WYOMING STATE GEOLOGICAL SURVEY
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Field guide for the Alcova area, Natrona County, Wyoming

by
Peggy Knittel, Dana P. Van Burgh, Jr., Terrence J. Logue, Beecher Ed Strube, and Richard W. Jones

EDUCATIONAL SERIES NO. 2
LARAMIE, WYOMING
2004

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First printing of 2000 copies by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

Field guide for the Alcova area, Natrona County, Wyoming, by P. Knittel, D.P. Van Burgh, Jr., T.J. Logue, B.E. Strube, and R.W. Jones. ISBN 1-884589-35-9.

Front cover: Aerial photograph of Alcova Reservoir taken from approximately 1000 feet altitude. View is to the southwest with Alcova Dam in the foreground and Fremont Canyon in the background. The photograph was taken in 1984 by Jim Todd; courtesy of the U.S. Department of the Interior, Bureau of Reclamation.

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by
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Published in cooperation with the Wyoming Field Science Foundation, Casper, Wyoming

Laramie, Wyoming
2004

About the stratigraphic column and cross sections

Geologically, this is the story of "what it is and how it got that way." A little background information will be helpful in understanding the terms and concepts that geologists use to tell this story.

Most of the rocks around Alcova are sedimentary. They were formed of particles (sediment) carried and deposited by water, wind, or precipitated from solutions and then buried, compacted, and glued (lithified) to become rocks. Sediments are originally deposited or accumulated in horizontal layers. Younger layers are deposited on top of older, so unless the area had been disturbed, sedimentary rocks near the top of a ridge should be younger than those at the bottom. It is safe to assume that whenever layers of sedimentary rock are not horizontal, they have been moved (tilted) after they formed.

The field guide tour starts in rocks that were deposited somewhere in the middle of geologic time. Therefore, if will be helpful to refer to the *stratigraphic column*, a tabular listing of rocks from oldest to youngest. The column provides several items of information:

1) Geologic time. Geologists seldom deal with numbers of years old when speaking of the age of rocks. They divide geologic time into named units similar to the arbitrary divisions that historians assign to the more recent times, such as the "Dark Ages" or the "Atomic Age." Thus, geologists speak of the "Cretaceous Period," the "Triassic Period," and so forth. With a little practice, the system will become quite familiar and very convenient to use.

2) Formation name. A geologic *formation* is a grouping of rock layers that can be distinguished from overlying and underlying layers and their *areal* (pertaining to an area on the surface of the earth) extent mapped, because of their similar physical characteristics. Most rock formations have been given formal names, which relate to the geographical area in which they were defined. For example, the Alcova Limestone was named for exposures near the town of Alcova. Symbols are used on maps and in other places when there is not enough space for the entire formation name. These symbols generally consist of two parts: the first letter (or special combination of letters) is capitalized and indicates the age of the formation; the last letter(s) are lower-case and indicate the formation name. For example, the symbol ŦRc stands for the Triassic Chugwater Formation and ŦRa is used for the Triassic Alcova Limestone Member of the Chugwater Formation. Most geologic photographs in this guide are annotated. The formations are labeled and their boundaries (contacts) marked.

3) Rock type. This is a description of the type of rock or rocks that comprise the formation and may include color, other physical characteristics, and thickness where not given separately.

4) Origin of rock. This is a short description of the location or conditions under which the rocks were deposited or in the case of volcanic or metamorphic rocks, the conditions under which the rock formed.

The illustrations to the right of the stratigraphic column are called *diagrammatic cross sections* because they show the general idea instead of the exact picture and they are not to scale. A *cross section* shows what geologists think lies below the surface—the structure of the rocks. It is like looking at the edge of a layer cake, but in this case, the layers are different rock formations. The inset map shows the location of a cross section. The top cross section shows the formations as they might have looked when originally deposited in horizontal position. Notice how it resembles the stratigraphic column with the younger rocks overlying older rocks. The bottom cross section gives a general idea of what the area beneath Alcova would look like today if it were possible to cut through it and look at the edge.

The symbols and colors on the cross sections, if referred to while using this guide, correspond with those on the geologic map and stratigraphic column. The bottom cross section will help one visualize and locate the structures which are discussed in the guide.

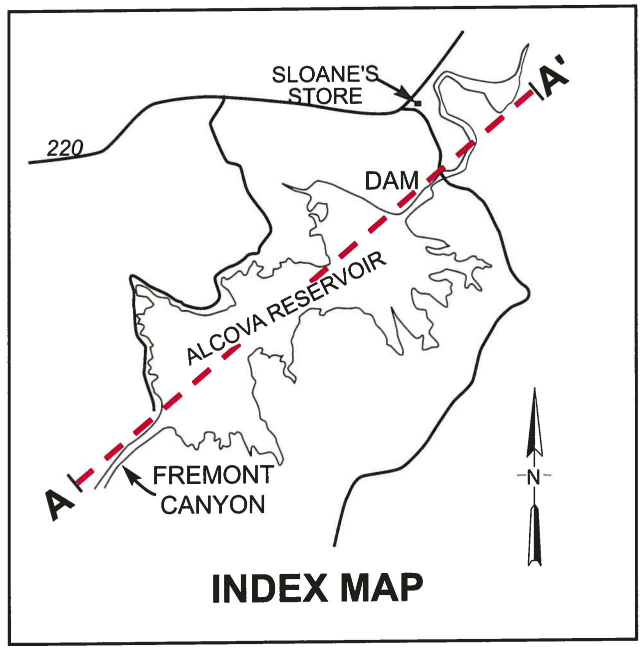
Structure refers to the configuration of the rock layers in the subsurface. The term *anticline* is applied to an upward fold; *syncline* refers to a downward fold, and a *fault* is a break or disruption in the layers. Anticlines and synclines may range from a few feet across to many miles. The center of the fold is called the *axis*, and is often indicated by a line showing its location on a geologic map. On the geologic map foldout in back, anticlinal and synclinal axes are indicated by a thin red line with arrows. An asymmetric anticline is one in which one side of the fold is steeper than the other side.

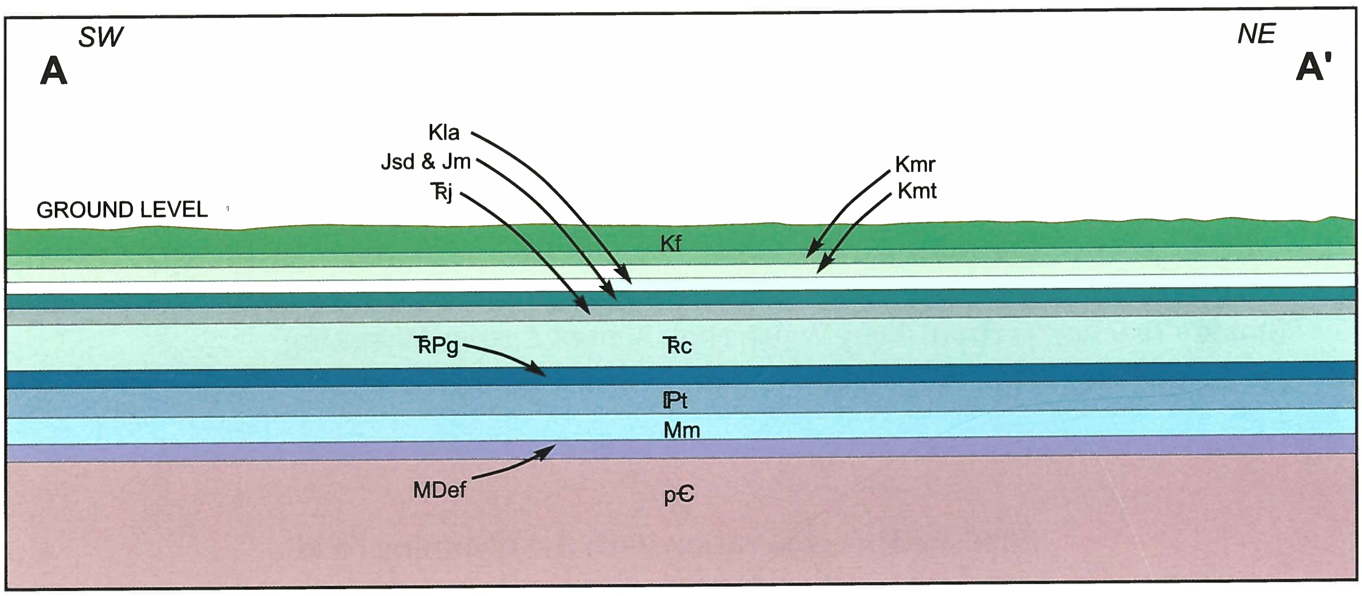
Stratigraphic column of rocks present in the Alcova area

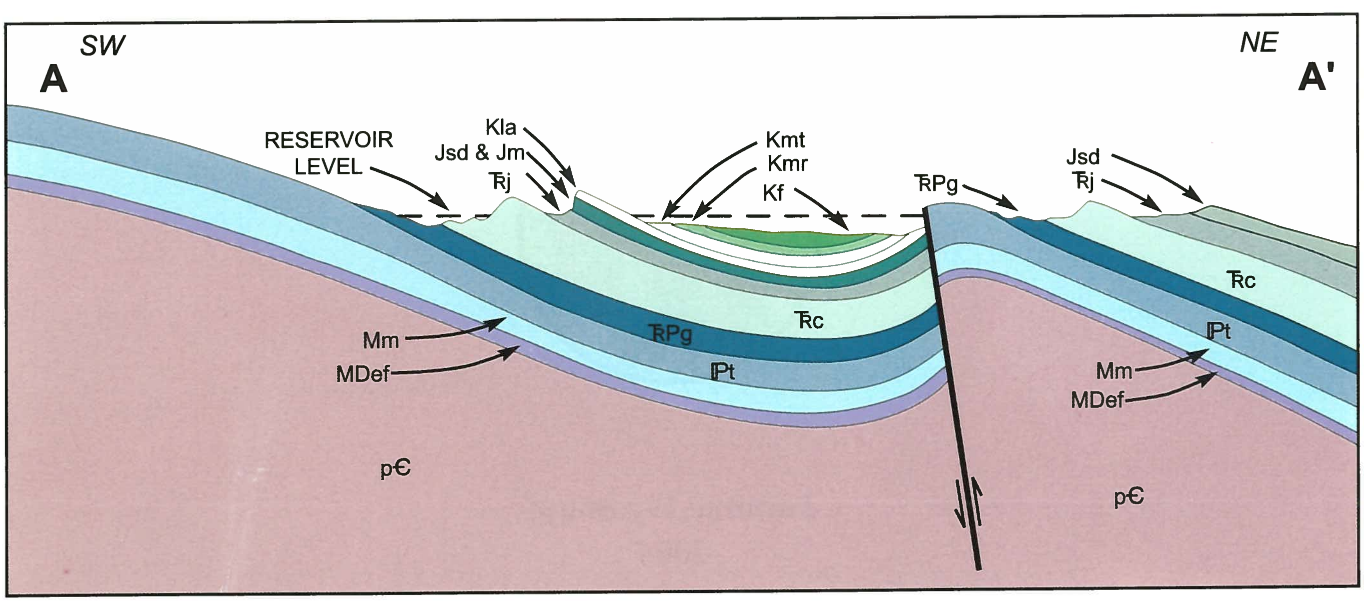
(adapted and modified from column prepared by John Kerns)

Years ago		Geologic time period			Formation* and map (or photo) symbol	Rock type and color	Approximate thickness (in feet)	Origin (depositional environment)
0-1.8 million	CENOZOIC ERA	Quaternary			Alluvium (Qal)	Sand, gravel, and silt, variable color	variable	Stream
1.8-65 million	CENOZOIC ERA	Tertiary	Miocene		Split Rock Fm. (Tsr)	Conglomerate and claystone, gray to white	0 to 700	Stream
			Oligocene		White River Fm. (Twr)	Siltstone, claystone and sandstone, variegated to gray to white	0 to 500	Stream
			Eocene		Wind River Fm. (Twdr)	Sandstone and conglomerate, gray to white, arkosic	0 to 200	Stream
65-144 million	MESOZOIC ERA	Cretaceous		Late	Niobrara Fm. (Kn)	Shale, gray to yellow, chalky	300+	Marine
					Carlile Sh. (Kcl)	Shale, dark-gray, soft	337	Marine
					Frontier Fm. (Kf)	Shale and thin sandstone, gray	660	Marine
					Mowry Sh. (Kmr)	Shale, silver-gray	260	Marine
				Early	Muddy Ss./ Thermopolis Sh. (Kmt)	Thin sandstone, gray, within shale, black	190	Marine
					Lakota Ss. (Kla)	Conglomerate and sandstone, tan to yellow	90	Stream
144-206 million		Jurassic			Morrison Fm. (Jm)	Shale, siltstone, mudstone, and sandstone, variable color	210	Stream
					Sundance Fm. (Jsd)	Sandstone, shale, and siltstone, gray-green	250	Marine
206-248 million		Triassic			Jelm Fm. (₨j)	Siltstone, shale, and limestone, pink-red	310	Tidal flat
					Alcova Ls. Member (₨a)	Limestone, lavender-gray	34	Marine (algal)
					Chugwater Fm. (₨c)	Siltstone, shale, and sandstone, red	780	Tidal flat
248-290 million	PALEOZOIC ERA	Permian			Goose Egg Fm. (₨Pg)	Shale, siltstone, and limestone with gypsum, red-orange	370	Marine and tidal flat
290-323 million		Pennsylvanian			Casper Fm./ Tensleep Ss. (ℙt)	Sandstone, white to yellow to tan	550	Eolian and marine
323-354 million		Mississippian			Madison Ls. (Mm)	Limestone, blue-gray	370	Marine
354-417 million		Devonian			Englewood Fm./Fremont Canyon Ss. (MDef)	Sandstone, white, gray, red, and brown	203	Tidal flat to marine
417-543 million		Silurian Ordovician Cambrian			NO ROCKS PRESENT IN THIS AREA			
543 million-2.5 billion	PRECAMBRIAN	Proterozoic			NO ROCKS PRESENT IN THIS AREA			
2.5-4.5+ billion		Archean			Granite (p€)	Granite (pink to reddish brown)		Magmatic— dated at 2.8 billion years

Cross sections of the Alcova area







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Acknowledgments for the First Edition

Many people have provided assistance during the two-year development of the Alcova Field Guide. Some deserve special recognition. Without Mrs. Donald Becker's willingness to raise money, the project would still be a dream. W. H. "Skip" Curry, Carl Jenkins, and Bart Rea supplied their usual great amount of expertise and friendly counsel. Terry Logue provided the advise of a master teacher as well as some of the drawings. Artist and illustrator Gary Keimig made drawings at the drop of a hat and assisted in the overall preparation. Chuck Ward with the Wyoming Game and Fish Department, as usual, provided help as needed. In addition, we received fine cooperation from the U.S. Bureau of Reclamation, U.S. Soil Conservation Service (George Dern), Gard Talbot's Engineering Supplies, Mountain States Lithographing, and The Photograph Lab. Bill Weber and June Brenan solved our drafting problems. Nat and Norma Fowler provided boat transportation.

Many thanks are due the families and friends who tolerated us during the project; the colleagues who helped with time and ideas; the administrators for their encouragement - especially M.F. Griffith who is always willing to consider an idea. Field Science students from the past 10 years have provided the pleasant experience and inspiration to make a project like this worthwhile.

Initial financial contributions for the Alcova Field Guide came from: The Wyoming Geological Association, Marathon Oil Company, Dr. & Mrs. Donald Becker, Tom Stroock, Casper College, W. H. Curry, Harry Ptasynski, Echo Oil Corporation, John Wold, Dr. Edward Reasoner, G.R. Veronda, Dana Van Burgh, Jr., and Natrona County School District No. 1.

Money from the sale of the Alcova Field Guide will be used to cover printing costs, which far exceeded initial estimates and funds available. Any additional income will be channeled into future publications or projects of the Wyoming Field Science Foundation.

Acknowledgments for the Second Edition

The revision of the Alcova Field Guide would not have been completed without the persistent encouragement and help of Sandy Leotta. Dana P. Van Burgh, Terry Logue, and Beecher E. Strube worked on revising the road log and updating the information in the guide. Kerry Richard was responsible for the first draft of the revision and additional contributions were made by Gary Keimig, Terry Logue, Al Allen, Russell J. Hawley, Bart Rea, and Carl Jenkins.

Lance Cook, former Wyoming State Geologist, supported the Wyoming State Geological Survey's (WSGS's) efforts for this project since its inception and allowed funds to be expended from the Survey's budget for preparation and printing this guide. Richard W. Jones, Editor and Senior Geologist with the WSGS, provided technical review and editing, project coordination, additional information, and slight reorganization of the publication. Jaime R. Moulton, Assistant Editor at the WSGS, compiled the color photographs for the birds, mammals, and fish shown in this publication; compiled the descriptions for the fishes and checked animal species names; prepared the color graphics using revised originals from the First Edition; compiled a new aerial photograph from color transparency stereopairs provided by the Surficial Processes and Geohydrology Section of the WSGS; and created a new design and layout for the field guide. Brooke Culver, Editorial Intern at the WSGS, assisted with scanning and photograph annotations. Dr. Ronald L. Hartman, Director of the Rocky Mountain Herbarium and Professor of Botany at the University of Wyoming, helped identify plant species and revise some species nomenclature.

Additional photographs were obtained from Dana P. Van Burgh, Jr., Alvin Burtsch, University of Wyoming American Heritage Center, Wyoming State Archives, U.S. Geological Survey, U.S. Bureau of Reclamation, and the Casper College Goodstein Foundation Library Western History Collection. Jaime R. Moulton (designated JRM) took digital photographs of the outcrops in August 2004 and assembled some digital images into a single image or panorama. Color images of some plants were added in September 2004. Annotations for the digital images were added by Richard W. Jones using the original photographs in the First Edition where possible, and he assumes full responsibility for any errors, omissions, or misinterpretations.

Introduction

The Alcova Field Guide is an outgrowth of a Field Science course that was started by Dana P. Van Burgh, Jr. and Beecher E. Strube in 1963. High school students that had been on Field Science trips came back later and told about taking their family to Alcova but asked if they had told the story correctly. The original idea for the field guide was to have a few annotated photographs and descriptions of geologic, biologic, and historic interest. This gradually evolved into the original 60-page First Edition of the Alcova Field Guide compiled by Peggy Knittel that was published in 1974. A companion volume, A Field Guide to the Casper Mountain Area, was published in 1978. Terry Logue joined Van Burgh and Strube in 1973 and together they have introduced thousands of students and teachers to the geology, biology, and history of the Casper area. Field Science is taught on a school bus as students bounce around the many environments and stop to examine the geologic features and historical sites to gain firsthand knowledge of the Casper area.

What this is, and how to use it

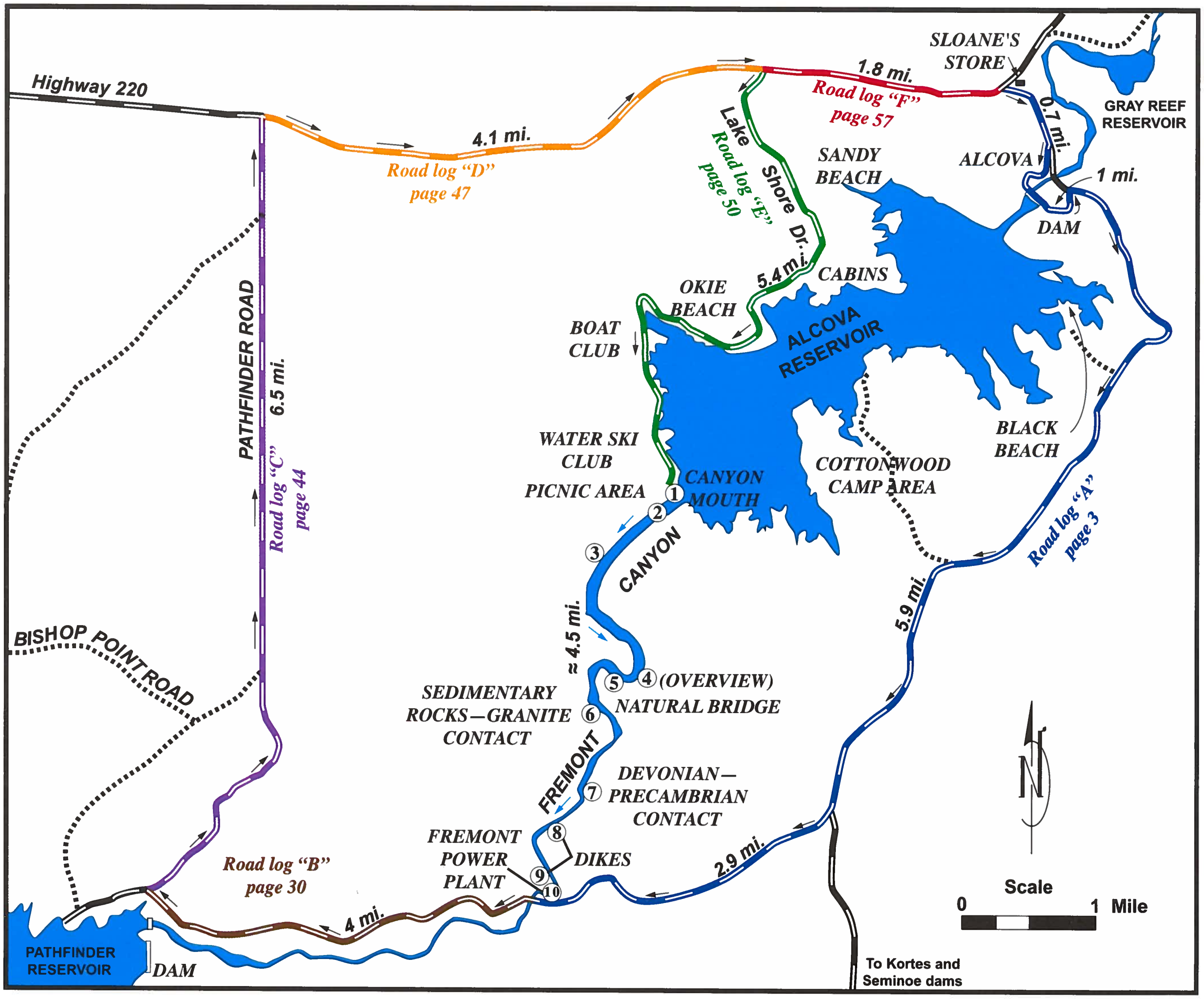
This field guide has been prepared to aid readers in understanding and appreciating the Alcova area. It includes information on the geology, natural history, plant and animal life, and cultural history of the vicinity. Visitors often wonder why some of the rocks around Alcova are red, or what is the name of the abundant yellow flowers along the road, or how workers managed to construct Pathfinder Dam with the crude equipment available in the early 1900s. This guide will start the user toward answering those questions and others.

The field guide covers a route that encircles Alcova Reservoir, beginning and ending at Sloane's Store. Information is arranged in "road log" form with mileage starting from zero at the store. From there, the route goes past Alcova Dam and along the eastern side of Alcova Reservoir; crosses the Platte River and proceeds west to Pathfinder Dam; from there to State Highway 220; along Highway 220 to Lake Shore Drive; follows Lake Shore Drive to Alcova Boat Club and Fremont Canyon and returns to Highway 220; and finally covers the section from Lake Shore Drive/Highway 220 junction to Sloane's store.

The guide is written as a self-guiding tour, allowing users to set their own pace and concentrate on their own interests. Each of the six sections described above is color-coded to the route map (**Figure 1**) and the complete tour covers a distance of 36.7 miles. For those with access to a boat, this guide includes a boater's tour of Fremont Canyon with 10 described locations.

Useful reference items included in this guide are the stratigraphic column, cross sections, geologic map, air photograph, satellite image, and glossary of geologic terms (**Appendix A**). The stratigraphic column and cross sections are located on the foldout in front of this publication; the geologic map, air photograph, and satellite image are located on the foldout in back of this publication. The map and stratigraphic column on the foldout pages can be unfolded so they may be referred to continuously while using this guide. These foldouts will help clarify the geologic story and assist the reader in visualizing what is seen on the ground and in the photographs.

Because this field guide is designed for use by people traveling by car, only the most conspicuous plants, birds, and mammals common to the area are included. For sake of completeness, the most common fish in Alcova Reservoir (a popular fishing area) are also included. Photographs of the main animal species (excluding insects) are provided throughout the text; a brief description and other characteristics of the species are given in **Appendix B**. Descriptions of the fish species were derived from the detailed descriptions given in Baxter and Stone, 1995. An **Index** to the plant and animal species is provided on page 82 and is cross-referenced to the page numbers where the species are described in the text. This index is by no means complete or exhaustive. Common names and species names are those presently used by the Wyoming Game and Fish Department. Contact that agency for information on wildlife and hunting and fishing.



① Circled numbers are locations for the boat log (p. 59).

Figure 1. Index map of the field trip. Road log colors in this map correspond to the colors on the left edge of each page throughout this publication. Number below each road log designation indicates page in this guide where that road log begins.

Road logs

A road log is designed to allow use of a vehicle's odometer, prominent landmarks, and highway mileage signs to locate the features described. The number farthest to the left is an item number for a feature described in the text. This provides a quick reference or cross reference later in the text. The number to the right of the item number is the interval between points on the road log. The cumulative mileage from the starting point is in parentheses after the interval. For example, item number 5 (page 9) should be read after traveling 0.6 miles from the starting point. Although these mileages are relatively accurate, your mileage may vary depending on your vehicle's odometer. In this way, material is read in correlation with what is seen. For users who wish to travel the route or route segments in reverse, simply recalculate using the mileage intervals between points on the road log.

Road Log A: Alcova (Sloane's Store) to Fremont Tunnel

Bobcat—Wyoming Game and Fish Department, 1994

0.0 (0.0) **Set your vehicle's trip odometer to 0.0 at Sloane's Store to start the road log.** Sloane's Store (**Figure 2**) is at the intersection of County Road 407 and Highway 220. The store was first known as Sloane's Company Store, located in the old Alcova Mercantile.

Figure 2. Sloane's Store is the beginning of the trip. Photograph by JRM, August, 2004.

Mr. Sloane moved the store to its first separate location half a mile north of the present store and then to its present location when the highway was moved. Although there have been a number of different storeowners through the years, Sloane's Store has been in continuous operation since 1918. It is more than just a convenience store/ gas station, carrying everything from aspirin to fishing licenses and offering the fishing report and the weather report along with the local gossip not to mention their famous ice cream cones.

1. The first annotated photograph (**Figure 3**) in this guide uses names to identify the rock formations. The rocks in this photograph are likely the most noticeable in the area. The red cliff is formally named the Red Peak Member of the Chugwater Formation. Commonly this unit is called the Chugwater Formation, and therefore will be referred to as such throughout this guide.

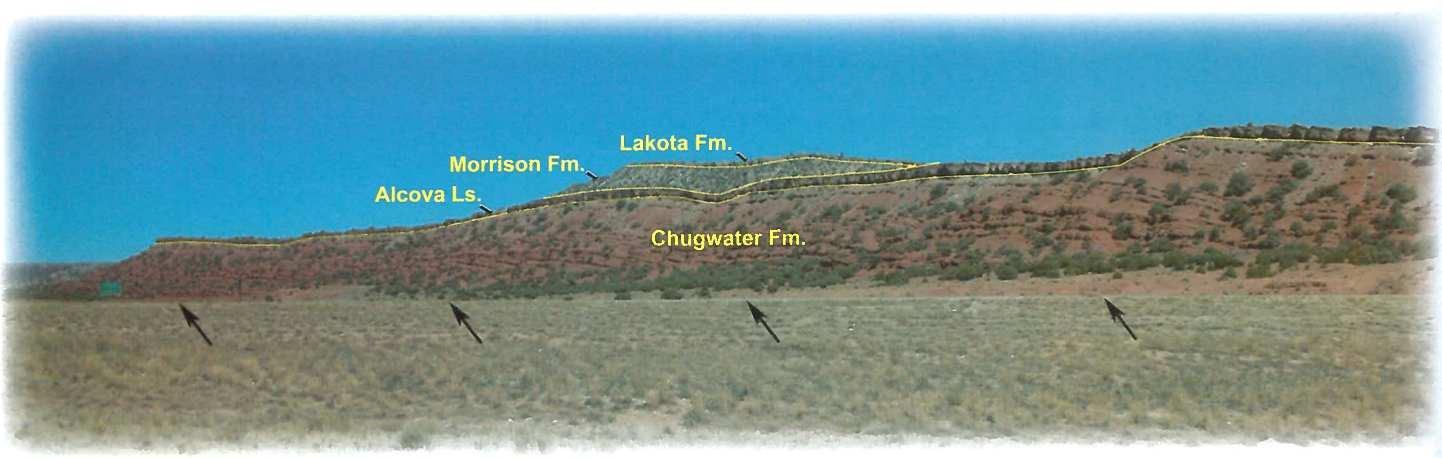


Figure 3. View northwest from Sloane's Store of red cliffs (Chugwater) capped by Alcova Limestone. Arrows indicate road grade of U.S. Highway 220. Photograph by JRM, August, 2004.

The red color of the Chugwater indicates it probably formed in a tidal-flat-type environment where the water was shallow. Iron minerals in the shales, siltstones, and sandstones deposited under these conditions were exposed to oxidation (or rusting), which caused the pervasive red color.

Cliff swallows—Wyoming Game and Fish Department, August, 1981

The gray Alcova Limestone (formally named the Alcova Limestone Member of the Chugwater Formation) rests on the Chugwater. Formation of limestone requires deeper (but still relatively shallow) water. Its presence indicates that a sea moved into the area, probably from the west. Limestone in the arid West is usually quite resistant to erosion, and where less resistant rocks underlie and overlie it, the limestone stands out in bold relief, forming ridges or hogbacks, as the Alcova does here.

The perspective of the photograph causes part of the Morrison and Lakota formations to appear as though they rest on top of the Alcova. Actually, they are on a separate ridge and, though hidden from view by the Alcova ridge, the Jelm and the Sundance formations are also present. Each of these rock types will be discussed as a closer look becomes possible.

2. The Alcova tour begins on the site of a town that, over a century ago, many thought would be one of the biggest tourist attractions in the west. The 1891 *Natrona Tribune* reported that big plans existed for the little town of Alcova. The men who formed "The Alcova Hot Springs Company" had visions of this scenic spot becoming one of the greatest health resorts in the west. The hot springs (**Figure 4**) where the dam is now located, were purchased by a large eastern syndicate and land was secured for the town site. The name "Alcova" was reportedly derived from the "nest of coves" where the hot springs were located in the canyon east of the town; however, the name may have been derived from "alcove" which is the architectural term for an arched opening in a wall.

Streets for the new town were laid out and plans were drawn up for the buildings that were to line the streets. The company announced that they would be establishing

Figure 4 (right). Hot springs in Alcova Canyon, circa 1894. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

a daily stage line from Casper as soon as the resort was ready for operation. Promoters even speculated about putting in a railroad line, and a fleet of small steamers and sailboats to navigate the Platte River between Casper and Alcova.

Advertised as possessing wonderful medical qualities, the water of the springs was heralded as beneficial in chronic diseases such as rheumatism, gout, joint stiffness, and so forth. For this reason, the baths were expected to draw thousands of visitors. Construction of hotels and bathing accommodations was to be on a large enough scale to meet the needs of such crowds.

Unfortunately, the company encountered financial difficulties and the work that had barely started was suspended. Living on dreams, the developers continued to sell lots, and in 1898, attempts were again made to realize their plans. New pamphlets were issued which described the positive aspects of the area: "Nature with generous care having provided hot springs, climate, scenery, and raw materials sufficient to build a city that will be an honor to her majesty awaits the magic and charm that will improve with modern facilities her wondrous work for the healing of mankind."

The dreams of the health spa advocates were not realized and the Alcova area showed little development. The town of Alcova was established, however, as a stage stop (**Figure 5**) and settlement (**Figure 6**) between Muddy Gap and Casper. It soon had a school, post office, general store, and offered a substantial all-season bridge over the Platte River (**Figures 7** to **10**). Alcova did not show much growth until the early 1930s when the U.S. Bureau of Reclamation (USBR) began construction of Alcova Dam. At that time, Alcova became a "boom town" construction camp (**Figures 11** and **12**).

Figure 5 (left). Casper-Alcova stage stopped in front of Alcova Post Office, circa 1912.

Figure 6 (right). Early photograph of Alcova townsite, circa early 1900s; arrow points to Post Office. Photograph from American Heritage Center, University of Wyoming (used with permission).

Figure 7 (left). The first school house at Alcova, date unknown.

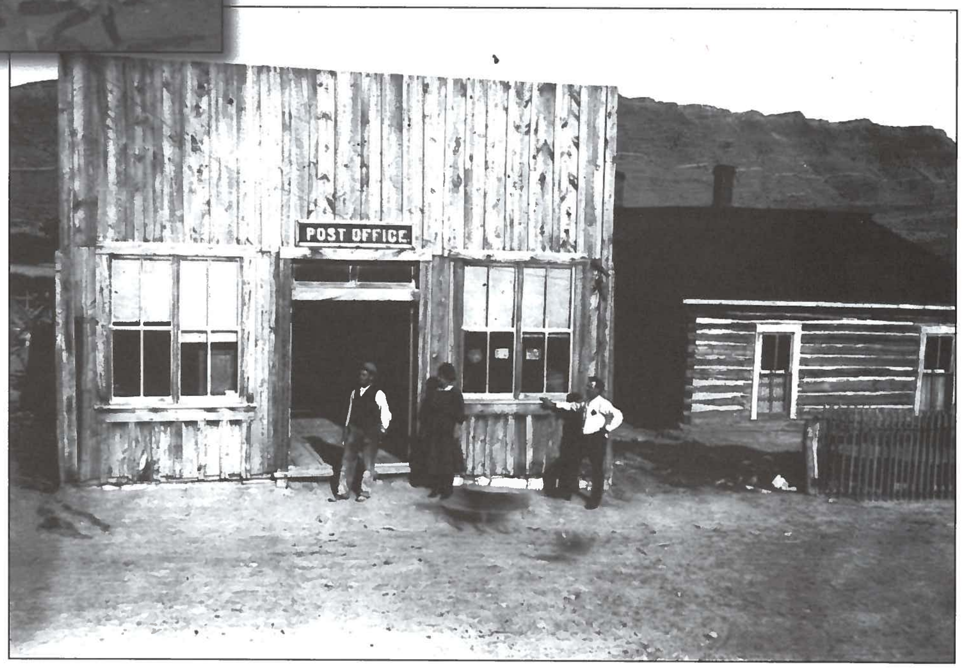


Figure 8 (right). Post Office at Alcova, date unknown.

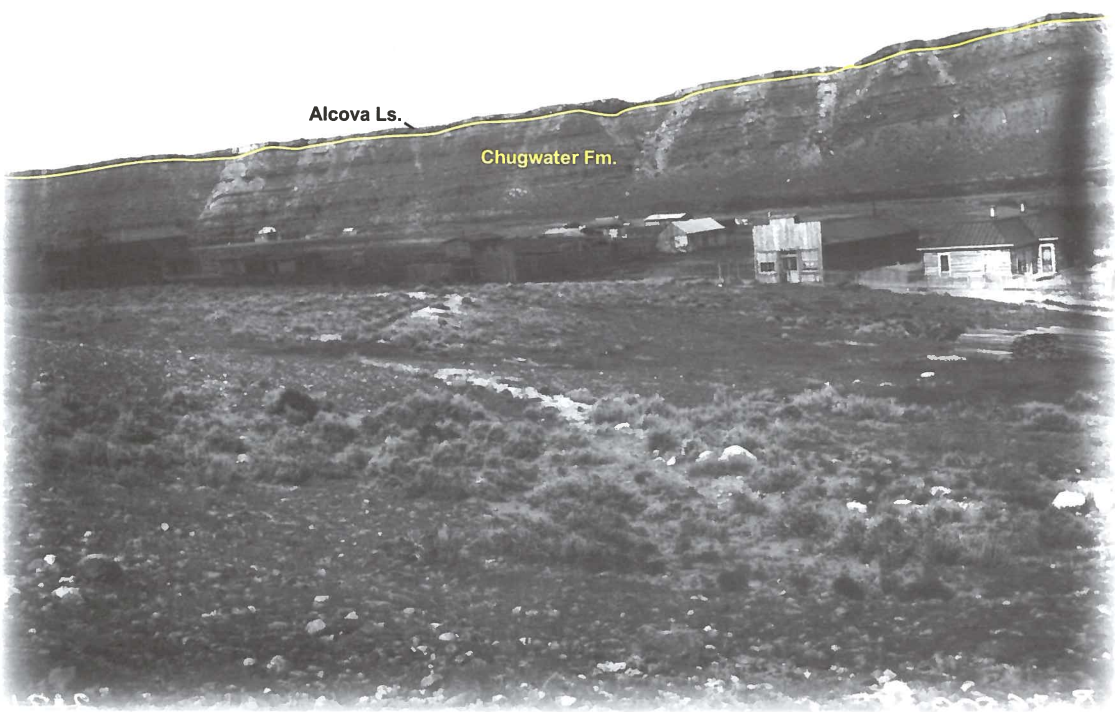


Figure 9. Early settlement of Alcova, circa early 1900s. Photograph from American Heritage Center, University of Wyoming (used with permission).

Figure 10. Bridge over North Platte River, circa 1899, near Alcova townsite. View to southwest looking upstream into Alcova Canyon. Photograph by W.C. Knight, courtesy W.C. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

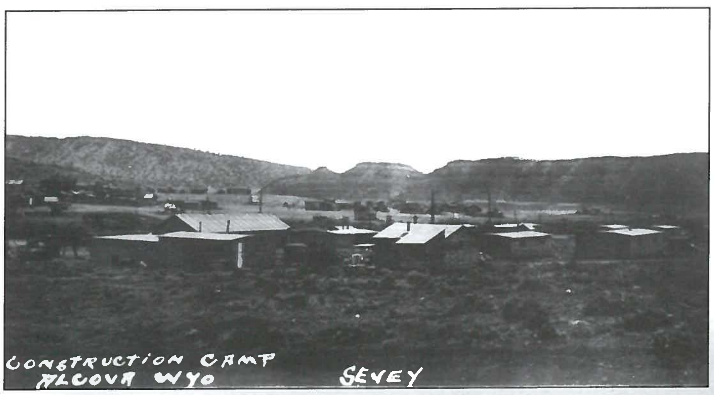


Figure 11 (left). Construction camp at Alcova townsite, circa 1930s. View to east from bridge over North Platte River.

