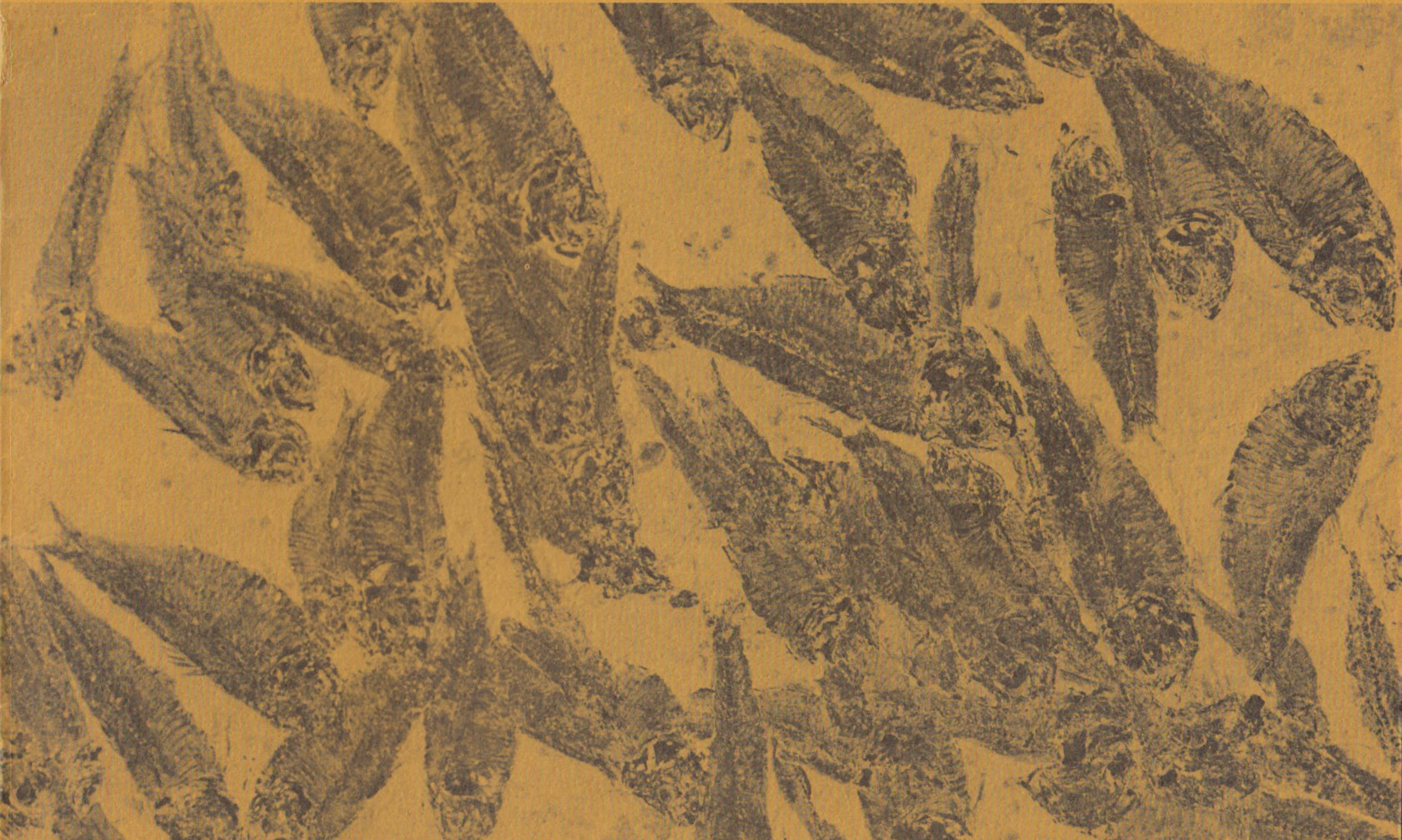
THE FISH OF FOSSIL LAKE

by Richard W. Jackson

the story of Fossil Butte National Monument



THE FISH OF FOSSIL LAKE

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Published in cooperation with the National Park Service, U.S. Department of the Interior, for the benefit of visitors to Fossil Butte National Monument, Wyoming.

Why do paleontologists devote their lives to studying fossils? And why are collectors equally devoted to searching for them? These questions probably won't be satisfied by an occasional visit to a museum where the significance of our prehistoric heritage may be missed among the more eye-catching exhibits. Compared to a complete dinosaur skeleton for instance, the sight of a row of fossils behind glass often can be dull. But, a visit in the outdoors to one of the world's great fossil beds, on the other hand, can make the story behind those fossils come alive.

This book grew out of many trips to Southwestern Wyoming where I collected fossils from the famous Green River Formation. It is intended as a guidebook for visitors to Fossil Butte National Monument who, having seen what is here, become fascinated, as I have, with the incredible story of how these fish came to be preserved.

