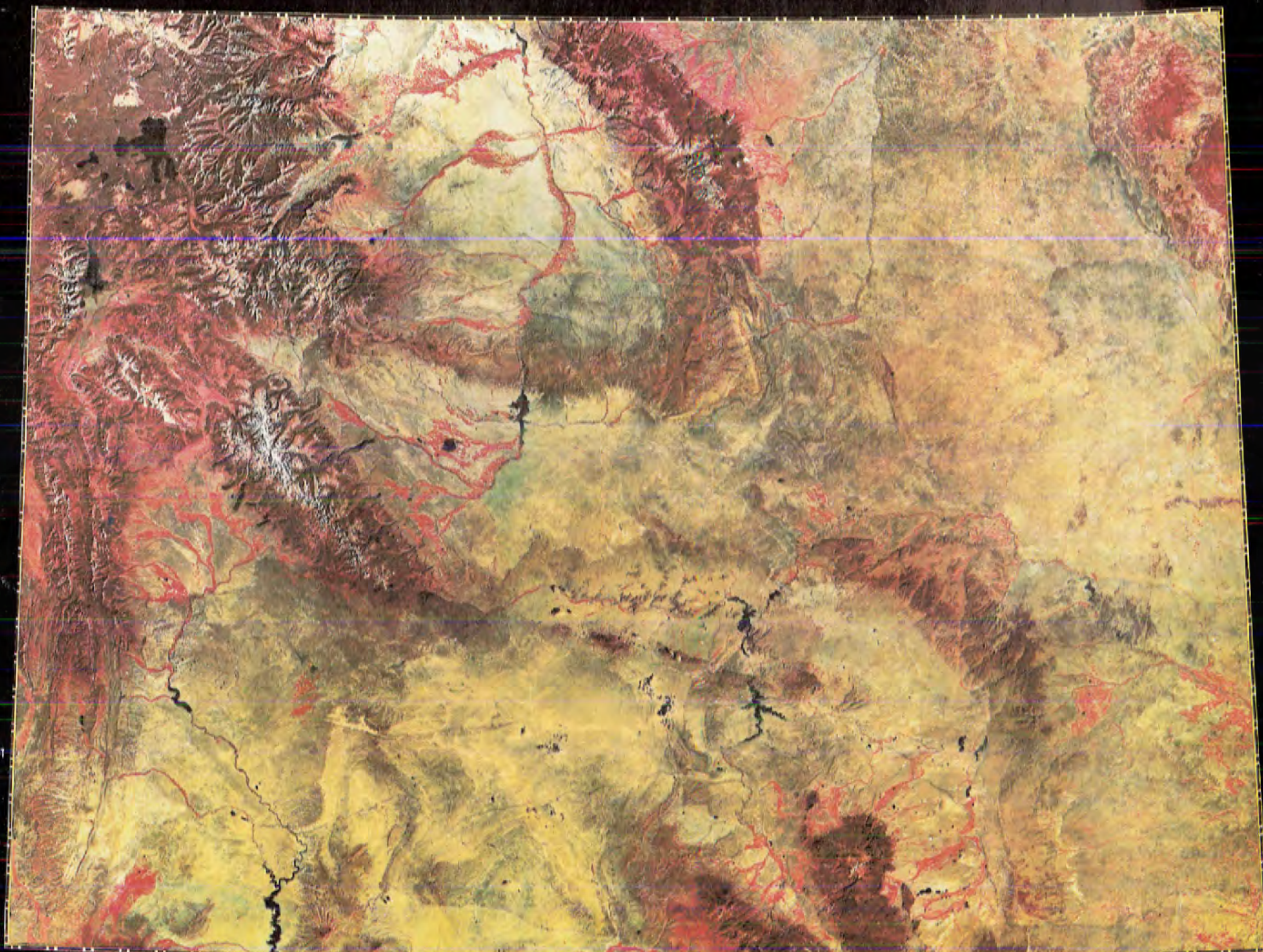
Richmond, G.M., 1976, Pleistocene stratigraphy and chronology in the mountains of western Wyoming, *in* Mahoney, W.C., editor, Quaternary stratigraphy of North America: Dowden, Hutchinson and Ross, Inc., Pennsylvania, p. 353-379.