Figure 12 (below). View to north of Alcova in the early 1930s. The ridge on the skyline is capped by the Lakota Formation and the darker ridge below is capped by Alcova Limestone. Arrow indicates approximate intersection of present-day County Road 407 and U.S. Highway 220. Photograph from U.S. Bureau of Reclamation.

3. The abundant purple-flowered plants along the road from Sloane's Store to the dam (and between here and Casper) are a domestic species of clover known as alfalfa. The plant is readily identified as a clover by its clusters of three leaflets (**Figure 13**). The flowers resemble those of sweet clover, and petals vary from blue to purple in color (rarely pink or white). Due to its high protein content, alfalfa is among the most valuable forage crops. The scientific name of this plant is *Medicago sativa*.

Figure 13. Alfalfa is common in the area around Alcova. (a) It has small purple flowers and appears dark green from a distance (photograph by JRM, September, 2004). (b) Sketch of alfalfa plant (by Gary Keimig) shows the small flowers on the ends of the stems.

A plant's scientific name is a Latin one consisting of two parts: genus and species. These two names are unique to a species and serve to distinguish the plant from all other plants. The genus name is capitalized; species is written in all lower-case letters; and both are printed in italics, or they can be underlined or printed in boldface type. In the example above, *Medicago* is the genus and *sativa* is the species. Called the binomial system of nomenclature, it is used to describe all life forms.

4. 0.2 (0.2) Looking south across the town of Alcova (**Figure 14**). Chugwater, Alcova, Sundance, Morrison, and Lakota formations are on the left; Goose Egg Formation ahead and right; and Tensleep Sandstone on the far right.

Near the road for the next 0.3 mile one can see evidence of the pits from which "fill" material was excavated for the building of Alcova Dam. The pits are in the Goose Egg Formation, discussed below.

The hardy tree-like evergreen shrubs found in this area are Rocky Mountain junipers, *Juniperus scopulorum*. Some authorities believe *Juniperus monosperma*, or one-seed juniper, is also present. Juniper shrubs are related to cedars, and therefore have a red "heartwood" with "cedar chest" fragrance. Junipers have scale-like leaves, and bear small bluish berries that take the place of cones found on other evergreens (**Figure 15a**). The berries take two years to

Mule deer—Wyoming Game and Fish Department, February, 1988

Figure 14. View to south from about 0.3 mile east of Sloane's Store (take dirt road to east before paved road turns to the south). North Platte River on left; Alcova Limestone in center of photograph outlines the nose of Alcova anticline. Photograph by JRM, August, 2004.

mature, and can be a source of food as well as medicine. Usually found in rather dry areas, junipers seldom grow straight or tall enough for lumber. Mature junipers have a gnarled appearance and a rounded crown (**Figure 15b**).

5. 0.4 (0.6) **Turn right on paved access road to Alcova Dam.** This road is on the Goose Egg Formation. The red parts of the Goose Egg formed like the Chugwater, by oxidation of the iron minerals in tidal flats. However, the red beds are not alike. The Chugwater is a darker red, but toward the dam, road cuts in the Goose Egg Formation display red beds with white gypsum beds and gray limestone or dolomite beds, producing a lighter red color overall. The gypsum (calcium sulfate) formed when large amounts of seawater evaporated, leaving the mineral gypsum behind; the limestone (calcium carbonate) or dolomite (calcium magnesium carbonate) formed in deeper water.

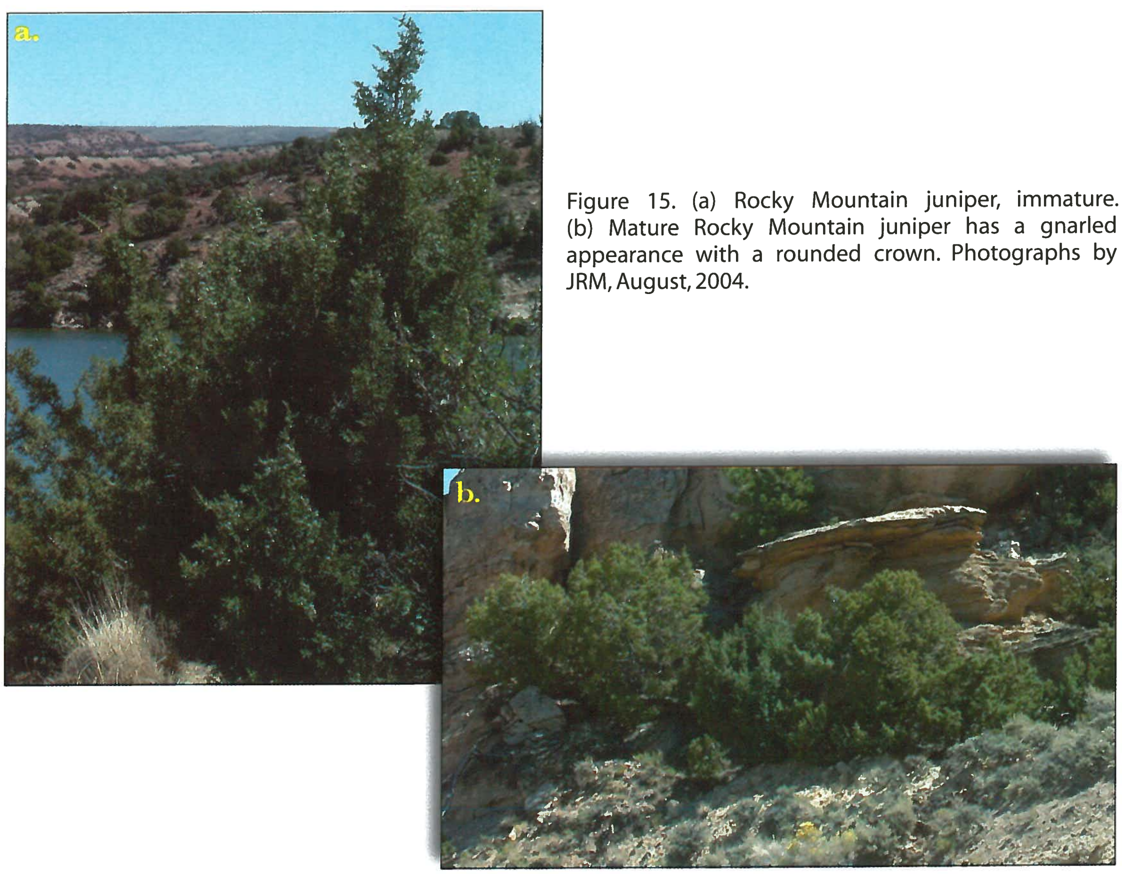


Figure 15. (a) Rocky Mountain juniper, immature. (b) Mature Rocky Mountain juniper has a gnarled appearance with a rounded crown. Photographs by JRM, August, 2004.

Mountain cottontail rabbit—Wyoming Game and Fish Department, December, 1990

Obviously, the Goose Egg had a varied origin, indicating that conditions in this part of Wyoming were prone to change during that time, roughly 250 million years ago.

The showy white or yellow flowers found on the roadside here and throughout the Alcova area are members of the Loasa or evening star family. There are two species identified in the area, *Mentzelia decapetala* (**Figure 16**) and *Mentzelia pumila* (**Figure 17**). The first, *M. decapetala*, is identified by ten long white to creamy-white petals. The plant is one to three feet tall with flowers three to six inches in diameter (Haddock, 2001). Some common names for this species include evening starflower and tenpetal stickleaf. *M. pumila* is distinguished from *M. decapetala* by smaller flowers. The flowers are white to yellow and a total of two inches across.

Figure 16 (left). Ten-petal stickleaf or blazingstar.

Figure 17 (right). Desert blazingstar or dwarf mentzelia.

These plants can be up to three feet tall (Kinsey, 2003). This plant could be synonymous with *M. multiflora* (USDA, NRCS, 2004), but according to one of the authors (Strube) and Dorn (2001), the correct species name that should be assigned to this plant is *M. laevicaulis*.

Species within this family are commonly called stickleaf or blazingstar. Both of the above species are covered by short barbed hairs that catch on clothing, hence the name stickleaf. The flowers on these plants usually bloom in late summer and open in the afternoon and remain open most of the night. The petals are slightly luminescent and can be seen in the dark. Blazingstars generally grow in rocky or sandy soil.

6. 0.4 (1.0) **Stop at the locked gate** (vehicles are no longer allowed to cross the dam) **and walk to the middle of the dam.** Note: this is optional, depending on current access and security restrictions to the dam.

Alcova Dam was built from 1935 to 1938 as the storage portion of the Kendrick Irrigation Project, which included a system of canals to provide water to a large area of land between Alcova and Casper. An earth fill dam, it is 763 feet long and 260 feet high. The reservoir has a capacity of 190,000 acre-feet. The USBR oversees operation of the dam, along with the other dams in the North Platte system.

In a report for the U.S. Geological Survey written in 1929, geologist Wilmot H. Bradley noted that: *At present the local irrigation development in the vicinity of Casper, Wyoming, is* *inadequate to supply the stockmen with winter feed and to furnish the city of Casper and nearby oil fields with the necessary foodstuffs...* Others were also concerned, and Bradley was commissioned, along with USBR engineers, to select a possible site for a dam in Alcova Canyon.

At Alcova, the North Platte River flowed through a deep, narrow canyon, the ideal setting for a dam (**Figures 18** and **19**). However, within this short canyon were relatively soft and porous rocks (Tensleep Sandstone) and several artesian hot springs. Bradley (1935) reported that only one spot would successfully support a dam: *in order to avoid the possibility of this* [water] *loss or the possibility of danger to the dam...the core wall of the dam is to be placed downstream, below the lowest probable outlet of the artesian system* (from "Geology of the Alcova Dam and Reservoir Sites, North Platte River, Natrona County, Wyoming"). To avoid the potential problems within Alcova Canyon, the dam was, in fact, built downstream of the canyon (**Figures 20** to **23**). Before construction could begin, the hot springs that had caused so much interest years before had to be plugged.

Figure 18 (above). Alcova Canyon (circa 1899) cuts through Tensleep Sandstone in Alcova anticline. View looking downstream (northeast) from west side of canyon. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

Figure 19 (right). One of the proposed locations for Alcova Dam. Oblique air photograph looking upstream (southeast); compare with photograph on cover to see area now inundated. Photograph from U.S. Bureau of Reclamation.

In 1952, Alcova Power Plant was built below the dam (**Figure 24**). The power plant capacity is 36,000 kilowatts. Instead of filling the tubs and pools of that "luxurious bathing resort," water from the hot springs is utilized in heating the power plant. The electricity generated at Alcova goes into the regional power grid and is used in Casper, Alcova, and other towns in the area.

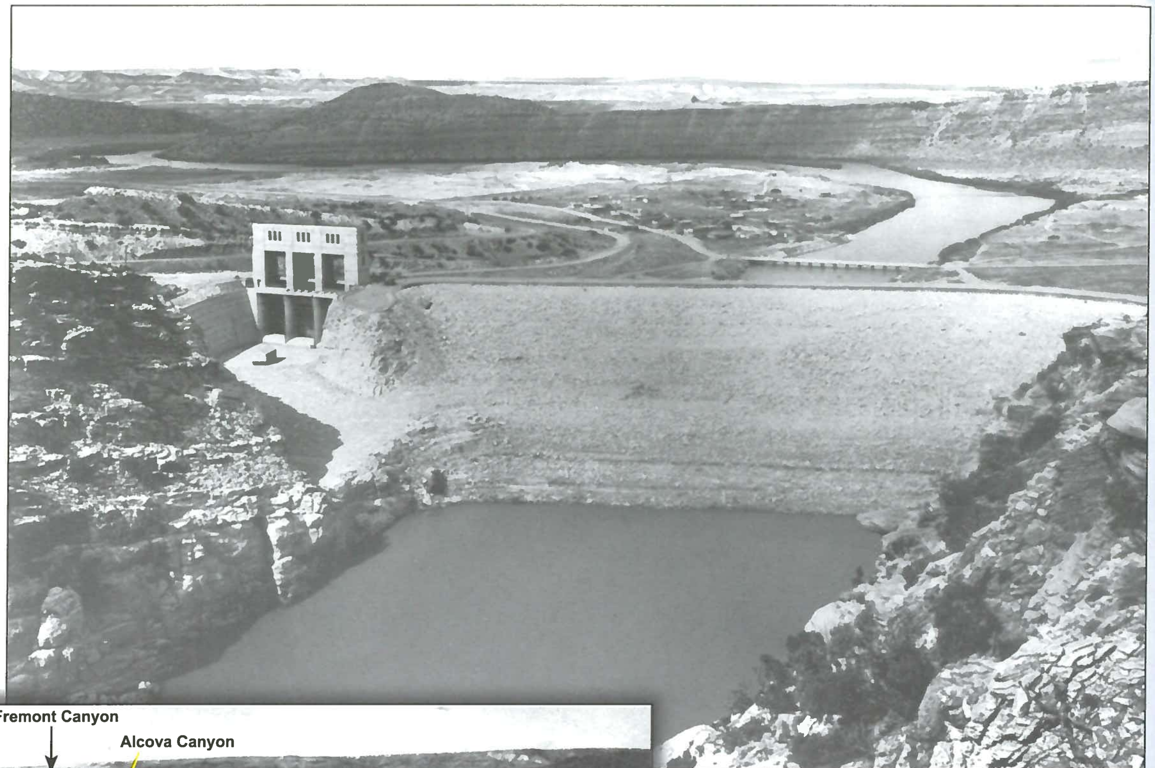
Turkey vulture—Don DesJardin

The ridge against which Alcova Dam is constructed is part of the Alcova anticline (see cross sections on the front foldout for anticline information). The walls of the canyon (**Figure**

Figure 20 (above). View looking upstream from approximate location of the proposed Alcova Dam. Note that the location is just east of the canyon proper. Photograph from U.S. Geological Survey.

Figure 21 (right). Oblique air photograph of completed dam, power plant, and other facilities, with reservoir filled. Photograph from U.S. Bureau of Reclamation.

Figure 22 (left). Excavating the foundation and canyon walls for Alcova Dam.



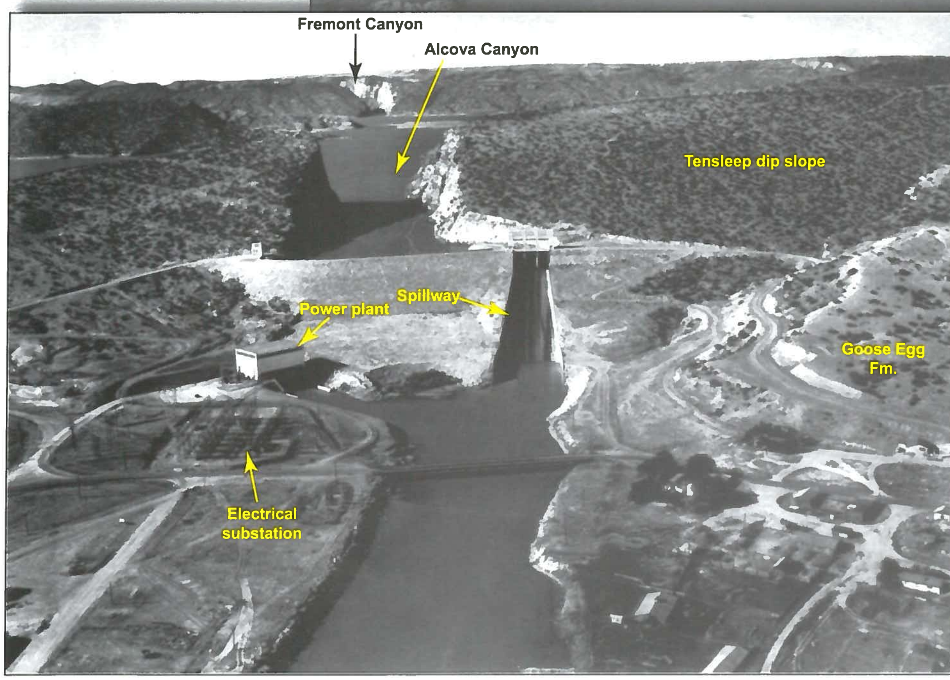


Figure 23 (above). The upstream side of Alcova Dam with reservoir partially filled. The spillway on the left side of dam also has powered floodgates that can be opened if necessary. Photograph from U.S. Bureau of Reclamation.

Figure 24 (left). Oblique air photograph of downstream side of the completed dam and power plant. Photograph from U.S. Bureau of Reclamation.

25) show the curve of the rocks in this fold, which formed about 70 million years ago. The rock forming the ridge is the Tensleep Sandstone (also known in this area as the Casper Formation), which consists of sandstone deposited about 300 million years ago. "Cross-bedding" is apparent in this formation, especially along the canyon rim. A closer look at cross-bedding is possible at the entrance to Lake Shore Drive, and it will be described more extensively at that time.

If one stood near the middle of the dam and looked westward across the reservoir, it is possible to see the mouth of Fremont Canyon (**Figure 24** and **Cover**), also composed of Tensleep Sandstone. The cross sections of the area show how this is possible. The North Platte River carved out both of these canyons and, over time, removed younger formations that once completely covered this area. Some of this rock is still in place as the high ridge west of the boat facilities. **Figure 19** shows the area now inundated by the reservoir before the construction of Alcova Dam.

Figure 25 (left). Alcova anticline as viewed from upstream side of Alcova Canyon near the cabin area. Steep west limb of anticline can be seen in canyon wall closest to boat. Photograph by JRM, August, 2004.

7. 0.4 (1.4) **Return to vehicle. Turn around and return to County Road 407.** Turn right (south) onto county road. The sandy soil for the next two miles provides favorable conditions for the growth of an evergreen shrub with sword-like leaves, commonly known as yucca, Spanish bayonet, or soapweed yucca (**Figure 26**). Its scientific name is *Yucca glauca*. Indians used the roots of yucca as soap, single leaves as needles, and bunches of leaves as brooms. Fiber of the leaves was woven for cloth. In early summer, the plants produce tall spikes of waxy, greenish-white flowers whose petals are edible and taste much like lettuce.

This genus is noted for an interesting case of symbiosis (a mutually favorable interrelationship between two organisms which is necessary for their survival). Yucca is visited by a night-flying moth, known as *Pronuba*. This moth is believed to be the only organism that can pollinate (transfer tiny pollen grains to appropriate parts of the plant during fertilization) the yucca.

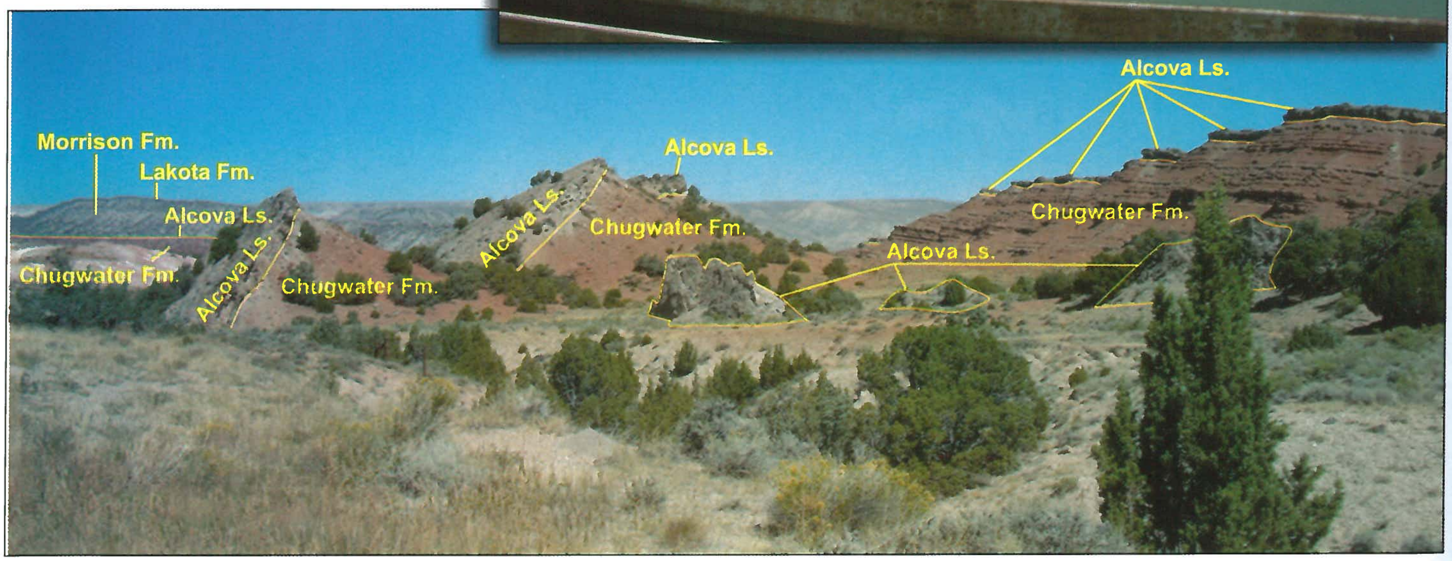
Route crosses bridge over Platte River. The power plant and spillway can both contribute to the river (**Figure 27**), but in dry years, all the water in the river flows through the power plant.

8. 0.8 (2.2) The approximate location of the axis (center line) of Alcova anticline can be estimated by observing the dipping (tilting) layers of Chugwater and Alcova. Steeply dipping beds or layers of rock form ridges called "hogbacks" which are quite apparent along this section of road (**Figure 28**). The layers dip away from the axis of the anticline, which runs up the valley east of the Alcova hogbacks.

Figure 26. Soapweed yucca with flower spikes seen in spring.

Figure 27 (right). Alcova Dam and power plant from bridge over North Platte River. Water gap in Tensleep Sandstone on skyline forms Alcova Canyon. Photograph by JRM, August, 2004.

Figure 28 (below). Hogbacks of Alcova Limestone are on steeply dipping west flank of Alcova anticline in left foreground; isolated areas of Alcova in center foreground are dipping toward viewer; and Alcova on skyline is on gently dipping east flank of the anticline. Photograph by JRM, August, 2004.



The aerial photograph (**Figure 29**) shows the up-turned layers near the end of Alcova anticline and fault. The Alcova hogbacks in the annotated **Figure 28** are to the left of the road, which comes from the bottom of the photograph. The steeply upturned Windy Hill Member (the uppermost member) of the Sundance Formation occurs on the outside of the turn. On the inside of the curve are very steeply dipping layers of Sundance, Morrison, and Lakota formations. In the lower right of the photograph is a small bay near the Black Beach recreation area.

9. **0.5** **(2.7)** Alcova Limestone can be seen to the left (east), Sundance to the right (west). Lakota, Morrison, and Sundance formations are evident in the hogback to the west.

The ragged-looking plant with numerous yellow flowers found abundantly in the dry soil along the road is a member of the sunflower family known as gumweed (**Figure 30**). Flower heads are about one inch wide and

White-tailed deer—Wyoming Game and Fish Department, January, 1987

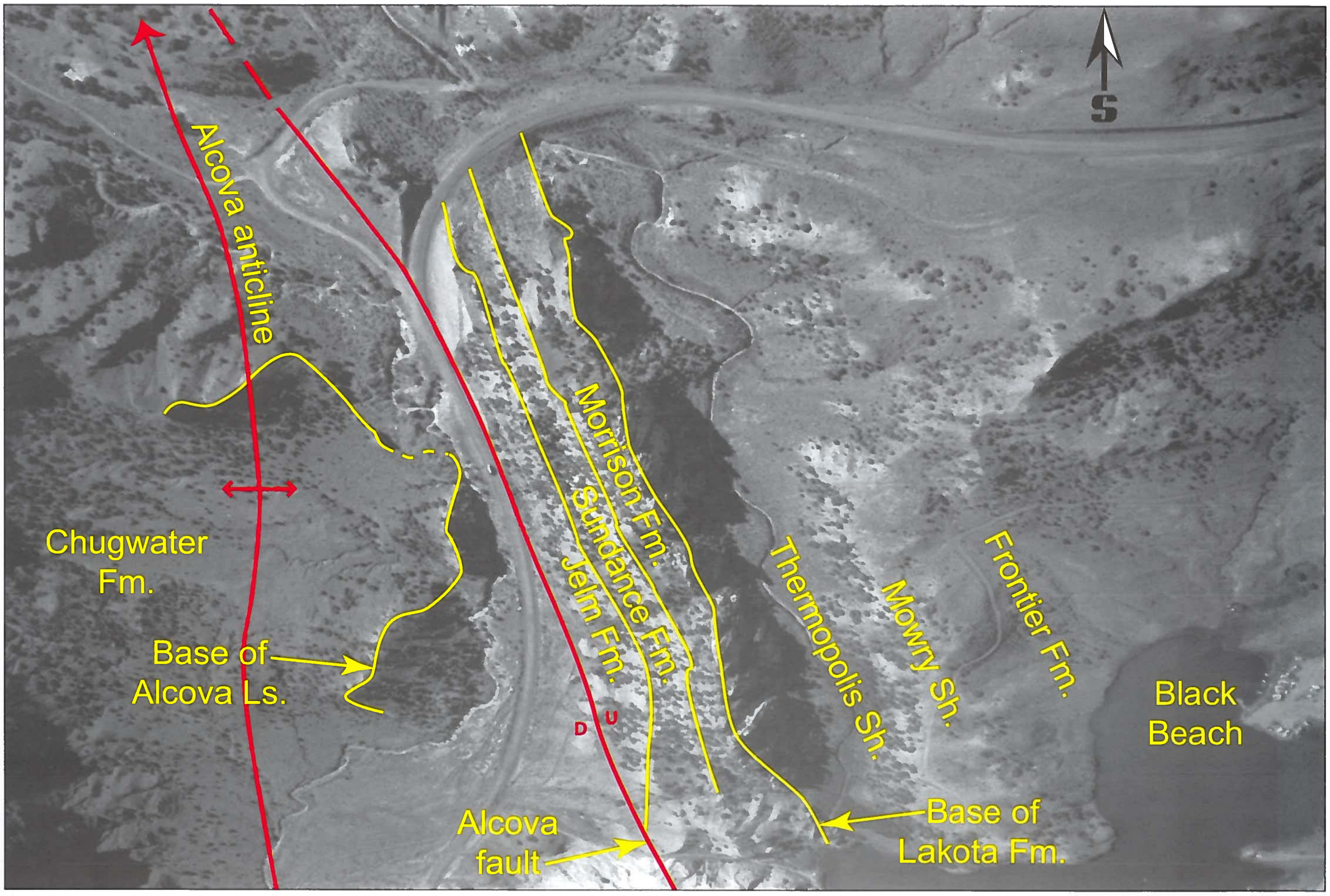


Figure 29. Vertical aerial photograph of the geology near the sharp curve 3 miles south of Sloane's Store. Minor faults that displace the Alcova Limestone and contacts between Lakota, Thermopolis, Mowry, and Frontier formations are not shown.

bloom from middle to late summer. The plants are covered with a sticky substance secreted by the plant, thus explaining its common name. Gumweed was used by the Indians as a treatment for what we now identify as asthma and bronchitis, as well as a substitute for tea and chewing gum. The plant was also used to treat cases of poison ivy. Gumweed's scientific name is *Grindelia squarrosa*.

10. **0.3** **(3.0)** Crossing Alcova fault. The northeast side of the fault is the upthrown side. The southwest side is the downthrown side. The silvery-gray rock to the west is the Mowry Shale. (More about the Mowry at #14.) Note the steep dip of the rock layers to the southwest (**Figure 31**).

After rounding the curve, one can look back to the east (**Figure 32**) and observe

Figure 30 (below). Curlycup gumweed is a member of the sunflower family. Typical appearance on the ground with yellow flowers (photograph by JRM, September, 2004).

Whitetailed jack rabbit—Wyoming Game and Fish Department, September, 1981

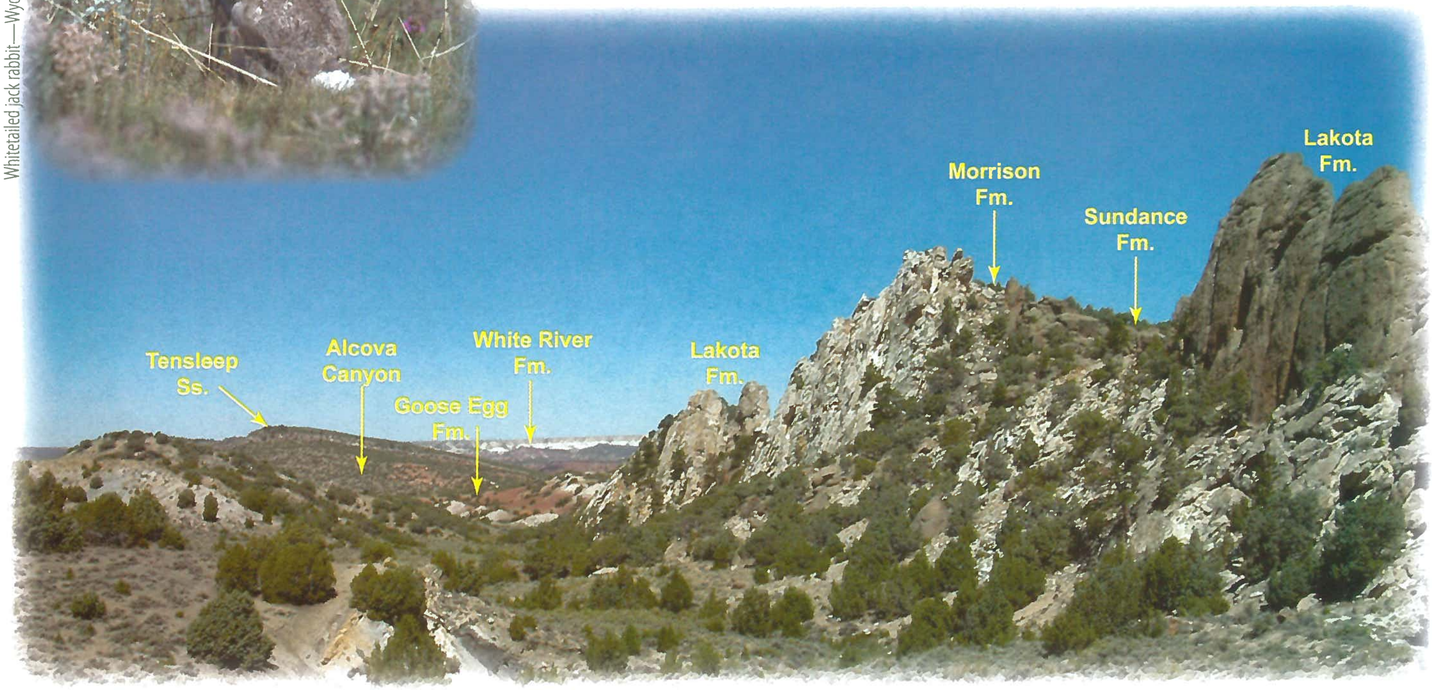


Figure 31. View to north of steeply dipping west flank of Alcova anticline. Resistant sandstone and conglomerate beds in the Lakota Formation comprise the prominent hogbacks. Photograph by JRM, August, 2004.

Figure 32. In this view to east of Alcova anticline, three parts of the anticline can be seen—(a) the gently dipping east flank, (b) the moderately dipping core of the fold (Jelm redbeds in middle of photograph), and (c) the steep west flank. Photograph by JRM, August, 2004.

three parts of the Alcova anticline: on the horizon are gently east-dipping rocks on the east limb of the anticline; in the middle foreground are south-dipping strata in the center of the fold; and the dark brown rocks on the left side of the photograph are steeply west-dipping rocks on the west limb of the anticline.

Striped skunk—William F. Wood, Humboldt State University

11. 0.2 (3.2) At this point in the tour, the road crosses a syncline, or downwarp of the rocks. This syncline runs approximately parallel to the Alcova anticline and fault but is more difficult to see than the anticline. Its presence can be determined from the layers of rock visible above the water along Alcova Reservoir. See both the cross section and geologic map foldouts.

12. 0.1 (3.3) The Frontier Formation (Upper Cretaceous) on the crest of the hill is dipping northeast into the syncline. From here to Fremont Canyon Power Plant, the rocks along the road become gradually older as the tour leads "down-section."

Geologists make sketches of a stack of layers of rock such as one might see when looking at the wall of a canyon. They call this a section. The law of superposition states that the youngest rocks which were deposited last are on top of (overlie) the oldest rocks, which were deposited first. So the sketch shows the oldest rocks at the bottom of the section and the youngest rocks at the top. The stratigraphic column in this publication is a section that shows the succession of rocks in the area. When geologists talk about going "down section," they mean they are moving across rock layers from younger toward older; "up section" means just the opposite.

13. 0.2 (3.5) **Continue straight ahead.** Black Beach camping and picnic ground is at right. From Black Beach, which is in black shales of the Frontier Formation, Sandy Beach can be seen to the northwest across the lake (**Figure 33**).

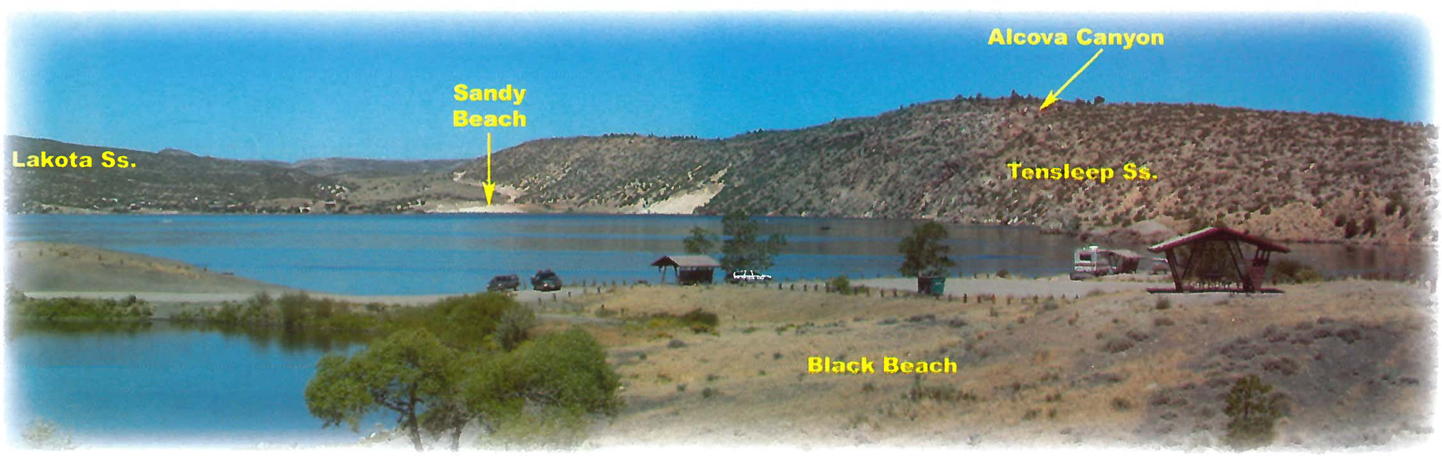


Figure 33. View to north across Alcova Reservoir from Black Beach. Alcova Canyon is practically hidden from view at this angle. Photograph by JRM, August, 2004.

14. 0.4 (3.9) The tour continues along outcrops of the Mowry Shale. This formation is marine in origin and contains the aluminum silicate clay known as bentonite, which was formed when fine volcanic dust blew into the area and was deposited in the sea. Bentonite is used today in various adhesives, cements, and ceramic fillers, in drilling mud and fire retardant, as sealants in reservoirs, and in kitty litter. Mowry Shale weathers to a light silver-gray color. If one shakes two or three small pieces of Mowry in their hand, it will make a clinking sound like broken pieces of a cup. This marine formation is famous for its fish scales but also contains pelecypods (clam-like animals) and ammonites (an extinct form of a cephalapod with a hard external shell) (**Figure 34**).

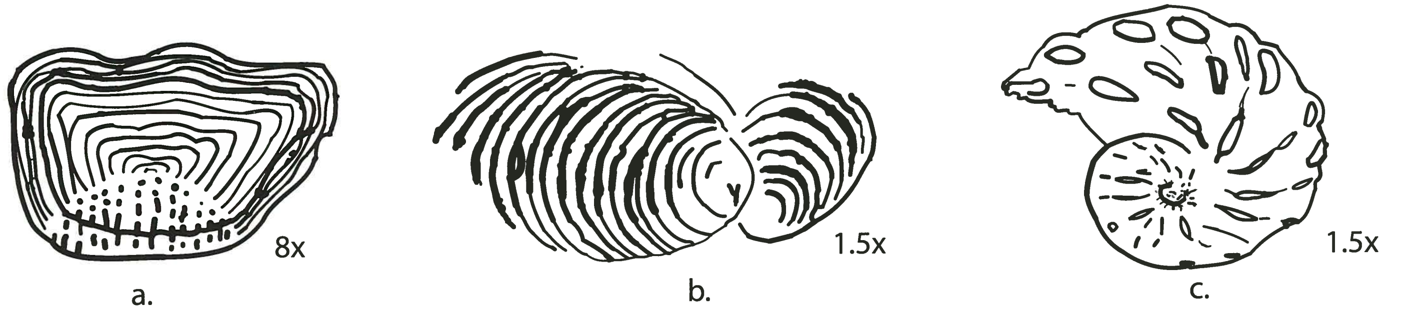


Figure 34. Fossils common in the Mowry Shale (Upper Cretaceous) include (a) fish scale, (b) pelecypod, and (c) ammonite; sketches by Terry Logue.

15. 0.2 (4.1) Very steep slope of Mowry with Ponderosa pine can be seen in valley to right (west).

16. 0.4 (4.5) A deposit of the Muddy Sandstone over black Thermopolis Shale is evident here.

17. 0.1 (4.6) Informal pullout presents an excellent view to north of the faulted side of Alcova anticline. The fault is located approximately where the water contacts the ridge (see geologic map foldout). Sandy Beach is along the far edge of the Alcova anticline.