My first discovery of a fossil seemed to hold out the thrilling opportunity of finding the answers to many questions about the Earth's dim prehistory. What could be more fascinating than assembling the pages of Earth's book in proper order? Little by little—for it is a monumental task—this is what fossils help us to do.

All the world over, traces can be seen of prehistoric times. Fossils are common, contrary to popular belief. They are found virtually anywhere sedimentary rock is exposed but they are usually incomplete bits and pieces. Only a few places on Earth produce fossils that show the intricate detail of a complete plant or animal. The Green River Formation, in Southwest Wyoming, the site of ancient Fossil Lake, is one of these rare places.

The formation has been known to scientists for many years as the source of some of the most perfectly preserved and highly valued fossil fish in the world. Since 1972 a significant portion of the site has been designated Fossil Butte National Monument, a part of the National Park System.

Most professional work on the Green River Formation has emphasized the deposits of oil shale. Several excellent publications thoroughly cover the subject, but they are difficult to find. Most literature about the fish themselves contains highly technical descriptions of fossils that are essential to the professional, but are of little value to general readers and visitors to Fossil Butte.

This book, therefore, attempts to present a non-technical summary of the professional thinking about Eocene life of Fossil Lake. Most of the information is not the result of extensive research on my part, but derives from the work of many devoted scientists to whom a large part of the credit must go. I sincerely hope that this work will prove useful and provocative for amateur and professional alike.

In addition to some personal notes about the region, I have tried to tell a brief history of fossil collecting around Fossil Butte. I hope thereby to share with readers the mood and sense of nostalgia that just being here gives me.

In making this book I have incurred many obligations. I thank Bruce Erickson, Curator of Paleontology at The Science Museum of Minnesota, for the encouragement and assistance he has given to this project. I also thank The Science Museum of Minnesota for granting me the privilege of photographing their specimens. I am indebted to Peter Ganzel of The Science Museum of Minnesota for providing many of the photographs. My sincere appreciation goes to the Wyoming State Archives and Historical Department for helping me research the town of Fossil, Wyoming. My thanks go to Lance Grande, who supplied reference material, provided photographs of specimens to which I did not have ready access, and offered suggestions and information which improved the contents of this manuscript. My special thanks go to the National Park Service staff at Fossil Butte National Monument who kindly permitted use of their photographs and initiated publication of this book in cooperation with the Dinosaur Nature Association. Also, I must express my appreciation to my wife, Alice, who did my proof reading, although this subject does not excite for her the inflammable interest I have always had.

Photos:

Lance Grande: back cover, inside front cover, page 16 **Lepisosteus,** and 17, **Xiphotrygon**

John Cummings: page 4

The Science Museum of Minnesota: page 11, 15, and 16 **Phareodus**

Field Museum of Natural History, Chicago: page 17 **Amia**

National Park Service: page 18 (turtle)

University of Wyoming: page 19

U.S. Geological Survey: page 20

Florence Jckowski Crawford, Pocatello, Idaho: page 22 (photo print by John Cummings)

Donald Julian, Kemmerer, Wyoming: page 23 (tavern photo print by John Cummings)

All other photos by the author

Fossil Preparation:

Lance Grande: page 11, 16 **Lepisosteus,** and 17

Ted Fremd: page 18 (turtle)

All other fossils prepared by the author

Book Design:

Christina Watkins Fall

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Entombed in the craggy limestone butte are countless millions of fossils, each a small miracle of preservation in 50,000,000-year-old stone. Only a tiny fraction of the fishes have been uncovered, but enough to signal a place of major paleontological significance.

I. THE THRILL OF DISCOVERY

The outline of a fish on the exposed rock ledge cast a faint image in the morning sun. Working into the side of the butte, it had taken me about two hours to remove the thick overburden to reach the layer where it lay. Although a thin layer of limestone still covered it, the familiar shape of a fish was clear, even to an amateur such as myself.

This was my first trip to Southwest Wyoming. I had come in search of fossil fish in the famed Green River Formation, the source of some of the best preserved fossils in the world. This first trip was devoted primarily to learning the nature and extent of the area's fossil deposits. I picked a butte for exploration and, after a long hike, through sagebrush, scaled its heaps of limestone to the layer that tells of life 50 million years ago in the Eocene. Rest periods were frequently necessary to get the oxygen I was used to at lower elevation. I was tired upon reaching the ledge, but my efforts soon led to discovery of that first fish. I have since found many fish that have been larger and of finer quality, but the fish uncovered on that first day is the one I remember most.

It lay against the edge of a large sheet of limestone and was approximately 25 centimeters (10 inches) long. Part of the tail appeared to be missing due to erosion on the face of the butte. Although I didn't have the slightest idea what kind of fish it could be, the shape reminded me very much of a sunfish. I was in no rush to remove it from the sheet of rock. It had been lying in exactly the same position for millions of years and a few minutes one way or the other didn't seem to make any difference now.