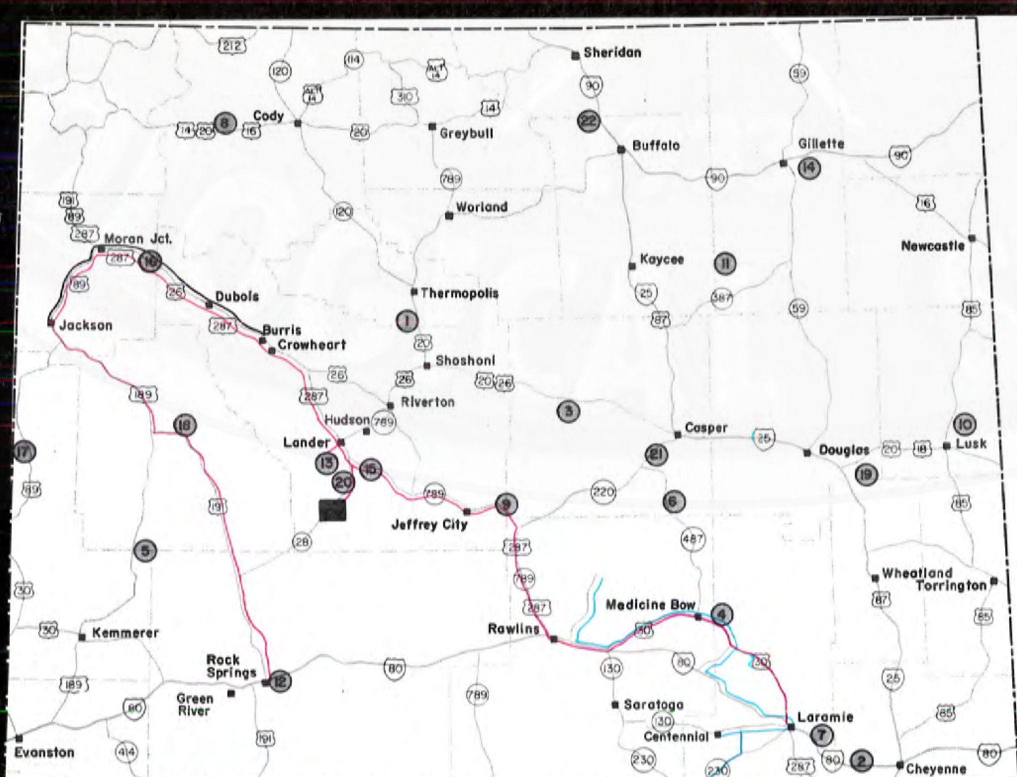
Seeland, David, 1978, Sedimentology and stratigraphy of the lower Eocene Wind River Formation, central Wyoming: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 181-198.

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

Winterfeld, G.F., 1986, Laramide tectonism, deposition and early Cenozoic stratigraphy of the northwestern Wind River Basin and Washakie Range, Wyoming: Ph.D. dissertation, University of Wyoming, Laramie, 248 p.

STATE OF WYOMING
1933
GEOLOGICAL SURVEY





GUIDES TO WYOMING GEOLOGY AVAILABLE FROM THE GEOLOGICAL SURVEY OF WYOMING

Route of this road log

Stops in Bulletin 55 (Traveler's Guide to the Geology of Wyoming)

Route of PIC 20 (Jackson-Dinwoody road log)

Route of PIC 21 (Southeastern Wyoming road log)

Area of PIC 23 (South Pass Gold Mining District)

A geologic tour of Wyoming from Laramie to Lander, Jackson and Rock Springs