18. 0.3 (4.9) Road to right (west) at crest of hill presents an excellent view of the lower part of Alcova Reservoir to the northeast and north (**Figure 35**). The dip slope of the Lakota is primarily covered with juniper with an occasional Ponderosa pine. The conglomerate in the Lakota ridge consists of small stones cemented together. The gravel in this conglomerate was transported from an uplift in Utah. The Lakota

Blacktailed jack rabbit—U.S. Fish and Wildlife Service

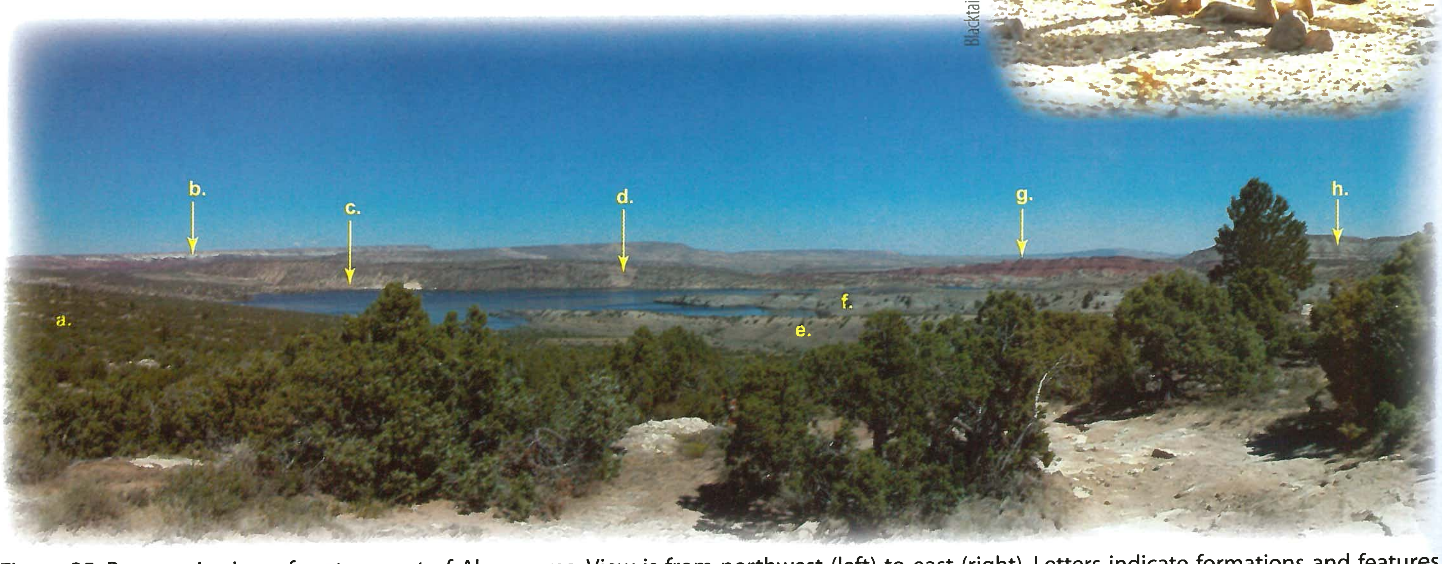


Figure 35. Panoramic view of eastern part of Alcova area. View is from northwest (left) to east (right). Letters indicate formations and features of interest: (a) dip slope of Lakota Formation, (b) White River Formation, (c) Sandy Beach and Tensleep Sandstone, (d) Alcova Canyon, (e) Muddy Sandstone, (f) Mowry Shale, (g) ridge of Alcova Limestone and Chugwater Formation, and (h) ridge of Lakota, Morrison, and Sundance formations. Photographs by JRM, August, 2004.

is very resistant to weathering, so it is often left to form the top of ridges (**Figure 36**) after other rock has been eroded away. This formation is over 140 million years old and marks the beginning of the Cretaceous Period in Wyoming.

Figure 36. Outcrop of conglomerate and sandstone in the Lakota Formation. Photograph by JRM, August, 2004.

19.	0.2	(5.1)	The road crosses the contact between the Morrison and Sundance formations.
20.	0.4	(5.5)	**Continue straight ahead on paved road.** Cottonwood Beach turn-off to the right (west). On this hillside are, bottom to top, Jelm, Sundance, Morrison, and Lakota formations (**Figures 37** and **38**). The Sundance and Morrison are famous for the abundant fossil records they contain.

Figure 37. The stratigraphic sequence exposed along Cottonwood Creek. The resistant conglomerates (dark brown boulders) in the lower Lakota Formation (Lower Cretaceous) litter the slope from the top of the ridge down to the Jelm Formation (Triassic). Photograph by JRM, August, 2004.

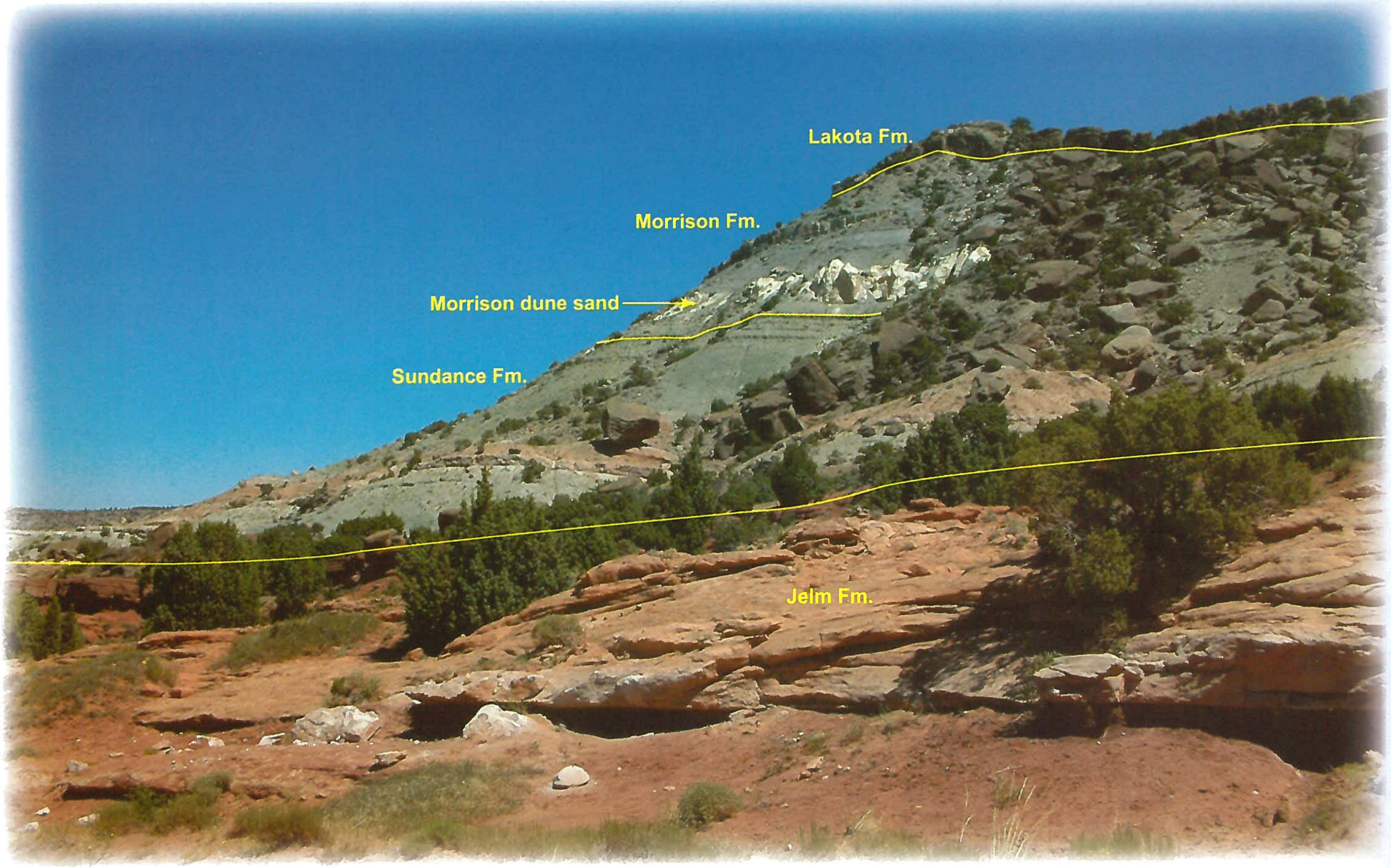


Figure 38. Jurassic through Lower Cretaceous rocks exposed along Cottonwood Creek. The uppermost part of the Sundance Formation, known as the Windy Hill Member, is below the distinctive white dune sand in the Morrison Formation; outcrops to the right of this unit are obscured by the extensive talus of Lakota. Photograph by JRM, August, 2004.

OPTIONAL SIDE TRIP. Turn west on Cottonwood Beach road to examine beautifully exposed Morrison, Sundance, and Jelm formations. If time permits, take the Cottonwood Creek Dinosaur Walk trail to see the Sundance and Morrison close up. From the beach, one can view the entire stratigraphic sequence from Triassic to Cretaceous on the north side of Alcova Reservoir (**Figure 39**).

Figure 39. Formations exposed across reservoir from Cottonwood Creek recreation area. The white object below the arrow pointing to the base of the Alcova Limestone is a semi-truck on Lake Shore Drive. Photograph by JRM, August, 2004.

Bald eagle—Dave Menke, U.S. Fish and Wildlife Service, June, 2003

Rabbitbrush, another member of the sunflower family, grows abundantly in poor soil. These shrubs are 2 to 3 feet tall, have narrow leaves, and numerous small heads of yellow or orange flowers. Eight or nine species of rabbitbrush are reported for this area. The common or rubber rabbitbrush, referred to by Dorn (2001) as *Ericameria nauseosus* (**Figure 40**) but also known as *Chrysothanmus nauseosus* (USDA, NRCS, 2004) blooms from August through October and adds a wonderful spot of color to the countryside. Indians used this shrub for dyes, fuel, and medicine. It serves as winter browse for pronghorn, deer, jack rabbits, and elk (not often found in the area).

Sagebrush is perhaps the most abundant shrub found in Wyoming—it grows almost everywhere along the Alcova tour. These shrubs, which are also members of the sunflower family, provide food and shelter for many species of wildlife. The evergreen leaves of this plant can be boiled to make a bitter tea, thought by Indians to possess various medicinal qualities. Sagebrush blooms in late summer and early fall, producing inconspicuous yellow-green flowers.

There are three species of sagebrush common in the Alcova area, big sagebrush, silver sage (local name), and prairie sagewort (**Figure 41**). The most conspicuous species is big sage (*Artemesia tridentata*), which can grow up to 10 feet tall. However, "big" is a rather poor name for this sage, as it is often quite small. (This shows the benefit of using scientific names to identify plants!) The leaves of this plant are wedge-shaped with three divisions or "teeth" at the end of each leaf. In its Latin species name, *tri* means "three," and *dent* means "tooth." It is a poor livestock food and competes with grasses for water and nutrients. It is, however, important browse for deer, elk, and pronghorn antelope during the winter and provides habitat for sage grouse and other birds. The sagebrush root system can extend down 2 meters (6.6 feet) or more, but also has shallow roots that may extend laterally to a distance of 1.5 meters (4.9 feet) that enables it to utilize summer rain.

Silver sage (*A. cana*, **Figure 41b**) grows to 2 to 3 feet in height and has long narrow, toothless leaves covered with numerous silver hairs, woody stems, and a good tap root. Another sagebrush species, *A. ludoviciana*, may occur locally but this is herbaceous and has rhizomenous (horizontal) roots.

Prairie sage (*A. frigida*, **Figure 41c**), growing only 8 to 12 inches tall, is the smallest of the three species in the area. The leaves of this species are deeply divided and often have a feather-like appearance. Prairie sage is more commonly found at higher elevations (7000 to 10,000 feet), but may be found in lower areas which are not overgrazed.

Figure 40. Rabbitbrush, photograph by JRM, August, 2004.

Figure 41. Three types of sagebrush in the Alcova area include (a) big sagebrush, (b) silver sage, and (c) prairie sage. Sketches by Gary Kiemig.

Morrison Formation

The Morrison Formation has yielded some of the most significant dinosaur finds in the world. These rocks at Alcova are, indeed, the real "Jurassic Park!" The Morrison Formation at Alcova is beginning to yield many significant dinosaur finds, starting with the discovery of "Sniffles," a small theropod raptor. This dinosaur, discovered by an elementary Field Science class with the help of Kent Sundell, Geology Professor at Casper College, resulted in the establishment of the Dinosaur Trail at Cottonwood Creek. Here and at other places around Alcova Reservoir, dinosaur bones may be found in place (**Figures 42a** and **42b**).

During Jurassic time about 150 million years ago, this area had a much different climate. Picture a great range of mountains to the west with swift, small rivers flowing across Wyoming to the northeast. At flood stage, they often trapped the dinosaurs and buried them in the deeper channels where we commonly find them. These rivers flooded into lowland gardens of lush vegetation near the banks and onto near sea-level delta plains to the east. The weather was tropical with seasonal wet and dry periods, which created the multicolored banding of red, gray, green, and maroon mudstones in response to the availability of water and oxygen as floods swept over the banks. The wet and poorly drained lowland created rich forests, savannas, and swampy ponds rich in verdant plant growth. This provided food for the dinosaurs in the form of cycads, ferns, conifers, and some other now extinct gymnosperms. In the moist lowlands horsetail rushes, algae, psilophytes, and club mosses grew in profusion.

The caliche or limestone pebble beds in the Morrison may represent a regional desert condition or hot dry interlude about mid-Jurassic time. This part of the Morrison is referred to as the Boundary Caliche Marker. The caliche forms when calcium carbonate at the surface dissolves in rainwater and migrates down into the soil; as the water in the soil evaporates, calcium carbonate is deposited in the form of limestone pebbles. Sandstone beds up to 38 feet thick are found below the caliche in the Cottonwood Creek Dinosaur Walk area. The sandstone represents lithified windblown sand that occurred in ancient sand dunes. The dune sands (**Figure 38**) are not found above the caliche marker and they do not yield bones because the dune environments were poor feeding grounds for dinosaurs.

At Alcova, the best bone finds occur in channel sandstones above the caliche marker. There are no bone finds below the marker! However, dinosaur tracks have been found below the caliche, indicating that dinosaurs were present but conditions were not favorable for preservation of dinosaur bones.

The Morrison is distinctive from the Sundance Formation beneath it. The base of the Morrison is a short distance below the white, cross-bedded dune sandstone (**Figure 38**). It overlies tan beach sandstone

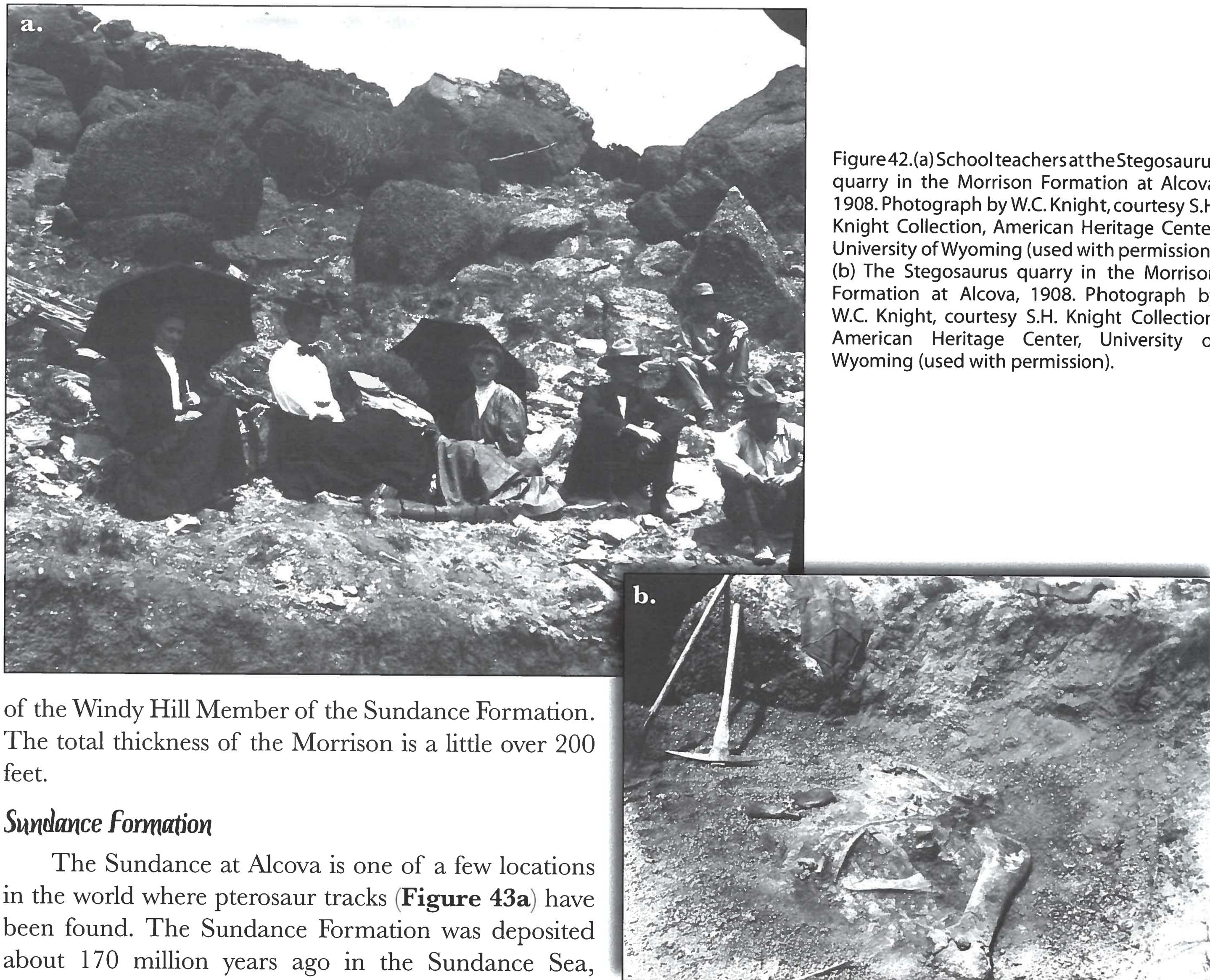


Figure 42. (a) School teachers at the Stegosaurus quarry in the Morrison Formation at Alcova, 1908. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission). (b) The Stegosaurus quarry in the Morrison Formation at Alcova, 1908. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

of the Windy Hill Member of the Sundance Formation. The total thickness of the Morrison is a little over 200 feet.

Sundance Formation

The Sundance at Alcova is one of a few locations in the world where pterosaur tracks (**Figure 43a**) have been found. The Sundance Formation was deposited about 170 million years ago in the Sundance Sea, which entered the area from the north. Evidence of the movement of the sea is contained in the formation itself. At the bottom of this formation are beach sands; above are rocks typical of deeper water; and at the top are more beach sands.

Pterosaur tracks in the Alcova area were first discovered in the Jurassic age Sundance Formation in 1976 by Herschel Nickerson. Terry Logue identified a number of these tracks, did further research on the track site, and was instrumental in preserving them. In 1978, slabs of sandstone bearing tracks were collected and are now a part of the collections at the Geology Museum in Laramie, and the Werner Wildlife and Tate Museums in Casper.

The Alcova tracks are found in cross-bedded, ripple-marked sandstone, which contains microscopic remains of echinoderms, foraminifera (a single-celled organism with a calcite or silica shell), and calcite spheres known as oolites that exhibit circular patterns in cross section. Based on what is now known about plate tectonics, the Alcova area would have been very close to the equator at the time the tracks were made. Conditions may have been similar to what the Persian Gulf is like today.

The appearance of the sandstone and the impression of the tracks would indicate that the sediment was once part of the beach of the Sundance Sea. Ripple marks are the result of wave action and cross-bedding is likely a result of longshore transport of sediment. Associated with some pterosaur tracks, trace fossils of small organisms that burrowed in the sand have been found. This would indicate that invertebrates were living on or in the sands of the beach.

Pterosaurs were flying reptiles that appeared first in the Triassic and were extinct by the end of the Cretaceous. Pterosaurs had forelimbs modified for flying, small weak hind legs, and a long beak with sharp teeth. They had hollow bones and were probably good gliders. Tests done with models indicate they could take off by simply extending their wings in a wind of only about 15 miles per hour.

Tracks of two different species of pterosaurs have been found in the Alcova area. The scientific name given to the trackways are *Pteraichnus saltwashensis* and *Pteraichnus stokesi*. Tracks have been found near the top of the Sundance Formation as well as in the lower part of the overlying Morrison Formation.

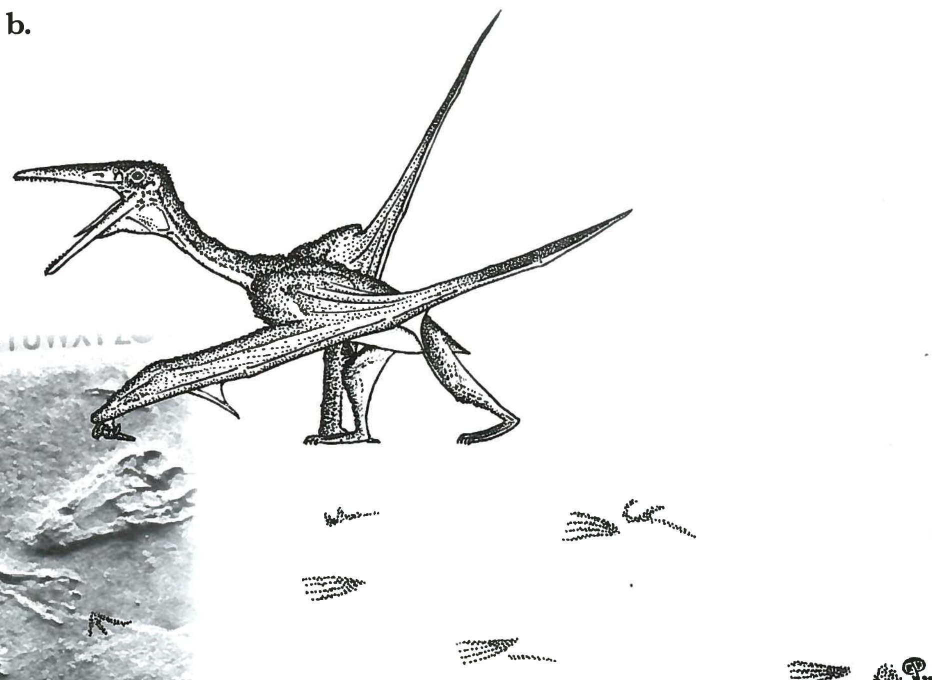
The track maker left impressions of the digits of both the forelimbs and hind limbs in the sandy beach of the Sundance Sea. Over time, the sand was cemented with calcium carbonate and changed into sandstone. The Sundance Sea slowly receded northward and the old shoreline was gradually lifted above sea level as the Rocky Mountains formed.

Tracks collected from the Alcova area show that the hind feet of the pterosaurs were webbed. The forelimbs, which were modified for flight, had three claws. The presence of the impression of three digits near the impression of the hind feet shows that the pterosaurs used their wings for walking when they were on the ground (**Figure 43a**).

Based on clues left in the rocks, we can imagine pterosaurs walking awkwardly along the beach (**Figure 43b**). The wings were folded back so the pterosaurs could use the wings, like crutches, to help walk. The short, weak hind legs had splayed-out, flat feet. They probably stopped from time to time to scratch in the sandy beach looking for a meal of invertebrates. They left distinctive tracks of the three-clawed wings and the webbed hind feet.

A very common fossil in the Sundance Formation is a gray, bullet shape, which was once an internal structure in the tail portion of a squid-like creature, the belemnite *Pachyteuthis densis* (**Figure 44a**). A round, flat clam (*Camptonectes bellistriatus*) (**Figure 44b**) as well as the bivalve pelecypod (*Gryphaea sp.*) (**Figure 44c**) are also common in the Sundance.

b.



a.

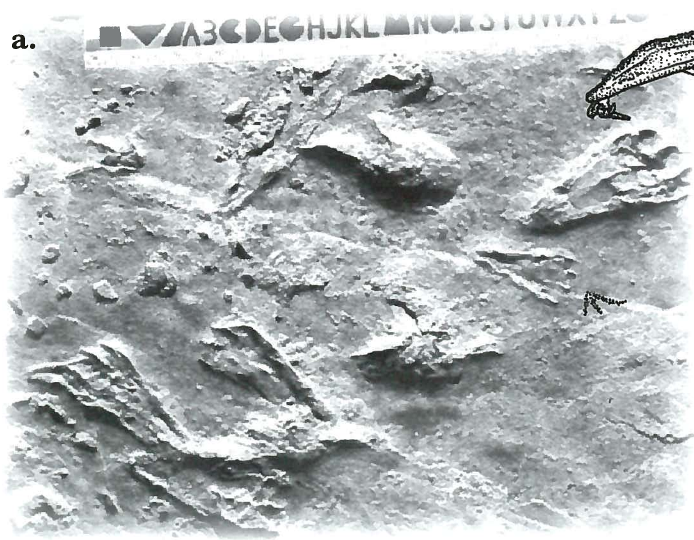


Figure 43. (a) Casts of pterosaur tracks in Sundance Formation, and (b) Artist's interpretation of a Jurassic pterosaur walking along a beach leaving tracks. Drawing courtesy Russell J. Hawley, 1999.

Black billed magpie—Wyoming Game and Fish Department, January, 1977

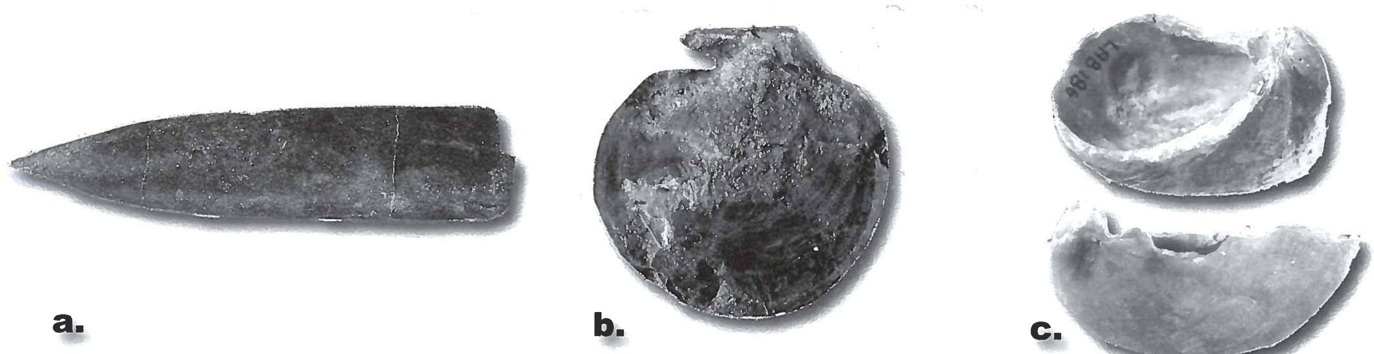


Figure 44. Common invertebrate fossils from the Sundance Formation include the belemnite *Pachyteuthis sp.* (a), the brachiopod *Camptonectes sp.* (b), and the pelecypod (clam) *Gryphaea sp.* (c). Photographs from Fossils of Wyoming, Wyoming State Geological Survey Bulletin 54.

Item #	Interval (miles)	Cumulative (miles)	
21.	0.4	(5.9)	Alcova Limestone and the Chugwater Formation can be seen to the east on the top of the ridge.
22.	1.0	(6.9)	Alcova Reservoir can be seen to the northwest.
23.	0.3	(7.2)	Here the reddish Goose Egg Formation with its gray gypsum and limestone beds is evident.
24.	0.4	(7.6)	Fork in road. **Turn right (west) on County Road 408 to Pathfinder Dam and Reservoir.** County Road 407 (to the left) goes to Kortes and Seminoe reservoirs, and on to Sinclair and Rawlins. For the next few miles, the road is in the Oligocene-age White River Formation, the same white rocks that form the high ridge west of the Alcova area.
25.	1.0	(8.6)	Exposures of sandstone in the White River.
26.	0.6	(9.2)	The Mississippian-age Madison Limestone can be seen on the hillside to the right (north). Notice the typical weathering patterns of limestone.
27.	0.3	(9.5)	The Fremont Canyon Sandstone (right) is a marine sandstone considered to be Devonian in age. It was deposited on the weathered, eroded surface of the Precambrian rocks. Over 2 billion years of the earth's history is missing (no record is preserved in the form of datable rocks) between these formations. The higher bank in this short road cut shows the contact between the Fremont Canyon Sandstone and the Precambrian rock (**Figure 45**). The top of the Precambrian shows weathering before the Fremont Canyon Formation was deposited on top. Remember, about 2 billion years is missing between

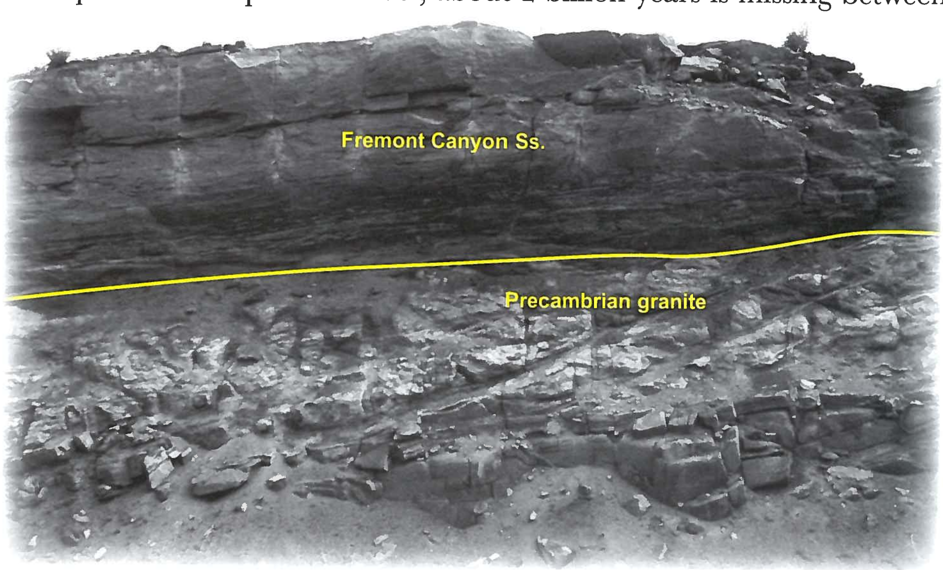


Figure 45. The unconformity between the Devonian Fremont Canyon Sandstone and Precambrian granite represents a time span of over 2 billion years.

these two layers so it is not surprising that the top of the Precambrian is weathered. In Fremont Canyon itself, this contact is sharper. The Precambrian rocks, which extend over a wide area, are primarily pinkish granites about 2.4 billion years old. Devonian rocks are from 354 to 417 million years old.

Granite is an igneous rock that forms when molten liquid rock below the earth's surface (called magma) cools slowly to a solid state. The slow cooling allows the minerals in the magma to form relatively large crystals, which, in granite include the light-colored minerals quartz (white) and feldspar (pink to reddish-brown), plus some dark-colored hornblende (black) and mica. Granite shows up in marked contrast with the sedimentary rocks, which cover most of the Alcova area.

Granite tends to have a large number of vertical cracks or joints (**Figure 46**). These joints are thought to have formed when stress occurred during cooling but could also be related to relief of stress when the area was uplifted, the overlying rock eroded, and the granite exposed. Joints make it possible to distinguish the granite from adjoining sedimentary rocks. Granite rounds as it weathers, so many outcrops of granite tend to look like domes. This characteristic rounding (known as *exfoliation*) helps in identifying granite outcrops from a distance. Of course Fremont Canyon was cut vertically into the granite, exploiting the granite's vertical joints.

28. 0.3 (9.8) Near the uphill end of the guardrail. The contact between the sedimentary Fremont Canyon Sandstone and the igneous granite is evident in the valley to the right (**Figure 47**).

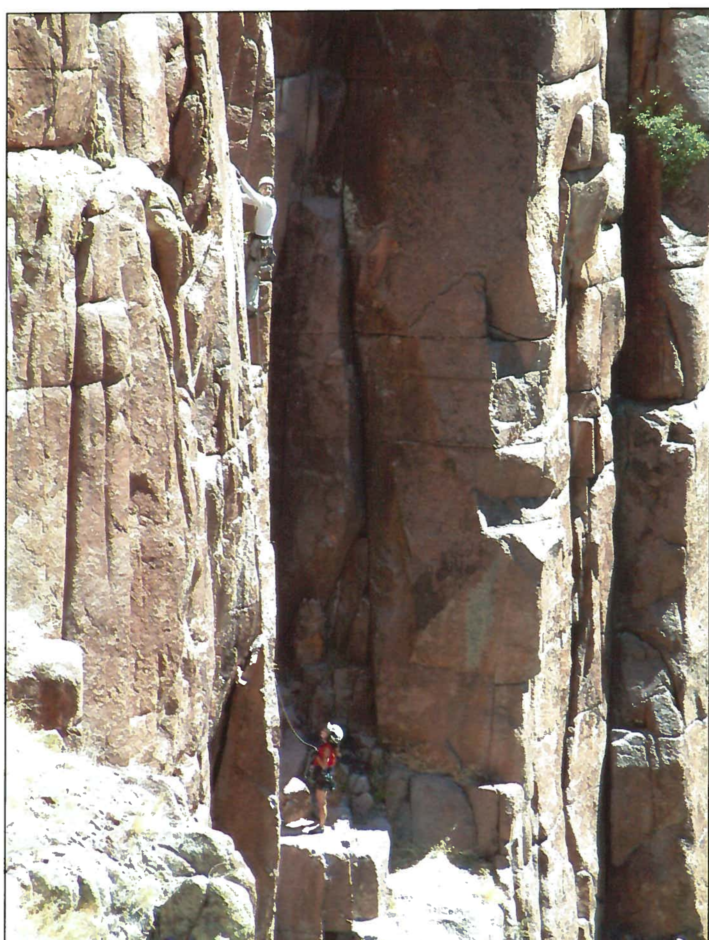
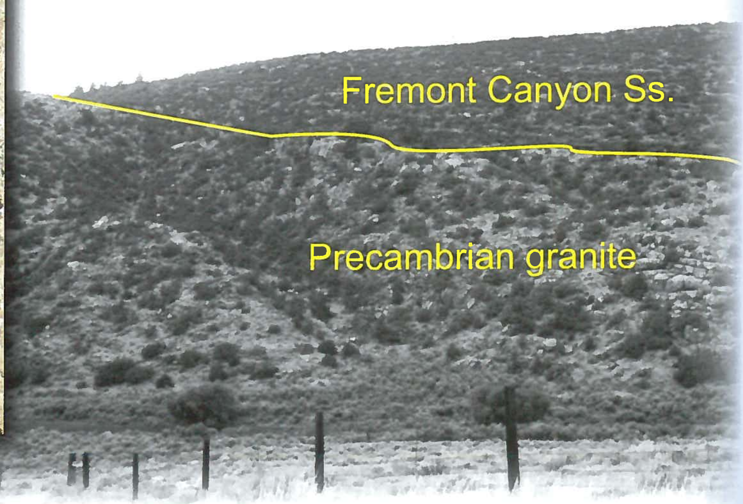


Figure 46 (left). Vertical jointing in Precambrian granite, Fremont Canyon. Photograph by JRM, August, 2004.

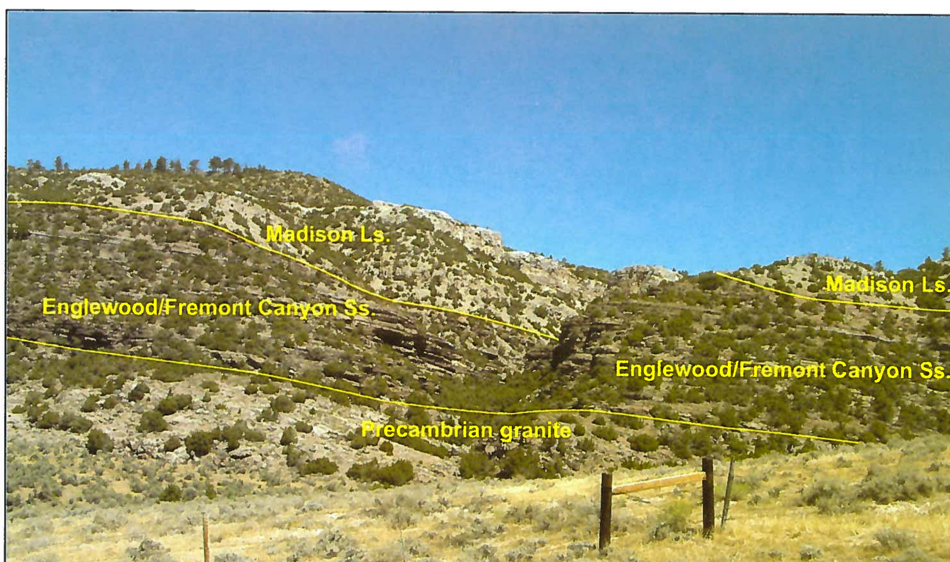
Figure 47 (below). In areas where even poorly exposed, the Fremont Canyon Sandstone is dark brown and has very obvious bedding compared to the pinkish, massive-looking granite below. View to north from county road.



The Fremont Canyon was previously mapped as Flathead Sandstone (Middle and Late Cambrian in age) or Deadwood Formation (Late Cambrian and Early Ordovician in age), but new work on these rocks (Sando and Sandberg, 1987) has revised the terminology and ages. A new formation was named the Fremont Canyon Sandstone for the rocks exposed in this area and the "type section" defined for the exposures north of the road (**Figure 48**). The formation was assigned an age of Late Devonian (from 354 to 370 million years ago). A thin (17 feet) limestone unit above the Fremont Canyon known as the Englewood Formation also occurs in this area and is mapped with the Fremont Canyon since it is too thin to be mapped separately.

Coyote—Wyoming Game and Fish Department, 1994

The large pine trees in the parking lot (**Figure 49**) to the right of the tunnel entrance (also found in Fremont Canyon and at the end of Lake Shore Drive) are Ponderosa pines (*Pinus ponderosa*). These pines, often called Western Yellow pine, Bull pine, or Blackjack pine, may be distinguished from other pines by their long (3 to 7 inches) needles, which occur in clusters of two or three. The bark of the Ponderosa pine is generally yellow-brown or red-brown with vertical ridges, which give the bark a scaly appearance. The cones of this species are reddish-brown and have spines at the end of each scale. Ponderosa pines are an important source of lumber. Nutcrackers, squirrels, and many other kinds of wildlife consume the seeds of the cones.



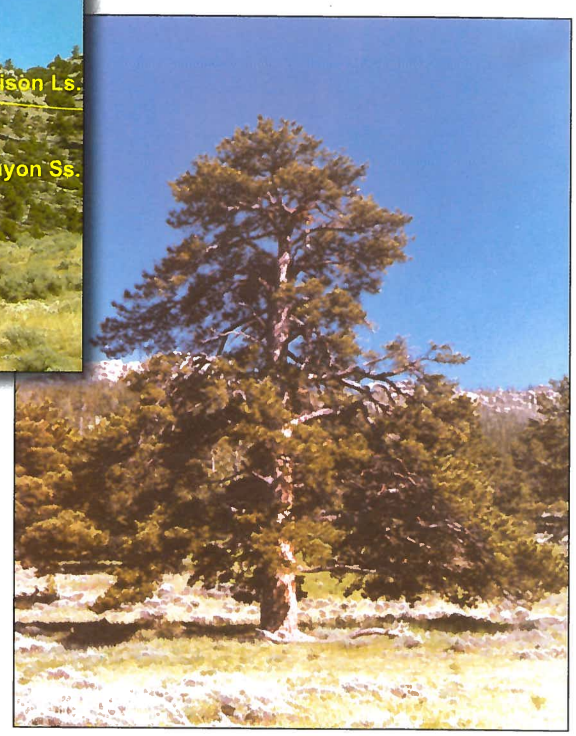


Figure 48 (above). Near the type section for the Fremont Canyon Sandstone. View to north from county road. The Fremont Canyon is 186 feet thick and the Englewood Formation is 17 feet thick, overlain by about 260 feet of Madison Limestone. Photograph by JRM, August, 2004.

Figure 49 (right). Ponderosa pine have long needles, scaly appearing bark, and spines on each seed of their cones.

Splotches of orange, gray-green, brown, and black color on the rocks in this area are masses of minute organisms called lichens (pronounced "likens"). A lichen consists of two organisms, a fungus and an algae, which live in close cooperation. Lichens secrete organic acids that break down the rocks. The algae produces food by photosynthesis for the pair while the fungus absorbs necessary minerals and holds the lichen to the rocks, an arrangement of mutual benefit which is another example of *symbiosis*. This biologic weathering process helps produce soil.

29. 0.8 (10.6) Bridge across Fremont Canyon. **Turn left.** Optional Stop: to the right is a parking area and overlook into the canyon (**Figure 50**). Ahead is the vehicle access tunnel to Fremont Canyon Power Plant. The tunnel was constructed in 1956 and is 1700 feet in length. This is the power plant at the head of Alcova Reservoir (see **Location 10, Boat trip log**). This is the end of Road Log A. Do not reset your odometer (unless you have taken some of the side trips).

Figure 50. Fremont Canyon at the bridge over the North Platte River. View is to the east. Fenced area in upper left is the parking area and overlook; arrow indicates Ponderosa pine tree. Two climbers (circled) are scaling the vertical canyon walls. Note vertical jointing system and the rounded forms of the Precambrian granite. Photograph by JRM, August, 2004.

Road Log B: Fremont Tunnel to Pathfinder

Badger—Gary M. Stolz, U.S. Fish and Wildlife Service, 2001

Item #	Interval (miles)	Cumulative (miles)	
		(10.6)	This road log begins after crossing the Fremont Canyon Bridge.
30.	0.3	(10.9)	Quaternary alluvial deposits are present along the road at this location. The Quaternary extends back only about 1.8 million years. An alluvial deposit or *alluvium* is composed of detrital material (clay, silt, sand, and coarser material) deposited by streams on river beds or floodplains and is generaly of recent age and poorly consolidated. There are a few Limber pine (*Pinus flexilis*) in this area. This pine is found in areas that are between 7000 and 13,000 feet elevation. Needles occur in clusters of five, less than 4 centimeters (1.6 inches) long and slightly curved. The branches are quite flexible.
31.	0.5	(11.4)	Good view of Fremont Canyon to the left rear.
32.	1.4	(12.8)	To southeast is the beginning of the lower part of Fremont Canyon (**Figure 51**). Most of the water flowing out of Pathfinder Reservoir goes through the Fremont Canyon Power Plant but a small amount of water is allowed to flow in the river channel to maintain a fishery. In years past, this stretch of the river was allowed to dry up.
32.	0.2	(13.0)	The most abundant wild cottonwood is *Populus angustifolia*, or the Narrowleaf cottonwood (**Figure 52a**). This tree is common along streams and in foothills at moderate elevations (6000 to 8000 feet) throughout Wyoming. Sometimes confused with willows (**Figure 52b**) because of their narrow leaves (**Figure 52c**), Narrowleaf cottonwoods have rough

Figure 51. Beginning of lower part of Fremont Canyon that eventually leads to Alcova Reservoir. From this point to the mouth of the canyon is over 6 miles of very steep and rugged canyon. Photograph by JRM, August, 2004.

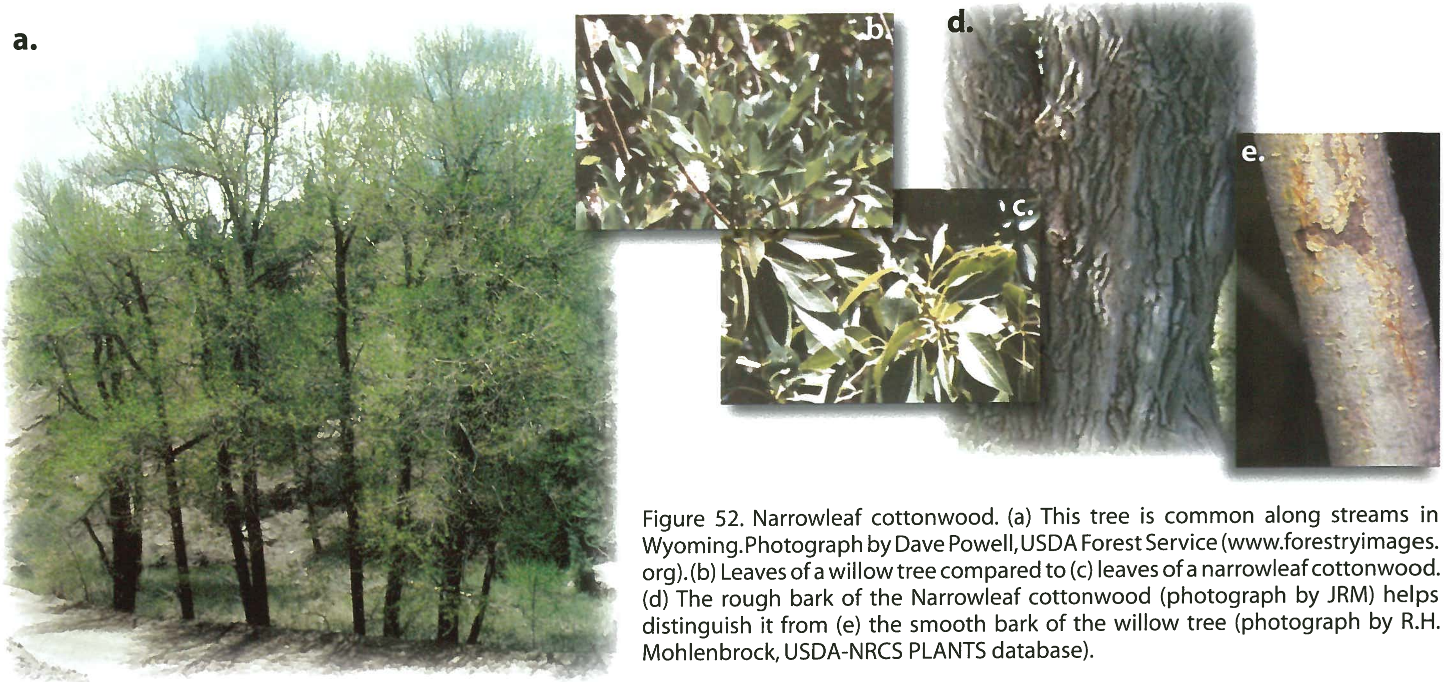


Figure 52. Narrowleaf cottonwood. (a) This tree is common along streams in Wyoming. Photograph by Dave Powell, USDA Forest Service (www.forestryimages.org). (b) Leaves of a willow tree compared to (c) leaves of a narrowleaf cottonwood. (d) The rough bark of the Narrowleaf cottonwood (photograph by JRM) helps distinguish it from (e) the smooth bark of the willow tree (photograph by R.H. Mohlenbrock, USDA-NRCS PLANTS database).

Item #	Interval (miles)	Cumulative (miles)	
			bark (**Figure 52d**) while willow bark (**Figure 52e**) appears much smoother. Both cottonwoods and willows are in the same plant family, Salicaceae.
33.	0.2	(13.2)	Gravels now exposed in this road cut (**Figure 53**) were deposited by a river. Note how the individual pieces were rounded as the stream rolled them along.
34.	0.2	(13.4)	**Keep right.** Road to the left leads to the south side of Pathfinder Reservoir.
35.	0.3	(13.7)	Footings left from construction of the power plant and tunnel in the mid 1950s. Pathfinder Reservoir can be seen to the left.
36.	0.2	(13.9)	Tunnel inspection access structure to the right and small building on left which may have been used for storage of explosives, a jail, and bank during construction of Pathfinder Dam. Also, note footings for other buildings in this area.

Raccoon—Wyoming Game and Fish Department

Figure 53. Alluvial gravels probably deposited by the North Platte River at an earlier time when the level of the river bottom was higher.

Item #	Interval (miles)	Cumulative (miles)	
37.	0.6	(14.5)	Scenic overlook road left. Ferris Mountains are visible across the reservoir (**Figure 54**).
38.	0.2	(14.7)	**Turn left to Pathfinder Dam and picnic area.** Park vehicle and walk to the dam (**Figures 55** and **56**). Pathfinder was one of the first dams constructed under the auspices of the USBR. The dam was named in honor of explorer Lt. John C. Fremont. In 1842, somewhere in this section of the canyon (**Figure 57**), the "Great Pathfinder" as Fremont was nicknamed, lost much of his equipment when his boat overturned. An account of this mishap is found in *Exploring with Fremont: The Private Diaries of Charles Preuss, Cartographer for John C. Fremont on His First, Second, and Fourth Expeditions to the Far West:*

Least chipmunk—Wyoming Game and Fish Department, June, 1991

> *Platte River... before sunrise the boat was made ready and packed... we shoved off. The water was not as deep as it appeared to be... In general everything went well for about an hour. Then we came to a spot where the river was flanked on both sides by rocks 100-200 feet high. We heard the roaring of the water... The passage was often so narrow that there was just enough leeway for the boat, but the men were adept at handling it... [Then] Higher rocks*

Figure 54 (left). View to west across Pathfinder Dam and Reservoir from the scenic overlook. Arrow shows vertical diabase dike (see Item 39). Photograph by JRM, August, 2004.

Figure 55 (above). View to west across Pathfinder Reservoir from the dam. Arrow shows vertical diabase dike on Pathfinder Mountain (see Item 39). The Ferris Mountains are on the skyline.

Figure 56 (left). Pathfinder Dam overlook on the south side of Fremont Canyon just east of the dam. View is to the north.

Figure 57. Head of upper Fremont Canyon looking downstream, about 1909 before Pathfinder Reservoir began to fill. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

appeared ahead of us... the water roared worse than before... This waterfall was later generally claimed to have been five feet high... The height did not matter anyway; it was the rocks.

We paid little attention to either the height or the rocks just now... Off we went... through the white foam. We got through nicely -- but alas, below the fall lay a piece of rock, invisible because of the water and foam. This caused our misfortune. In a trice I was in water up to my neck, no ground under my feet... I half swam, half drifted to the next rock. Here I found ground, held on the rock firmly, and now had a chance to look around. What a depressing sight! The boat was upside down; some men held on to it, while others hung like me on projecting rocks. Fremont already stood close to the shore... The first few minutes everybody thought only of getting himself on dry ground. Through careful sounding and some swimming I was soon on the shore... The others were on the opposite shore and had in the meantime pulled the boat there, still upside down. Now we had time to contemplate our adventure... My book I had saved... My compass was safe in my pocket... Everything else was in the water and we now started to fish things out, beds, buffalo hides... the tent and a few other things were soon on dry ground. But these were trifles! Where were the sextant, the pair of compasses, the large telescope... the books, the journal with astronomical and barometrical observations? Everything was gone to the devil...

The dam, which is classified as a cyclopean rubble, masonry arch, gravity type dam, rises 214 feet from bedrock in the canyon floor and has a crest length of 432 feet. It tapers from a base width of 97 feet to a top width of 11 feet. The dam was proposed by the newly created USBR in the early 1900s (**Figure 58**) in a program to reclaim the arid West by building dams to store water for irrigation projects. This dam was built using techniques developed for Buffalo Bill Dam near Cody, which was completed earlier. Pathfinder Dam was completed in 1909 for a cost of about $2.2 million in about 4 years. It was the first dam on the North Platte River system. The dam was added to the National Register of Historic Places in 1971. A museum describing the history of the dam and its construction is located at the dam site.

Deer mouse—Wyoming Game and Fish Department, November, 1976

The first item of construction was to divert the North Platte from its original riverbed by driving a tunnel on the north wall (**Figure 59**). Next, the riverbed at the dam's base and the canyon walls had to be prepared (**Figures 60** and **61**). Huge coarse-grained granite blocks (2 to 3 feet thick) quarried (**Figures 62** and **63**) within one-quarter mile of the

Figure 58 (above). Site proposed for Pathfinder Dam in upper part of Fremont Canyon. View is to the west slightly downstream from the site. Pathfinder Mountain is on the skyline; arrow shows a vertical diabase dike (see Item 39). Photograph by U.S. Bureau of Reclamation, 1904.

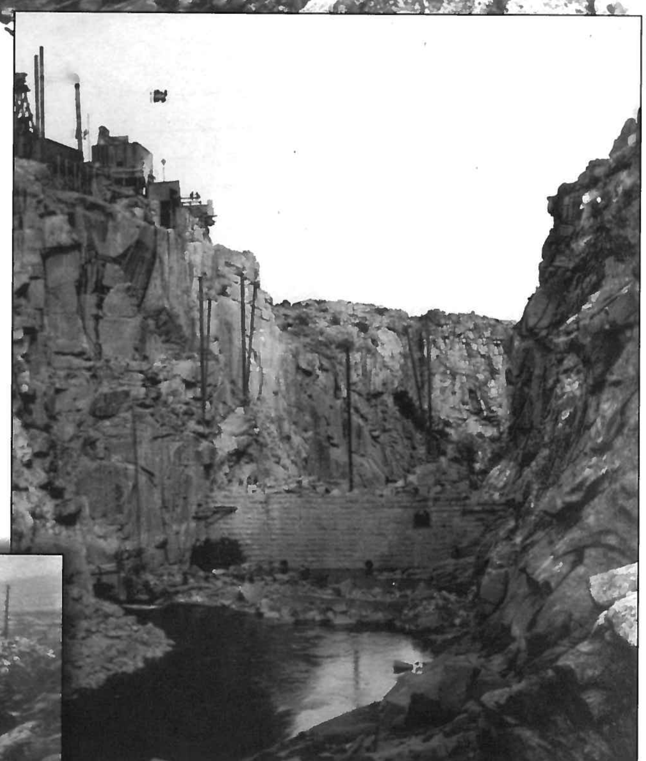


Figure 59 (right). Upper face of Pathfinder Dam as of September 24, 1907. North Platte River is diverted through tunnel in lower left.

Figure 60 (left). Early part of construction of Pathfinder Dam after river was diverted through tunnel.

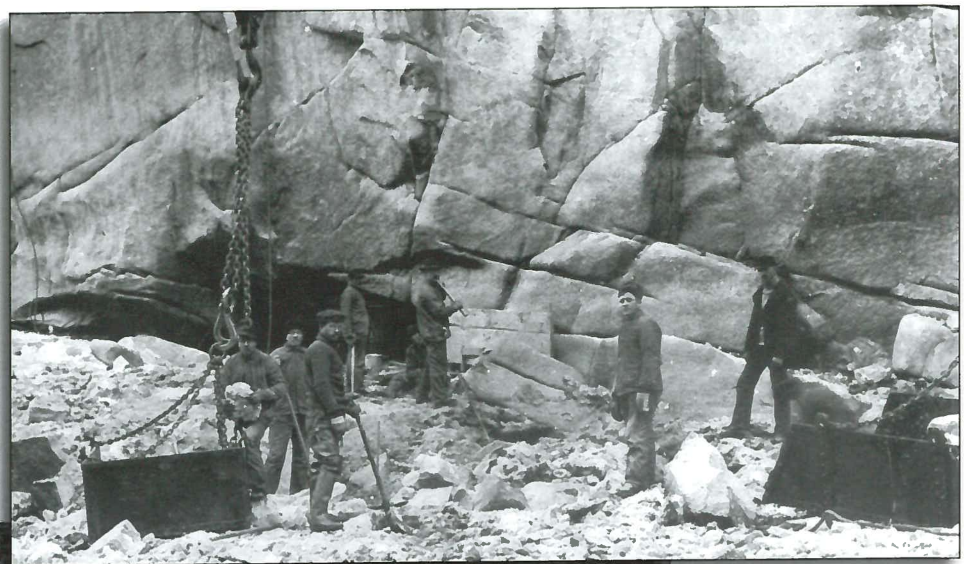


Figure 61 (right). Preparing the river bed and the canyon walls required removal of all loose material and exposing fresh, unweathered bedrock.

Figure 62 (above). Quarries for granite blocks at Pathfinder Dam, circa 1909. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

Figure 63 (right). These hydraulic drilling machines were used to quarry the large granite blocks for the dam and were some of the only mechanized equipment available.

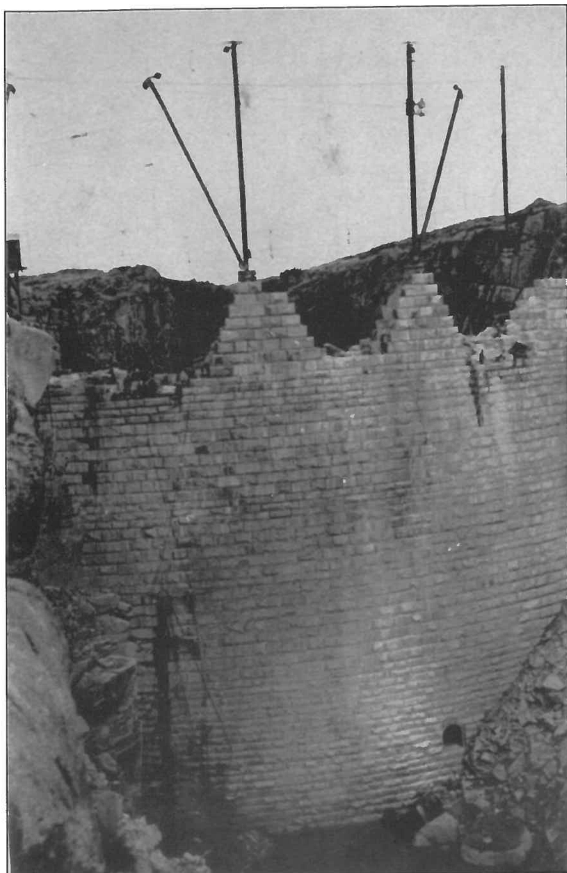
Rough-legged hawk—Wyoming Game and Fish Department, January, 1974

dam were used for facing (**Figure 64**). Irregularly shaped backing stones weighing up to 10 tons were mortared into place following the difficult prying and lifting necessary to align them. Narrow gauge tracks (**Figure 65**) comprising a tramway system connected cement sheds and quarry to the canyon's edge and mixing house (**Figure 66**). Due to the slight grade of the track, two men could move the cars (trams) containing the 10-ton rocks to the canyon's edge. Hoists (**Figure 67**) then lowered the rocks to the dam.

Figure 64 (right). Large cut granite blocks were moved from the rail cars onto the face of the dam with a hoist and tramway system.

Figure 65 (left). Loading granite facing blocks at the quarry onto narrow gauge trams. Notice the hoisting system and booms with the steel cables.

Figure 66 (right). The cement was prepared in sheds (long buildings on right) and transported to the mixing houses near the canyon's edge where it was combined with sand and aggregate to make concrete or moved to the dam to be used as mortar. Part of the quarry is seen in the foreground. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).



The inner portion of the dam between the facing and the backing stones was filled with waste rock and mortar (**Figure 68**). Amazingly, the only steel used in the entire dam reinforces the upper 30 feet of the dam's faces. About 48% of the volume of the structure is entirely blocks of native granite set in concrete. Each surface of the granite blocks had to be prepared and free of weathering to ensure bonding with the mortar. Fill material was loaded into horse-drawn dump wagons (**Figure 69**). In 1910 during the construction of a dike designed to close a gap south of the dam, a Marion steam shovel, Model 40 1.5-yard dipper (**Figure 70**) was acquired. In order to transport it to Pathfinder, the shovel had to be dismantled in Casper, hauled by wagon, and rebuilt at the dam site. When completed, the dam spanned the total height of the canyon and then some (**Figure 71**). It created a reservoir that could hold about one million acre-feet of water from both the North Platte and the Sweetwater rivers.

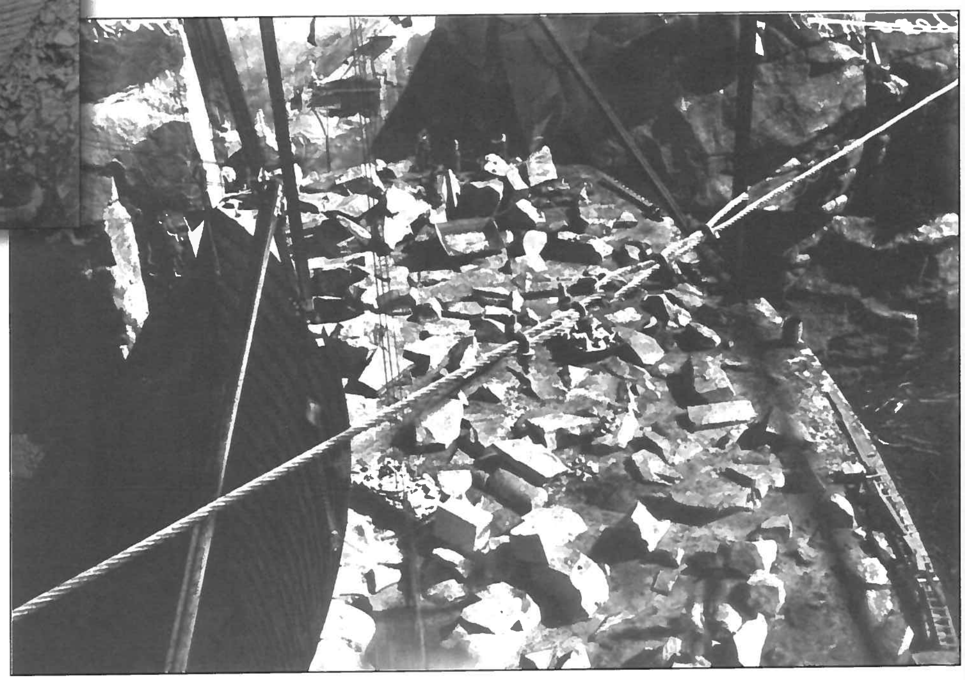


Figure 67 (above). The hoist system used to place construction materials on the dam.

Figure 68 (right). Pathfinder Dam, circa 1909, showing placement of granite blocks and rubble. Photograph by W.C. Knight, courtesy S.H. Knight Collection, American Heritage Center, University of Wyoming (used with permission).

Figure 69 (below). Loading wagons underneath with fill material excavated nearby and moved up a ramp. Most of the construction tasks were accomplished by just men, horses, and simple equipment.

Figure 70 (left). A steam shovel was used at the construction site only after the main part of Pathfinder Dam was completed.

Figure 71 (right). The upstream end of completed Pathfinder Dam. Because the height of the dam exceeded the height of the canyon walls, a retaining dike had to be constructed south of the dam and a spillway system built on the north end of the dam to handle excess water in wet years.

Laborers were generally unskilled immigrants who were paid 35 cents an hour and worked 6-day weeks with a minimum of primitive mechanical help. Freight wagons (**Figures 72** and **73**) hauled material, equipment, and supplies 45 miles from Casper (charging $1 per hundredweight) to the crude construction camp (**Figure 74**). Many of the workers lived in tents (**Figure 75**) and bravely endured high winds, summer heat, blizzards, and intense winter cold.

Golden eagle—Wyoming Game and Fish Department, October, 1985

Some workers did manage to raise families at the construction site. According to a monograph on Emilie Mosher compiled by Edmund Toy, Mrs. Emilie Mosher was born Emilie Demorest on November 4, 1906 in a tent only a few hundred yards upstream from the site of Pathfinder Dam. Her parents were Charles and Ettah Demorest. Her father was

Figure 72 (left). Freight wagons from Casper and other places hauled materials and supplies to the Pathfinder Dam construction site. Rocks and water were the only resources offered by the site itself.

Figure 73 (right). A closer view of the wagon trains used to haul supplies to Pathfinder. Note the white tents in middle background used to "house" construction workers.

Figure 74 (left). Part of the temporary buildings at Pathfinder Dam construction site. Alcova was the only settlement nearby, and it didn't offer that much either.

Figure 75 (above). The construction camp at Pathfinder Dam, circa 1912. At the time this photograph was taken, the dam had been completed, and the south dike was nearly finished.

contracted by a Denver company to haul sand and wood from the Pedro Mountains to the Pathfinder Dam construction site. After Emilie's birth, the Demorests moved to a cabin downstream from the dam (**Figure 76**). She was told that as an infant she had been "placed in the oven of our cooking stove for some time to keep me warm." She was delivered by Dr. Homer R. Lathrop. In an interview many years later, Emilie complimented him for doing "marvelous work" at the construction site: "He did all the medical work, from dental to broken bones."

Horned lark—Wyoming Game and Fish Department, June, 1978

Figure 76 (left). The first permanent buildings at Pathfinder Dam were cabins for families.

39. **Figures 77** and **78** show a geological formation known as a dike. A dike is formed when molten rock beneath the earth's surface is forced into a nearly vertical crack in the existing rock. Dikes vary from a few inches to many feet in width and from a few feet to many miles in length. The dike may be somewhat wider than the original crack because of the melting action of the very hot molten rock. Along the edges of the dikes, the granite may have been altered by this heat.

In Fremont Canyon along Alcova Reservoir and around Pathfinder Dam (**Figures 54** and **55**), the dikes are younger than the Precambrian granite into which they are intruded, but older than the Devonian Fremont Canyon Sandstone, which has not been intruded. The dikes are definitely Precambrian in age and probably 1.5 billion years old if not older. The intrusive activity which formed the dikes took place well beneath the surface and the dikes (along with the granites) have been exposed by erosion when the area was uplifted.

These dikes are composed of a rock called *diabase*, a heavy, dark, greenish-gray to black rock that often turns rust brown on faces that have been exposed to the weather. It is possible to study some of these dikes more closely while making the boat trip up Fremont Canyon; the Boat Log has additional photographs of dikes.

Figure 77 (right). Diabase dikes (below arrows) on Pathfinder Mountain intrude Precambrian granite west of Pathfinder Dam. Photograph by JRM, August, 2004.

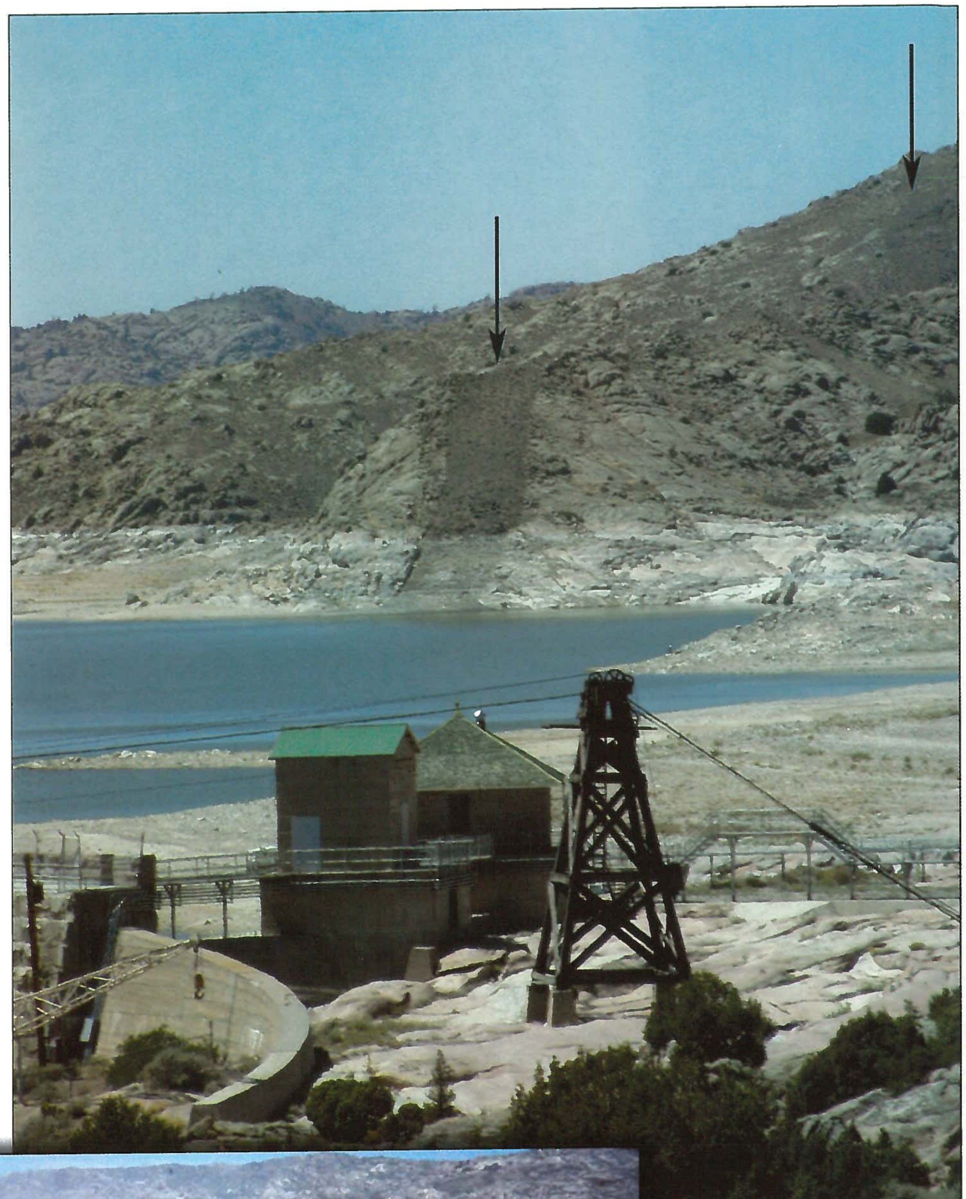
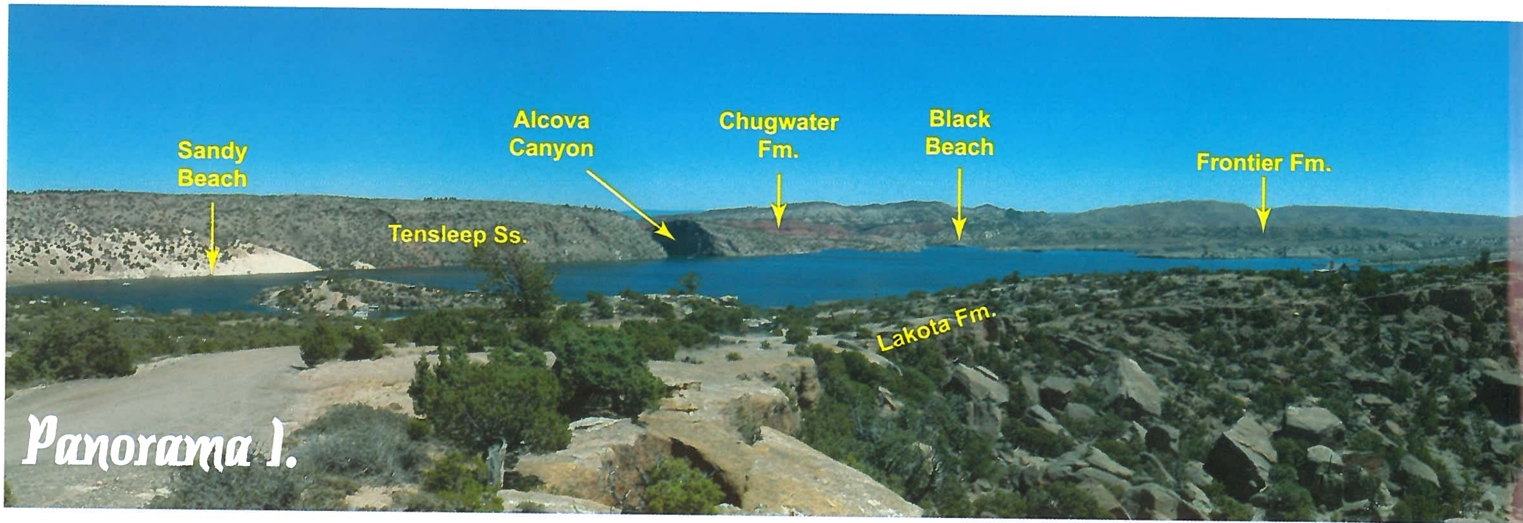
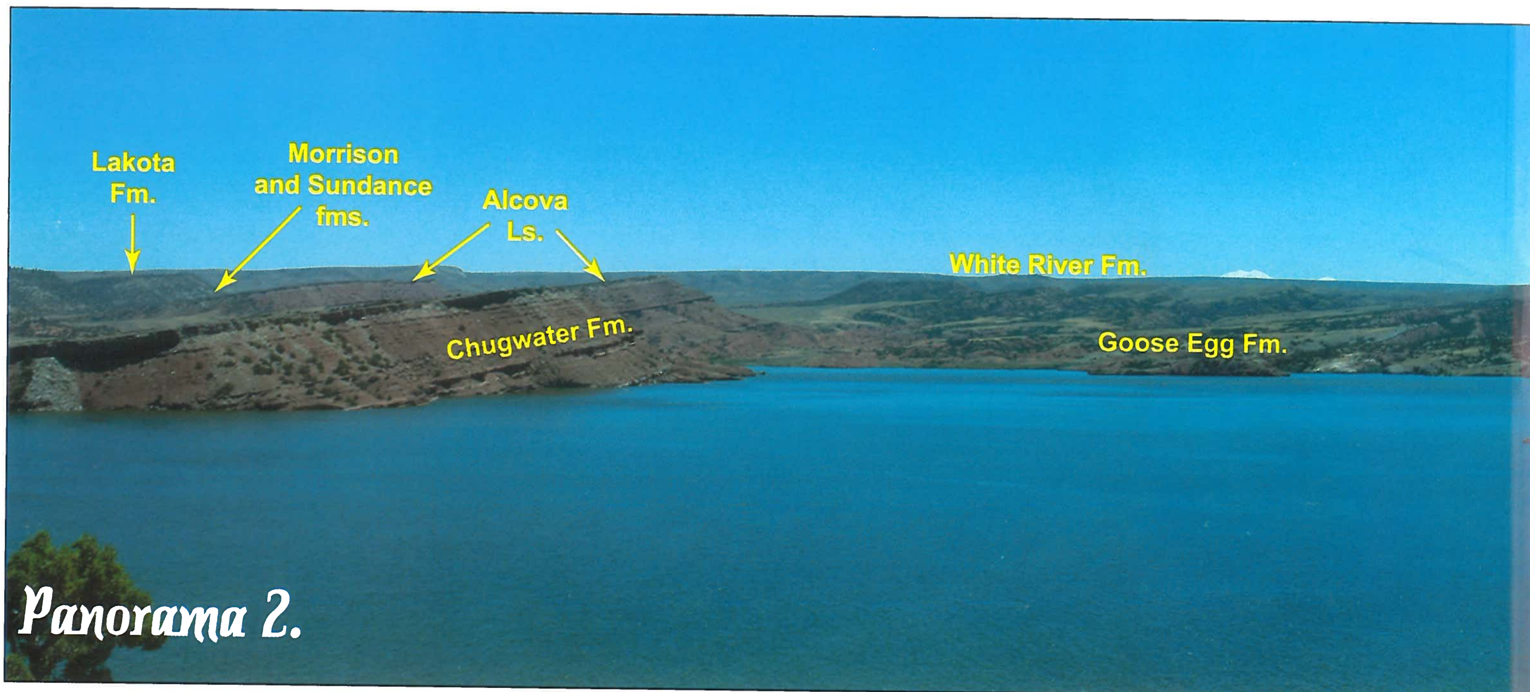


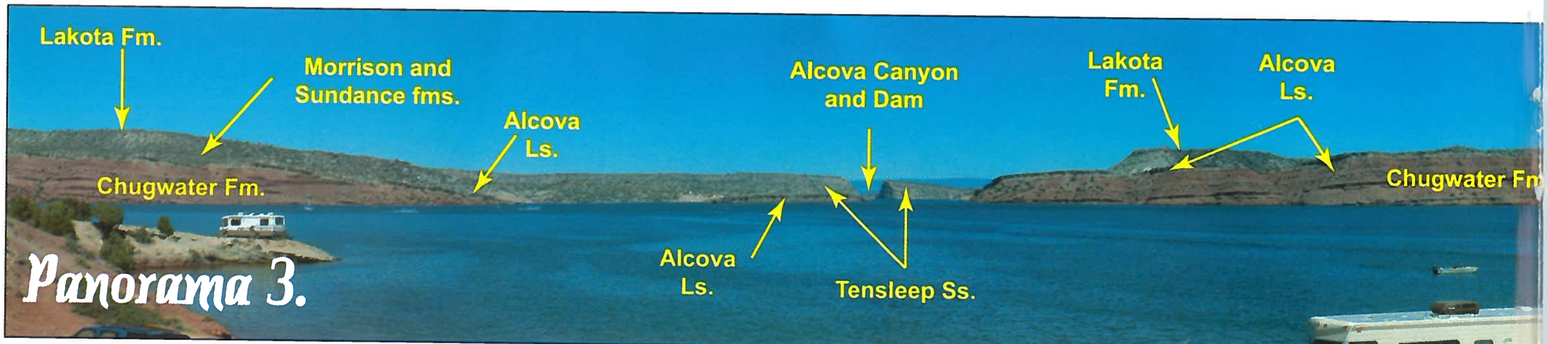
Figure 78 (below). The south wall of Fremont Canyon just below Pathfinder Dam contains a black diabase dike that intrudes Precambrian granite. The dike is the dark vertical band on the left side of the photograph. In wet years when Pathfinder Reservoir is completely full and not enough water can be run through Fremont Canyon Power Plant, the dam is allowed to "spill" around its north end, creating a very impressive waterfall into the canyon below.



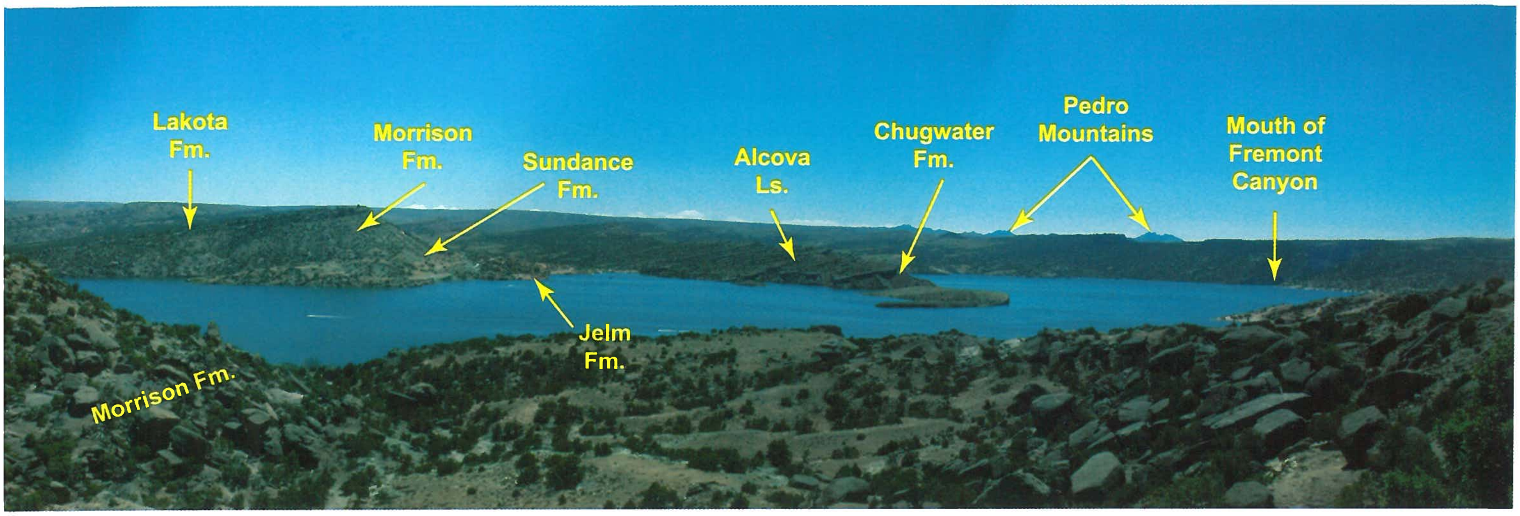
East to southwest view of Alcova Reservoir; Sandy Beach (left edge) to Casper Boat Club (right edge). Formations are also labelled on Figures 96 and 99. Viewpoint for panorama is at Item 55, about 1 mile after turning onto Lake Shore Drive from U.S. Highway 220. Photographs by JRM, August, 2004.

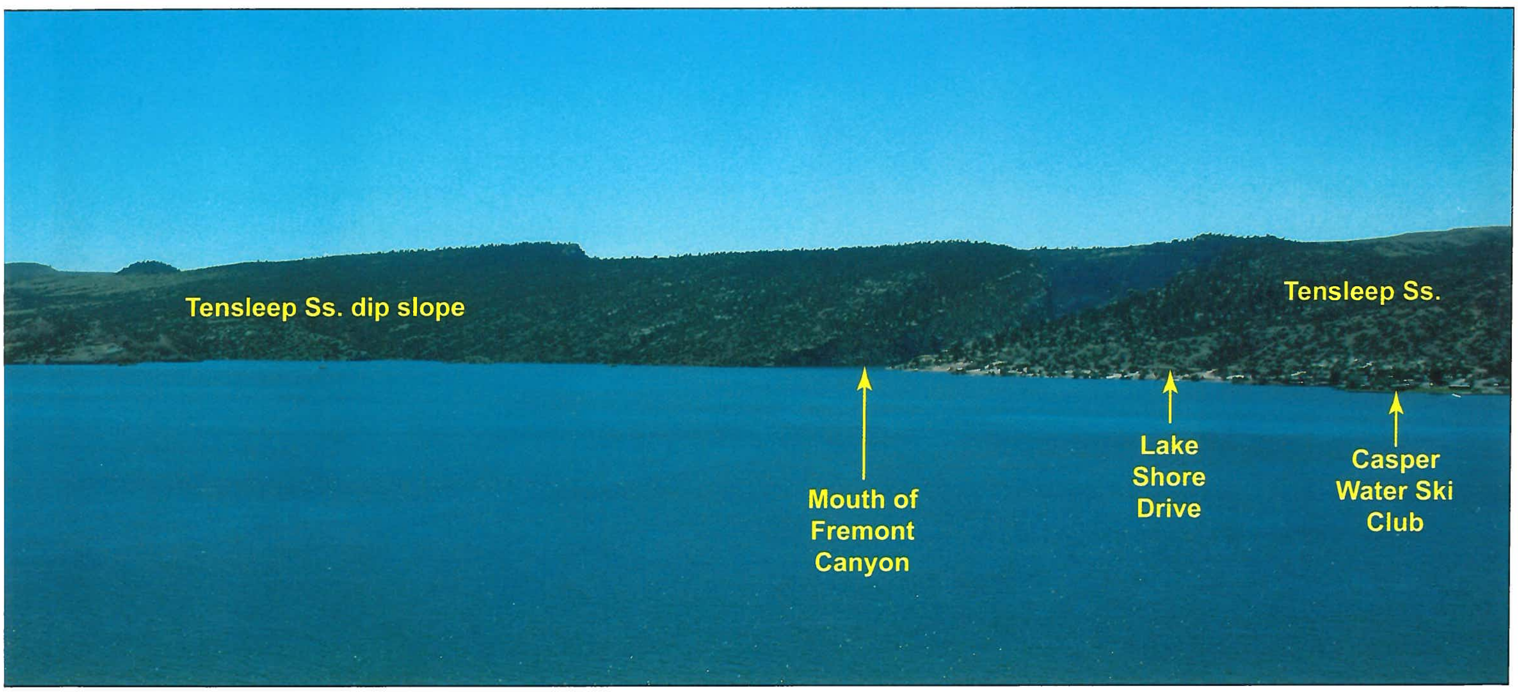


Southeast to southwest view of the upper end of Alcova Reservoir; Cottonwood Creek area (left edge) to Casper Water Ski Club (right edge). Formations and locations are also labelled on Figure 101. Viewpoint for panorama is at Item 61, the turnout with the stone steps on the north side of Alcova Reservoir along Lake Shore Drive. Photographs by JRM, August, 2004.



Northeast to southeast view of Alcova Reservoir; Lakota Fm. outcrops (left edge) to mouth of Fremont Canyon (right edge). Formations and locations are also labelled on Figures 106 and 107. Viewpoint for panorama is at Item 70, end of Lake Shore Drive at the mouth of Fremont Canyon. Photographs by JRM, August, 2004.


Lakota
Fm.
Morrison
Fm.
Sundance
Fm.
Alcova
Ls.
Chugwater
Fm.
Pedro
Mountains
Mouth of
Fremont
Canyon
Jelm
Fm.
Morrison Fm.


Tensleep Ss. dip slope
Tensleep Ss.
Mouth of
Fremont
Canyon
Lake
Shore
Drive
Casper
Water Ski
Club


Morrison and
Sundance fms.
Goose Egg Fm.
Fremont Canyon

Road Log C: Pathfinder Dam to Highway 220

(14.7) **Return to vehicle from dam and back to county road. Follow continuation of County Road 409 (north) to State Highway 220.**

40. 0.8 (15.5) Pathfinder cemetery is located to the right of the road. There were no fatalities during the construction of the dam. However, in 1912, during the construction of a covered ladder, a cable broke and five men were killed. Two of those killed are buried here. The other graves are those of people who lived at the dam site.

Wyoming's state flower, Indian paintbrush (**Figure 79**) is so named because of its resemblance to ragged brushes dipped in paint. The color of paintbrush is not that of the flower petals, but of the bracts that surround the tiny green flowers.

Figure 79. The bright red species of Indian paintbrush is the Wyoming State Flower.

Paintbrushes come in a wide variety of colors, generally varying shades of yellow, pink, orange, and red. This vast color range is a result of the hybridization (crossbreeding) of many species. Thus, they are usually identified as *Castilleja sp.* — *Castilleja* being the genus to which all species of paintbrush belong, and *sp.* indicating that the species is unknown. Wyoming's state flower is a distinct bright red species of paintbrush, *Castilleja linariaefolia*.

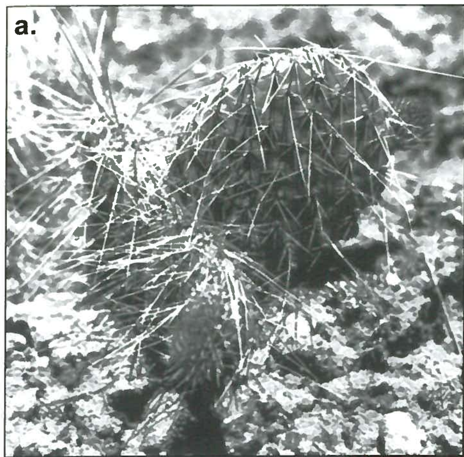
Paintbrushes are semi-parasitic, meaning they make only a portion of the food they need. The roots of paintbrushes invade the roots of other plants (sagebrush in particular) and absorb food made by that plant. For this reason, it is extremely difficult to transplant Indian paintbrush to home gardens.

41. 1.1 (16.6) Driving on the upper conglomerate member of the White River Formation (Oligocene). The formation is known for the abundance of mammal fossils it contains, including rabbits, oreodonts, saber tooth cats, camels, and horses. The White River forms the tall white "palisades" seen along Shirley Rim to the southeast, along Beaver Divide to the west, and east of Douglas where it is exposed in extensive badlands. The upper member of the White River is light gray, soft conglomeratic tuffaceous sandstone and conglomerate that is somewhat more resistant than the softer rocks of the lower part of the White River exposed below the rim to the east.

Prickly-pear cacti, *Opuntia polyacantha*, are well adapted to the dry conditions of this area. Their thick fleshy stems are composed of tissue that stores water when the supply is plentiful. The entire plant is coated with a waxy substance that prevents the loss of precious stored water through evaporation, as do the modified spiny leaves (**Figure 80a**). In an emergency, it can serve as a source of water and food. Beautiful large yellow flowers appear in late spring (**Figure 80b**).

Antelope—Wyoming Game and Fish Department, November, 1988

42. 0.8 (17.4) Intersection with the road west to Bishop Point recreational area on Pathfinder Reservoir. **Continue north on county road.** In the



distance to the west is the Sweetwater River, which flows into Pathfinder. The Sweetwater area includes Independence Rock, Split Rock, and Devils Gate, famous landmarks along the Oregon Trail.

Dense purple flower heads and spiny leaves characterize the Canada thistle, *Cirsium sp.* (**Figure 81**), which grows throughout Wyoming. This thistle has deep spreading roots, which allows it to flourish in dry soils. Canada thistles bloom from June to August. It has been declared a noxious

Figure 80. The Prickly-pear cacti occur in much of Wyoming's desert areas and are characterized by (a) long spines on the leaves and (b) yellow flowers when it blooms.

Desert cottontail rabbit—Wyoming Game and Fish Department, August, 1983

Figure 81. Canada thistle is a noxious weed that is common in Wyoming's dry soils. Photograph by JRM, September, 2004.

weed in at least 37 states and is very hard to eradicate. It is believed Canada thistle was brought to the U.S. from Canada with hay for General Burgoyne's army in the late 18th Century.

43. **0.4** **(17.8)** To the west is the core of the Granite Mountains uplift. This uplift, although not very obvious today, was once a high, east-west trending mountain range that was formed during the Laramide Orogeny some 50 to 60 million years ago. This range may have been as high as parts of the Wind River Range or Bighorn Mountains, but in late Tertiary the core of the range collapsed, leaving Precambrian granite knobs surrounded by late Tertiary sedimentary rocks. The margins of this uplift remained somewhat higher than the collapsed core of the uplift, as can be seen today in the Rattlesnake Hills to the north and a series of small east-west trending ranges (including the Ferris and Seminoe mountains) that are visible to the south (**Figure 82**) from this area.

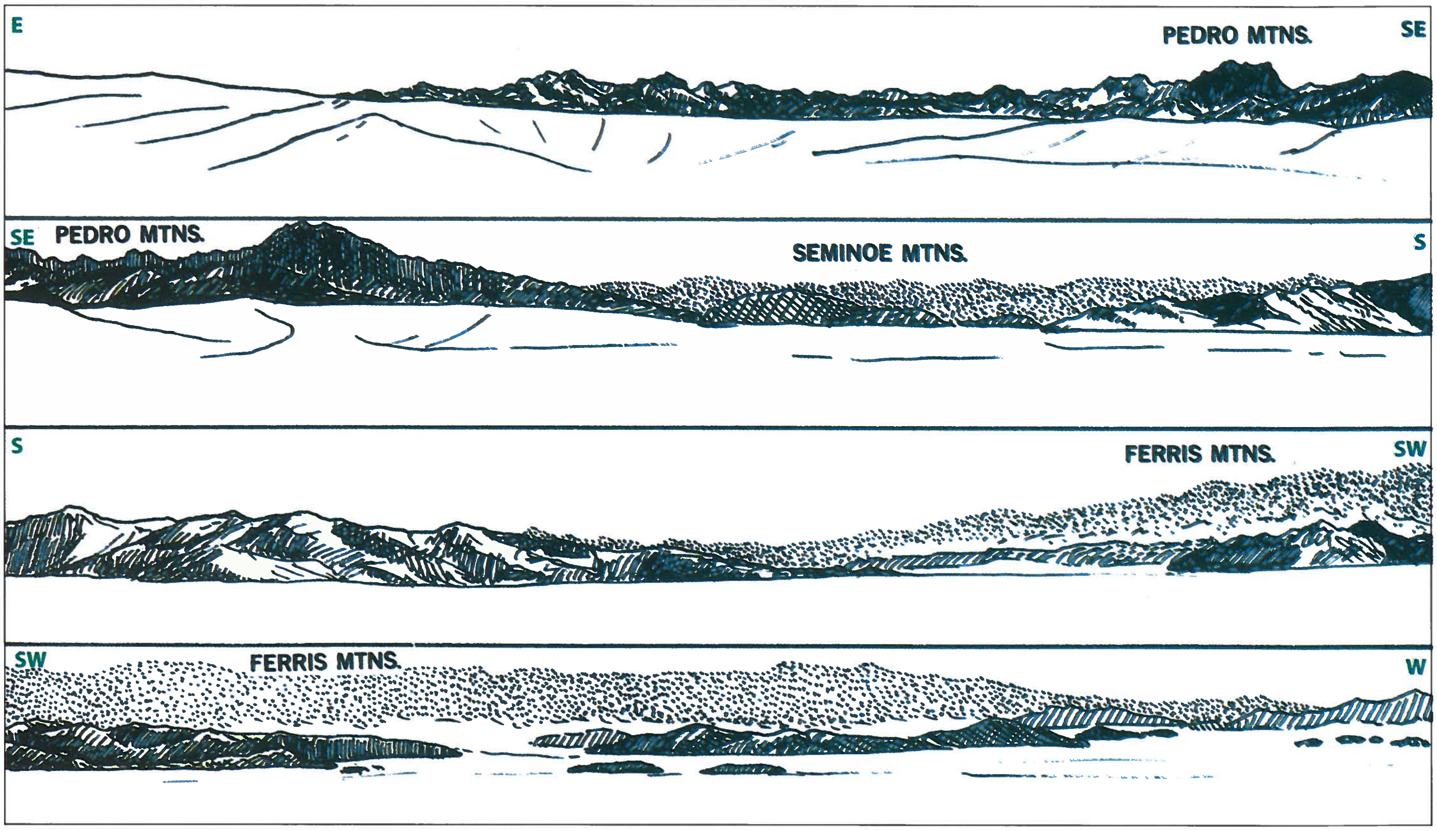


Figure 82. Four-panel east-west panorama showing major features south of Pathfinder Reservoir. View from top of White River Formation on County Road 409 about 3.2 miles south of intersection with Highway 220. Approximate compass directions are shown in green at the top of each panel. From an original sketch by Gary Keimig; modified by adding directions to panels.

To help orient this panorama, the Pedro Mountains (part of the Precambrian granite knobs in the core of the Granite Mountains uplift) are approximately in line with the highway to the south. Farther south and west of the Pedro Mountains are the Seminoe Mountains through which the North Platte River has carved a canyon. West of this are the Ferris Mountains, and farther west (but not visible here) are the Green Mountains and Crooks Gap. The satellite image of central Wyoming in the back foldout of this guide shows these ranges quite well and one can even see some of the faults that bound the Granite Mountains.

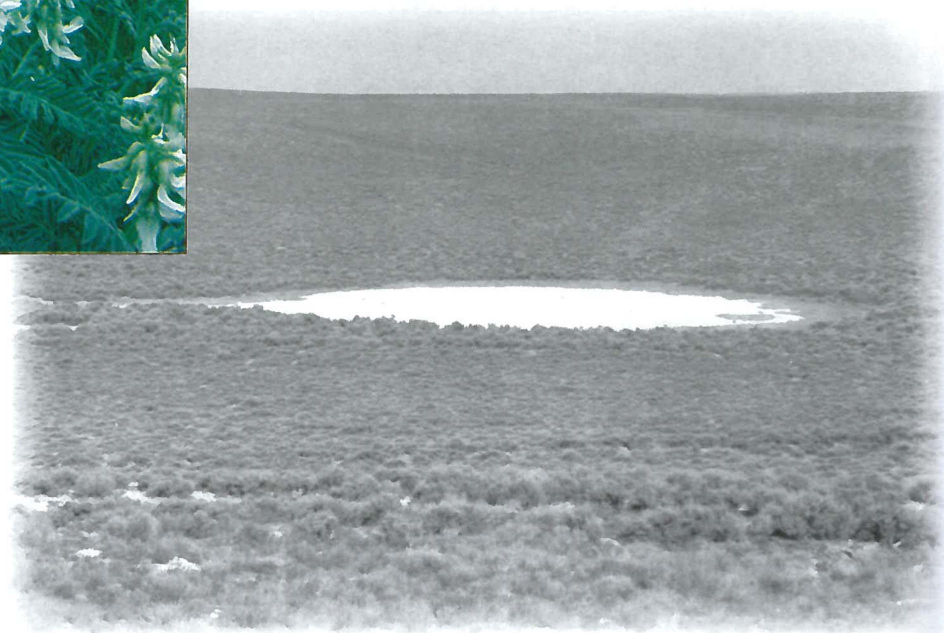
Note the white flowers in abundance along the road in the spring or early summer. These are White locoweed (*Oxytropis sp.*) and grow eight to twelve inches high (**Figure 83**). Most livestock avoid eating locoweed unless feed is scarce; they can be poisoned by eating this noxious weed. Horses never completely recover once they have eaten it.

44. **2.8** **(20.6)** To the left (west) is a *playa lake*, an intermittent lake that contains water only after a heavy rain (**Figure 84**). These may become very saline or alkaline when they dry up; only certain plants with high tolerances to these conditions will grow in playa environments.

45. **0.4** **(21.0)** **Turn right (east) onto Highway 220.**

Figure 83 (left). White or Rocky Mountain locoweed. Photograph by Aleen Kienholz, used with permission.

Figure 84 (below). A playa lake is an intermittent body of water.



Road Log D: Highway 220 to Lake Shore Drive

46. (21.0) To the north (left) badlands of the White River Formation can be seen (**Figure 85**). Badlands are regions of soft, easily eroded sedimentary rocks. The lower White River is composed of gray to white tuffaceous claystones, siltstones, and arkosic sandstones and conglomerates. Streams crossing the area cut the soft rock into a pattern of gullies and ridges. Very little plant life is present in badlands due, in part, to the rapid erosion rate. The White River Formation was much more extensive earlier in geologic time, probably filling most of the area's basins up to the mountain peaks. Remnants of the White River can be found on the Bighorn Mountains to the north and as far east as Pumpkin Buttes in the Powder River Basin 90 miles to the northeast.

Figure 85. Badlands in the White River Formation exposed along the rim west of the Alcova area. View is to the north from Highway 220.

Item #	Interval (miles)	Cumulative (miles)
47.	1.6	(22.6)

This turnout provides an overlook of Alcova Reservoir. Compare the reservoir site before the dam was constructed (**Figure 86**) with a recent photograph (**Figure 87**).

Red fox—Wyoming Game and Fish Department, February, 1994

Many grasses common to a plains environment grow in the Alcova area. The five grasses most likely to be seen on this field tour are described. Crested wheat grass, *Agropyron cristatum*, is a bunch grass that grows 1 to 3 feet tall (**Figure 88a**). Dark green leaf blades taper to sharp points. The seed heads of this grass are often two inches long and have an unusual flat, crested shape. This grass grows well in areas of little rainfall and is a valuable forage crop.

Cheat grass, *Bromus tectorum* (**Figure 88b**), has likely been encountered by all who have walked through open fields. When dry, the seed heads penetrate and adhere to clothing. Cheat grass is an invader, so it is found in areas that have been overgrazed or otherwise disturbed. This grass grows 1 to 2 feet tall and is not a good forage crop since the dry seed heads can penetrate the face tissues of grazing animals.

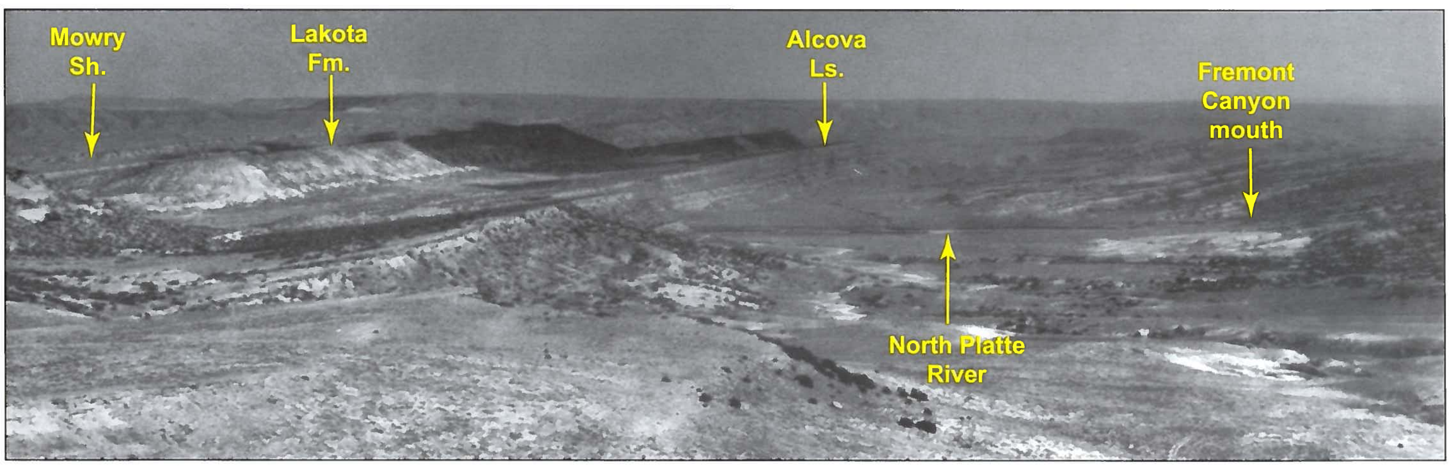


Figure 86. Overlook south of Alcova Reservoir site before the dam was constructed. Photograph from U.S. Geological Survey.

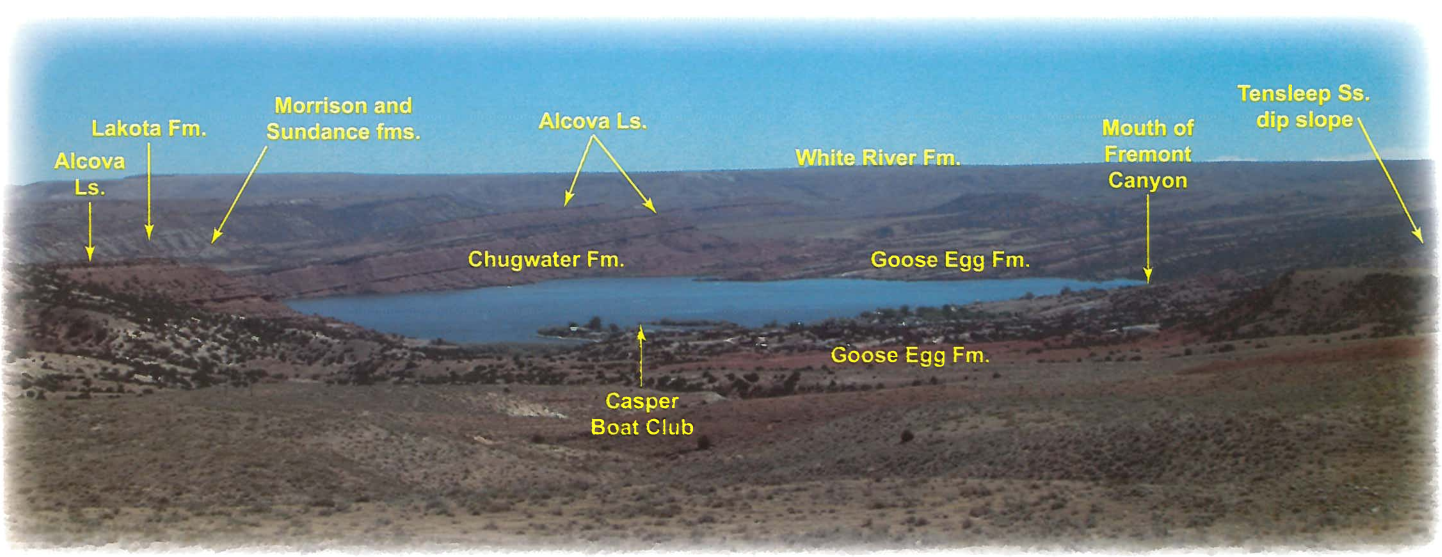


Figure 87. Upper part of Alcova Reservoir from overlook on Highway 220; view is to south. Photograph by JRM, August, 2004.

Indian rice grass, *Oryzopsis hymenoides*, is a nutritious food for livestock. The seed heads of this bunch grass are not dense like those of other grasses (**Figure 88c**); the seeds are suspended on long, slender structures.

Smooth brome grass, *Bromus inermis* (**Figure 88d**), is a cool-season grass and is considered invasive. This grass is commonly found in areas where the ground has been disturbed, such as in burn areas. Brome is an excellent grazing grass because it provides good nutrition to livestock and wildlife, and is a valuable crop grass for hay meadows. This grass will green in the fall, providing good pasture late into the year. Brome stands 1.3 to 3.2 feet tall, has flat blades, and flowers at maturity (Howard, 1996). Once the grass blooms, it begins to lose its nutritional value.

Foxtail, *Hordeum jubatum*, bears bushy seed heads with a purplish or pink sheen (**Figure 88e**). Growing well in open areas, foxtail provides fair ground cover, but is undesirable as forage because, like cheat grass, its seeds can penetrate the flesh of animals.

Figure 88. Grasses common to the Alcova area include (a) Crested wheat grass, (b) Cheat grass, (c) Indian rice grass, (d) Smooth brome grass, and (e) Foxtail. Sketches of cheat grass and smooth brome grass are modified from USDA-NRCS PLANTS Database / Britton, N.L., and Brown, A., 1913, Illustrated flora of the northern states and Canada, v. 1; remaining sketches by Gary Keimig.

Item #	Interval (miles)	Cumulative (miles)	
48.	0.5	(23.1)	The Sundance, Morrison, and Lakota formations can be seen in the small hill (**Figure 89**).
49.	1.0	(24.1)	Red cliffs to the left (north) are the Chugwater Formation.
50.	0.6	(24.7)	The thin gray Alcova Limestone caps the ridge to the left (north).
51.	0.3	(25.0)	**Turn right onto Lake Shore Drive.**


Western meadowlark—Wyoming Game and Fish Department, June, 1970

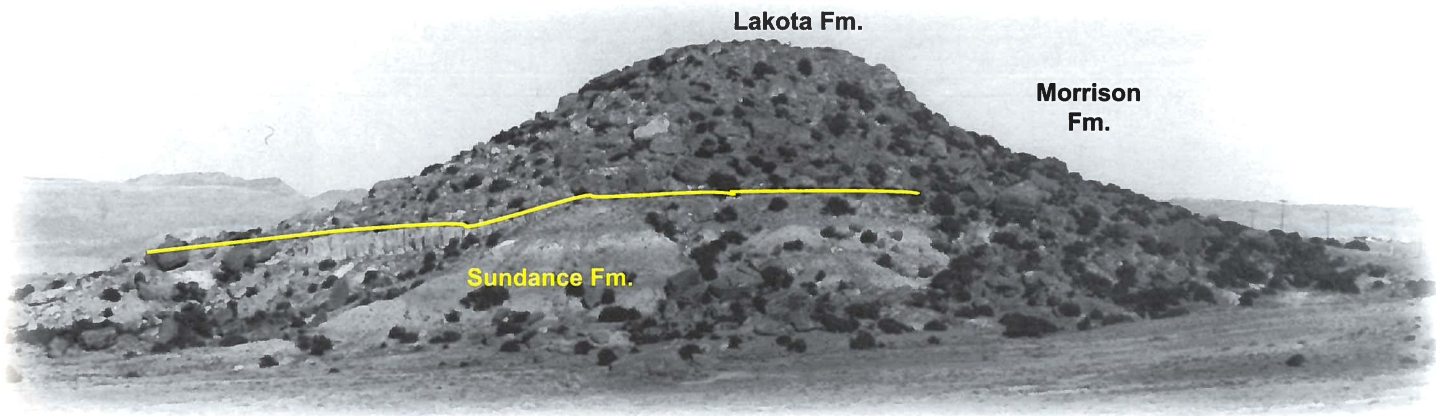


Figure 89. Small outcrop of Jurassic and Lower Cretaceous rocks south of Highway 220 about 2 miles west of intersection with Lake Shore Drive.

Road Log E: Lake Shore Drive

52. (25.0) **Proceed south on paved County Road 406.**

The core of Alcova anticline is formed of the cross-bedded Tensleep Sandstone. To the southeast, this ridge was cut by the North Platte River to form the narrow canyon in which Alcova Dam is located. Note the difference in appearance of the freshly broken and the weathered rock at the bottom and top of the outcrop. Much of the southwest flank of the anticline is missing due to the Alcova fault (see cross section on front foldout), but a hint of this limb of the anticline can be seen in the close-up of Alcova Canyon (**Figure 25**).

Cross-bedding is clearly visible in one part of the Tensleep Sandstone. Many layers, often of varying thickness, lie at different angles to each other. Cross-bedding occurs when sediments carried by wind or water are dropped (deposited). The general process is much the same as the way in which a snowdrift is formed. Changes in orientation of the small layers occur with changes in the direction of flow of the wind or water carrying the sediment (**Figure 90**). Different periods of intervening erosion also play a part (**Figure 91**).

53. 0.3 (25.3) In the next 0.1 mile, the road will first cross the approximate trace of the axis of the Alcova anticline and then the approximate trace of the Alcova fault along the reservoir side of Alcova anticline. A fault is a break in the rock along which movement has occurred. This fault allowed the lake side of the ridge to drop relative to the rest of the ridge. The Triassic Chugwater and Jelm formations now interface with the Pennsylvanian Tensleep Sandstone (see geologic map).

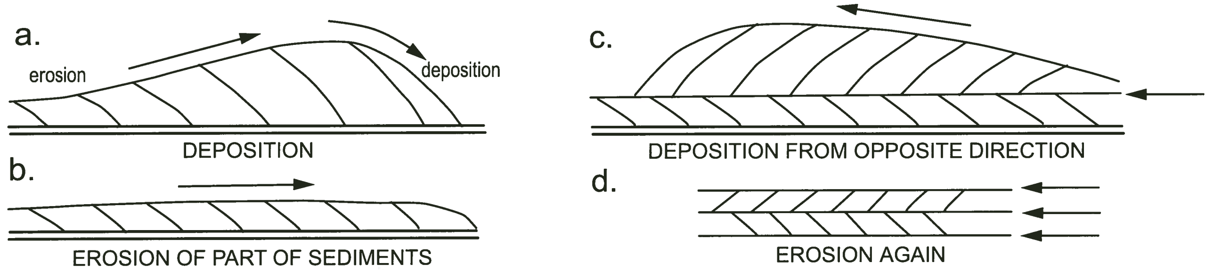


Figure 90. Diagrammatic cross sections showing origin of cross-bedding in sandstones. (a) Sediment is being transported from left to right, with erosion on the left and deposition on the lee side (right). If erosion continues without deposition (for example, when the current velocity increases), the top of the bedform is removed (b). With a change in current direction (c) deposition begins again until erosion once again removes the top of the bedform (d). Arrows indicate erosion surfaces.

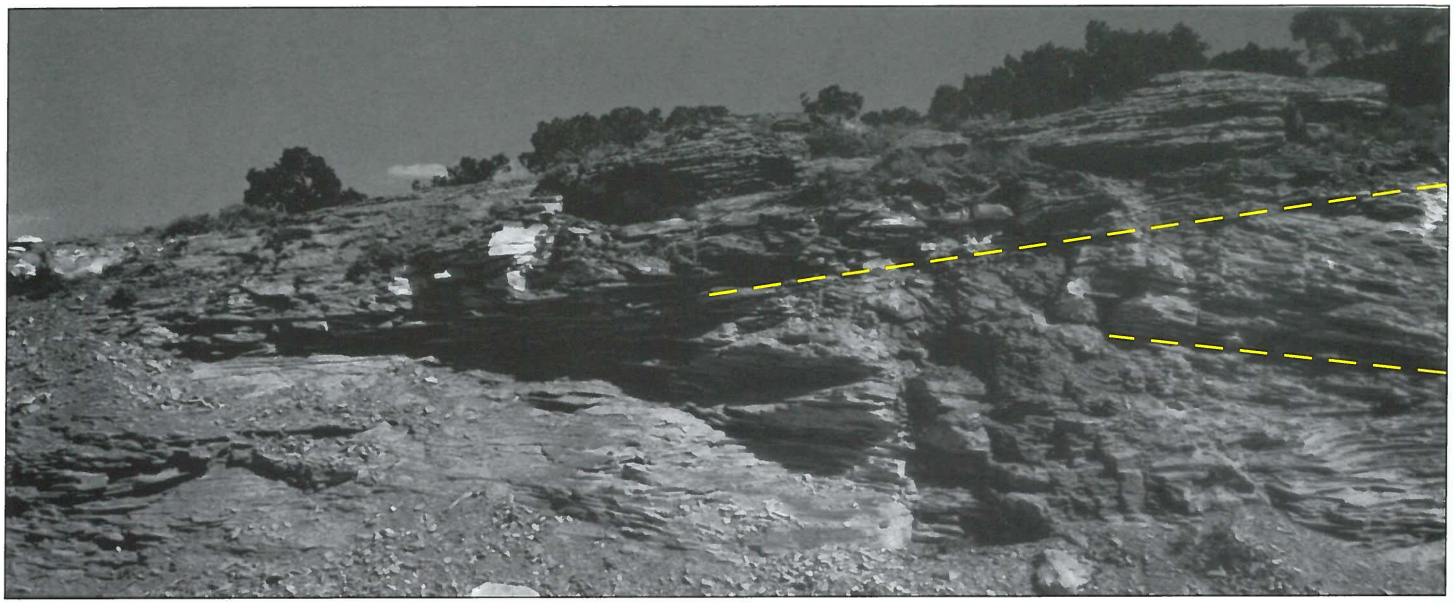


Figure 91. Cross-bedding in the Tensleep Sandstone is exposed on Alcova anticline. Note the erosion surfaces (dashed lines) showing individual sets of cross-beds.

54. 0.4 (25.7) **Continue on paved road.** To the left is the turn-off to Sandy Beach. Sandy Beach extends along part of the faulted lakeside face of the anticline (**Figure 92**). Sandy Beach is made of dune sand. A similar deposit is located at the last turn before the Casper Boat Club.

55. 0.3 (26.0) A turnout on the left. **Continue on paved road.** The view left shows the faulted and steeply dipping southwest flank of Alcova anticline. The notch the river cut into the anticline is called a *water gap*. In it one can see the anticlinal curve of the rocks (**Figures 93** and **94**). From this vantage point it is possible to view nearly all of Alcova Reservoir from Alcova to Fremont canyons (see **Panorama 1** in centerfold).

56. 0.4 (26.4) Lakota outcrops are present along the road for the next half mile. The base of this sedimentary formation is composed of rounded rock fragments of varying sizes cemented together by other minerals to form conglomerate rock (**Figure 95**). Because this unit is

Hooded merganser hen—Glen Smart, U.S. Fish and Wildlife Service, July, 2003

Hooded merganser drake—Tim McCabe, U.S. Fish and Wildlife Service, January, 2002.

Figure 92. Sandy Beach (white beach in lower left) on northmost side of Alcova Reservoir along southwestern flank of Alcova anticline. Compare with Figures 93 and 94 for annotations. Photograph by JRM, August, 2004.

Figure 93. View of southwest side of Alcova anticline from Lake Shore Drive (standing on top of the Lakota Formation). Many of the features on the opposite side of the reservoir are explained in the first segment of the road log. Photograph by JRM, August, 2004.

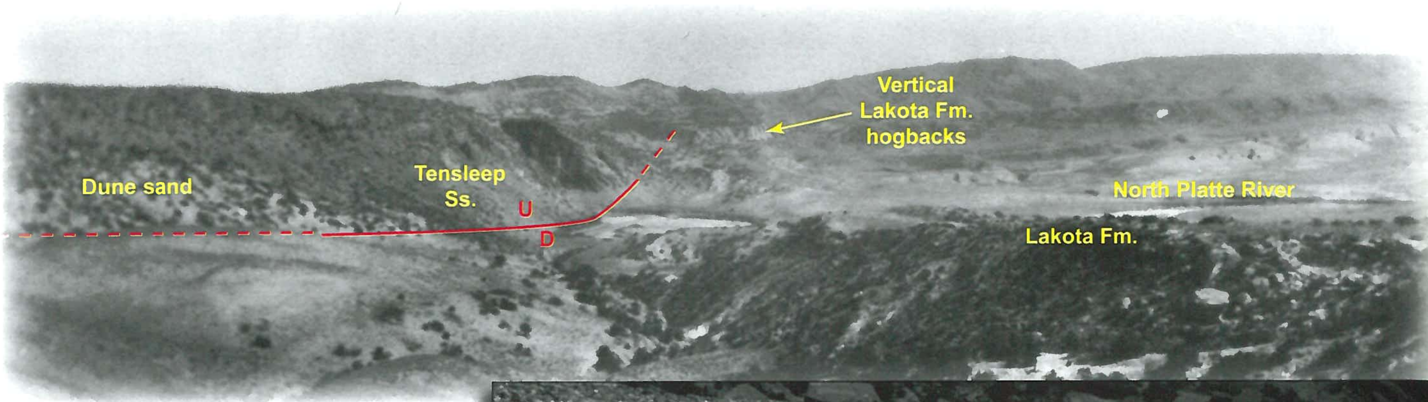


Figure 94 (above). Alcova Reservoir site shows approximate location of Alcova fault on southwest side of Alcova anticline. View from the west into Alcova Canyon in center of photograph. Photograph from U.S. Geological Survey.

Figure 95 (right). Close-up view of conglomerate in the Lakota Sandstone.

well-cemented and resistant to erosion, it often forms a distinctive dark brown, juniper-covered dip slope and a strong ridge overlying the less resistant Morrison and Sundance formations. The rest of the formation is a light-colored sandstone often called the Fall River Formation. In many parts of central and southeastern Wyoming, this sequence is more often called the Cloverly Formation.

Main entrance road to the cabin area. The contact between the Lakota and Morrison formations is on the slope to the right. Along the road ahead are numerous Lakota conglomerate blocks, which have fallen from higher up the slope.

57. **0.5** **(26.9)** At this point there are two excellent overlooks of Alcova Reservoir. Which formations can you recognize looking across the lake? The exposures of the Lakota, Morrison, Sundance, and Jelm formations in the Cottonwood Camp area are especially well seen (**Figure 96**).

58. **0.2** **(27.1)** Reddish Jelm sandstone.

59. **0.4** **(27.5)** Okie Beach sign.

60. **0.3** **(27.8)** A dip slope of the Alcova Limestone is apparent in the road cut. *Dip* is the geologist's term for the way a rock formation tips or slopes, measured in degrees from horizontal. Completely flat-lying rocks have a dip of 0° while vertical rocks have a dip of 90°. Steeply dipping rocks are generally more than 45° dip. The limestone is dipping to the northeast.

The Alcova Limestone is exposed in this road cut (**Figure 97**).

Pair of Canada geese—Wyoming Game and Fish Department, January, 1978

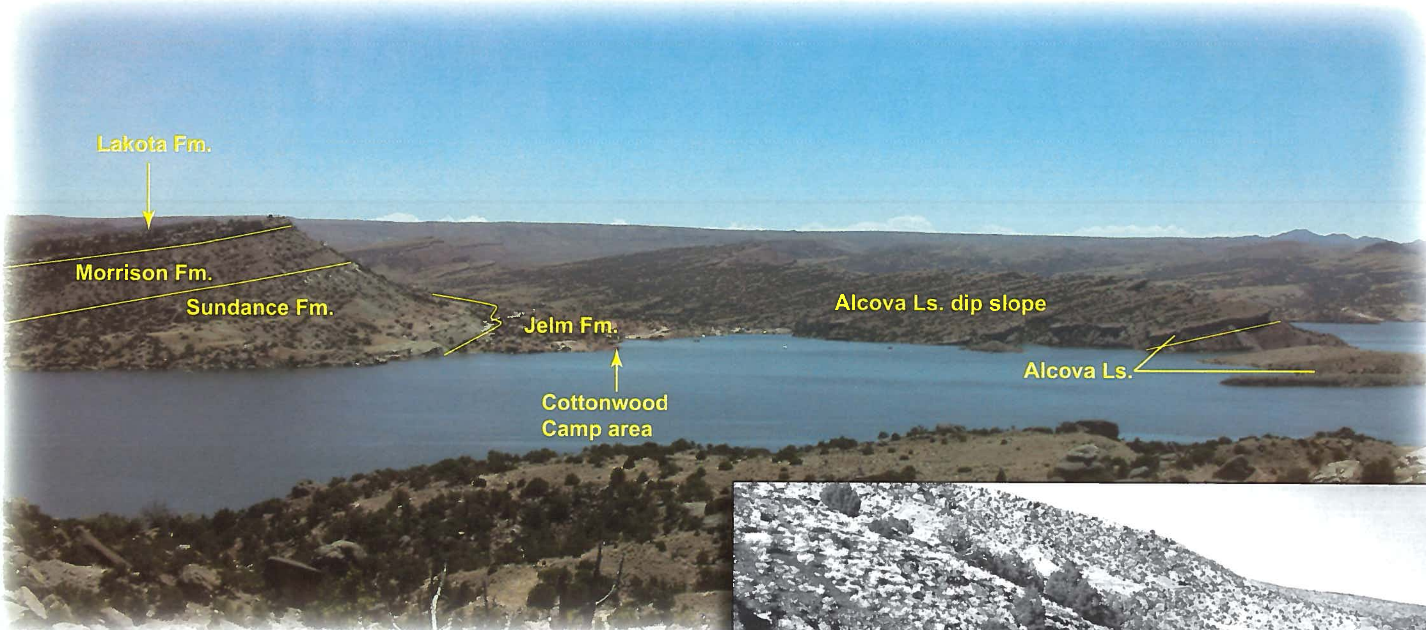


Figure 96 (above). Annotated view of Cottonwood Creek area from north side of Alcova Reservoir. This is part of Panorama 1. Photograph by JRM, August, 2004.

Figure 97 (right). Road cut along Lake Shore Drive shows the very distinctive contact between the Chugwater Formation and the Alcova Limestone.

Item #	Interval (miles)	Cumulative (miles)	
61.	0.2	(28.0)	At this overlook some sandstone steps lead to a good view of the lake, a close look at the Alcova, and an excellent view of the Chugwater across the reservoir. From this overlook, the mouth of Fremont Canyon and the area around Alcova Marina can be seen to the southwest (**Panorama 2** and **Figure 98**).
62.	0.1	(28.1)	At this small turnout, Fremont Canyon is visible across the lake to the southwest. The ridge ahead consists of the Tensleep and Goose Egg formations.
63.	0.3	(28.4)	This large turnout provides an opportunity to study variations in the Chugwater which cannot be seen at a distance (**Figure 99**).
64.	0.3	(28.7)	These modern sand dunes along the base of the Chugwater extend up the valley toward Highway 220.

Figure 98. View to south of upper end of Alcova Reservoir (excluding Fremont Canyon). Due to the perspective, contacts of the Tensleep, Goose Egg, and Chugwater formations could not be depicted. An enlarged version of this view is shown in Panorama 2. Photograph by JRM, August, 2004.

One of the trees growing along the road is not native to this area. An overall greenish-gray appearance and thorns on its branches help identify the Russian olive, *Elæagnus angustifolia* (**Figure 100**). It is likely some were planted at the boat club and their seeds (olives) spread along the cove. The Russian olive survives well in this dry, windy climate and in this area, are slowly overtaking the cottonwood trees. The cottonwoods are in decline here because of the lack of flooding in their traditional habitat, flood plains. The Russian olive produces large numbers of tiny, fragrant yellow flowers. Some birds, especially the waxwings, are fond of the olives.

Also found in this area is the tamarisk, *Tamarix pentandra* (synonymous with *T. chinensis*), commonly known as salt cedar. Tamarisk is a very attractive slender-branched shrub or small tree with minute, scale-like bluish-green leaves and panicles of pink or white flowers (**Figure 101**). They prefer bottom-lands and sandbars.

Item #	Interval (miles)	Cumulative (miles)	
65.	0.3	(29.0)	Turnoff to west goes to Alcova Estates.
66.	0.1	(29.1)	Entrance to the Casper Boat Club (a private club).

Figure 99 (left). Detailed view of Chugwater Formation exposed in road cuts along Lake Shore Drive. Alcova Limestone at top of hill. Chugwater consists of ledge-forming fine sandstones of variable thickness interbedded with siltstone and mudstone and very minor gray gypsum beds. The Goose Egg contains many more and much thicker gypsum beds as well as gray to white limestones. Photograph by JRM, August, 2004.

Figure 100 (below). The Russian olive is a prominent tree in the boat club/marina area on Alcova Reservoir. It has a distinctive greenish-gray color and its seeds (olives) are not edible for humans. Photograph by JRM, August, 2004.

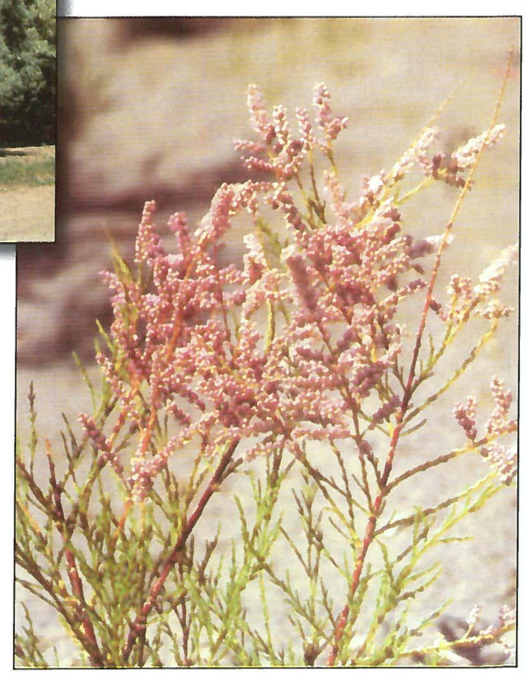


Figure 101 (below). The tamarisk or salt cedar is also common in the boat club/marina area of Alcova Reservoir. Photograph from Joe F. Duft, USDA-NRCS PLANTS Database, USDA, NRCS, 1992, Western wetland flora: Field office guide to plant species, West Region, Sacramento, CA.

Mallard drake, Wyoming Game and Fish Department, April, 1971

Item #	Interval (miles)	Cumulative (miles)	
67.	0.1	(29.2)	The Goose Egg formation is exposed from here to the mouth of Fremont Canyon.
68.	0.3	(29.5)	Alcova Marina, a public facility, offers food and rents boats. The marina is built on the upper Goose Egg, but the island to the east is in the Chugwater (**Figure 102**).
69.	0.5	(30.0)	Entrance to the Casper Water Ski Club (private club).

Common merganser hen and ducklings—Wyoming Game and Fish Department, June, 1994

Figure 102. View to east across Alcova Reservoir from near Alcova Marina. Island near the boat supports a stand of Russian olives. Photograph by JRM, August, 2004.

Item #	Interval (miles)	Cumulative (miles)	
70.	0.4	(30.4)	**Turn around point.** End of the road at Fremont Canyon. While at Alcova Dam (Item 6), it was suggested that you look to the southwest across the reservoir to this location. The rock exposed in the mouth of Fremont Canyon is the Tensleep Sandstone, which contains the distinctive cross-bedding. Remember, this same rock forms Alcova anticline. For a better understanding of how this is possible, refer to the cross sections, p. iv.

From this point, most of the features and locations visited earlier can be seen in **Panorama 3**, which sweeps across Alcova Reservoir from north to southeast. Parts of this panorama are annotated in the figures below. From the end of Lake Shore Drive, look southeast across the mouth of Fremont Canyon (**Figure 103**). The contact between the Goose Egg and the Chugwater formations is well exposed here and the

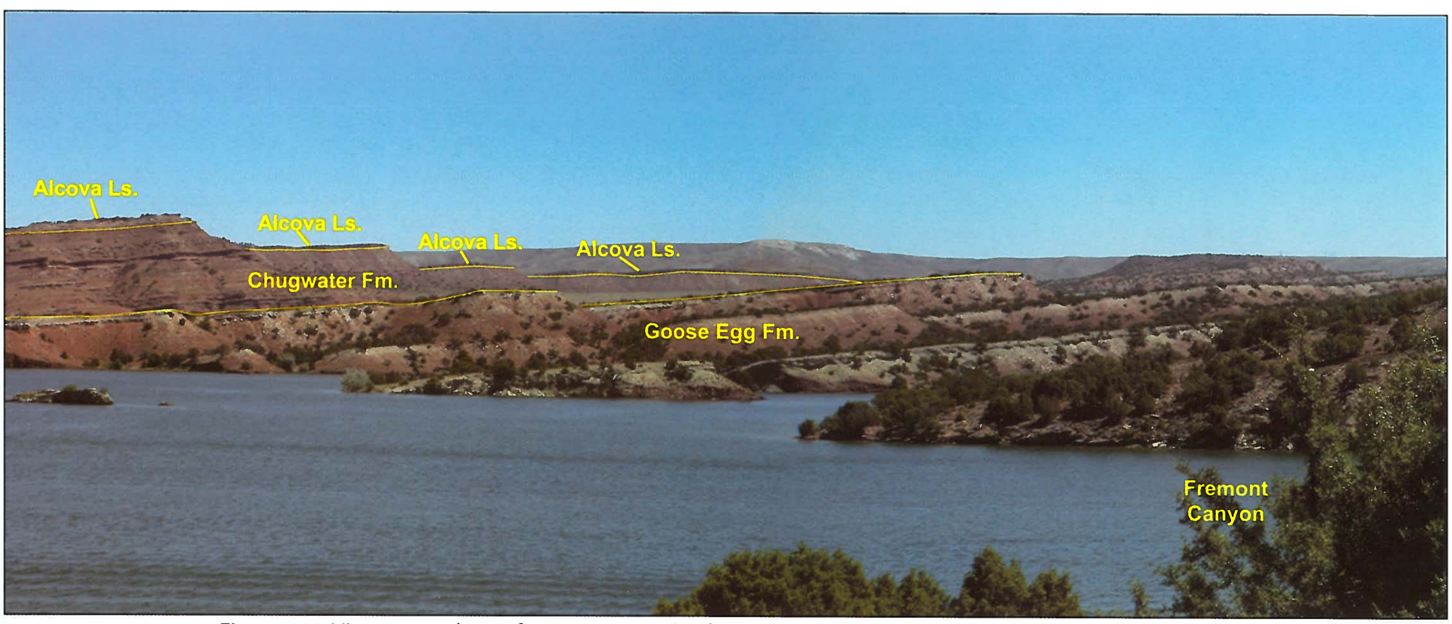


Figure 103. View to southeast from near mouth of Fremont Canyon. Photograph by JRM, August, 2004.

Tensleep dip slope can be seen to the west. Alcova anticline, the top of Alcova Dam, and the Tensleep Sandstone across the reservoir can be seen to the northeast (**Figure 104**).

Retrace route along Lake Shore Drive and resume road log at the Junction of Highway 220. It is suggested that this portion of the road log just completed be followed while returning to Highway 220. It will be easier to spot many of the formations while working backward and gives a different perspective on most of the geologic features.

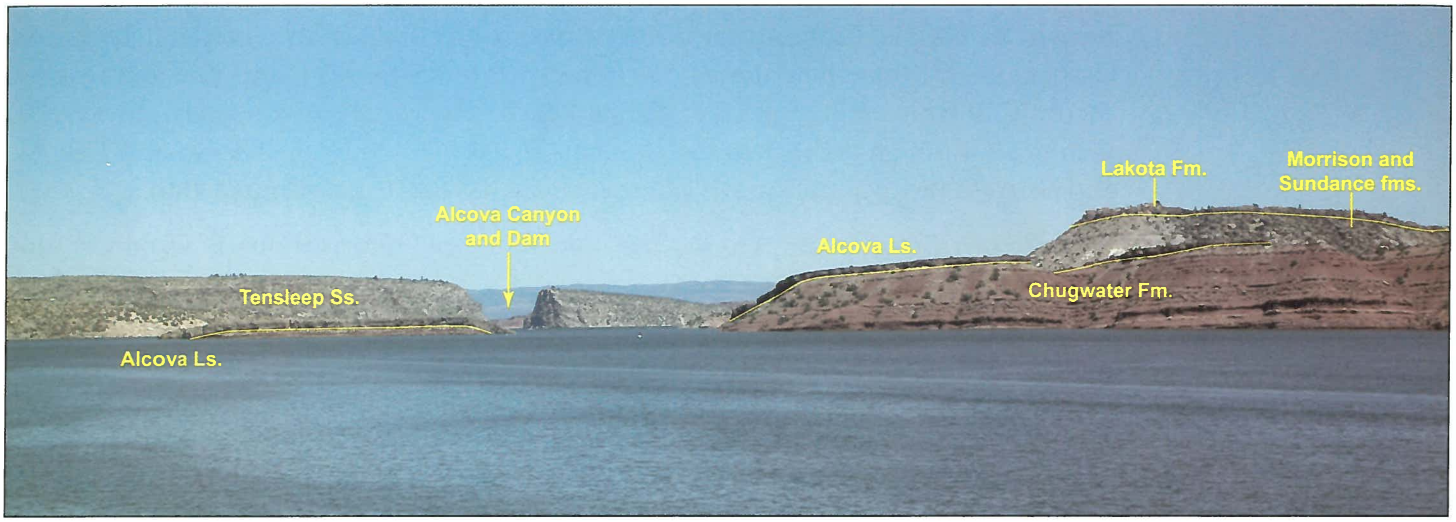


Figure 104. View to northeast across Alcova Reservoir from near mouth of Fremont Canyon. Alcova Dam is about 3.5 miles across the reservoir from this point. Photograph by JRM, August, 2004.

Road Log F: Junction (Lake Shore Drive and Highway 220) to Sloane's Store

71. 5.4 (35.8) Junction of Lake Shore Drive and Highway 220. **Turn right (east) towards Casper.** Driving on Permian Goose Egg Formation. To the north and west is an interesting unconformity of relatively young Tertiary rocks resting on much older Triassic formations (see stratigraphic column and geologic map foldouts in front and back).

In this unconformity, the light-colored Tertiary White River and Wind River formations are resting on Triassic formations (**Figure 105**). The Chugwater and other older formations were folded when the Rocky Mountains were formed at the end of the Cretaceous period and slowly exposed by a long period of erosion. Then the Tertiary

Figure 105. View to north from near intersection of Lake Shore Drive and Highway 220. The Wind River Formation cannot be seen from this vantage point. To view the unconformity described in the text and to see the rocks shown here in a different perspective, drive west on Highway 220 for about 3 miles observing the rocks shown on the geologic map. Photograph by JRM, August, 2004.

rocks were deposited in horizontal layers on top of the eroded Chugwater and other formations. When rock layers or formations that should have been present are missing, it is called an *unconformity*. If the rocks below the unconformity have been tilted or folded, it is called an *angular unconformity*. *Hiatus* is the term used for the missing time those formations represented. In this case, that is about 170 million years.

The White River and Wind River formations contain fossils of mammals that lived in this area during the time these rocks were deposited, such as the horse, camel, rhinoceros, and saber-toothed cat.

Item #	Interval (miles)	Cumulative (miles)	
72.	1.1	(36.9)	Coming out of the ridge to the right is the Kendrick Irrigation Project main canal. Known as Casper Canal, it carries irrigation water for an area between here and Casper. The 0.5-mile-long tunnel is driven through the Tensleep anticline and reaches Alcova Reservoir in the vicinity of Sandy Beach. The canal goes under Highway 220, then north through another tunnel that cuts ridges held up by the Alcova and Lakota, and emerges nearly a mile north where it enters the dug canal (**Figure 106**).
73.	0.4	(37.3)	The contact between the Goose Egg and Chugwater formations is visible at this location.
74.	0.3	(37.5)	End of road log. **Turn right to visit Sloane's Store; continue on to Casper if not stopping.**

Figure 106 (right). Casper Canal where it emerges from the dip slope of the Lakota Formation about 1.5 miles north of Item 72 on Highway 220.

Boat Log: Fremont Canyon

A boat log is a bit more difficult to follow than a road log because it cannot be tied to mileage. Therefore, watching carefully for the locations described is essential. One helpful hint in Fremont Canyon is to get a general idea of the surroundings on the way upstream and then to watch for specific locations when returning. The points of interest are numbered from 1 to 10, starting at the mouth of the canyon and ending at Fremont Canyon Power Plant where boat access ends (**Figure 1**). Total distance traveled one way is about 4.5 miles. Most of the photographs for the points of interest were taken coming downstream from the power plant.

To understand the origin of Fremont Canyon, a little imagination is necessary (**Figure 107** may help). First, visualize the entire area covered by a considerable depth of rock burying the features that we see now. Millions of years ago (perhaps as early as Oligocene), the North Platte River was flowing on an old surface, containing considerable volcanic ash from Yellowstone and other parts of the state, far above the present surface. The land was rather flat and the stream meandered (curved back and forth) in its path across the plain. As the river gradually wore away the sediments in its bed, it encountered the rock formations we see exposed in the canyon and around the lake. In all probability, regional uplift caused rejuvenation of the rivers and streams in the late Tertiary and a cycle of extensive erosion began. The river was trapped in its channel in the younger rock, so it had no choice but to cut through the older rock without much change in its course. This is called a *superimposed stream*. The North Platte River's course through Wyoming demonstrates superposition spectacularly in a number of places where it has cut deep canyons through seemingly impenetrable rocks and imposing mountain uplifts.

Muskrat—Wyoming Game and Fish Department

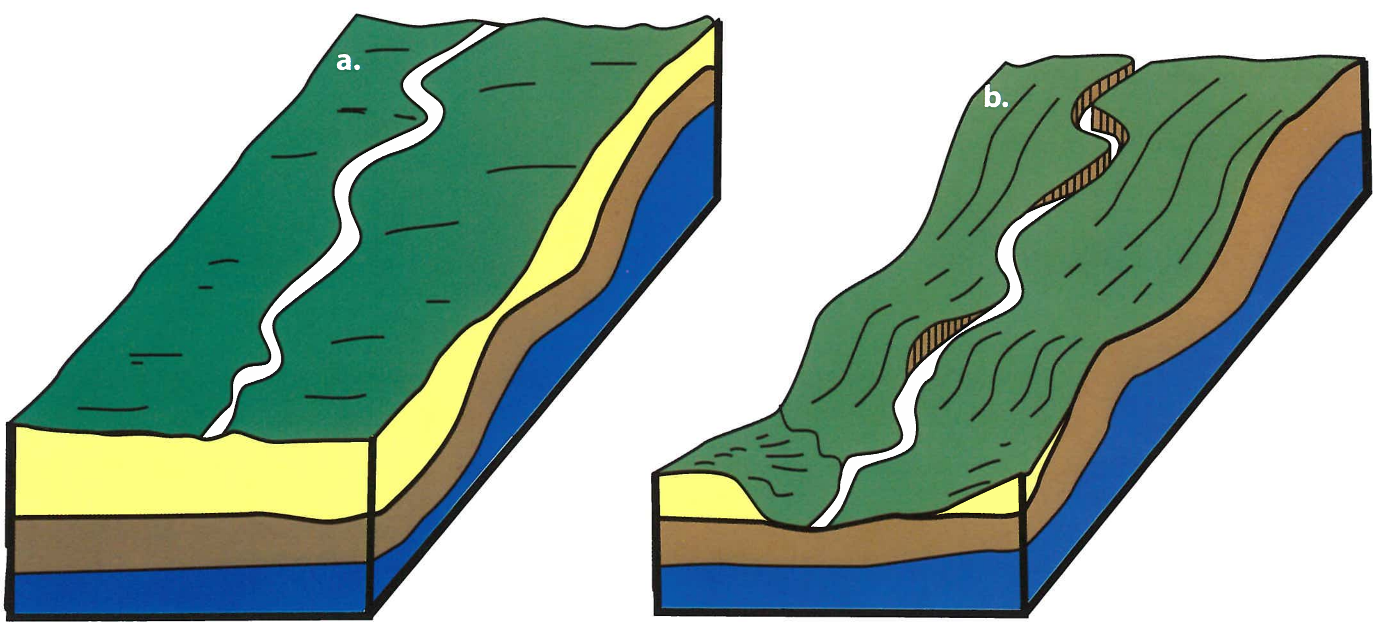


Figure 107. Development of a superimposed drainage. The stream in (a) flows over a surface of low relief developed in younger rocks. With regional uplift causing erosion of the younger rocks, the stream in (b) stays in its earlier channel but erodes into the older rock as it is uplifted. Sketches modified from originals drawn by Terry Logue.

Point 1

Approaching the mouth of the canyon, some reddish rock is visible on either side. This is the Permian and Triassic Goose Egg Formation, about 240 to 290 million years old. The canyon mouth is in the Tensleep Sandstone (or Casper Formation), which is Pennsylvanian in age, about 290 to 323 million years old. A closer look at one wall of the canyon mouth shows a remnant of the Goose Egg lying on the Tensleep (**Figure 108**). The Tensleep is usually exposed very high up on the canyon walls for most of the boat tour, so the best close-up views of this formation are between Points 1, 2, and 3.

The boundary line, or contact, between the Goose Egg and Tensleep gives an indication of the way the rocks dip (tilt) toward Alcova Lake. Because the rocks that form the canyon are dipping northeastward toward the lake, the exposed rocks are progressively older as one goes upstream through the canyon. Because the surface of a water body is always horizontal, it is very easy to observe even slight changes in the dip of rock units that intersect that surface along the shoreline.

Figure 108. Point 1. Mouth of Fremont Canyon; view to northwest along north side of canyon. Tree-covered dip slope marks the top of the Tensleep Sandstone.

Point 2

A beautiful formation, the Tensleep Sandstone is composed to a great extent of sharp quartz grains cemented into sandstone of a light buff color. A good example of cross-bedding like that discussed in Item 51 is evident along exposures of the upper part of the formation (**Figure 109**). Showing evidence of how the sand was deposited, the curved layers also present the position of the sand before it was buried and eventually became rock.

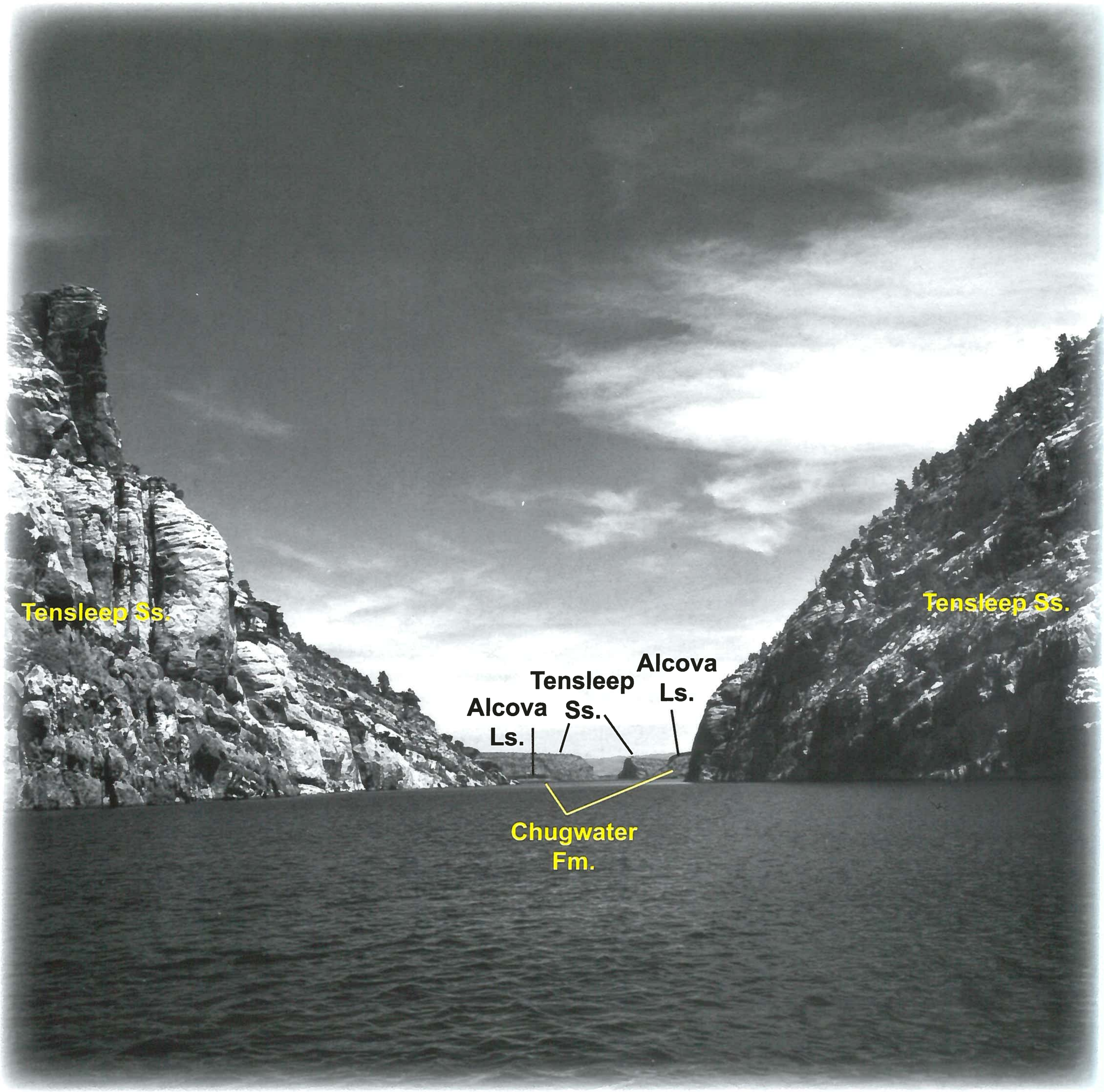


Figure 109. View downstream (northeast) and across Alcova Reservoir from just inside mouth of Fremont Canyon.

Point 3

There is a definite change in the rock at the contact between the Tensleep Sandstone and the older Madison Limestone (**Figure 110**). Note the cross-bedding of the Tensleep near the skyline, and its more massive appearance deeper in the formation. With a careful look, the Madison Limestone appears quite different from the overlying sandstone. A weak carbonic acid, formed when rainwater absorbs carbon dioxide while passing through the air, dissolves the limestone to form caves. A dry climate, like Wyoming's present day climate, limits this action. However, in a moist climate, the cave-forming activity is extensive. The Madison shows much evidence of collapsed caves or sink holes in the uneven upper portion of the formation, indicating that some time after the Madison was deposited (but before the Tensleep), the Madison was exposed to cave-forming conditions and that part of the formation was emergent. Many geologists (e.g., Allen, 2003) recognize a unit about 100 feet thick between the Madison and Tensleep known as the Amsden Formation. A reddish sandstone about 50 feet thick at the base of the Amsden represents a type of soil called terra rosa that was deposited while the area was emergent. The rest of the Amsden is limestone and dolomite deposited in marine conditions. Because the Amsden is usually not well exposed, it is included as part of the Tensleep Sandstone in this boat log. The Madison was deposited in marine conditions; therefore, it contains many marine invertebrate fossils.

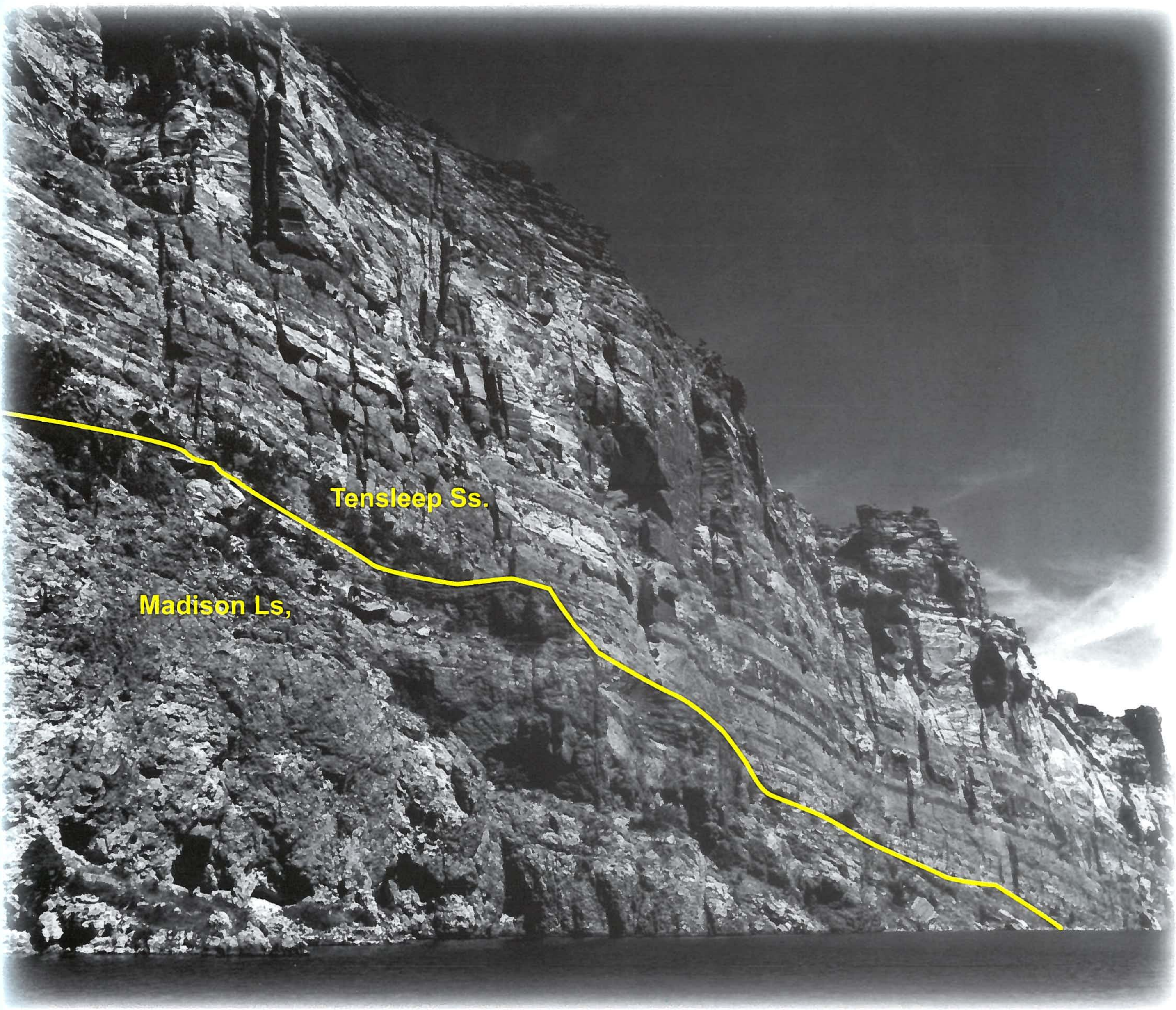


Figure 110. Contact between the Madison Limestone and the Tensleep Sandstone, north wall of Fremont Canyon.

Point 4

This natural bridge, which can be seen from the lake (**Figure 111**), is characteristic of limestone areas. Caves in limestone are often connected by smaller tunnels through which underground streams flow. When the limestone cave roofs weaken and collapse, the roof over the tunnel is left as a natural bridge. The canyon wall in this photograph is primarily Madison Limestone. The tall pines in the canyon are Ponderosa pines.

Figure 111. A natural bridge in the upper part of the Madison Limestone along south wall of canyon.

Point 5

Figure 112 was taken looking down from the canyon rim (near the natural bridge) because the broad sweeping curve is more apparent from the rim than from the lake. The meandering route of the river was determined long before it cut into this rock. The river channel was established on the plain that was the surface of younger rock which once completely covered the area. Three formations are visible. They range in age from Late Devonian (Fremont Canyon Sandstone) at the bottom to Pennsylvanian (Tensleep Sandstone) at the top, a span of about 80 million years. In this view, the collapsed areas in the top of the Madison are infilled with the reddish Amsden Formation, which is included at the base of the Tensleep.

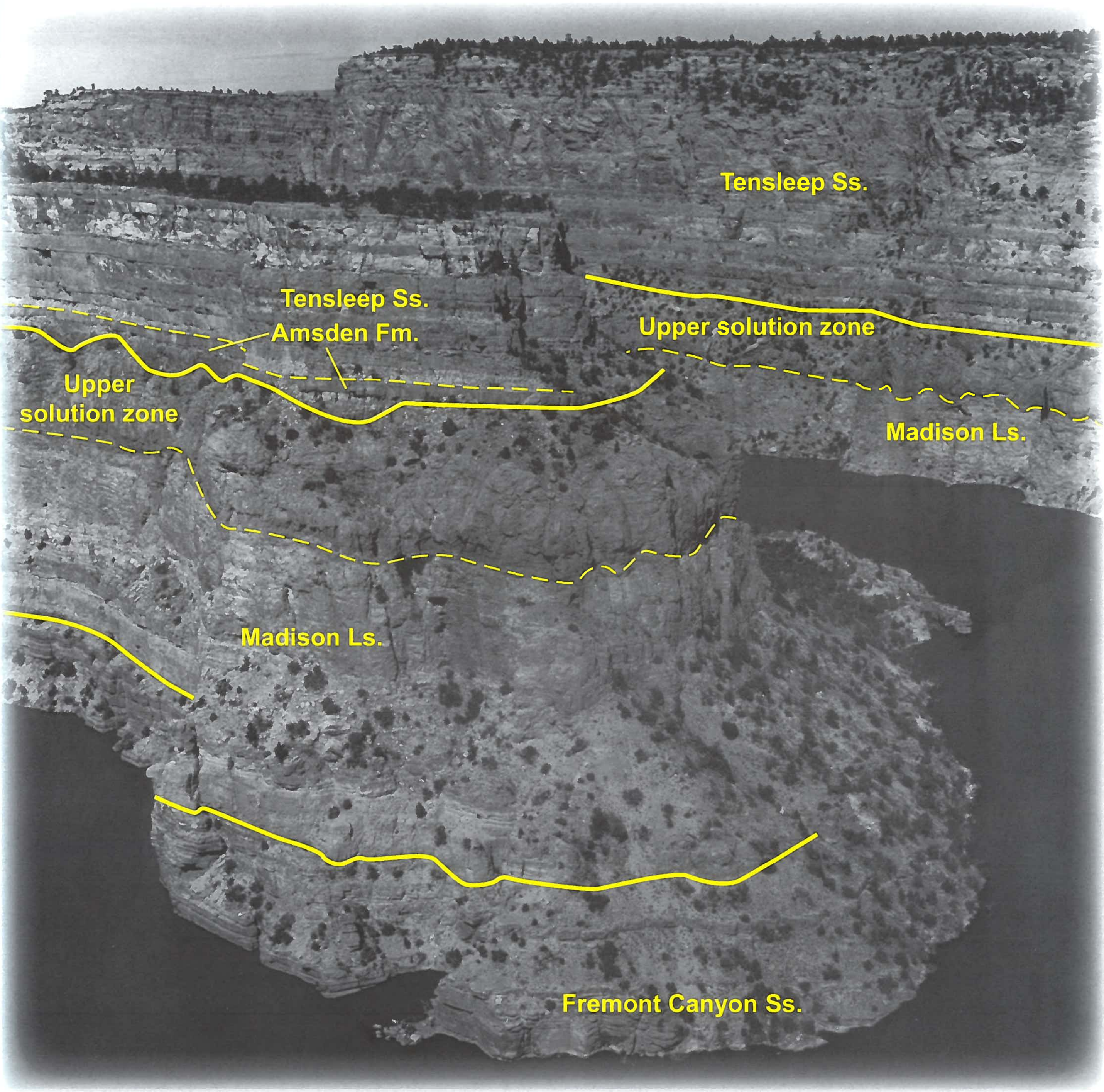


Figure 112. View to northwest of inside of the meander bend from east rim of Fremont Canyon.

Point 6

At this point (**Figure 113**), all four major formations that appear in the canyon are apparent. At the top is part of the Tensleep, which is the youngest formation at 290 to 323 million years old. Below this is the Mississippian Madison (323 to 354 million years old) with its typically pitted appearance, followed by the Fremont Canyon Sandstone deposited from about 370 to 354 million years ago. At either side of the photograph on opposite sides of the canyon are small exposures of the Precambrian granite. Over 2 billion years old, it is the oldest rock exposed in the area. As explained in the discussion of the new formation terminology (Item 27), a thin limestone of Early Mississippian age called the Englewood Formation caps the Fremont Canyon Sandstone, but even in the canyon, this unit is very difficult to see, and is therefore included in the Fremont Canyon Sandstone. An old photograph made in the canyon before the reservoir (**Figure 114**) shows the approximate position of the Englewood.

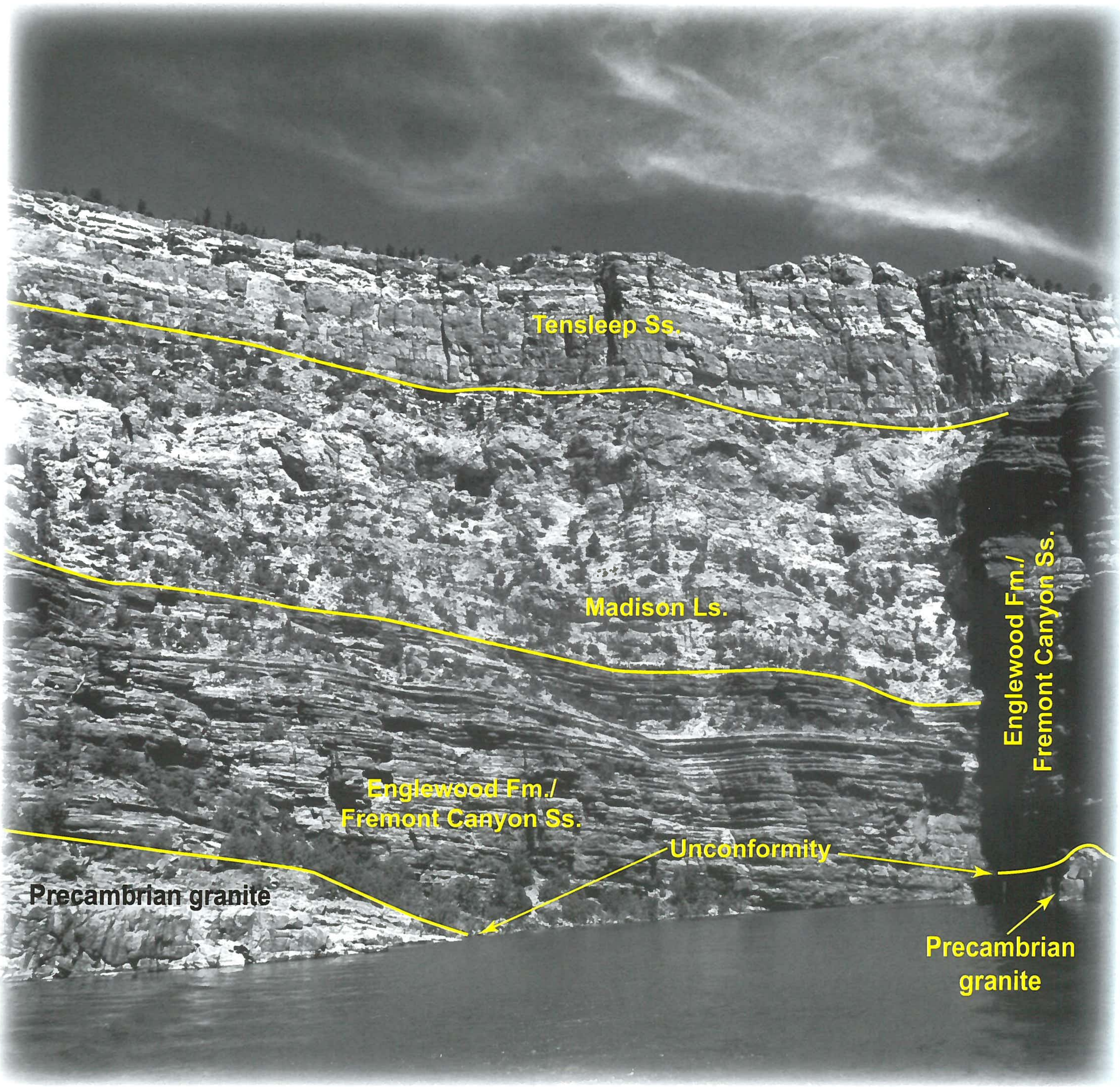


Figure 113. View downstream and across the canyon of the west wall of Fremont Canyon. The unconformity marks the contact of sedimentary rocks with the much older granite below.

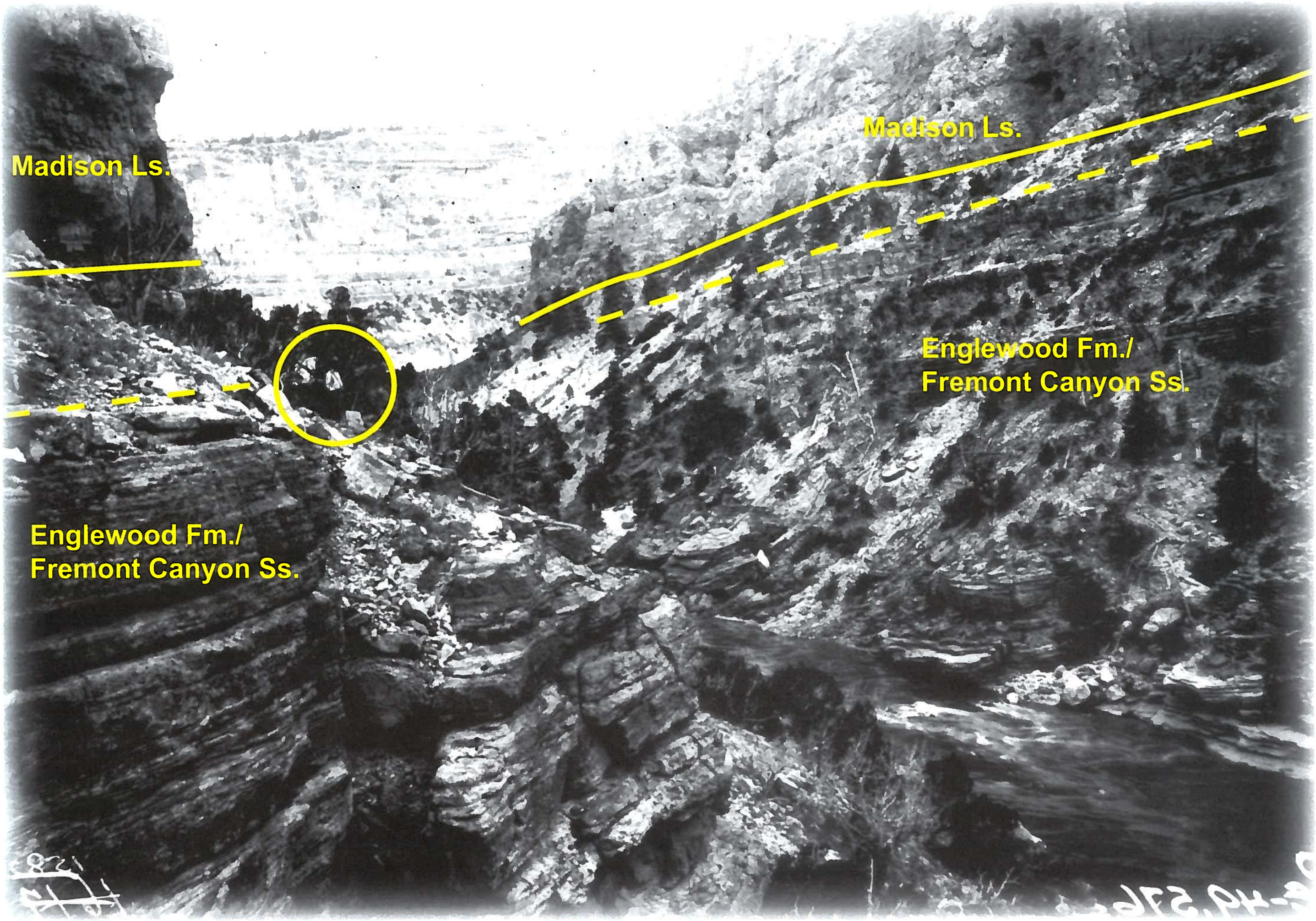


Figure 114. Historical photograph in Fremont Canyon. View is to north from the west wall of the canyon, probably farther downstream from Point 6. The inside of the meander bend described at Point 5 is in the distance. The circled area shows a person. The dashed line indicates the approximate position of the contact between the Englewood Formation and the underlying Fremont Canyon Sandstone. Photograph by W.C. Knight, courtesy of S.H. Knight collection, American Heritage Center, University of Wyoming (used with permission).

Point 7

A closer look at the contact between the Fremont Canyon Sandstone and the Precambrian granite (**Figure 115**) shows individual characteristics that help in distinguishing sedimentary rock from igneous rock. The sedimentary Fremont Canyon Sandstone shows horizontal bedding or layering. The igneous granite is broken with mostly vertical cracks, which are probably a result of stress that developed in the rock as it was cooling and changing from a liquid to a solid. Note the way the granite tends to round as it weathers. On the surface near Pathfinder, this rounding is apparent on a large scale.

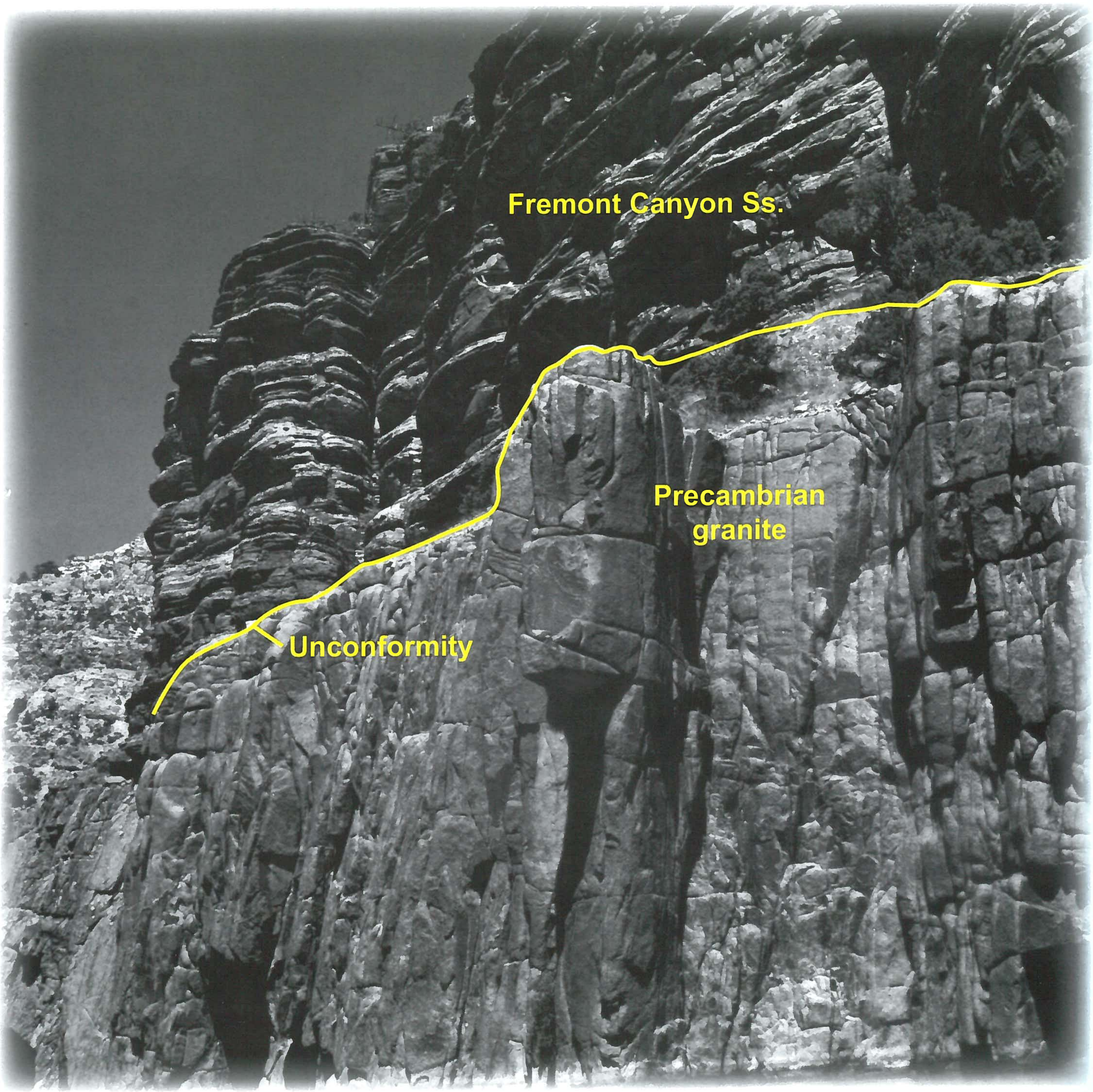


Figure 115. Unconformity between Precambrian granite and Fremont Canyon Sandstone on east wall of canyon. Note the distinctive jointing and weathering pattern in the granite.

Point 8

Sometime after the granite formed and cooled, it was fractured and intruded by a darker-colored igneous rock. This intrusion is called a dike (first explained in Item 39), several of which are visible in numerous places in the canyon. The dike is older than the Fremont Canyon Sandstone because the dike does not cut up into it (**Figure 116**). Were the dike younger than the Fremont Canyon Sandstone, it would have intruded that formation also. However, the dike is younger than the Precambrian granite.

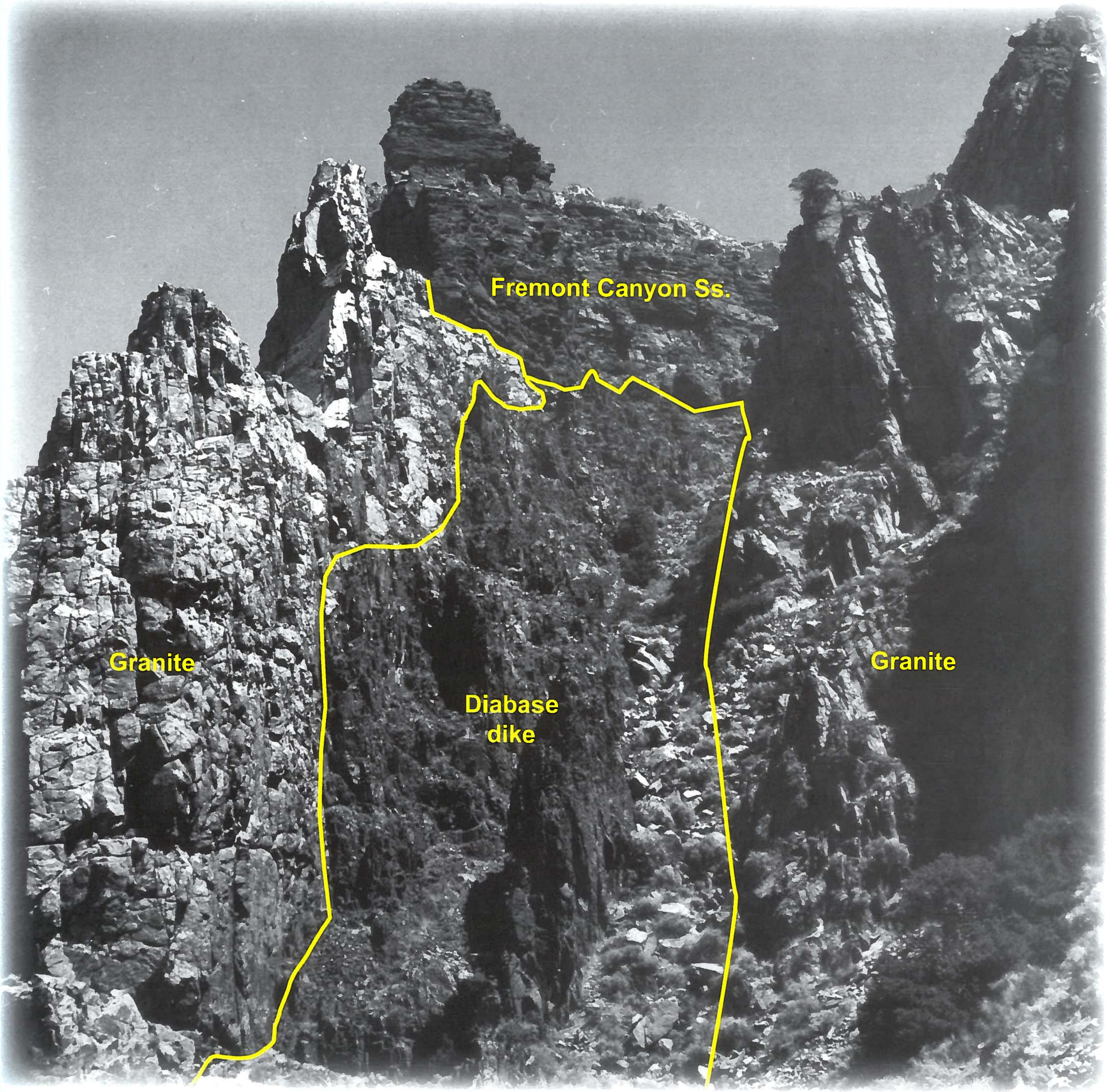


Figure 116. Diabase dike cuts vertically through Precambrian granite, east wall of Fremont Canyon.

Point 9

Additional evidence of dikes can be seen farther up the canyon from Point 8. At this location (**Figure 117**), a close look at the black igneous rock (diabase) of the dike is possible.

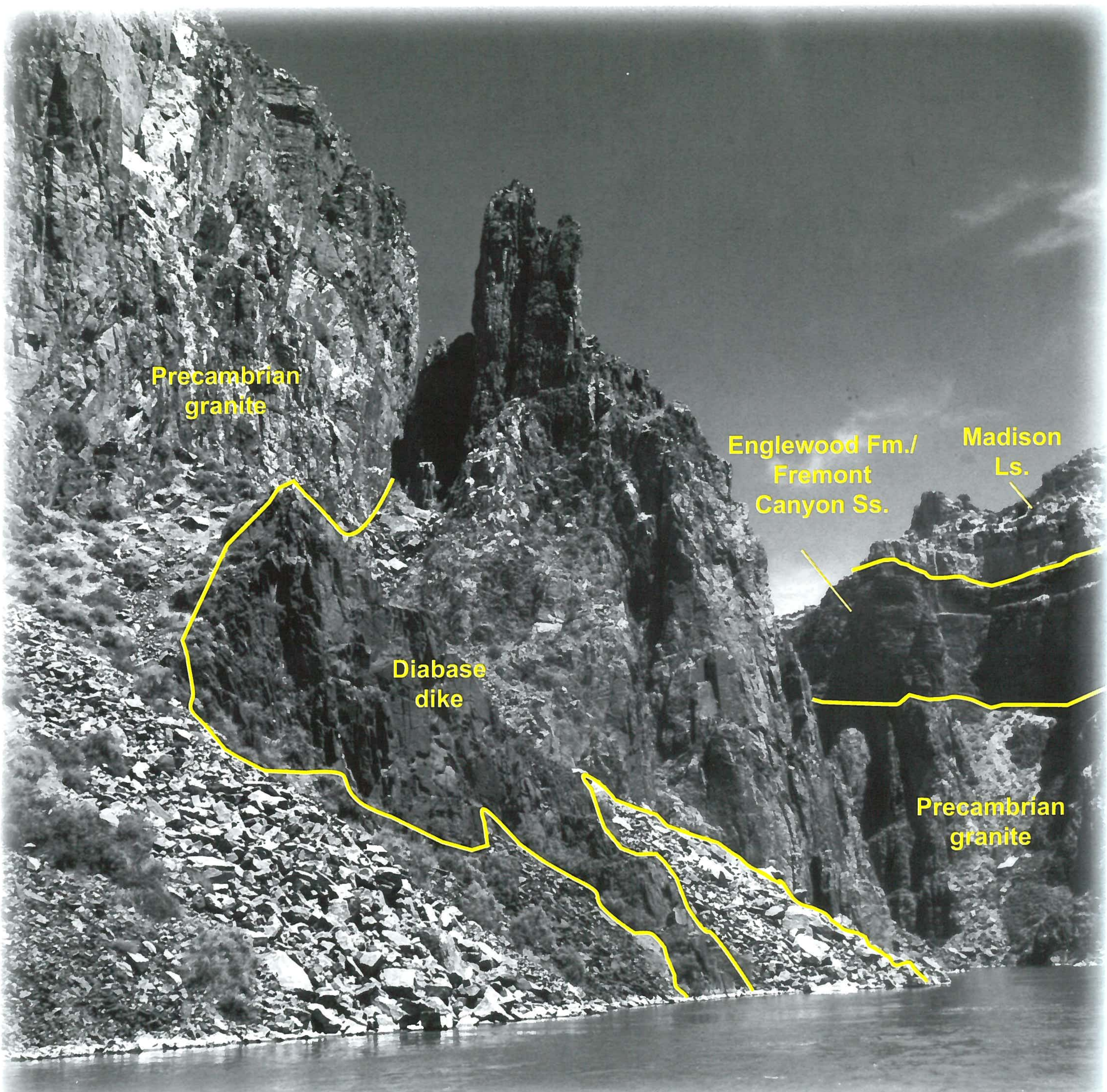


Figure 117. A short distance downstream from Fremont Canyon Power Plant, a diabase dike can be seen cutting Precambrian granite.

Point 10

Fremont Canyon Hydroelectric Power Plant was built by the USBR in 1961 (**Figure 118**). Use caution with boats in this area! A hydroelectric plant uses the pressure of water to turn a turbine, which is attached to an electric generator. Water for this power plant comes from Pathfinder Reservoir through a three-mile-long tunnel. The old river channel can be seen to the left of the building. The structure above the power plant is a surge tank or tower, measuring 246 feet high and 40 feet in diameter. Water coming through the tunnel creates great pressure that could cause damage when it is necessary to close a valve at the power plant and block the flow of water. The surge tank gives the water a place to "back up" in order to relieve this pressure.

Without Alcova Reservoir, Fremont Canyon would be almost completely inaccessible, with steep canyon walls near 800 feet high in some places (**Figure 119**). The power of a river to erode such a canyon in hard granite in a relatively short period of geologic time is truly remarkable.

Figure 118. Fremont Canyon Hydroelectric Power Plant.

Figure 119. The deepest part of Fremont Canyon before Alcova Dam was built and the reservoir filled. The North Platte River has cut through almost 800 feet of Precambrian granite. Photograph from Wyoming State Historical Society, the Stimson Collection (used with permission).

End of boat log. **Return to the canyon mouth** observing all the features from a different perspective.

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Appendix A: Glossary of geologic terms

These definitions are designed with special reference to the needs of this publication and may not be technically complete.

ALLUVIAL FAN: A fan-shaped deposit of soil and rock formed by a mountain stream when it flows onto an area of level ground. Caused by the reduction in velocity of the water.

ALLUVIUM: Unconsolidated clay, silt, sand, or gravel deposited during comparatively recent geologic time by a stream or other running water.

ANTICLINE: An upward bend in layered rocks.

BADLANDS: A region of soft and easily eroded sediment which has been cut by streams to form numerous gullies with sharp ridges between.

BEDDING: The layers of sediments in sedimentary rock.

CONGLOMERATE: A sedimentary rock composed of fragments or pebbles of rock cemented together by various minerals.

CONTACT: The surface where two different kinds of rock come together.

CROSS-BEDDING: A feature of many sandstones wherein the layers of certain beds form angles with other layers.

CROSS SECTION: A profile representation of the layers of rock beneath the surface.

DEPOSITION: The process by which layers of rock are laid down.

DIABASE: A dark-gray to black intrusive rock composed of labradorite (a gray plagioclase feldspar) and pyroxene (usually augite).

DIKE: Magma which has been forced into vertical cracks in older rocks and then solidified.

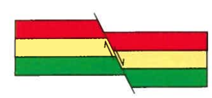
DIP: The angle at which a layer of rock is tilted from the horizontal.

DUNE: A hill or ridge of sand piled up by the wind.

EROSION: The wearing away of the land surface by natural agents such as wind and water.

EXFOLIATION: The breaking away of curved layers of rock from the main body of rock. Typical manner in which granite weathers.

FAULT: A break in the rocks along which movement has taken place.



FLANK: An area of rock sloping away from the center of an anticline or toward the center of a syncline. The limb of a fold.

FOLD: A bend in rock layers. Anticlines and synclines are types of folds.

FORMATION: A group of rocks which can be distinguished from other rock because of specific qualities or appearance.

GRANITE: A coarse-grained igneous rock composed essentially of feldspar and quartz with mica and/or hornblende.

HOGBACK: A sharp ridge of steeply dipping resistant rock.

IGNEOUS ROCK: A rock type formed by the cooling and solidification of molten material either above or below the earth's surface.

INTRUSIVE: A body of igneous rock that was forced into other rock beneath the surface and then solidified.

MEANDER: A loop-like bend in the course of a river or stream.

NATURAL BRIDGE: A naturally occuring stone arch that remains when surrounding rock has been eroded away.

OUTCROP: Part of a body of rock that is exposed at the surface.

REMNANT: Part of a structure that remains after the surrounding area has been eroded away.

SEDIMENT: Loose material such as mud, sand, or gravel.

SEDIMENTARY ROCK: Formed of sediments that have been deposited in horizontal layers; then compacted and cemented.

SINK HOLE: A depression in relatively soluble rock (such as limestone) resulting from the collapse of the surface into a cave.

SLUMP BLOCK: A mass of rock which has slipped downhill.

STRATIGRAPHIC COLUMN: A chart showing the rock formations of an area and their relation to one another.

STREAM LOAD: The material carried by a stream either dissolved, in suspension, or rolled along the bottom.

SUPERIMPOSED STREAM: A stream whose present course was established on rock burying an older structure. Uplift has caused it to maintain this course while cutting down into the older structure. Sometimes called "superposed."

SYNCLINE: A down fold of rock in which the strata dip toward the axis.

TOPOGRAPHY: The physical features of the surface of a region.

TREND: The direction or bearing of a structural feature.

UNCONFORMITY: A substantial break or gap in the geologic record, usually for a considerable span of time. Often, the strata above and below the unconformity are in angular (not parallel) contact.

UPLIFT: An elevation of a portion of the earth's surface.

WEATHERING: The mechanical or chemical breakdown of the rocks of the earth's surface.

Appendix B: Common birds, mammals, and fishes of the Alcova area

Birds

BALD EAGLE—*Haliaeetus leucocephalus* (National bird of the U.S.)

Field marks: Uniformly dark brown with white head, neck, and tail. Large birds of prey measuring 34-44 inches with a wing span of 7-8 feet.

Voice: Harsh cackle.

Habitat: Generally mountainous areas near a stream, lake, or river.

Habits: Predators and scavengers. Build bulky nests in trees and on ledges in canyons. Generally return year after year to the same nest.

Photograph: Bald eagle by Steve Maslowski, U.S. Fish and Wildlife Service.

BLACK BILLED MAGPIE—*Pica hudsonia*

Field marks: Plumage black glossed with greenish-blue. Belly and wing bar white. Long wedge-shaped tail. 17-21 inches long. Member of the crow family.

Voice: Harsh.

Habitat: Diet largely insects. Prey on other birds, eating eggs and young. On occasion cause damage to sickly or injured livestock. Build elaborate nests -- generally massive domed structures often 2 feet in diameter -- plastered with mud and lined with roots. 8-9 greenish-gray eggs.

Photograph: Black billed magpie by LuRay Parker, Wyoming Game and Fish Department, January, 1977.

CANADA GOOSE—*Branta canadensis*

Field marks: Dark brown on back and tops of wings with lighter under parts; broad white chin strap; black feet, bill, head, and neck. Both sexes look alike. Fully grown geese can weigh up to 18 pounds, measure 42 inches in length and have a wingspan of 66 inches.

Voice: Double-syllabled honking.

Habitat: Feeds on aquatic vegetation, roots, grasses, grain, and insects. Nest of aquatic vegetation lined with down and feathers. 5-9 cream to dull greenish-white eggs. Incubation time 4 weeks. Mates for life. Loses all flight feathers for a period during summer.

Photograph: Canada goose by Ron Maier, Wyoming Game and Fish Department, June, 1978.

CLIFF SWALLOW—*Petrochelidon pyrrhonota*

Field marks: Dark blue above; reddish-brown at throat to whitish near tail below. Whitish forehead, buffy rump, and square tail distinguish it from other swallows. 5-6 inches long.

Voice: Low and harsh.

Habitat: From prairies to mountain parks.

Habits: Diet largely insects. Constructs mud nest-like structures on the walls of canyons, under overhanging rocks, and along river banks. In gathering building material they scoop up mouthfuls of mud which they deposit in globules on the nest. Lay 4-5 white eggs marked with brown dots or blotches.

Photograph: Cliff swallows by LuRay Parker, Wyoming Game and Fish Department, August, 1981.

COMMON MERGANSER—*Mergus merganser*

Field marks: Large saw-billed duck mainly dark above and white below. Male: head dark glossy green; eye dark red; neck, white; most of wing, white with a black bar. Female: upper neck and head cinnamon brown; throat, white, under parts, white to gray. "Merganser shape" in flight: head, neck, bill, and body all horizontal.

Voice: Low croaks.

Habitat: Reservoirs and rivers as well as swift-flowing mountain streams.

Habits: Diet is carp, suckers, and other bony fish. Nests in holes in trees, old stumps, depressions in cliffs, and occasionally on the ground under low bushes. Nests are lined with grass, feathers, and down. Up to 12 pale buff eggs.

Photograph: Common merganser drake by John and Karen Hollingsworth, U.S. Fish and Wildlife Service.

GOLDEN EAGLE—*Aquila chrysaetos*

Field marks: Plumage uniform dark brown with crown edged with golden buff. Dark tail feathers. 30-42 inches long. Wing spread 6-7 feet.

Voice: Seldom heard.

Habitat: Ranges from prairies to mountains.

Habits: Predatory and scavenging. Diet includes small mammals and birds and occasionally fish. Build large nests of sticks on ledges and in trees. Often return to the same site to nest year after year. Two or three mottled eggs laid in late February or March.

Photograph: Golden eagle from a photograph by LuRay Parker, Wyoming Game and Fish Department, October, 1985.

HOODED MERGANSER—*Lophodytes cucullatus*

Field marks: Small saw-billed ducks. Adult male: head and neck black with a white triangular patch extending from behind the yellow eye to the rounded crest; breast and belly, white; sides reddish brown finely barred with black; back, black. Female: grayish-brown with white belly; wings and tail, dark brown; crest, small and yellowish. 16-19 inches.

Voice: Low croaks.

Habitat: Reservoirs and rivers as well as swift-flowing mountain streams.

Habits: Diet is carp, suckers, and other bony fish. Nests in holes in trees, old stumps, depressions in cliffs, and occasionally on the ground under low bushes. Nests are lined with grass, feathers, and down. Up to 12 white eggs.

Photograph: Hooded merganser hen by Glen Smart, U.S. Fish and Wildlife Service, July, 2003.

HORNED LARK—*Ermophilia alpestria*

Field marks: A pinkish-brown, ground-loving bird with short, black horn-like head feathers. Mainly brown above; forehead and throat yellow. Belly white; tail black; other feathers edged with white. Five to nine inches in length.

Voice: Musical, irregular.

Habitat: Open grasslands. Low prairies to the Tundra.

Habits: Diet is seeds and insects. Nests on ground. Females build nests -- 2.5-3 inches across and lined with grass -- usually at the base of prairie plants. Nests in late April. Usually 4 eggs. Walks instead of hopping.

MALLARD DUCK—*Anas platyrhynchos*

Field marks: Male: metallic green head, brownish-red breast, white neck band; olive bill.
Female: Mottled brown with orange bill. 24-28 inches, up to 3.5 pounds, wing spread 40 inches.

Voice: Boisterous quack.

Habitat: Ponds and freshwater marshes, wooded swamps, rivers and lakes.

Habits: Mainly vegetarian, but also eats insects and small fish. Nests in a down-lined hollow, up to 12 greenish-buff eggs. Incubate 4 weeks. Male abandons female after breeding season. Early migration -- among the first birds to return north.

Photograph: Mallard duck pair by LuRay Parker, Wyoming Game and Fish Department, February, 1982.

ROUGH-LEGGED HAWK—*Buteo lagopus*

Field marks: Adults blackish with base of tail white; forehead sometimes white. Strong hooked beak. 20-24 inches long.

Voice: Squealing cry.

Habitat: Prairies; occasionally mountainous areas.

Habits: Diet is small mammals. Builds nest of twigs and moss along steep cliffs. 2-6 blotched eggs. Soar in wide circles.

Photograph: Rough-legged hawk by LuRay Parker, Wyoming Game and Fish Department, January, 1974.

TURKEY VULTURE—*Cathartes aura*

Field marks: Adult, easily identified by bare, red heads; Imature: dark gray to black heads, nearly eagle-sized (wing spread, 6 feet). Overhead, great two-toned blackish wings with paler flight feathers. Often incorrectly called "Buzzards."

Voice: Usually silent. A hiss when cornered; a low grunt.

Habitat: Wide spread.

Habits: Feeds chiefly on carrion and refuse. Soars with wings set in shallow v-shape (more level when no wind). Rock and tilt unsteadily. Often referred to as birds of prey or raptors. May be mistaken for Eagle, but have smaller head and slimmer tail.

Photograph: Turkey vulture by Don DesJardin, used with permission.

WESTERN MEADOWLARK—*Sturnella neglecta* (Wyoming State Bird)

Field marks: Male: gray-brown streaked and barred with darker colors; three buff crown stripes; throat and belly, yellow; yellow breast crossed by black V; outer tail feathers, white.
Female: paler colored. 8-10 inches.

Voice: Melodious song.

Habitat: Open, lower elevations.

Habits: Diet is insects and seeds. Nests are built on the ground and are well concealed. Constructed of dried grass and weeds. Fence post sitters.

Photograph: Western meadowlark, unknown photographer, Wyoming Game and Fish Department, June, 1970.

Mammals

BADGER—*Taxidea taxus*

Field marks: Stout, flat-bodied, short-legged animals. Tails short and bushy. Gray, tinged with brown and black. Under parts dull gray or white. Top of head and snout black. White stripe on face from nose to top of head.

Habitat: Open prairies, parks, and meadows. Abundant in areas of loose, loamy soil.

Habits: Powerful diggers. Make their dens in holes they dig themselves, or in holes they take over and improve. Mate in late summer.

Food: Small mammals such as pocket gophers, prairie dogs, ground squirrels, and mice.

Young: Born in early spring. 1-4 per litter.

Photograph: Badger by Gary M. Stolz, courtesy of U.S. Fish and Wildlife Service, December, 2001.

BLACKTAILED JACK RABBIT— *Lepus californicus*

Field marks: Medium to large sized rabbit. Length 19-25 inches, feet 4-6 inches, ears 4-5 inches. Gray-black with white underside. Black stripe from tail onto rump. Ears black edged Lighter (but not white) in winter. Young have white spot on forehead.

Habitat: Grasslands and dry shrub lands.

Habits: Active year round. Nocturnal, feed in the early evening. Mate in spring and summer.

Food: Grasses and forbs. May sometimes damage crops.

Young: Born in summer fully furred with open eyes.

Photograph: Blacktailed jack rabbit, unknown photographer, courtesy of U.S. Fish and Wildlife Service.

BOBCAT—*Lynx rufus*

Field marks: Medium-sized cat with short tail, long legs, and normal-sized feet. Gray-buff, often with black spots. Short black tufts of hair on the tips of the ears. Tail has series of dark bands on upper surface.

Habitat: Brushy areas in canyons, draws, washes, and other rough areas.

Habits: Active year round, mostly at night. Mate in late winter. Female has den in rock crevice, hollow log, or under an overhanging ledge.

Food: Small mammals, birds, reptiles, and amphibians.

Young: Born in early spring. Furred with many spots. Blind at birth.

Photograph: Bobcat by LuRay Parker, Wyoming Game and Fish Department, 1994.

COYOTE—*Canis latrans*

Field marks: Slender animal with the general appearance of a furry, medium-sized German shepherd dog. Tail is bushy and is generally held low when the animal is running. Ears sharply pointed. Brown mixed with black. Face, forelegs, and ears pink to brown. Black tip on tail.

Habitat: Various environmental situations.

Habits: Active year round and primarily nocturnal. Shy and secretive. Make their homes in various structures such as holes in the ground, crevices in rocks and rotten logs. Mate in January or February. Yapping barks at dusk or dawn.

Food: Anything they can capture they will eat. Often eat plants and berries.

Young: Born in early spring. 5-6 per litter. Born with eyes closed. Covered with downy fur at birth.

Photograph: Coyote by LuRay Parker, Wyoming Game and Fish Department, 1994.

DEER MOUSE—*Peromyscus maniculatus nebrascensis*

Field marks: Small mouse with conspicuous ears, soft fur, and sharply two-colored tail. Tail shorter than head and body, and has no terminal tuft. The brown adults and gray young both have white under parts. Wide geographic and ecologic distribution.

Habitat: Mostly nocturnal. Nest in burrows located in the ground, in trees, in logs, under rocks, in buildings, or in other protected situations.

Habits: Range as far as 3 acres from nest when feeding. Active year round. Breed in warmer months.

Food: Mostly seeds, some insects and fruits.

Young: Born in summer. Average 5 per litter. Born naked and blind.

Photograph: Deer mouse by LuRay Parker, Wyoming Game and Fish Department, November, 1976.

DESERT COTTONTAIL—*Sylvilagus audubonii*

Field marks: Relatively small rabbit with long hind legs and long ears that are sparsely furred. 15-17 inches long, hind feet 3-4 inches long. Light gray-brown with white under parts. Orange-brown spot on throat extending to the chest between the front legs.

Habitat: Varying from dry desert-like areas to grasslands and shrub lands.

Habits: Primarily nocturnal. Active throughout the year. May rest in the open, but most commonly seek the refuge of shrubs, rocks, or burrows. Mate from early spring to late summer.

Food: Grasses, sedges, forbs, and shrubs.

Young: Average 4 per litter. Young born naked, blind, and helpless.

Photograph: Desert cottontail rabbit by LuRay Parker, Wyoming Game and Fish Department, August, 1983.

LEAST CHIPMUNK—*Eutamias minimus operarius*

Field marks: Slender squirrel-like mammal larger than most mice and smaller than ground squirrels. Ears conspicuous and nose pointed. Tail is almost as long as the body and only slightly bushy. Run with tails erect. Claws short and curved, and thus suited for climbing about in bushes and trees Red-brown to gray-brown with white under parts. Back has 4 light stripes and 5 black stripes. Center stripe is black and leads from head to tail. There are also two light stripes on the face.

Habitat: Arid situations such as sagebrush plains and hills, as well as moist environments in coniferous forests.

Habits: Active in daytime. Does not hibernate. Nervously scurries about gathering food into its cheek pouches. Underground burrow with entrance under a log, bush or rock and a nest at the end of a somewhat intricate tunnel system. Breeds in late spring and early summer.

Food: Fruits, nuts, berries, seeds, leaves, and stems. Some insects.

Young: 4-6 per litter. Born naked and blind.

Photograph: Least chipmunk by LuRay Parker, Wyoming Game and Fish Department, June, 1991.

MOUNTAIN COTTONTAIL—*Sylvilagus nuttallii*

Field marks: Much like desert cottontail -- darker with smaller ears and hind feet. Dull brown throat patch, ears more densely furred.
Habitat: Varying from dry desert-like areas to grasslands and shrub lands. Also found at higher elevations and in coniferous forests.
Food: Grasses, sedges, forbs, and shrubs.
Young: Average 4 per litter. Young born naked, blind, and helpless.
Photograph: Mountain cottontail rabbit by LuRay Parker, Wyoming Game and Fish Department, December, 1990.

MULE DEER—*Odocoileus hemionus*

Field marks: Medium-sized deer with extremely long ears and a rope-like tail. Color in the summer is a reddish-tan, and in the winter a blackish-gray. Rump and belly white. Tail white with a black tip. Face contrastingly marked -- muzzle lighter than forehead. Only males have antlers.
Habitat: Forests and open shrubby areas at both low and high elevations.
Habits: Mostly nocturnal. Spend daylight hours sleeping or resting at the base of a rock, tree, or other protective structure. Mate in October and November. Bound with peculiar up-and-down jumping motion.
Food: Browse on young shoots of shrubs. Also graze on grasses and forbs.
Young: Born in spring. Twins not uncommon.
Photograph: Buck mule deer by LuRay Parker, Wyoming Game and Fish Department, December, 1988.

MUSKRAT—*Ondatra zibethicus*

Field marks: Large aquatic brown rat-like animal. Fur thick and soft.
Habitat: Along, or in, streams, lakes, ponds, and swamps.
Habits: Live in houses constructed on aquatic vegetation and mud. Nocturnal. Can be seen gathering food in early morning or late evening. Breed during warmer months.
Food: Bulbs, roots, and stems of aquatic vegetation.
Young: 1-11 per litter. Sparsely haired and blind at birth.
Photograph: Muskrat by LuRay Parker, Wyoming Game and Fish Department.

POCKET GOPHER—*Thomomys sp.*

Field marks: Medium-sized, stoutly-built rodent. Small eyes, small ears, and short stout legs. Tail short, round, and sparsely furred. Deep fur-lined cheek pouches. Colored similar to the soil they inhabit.
Habitat: A variety of ecological niches.
Habits: Spend most of their time underground. Build elaborate tunnel systems. Each tunnel system usually inhabited by only one animal. Breed in the spring.
Food: Vegetarians.Generally eat grasses, forbs, and cacti.
Young: 4-6 per litter.
Photograph: Pocket gopher, photographer unknown, Wyoming Game and Fish Department, August, 1978.

POCKET MOUSE—*Perognathus sp.*

Field marks: Small rodents possessing fur-lined cheek pouches used to transport food to their burrows. Frequently colored like the soils in which they live.
Habitat: Arid or semi-arid regions.
Habits: Nocturnal. Dig rather complex tunnel systems. Store seeds, but do not truly hibernate. Breed during warmer months.
Food: Seeds.
Young: 3-7 per litter.
Photograph: Great pocket mouse by B. Moose Peterson/WRP, used with permission.

PRONGHORN ANTELOPE—*Antilocarpa americana*

Field marks: Small, graceful, hoofed animal. Light brown with two broad bands of white across the throat. Black areas on the face; white rump and belly. Males have horns consisting of dark horny material surrounding an outgrowth of bone. The outer covering is shed annually during the winter. The horns are large and have a decided notch or prong. An occasional female will be seen with short knobby horns.
Habitat: Prairies and sagebrush flats.
Habits: Active in the daytime. Usually found in groups or herds. Depend on sense of sight and rapid flight to escape enemies (can exceed 55 m.p.h.). Mate in late summer.
Food: Feed mostly on forbs and browse from various shrubs. Consume very little grass.
Young: Born in spring. Twins common.
Photograph: Antelope pair by LuRay Parker, Wyoming Game and Fish Department, October, 1980.

RACCOON—*Procyon lotor*

Field marks: Stout-bodied animal with a long tail with alternating rings of black and buff. Black to brown with lighter gray-brown under parts. Black mask across the area of the eyes. Rounded ears.
Habitat: Moist areas such as swamps, and along rivers or ponds.
Habits: Active primarily at night and early morning. Climb well and make dens in high, hollow trees. Occasionally live in holes in the ground or fallen trees. Mate in winter.
Food: Omnivorous -- corn, fruit, fish, small mammals, insects.
Young: Born in spring. 1-8 per litter. Young born blind with a sparse covering of a yellow-gray fur.
Photograph: Raccoon, phtographer unknown, Wyoming Game and Fish Department.

RED FOX—*Vulpes fulva*

Field marks: Slender dog-like mammal with a sharp pointed muzzle, long bushy white-tipped tail, and erect pointed ears. Exists in three color phases: the red, the cross (yellowish), and the silver.
Habitat: Varies from mountainous areas with timber to river bottoms and farmlands.
Habits: Active year round. Primarily active at night. Secretive and cunning. Mate in January and February. LIve in dens, caves, or burrows.
Food: A variety of animals and plants.
Young: Born in early spring. Furred, but blind.
Photograph: Red fox by LuRay Parker, Wyoming Game and Fish Department, February, 1994.

STRIPED SKUNK—*Mephitis mephitis*

Field marks: Black with two white lateral stripes on body. White cap on head. Bushy black-and-white tail. Head small, body stout, and tail long. Ears very small.
Habitat: Prairies, meadows, parks, and croplands.
Habits: Nocturnal. LIve in burrows in the ground. Secrete strong odor when alarmed. Mate in March or April.
Food: Omnivorous. Will eat almost anything edible such as insects, amphibians, reptiles, birds, eggs, small mammals, fruits, nuts, and carrion.
Young: Born in spring. 4-10 per litter. Born blind and helpless.
Photograph: Striped skunk by William F. Wood, Humboldt State University, used with permission.

WHITE-TAILED DEER—*Odocoileus virginianus*

Field marks: Medium-sized deer with moderately long ears and a broad, flat, bushy tail. Reddish in the summer, and gray in the winter. Face not contrastingly marked. White spot on throat, white eye rings, and a white ring on the muzzle are present. The tail is red-brown above and white below, and is waved like a flag when the deer runs. Only males have antlers.

Habitat: More brushy bottom lands than mule deer.

Habits: Active primarily at night and very secretive. Run with a loping gait very different from the bounce of the mule deer. Mate in the fall.

Food: Primarily browsers, but will eat a variety of grasses and forbs.

Young: Born in spring, normally as twins. Covered with white spots.

Photograph: Buck white-tailed deer by LuRay Parker, Wyoming Game and Fish Department, January, 1987.

WHITETAILED JACK RABBIT—*Lepus townsendii*

Field marks: Large jack rabbit with a white rump and tail. Total length 22 to 26 inches, hind feet 6-7 inches, ear length 4-5 inches. Light gray-brown in summer with white rump and tail. Molt to almost white in winter.

Habitat: Plains and open areas within mountains.

Habits: Mostly nocturnal, easily seen feeding in early evening. Rest in small depressions (referred to as "forms") which they construct at the base of large plants. Frequently enter burrows and may have their young in underground nests. Breed in summer.

Food: Primarily grasses and forbs, shrubs in winter.

Young: 5-11 per litter (often more than one litter per season). Born fully furred with open eyes.

Photograph: Whitetailed jack rabbit by LuRay Parker, Wyoming Game and Fish Department, September, 1981.

Fishes

BROWN TROUT—*Salmo trutta*

Description: Brown or olive above, yellow belly and sides with black and red to marroon spots. Fish found in clear water have bright color, fish found in turbid waters are silvery. Body elongate and compressed; head moderate; large terminal mouth with teeth on the jaws and tongue. Adults usually 12 to 18 inches long.

Habitat: Thrives in lakes and streams, prefers lower elevation streams with good cover.

Habits: Spawns in fall, preferably in fast waters if available. Diversified feeding habits, feeding mostly in the darkness. Considered to be the most difficult trout to catch by angling.

Photograph: Brown trout by LuRay Parker, Wyoming Game and Fish Department, November, 1978.

GRASS CARP—*Ctenopharygodon idella*

Description: Olive-brown, silvery on the sides and belly; scales on sides create a cross-hatched color pattern. Body elongate; large terminal mouth. Adult size varies depending on location.

Habitat: Large rivers and some other lakes and ponds.

Habits: No naturally reporducing populations in Wyoming. Diet is rooted aquatic vegetation.

Photograph: Grass carp by LuRay Parker, Wyoming Game and Fish Department, September, 1990.

LONGNOSE SUCKER—*Catostomus catostomus*

Description: Gray to black above, white or yellow below; breeding males often have red lateral stripe. Body slender; head moderate; inferior mouth, lips fleshy. Smaller scales and longer snout than white sucker. Adult up to 24 inches long.

Habitat: Prefers cooler water, most common sucker in montane and subalpine lakes; not found in turbid waters.

Habits: Spawns at lower temperatures than white suckers, but similar otherwise. Diet is mostly plant material. Both white and longnose suckers are long-lived.

Photograph: White (top) and longnose (bottom) suckers by LuRay Parker, Wyoming Game and Fish Department, September, 1979.

RAINBOW TROUT—*Oncorhynchus mykiss*

Description: Dark-green to blue-green above; sides silvery with distinct bright red or pink lateral stripe; densely spotted with small irregular black spots. Body elongate and compressed; head short, snout blunt and rounded; large terminal mouth, teeth on the jaws and tongue. Adults 10 to 12 inches in streams, trophy size in lakes and large rivers.

Habitat: Prefers fast waters in streams and rivers but also thrives in lakes.

Habits: Spawns between February and May, moves into smaller tributary streams to spawn. Diet is mainly insects, smaller fish, fish eggs, and freshwater shrimp.

Photograph: Rainbow trout by LuRay Parker, Wyoming Game and Fish Department, November, 1983.

WALLEYE—*Stizostedion vitreum*

Description: Brassy or olive color above, white belly; may have obscure saddle-like marks on dorsal surface. Body elongate; moderate head; large mouth, large canine teeth. Head and cheek usually scaleless. Adult can weigh over 18 pounds.

Habitat: Prefers lakes to rivers; thrives in elongate lakes with irregular shorelines.

Habits: Spawns when ice cover melts; usually spawns in a tributary stream, over rocky bottom of lakes or gravel in moving water. Lives in large schools. Diet is mainly smaller fishes, feeds at night. When hatched artificially, walley fry may become cannibals.

Photograph: Walleye by LuRay Parker, Wyoming Game and Fish Department, September, 1978.

WHITE SUCKER—*Catostomus commersoni*

Description: Color dusky to black above, shading to white below; breeding males are coppery colored. Body elongate; head moderate; inferior mouth, lips papillose but narrower than longnose sucker. Larger scales help to distinguish between white and longnose suckers. Adult rarely over 2 pounds.

Habitat: Prefer clear water over turbid waters; thrives in lakes and streams, avoids currents.

Habits: Spawns in spring and early summer, usually spawns in shallow water over gravel or sand beds, single female usually pairs with two males. Diet is mostly insects and crustacea, may feed on eggs of other fish.

Photograph: White (top) and longnose (bottom) suckers by LuRay Parker, Wyoming Game and Fish Department, September, 1979.

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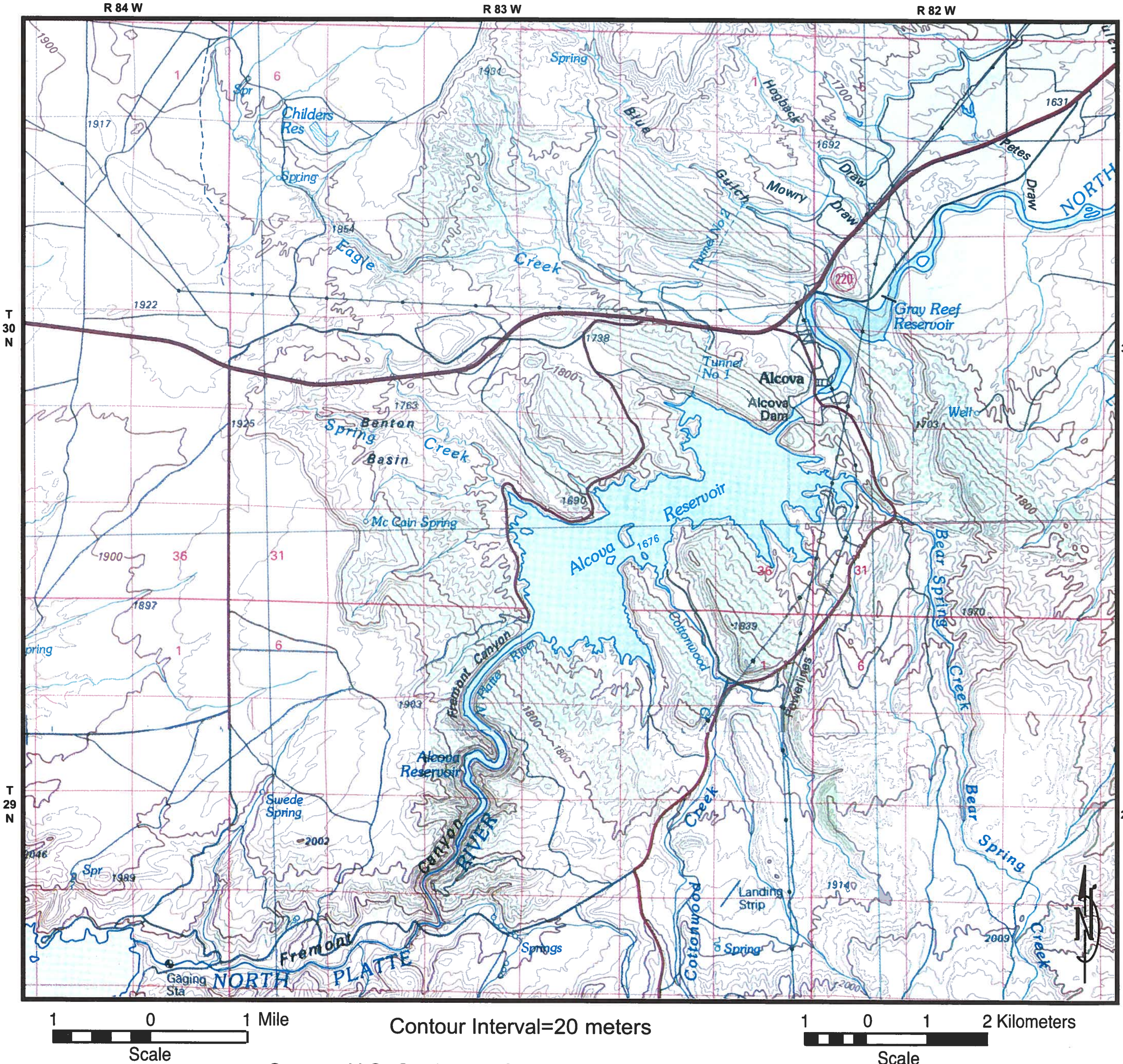
Notes

Notes

Topographic map of the Alcova area



Source: U.S. Geological Survey, 1:100,000-scale metric topographic maps of Casper, Wyoming (1983) and Shirley Basin, Wyoming (1984).

About the topographic map, aerial photograph, geologic map, and satellite image

Topographic map

This guide contains a separate topographic map at a scale of 1:100,000 (to left of this fold out) for the reader to compare the geology with the topography. The scales of the maps are very nearly the same. The geologic map for this field guide contains none of the details of the topography and cultural features. This is for ease in understanding the geology.

Aerial photograph

Geologists preparing geologic maps often use high resolution aerial photographs in order to see color and vegetation differences exhibited by the formations as well as to accurately locate formation contacts and other geologic features. These aerial photographs are usually taken by very high-quality cameras and sensors flown from an airplane at precise speed, altitude, and direction. Individual photographs are taken in sequence with a high degree of overlap so when used in pairs, they can provide a stereoscopic view (because each photograph is taken at a slightly different angle from the plane's flight). Compare the aerial photograph with the geologic map and see if you can identify different formations. Hint: the red rocks appear on the photograph as greenish-yellow or yellow; vegetation and water is dark. The colors shown are a function of the equipment used in photographing the area.

Geologic map

A geologic map shows the various types of rocks that appear at the surface (crop out) in the map area. This is done by drawing lines to define the area boundaries (called formation contacts) of each rock type. A formation symbol is included in each area to indicate the geologic age and name of the rock present. For those unfamiliar with the various formation symbols, a key is provided. For visual effect, the formations are often colored.

Most geologic maps include symbols to indicate the location of anticlines, synclines, and faults. A line with arrows pointing away from it indicates the axis of an anticline. Note the red line just below the words "Alcova Anticline" on the geologic map. A line with arrows pointing toward it would indicate a syncline. On the Alcova geologic map, a heavier black line indicates a fault or place where the rocks have broken and moved. The letters "U" and "D" indicate which side of the fault moved up and which moved down.

Geologic maps are usually superimposed on a base map that may contain a system for locating an area of point on the map (a "grid"), topography, highways and roads, and water features such as lakes, streams, rivers, etc.

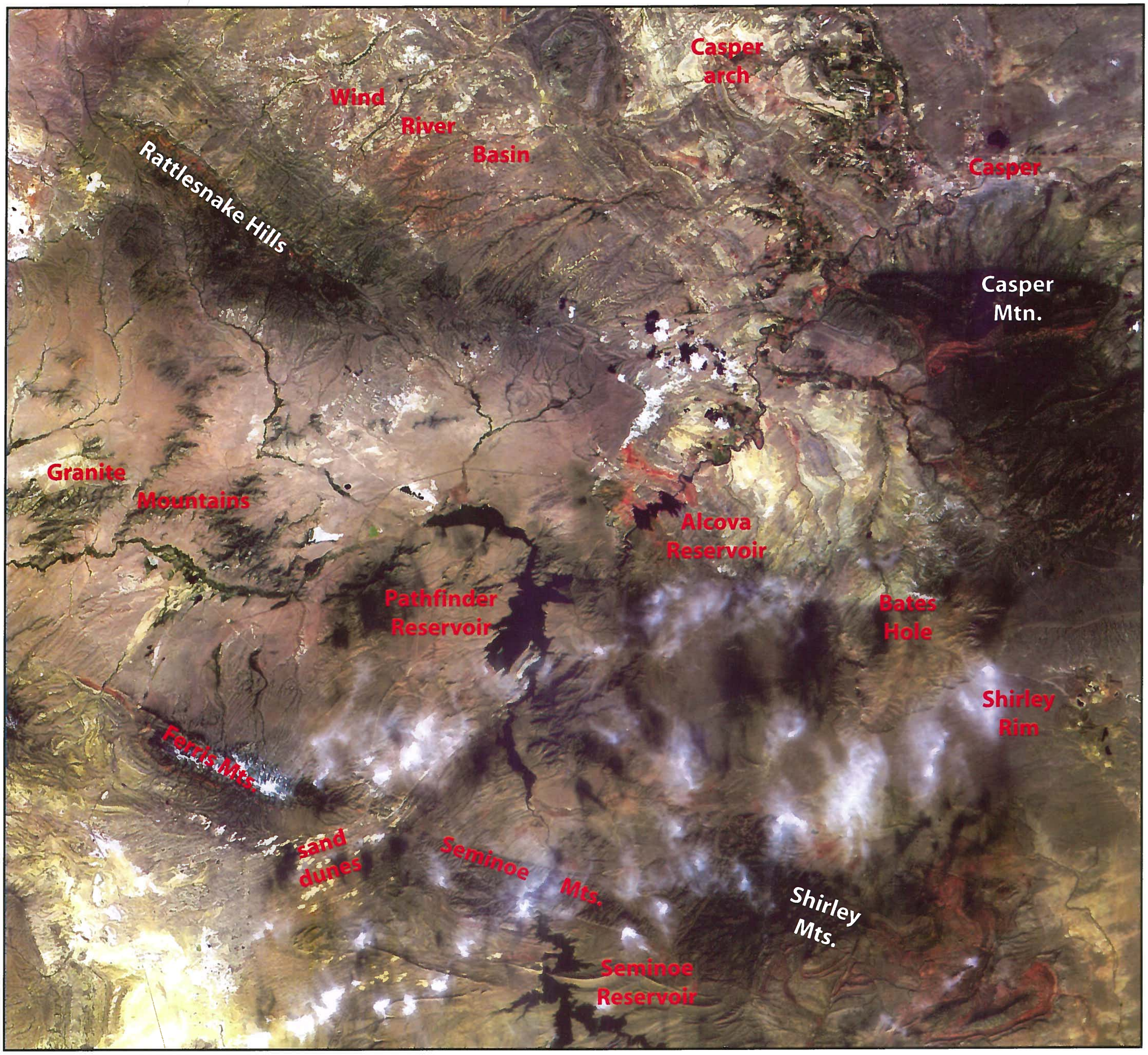
The grid on this map is Township, Range, and Section and is used to describe locations or land areas. This system is known as the Public Land Survey System (PLSS). The small squares indicate areas called *sections*. Sections are usually 1 mile by 1 mile and provide handy means for estimating distance. One section occupies 640 acres. A *township* consists of 36 sections, 6 miles by 6 miles. Many maps have additional grid systems that can be used with global positioning systems (GPS) units that use satellites to determine geographic position.

The geologic map of the Alcova area shows the outcrops of the various formations in colors that correspond to those shown on the stratigraphic column. Once you know your position on the map, you can determine what formation or rock type you are on and then relate that to its age, lithology (rock type), color, thickness, etc. by reference to the stratigraphic column.

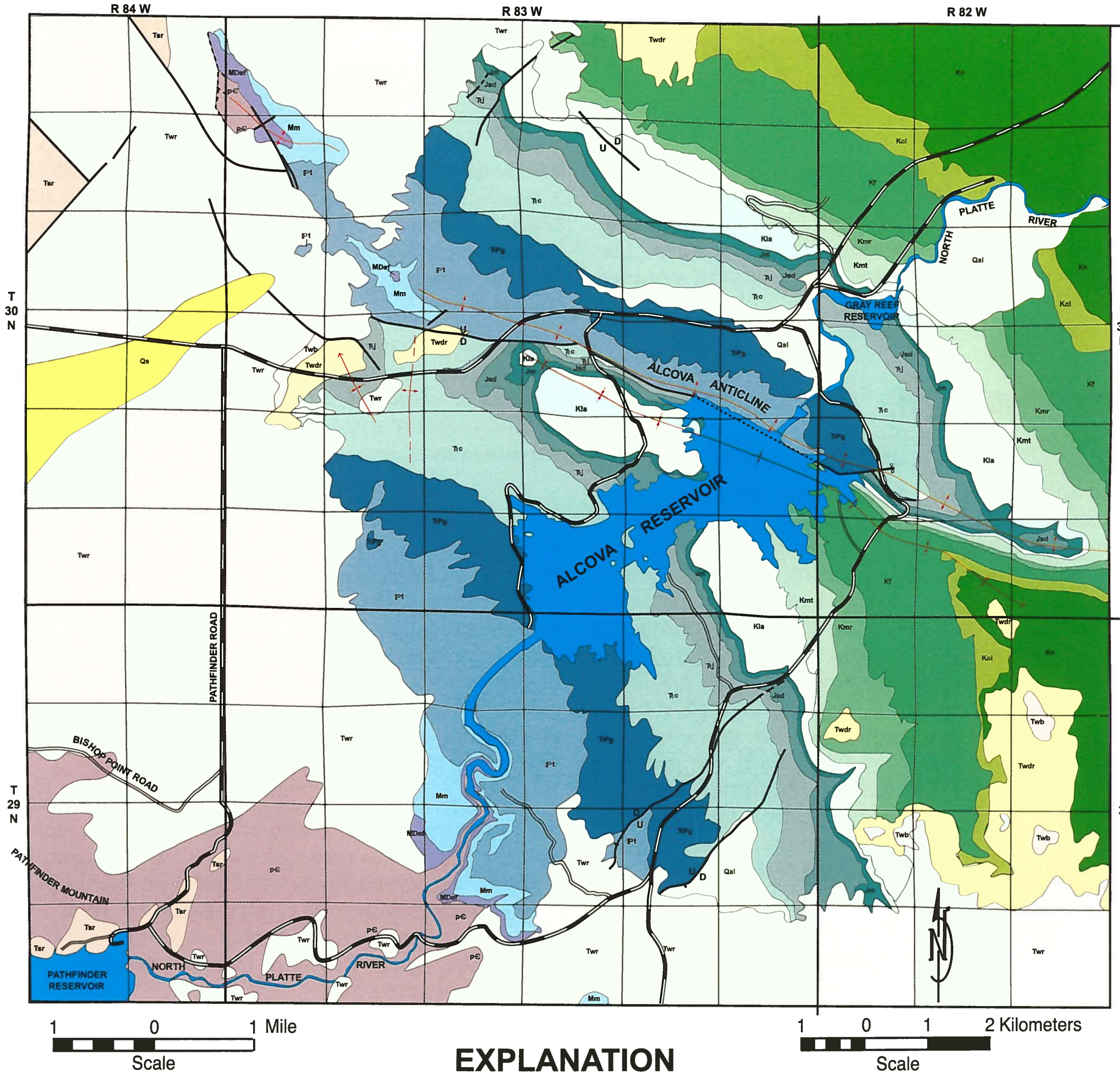
Satellite image

These are very helpful to geologists doing regional or statewide work because they cover large areas. In the satellite image of south central Wyoming, the red beds appear orange. As in the aerial photograph, the colors are not true colors but are dependent on the equipment used. The satellite images are not true photographs but instead are bits of remotely sensed digital data from various satellites.

Satellite image of the Alcova area



Geologic map of the Alcova area



EXPLANATION

Rock units

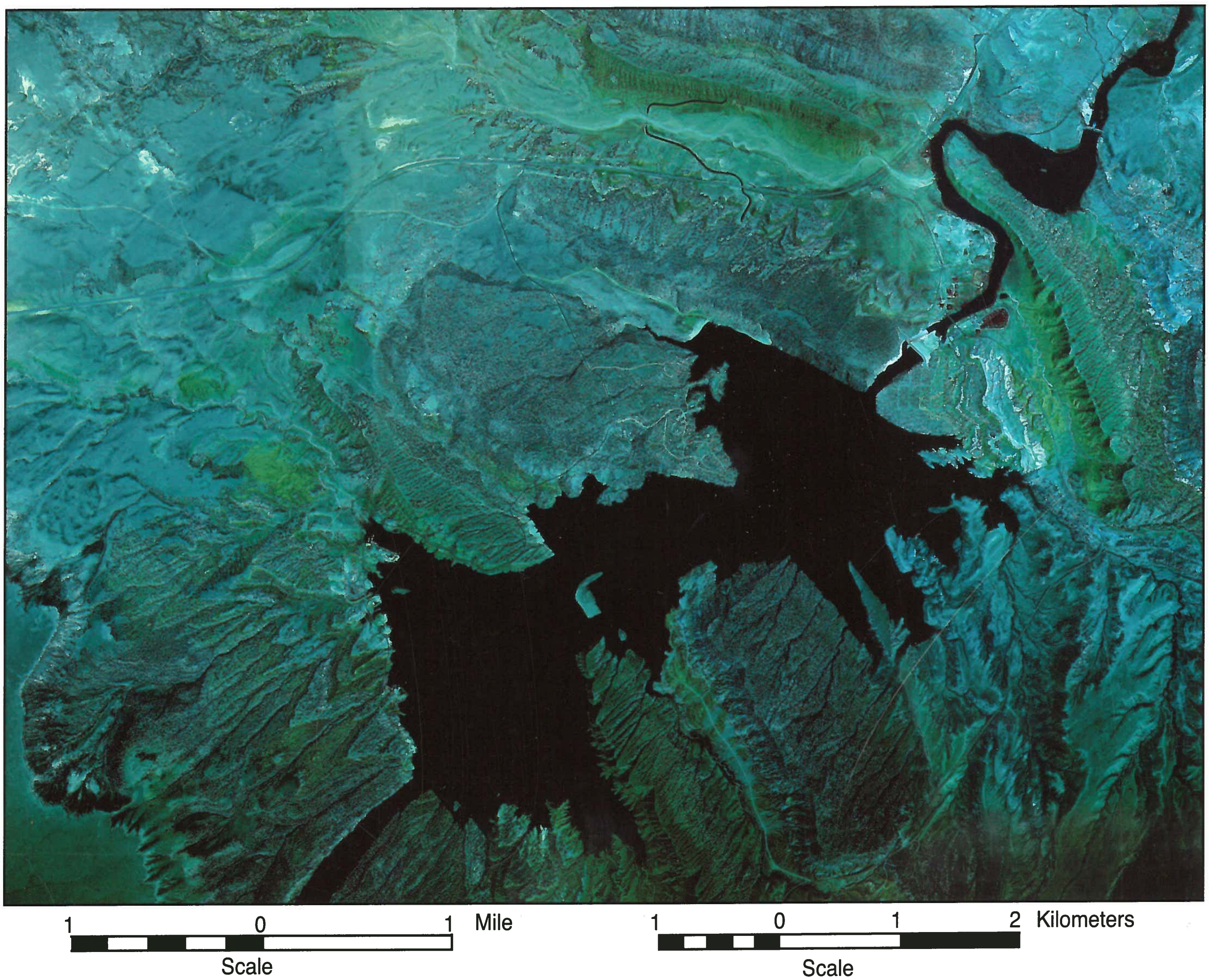
- Qs Windblown sand
- Qal Alluvium
- Tsr Split Rock
- Twr White River
- Twb Wagon Bed
- Twdr Wind River
- Kn Niobrara
- Kcl Carlile
- Kf Frontier
- Kmr Mowry
- Kmt Muddy/Thermopolis
- Kla Lakota
- Jm Morrison
- Jsd Sundance
- ₮j Jelm
- ₮c Chugwater/Alcova
- ₮Pg Goose Egg
- IPt Casper/Tensleep
- Mm Madison
- MDef Englewood/Fremont Canyon
- p€ Precambrian

Map symbols

- Synclinal axis, with direction of plunge
- Anticlinal axis, asymmetric; short arrow indicates steep limb
- Anticlinal axis, symmetric
- Fault showing relative movement
- Formation contact
- Paved road
- Gravel road

Modified from original map compiled by W.H. Curry, III, 1970, who used maps from Mitchell (1957), Sheffer (1951), Hares and others (1946), and Denson and Harshman (1969). Additional mappiing used to update this map included Love (1970), Love and others (1979), and Love and Christiansen (1985).

Aerial photograph of the Alcova area



Source: Color infrared aerial photographs 27-4-8 and 27-4-9 from U.S. Bureau of Land Management, Wyoming Office, CPIR Series, July 28, 1976, original scale 1:31,680; reduced to 1:55,000.

Selected references on the geology of Wyoming

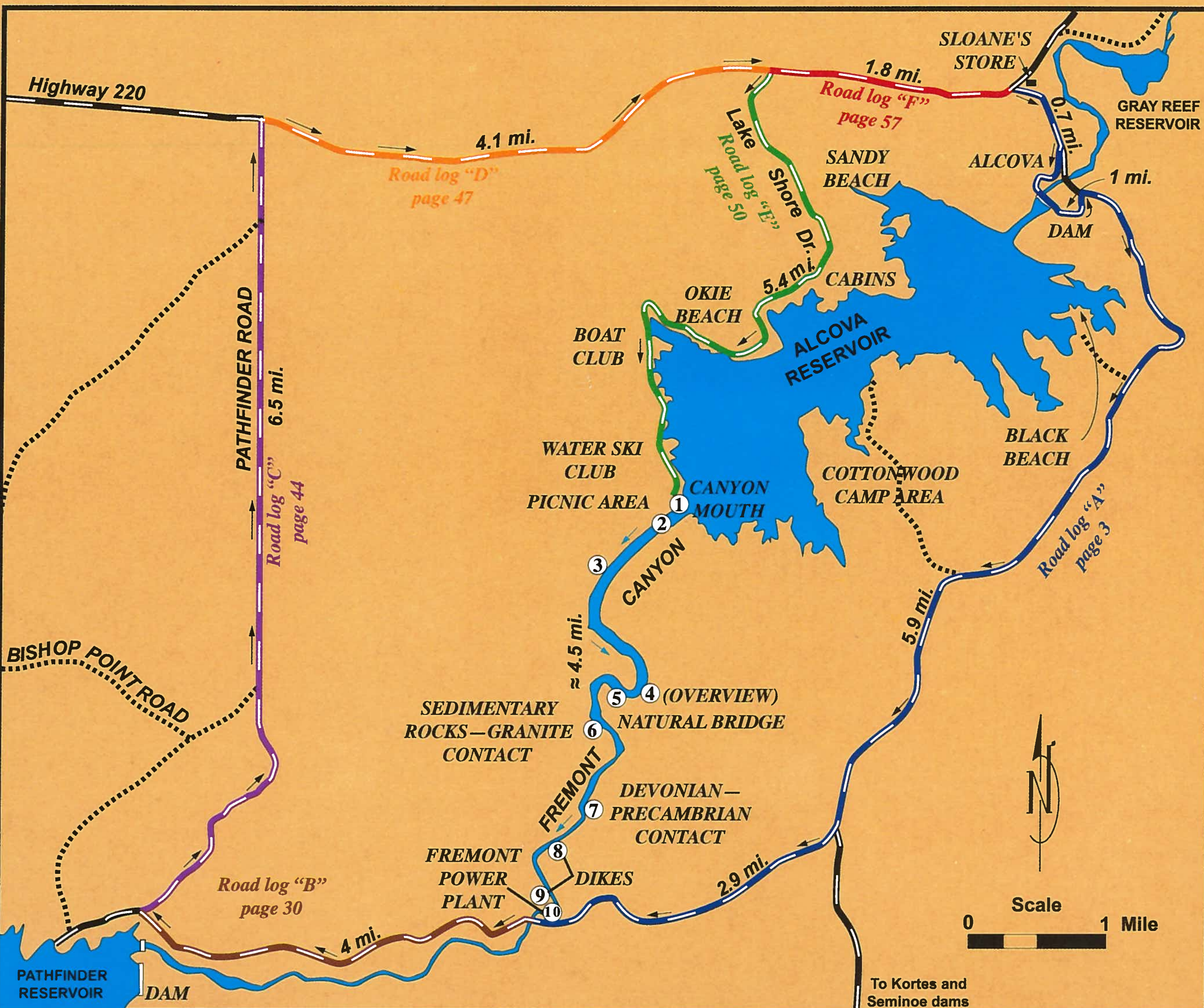
- Geologic map of Wyoming: U.S. Geological Survey, 1985, scale 1:500,000, 3 sheets, color, rolled only.
- Geologic highway map of Wyoming: GTR Mapping, 1991, scale 1:1,000,000, color, folded only.
- Traveler's guide to the geology of Wyoming: Wyoming State Geological Survey, 1988, Bulletin 67.
- Geology of Wyoming: Wyoming State Geological Survey, 1993, Memoir 5 (2 volumes plus CD-ROM of maps).
- Wyoming geomaps: Wyoming State Geological Survey, 1989, Educational Series 1 and Supplemental pamphlet of classroom activities for teachers (to accompany Educational Series 1).
- Roadside geology of Wyoming: Mountain Press Publishing, 1988.

The above publications, along with all topographic maps for Wyoming, most U.S. Geological Survey geologic maps of Wyoming, and other publications are available from the Wyoming State Geological Survey. Call for prices and to receive a free list of publications.

Dedication of Second Edition

The first edition of this guide recognized master field teacher F. Howard Brady who in the early years showed us how to do field courses. In this second edition we recognize the contributions of the Casper Water Ski Club members for more than thirty years of taking our classes up Fremont Canyon. Those members deserve recognition for their many hours of providing boat transportation for and interacting with Field Science students. Bob Iserman, Mike Phillips, Wayne Hales, and Rusty Hamar deserve special notice for their long-term dedication to the program.

A field guide to the Alcova area, Natrona County, Wyoming



① Circled numbers are locations for the boat log (p. 59).

Geology—Interpreting the past to provide for the future

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Educational Series 2

ISBN 1-884589-35-9

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