While still kneeling by the fish, a gust of wind blew from the top of the butte, picking up dust as it went. The dust gave the air a very definite alkaline taste, which I would become familiar with in years to come. I watched as the dust blew over the edge and settled in the valley below. The terrain sloped away sharply from the butte, and a sweeping panoramic view stretched in some directions for miles. Directly across the valley rose Fossil Butte. The same rock layers and ancient lake sediment I was kneeling on were vividly exposed in its side. The tans and buffs of the Green River Formation contrasted sharply with the bright purples and pinks of the underlying Wasatch Formation.

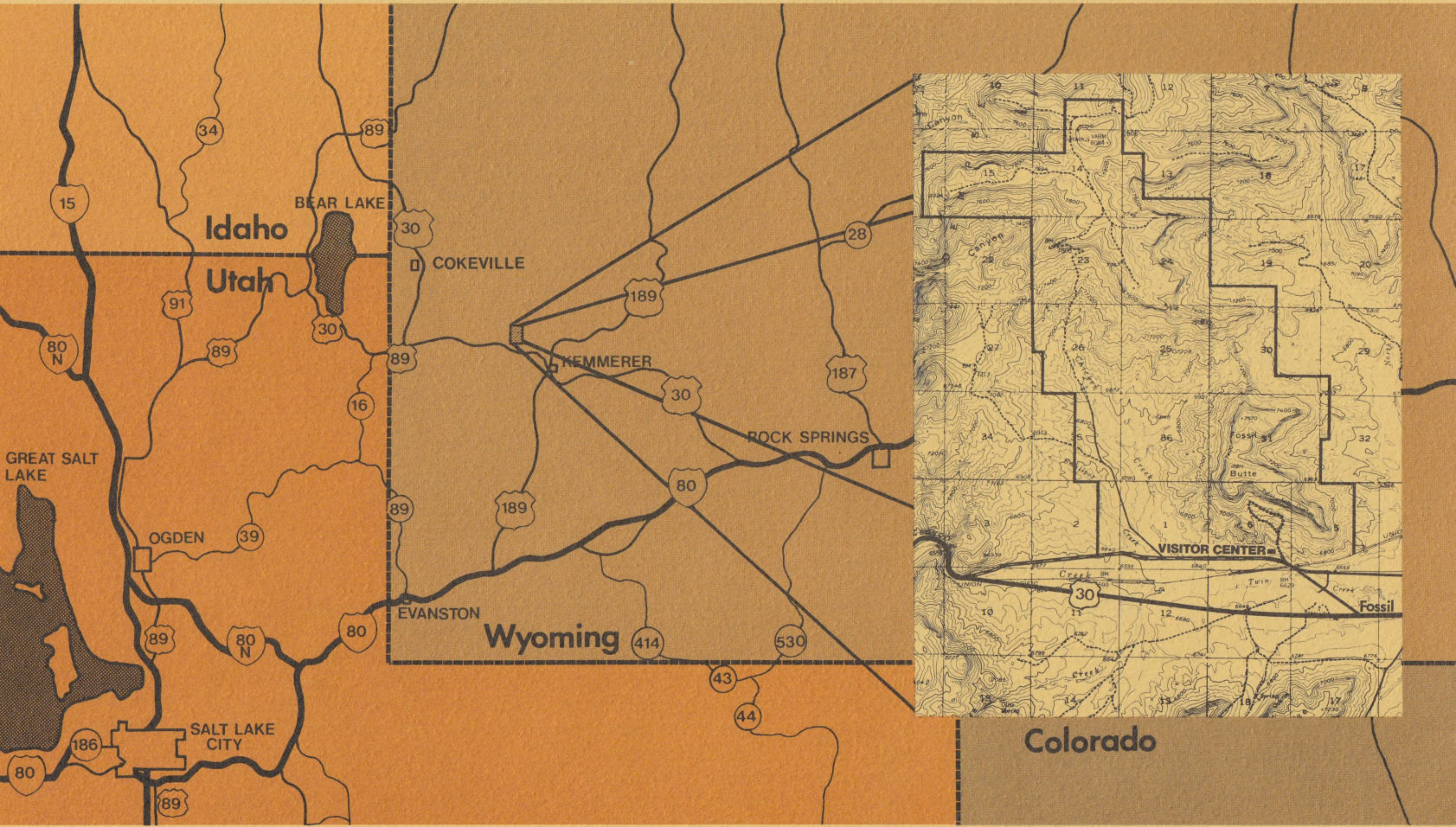
Other than the wind, the only thing that could be heard was the occasional sound of a flock of sheep, far in the distance. The sheep were moving up a hillside at the end of the valley, approximately two miles away, with a mounted sheepherder watching close by. They appeared only as tiny white specks among the scattered clumps of sagebrush. Although the front of my butte was a barren cliff, on the north side was a stand of large limber pine and Douglas-fir. It was twenty degrees cooler there, away from the hot sun and its bright reflection from light colored shale; an ideal place for consumption of immense quantities of lemonade. Here, high on the butte, was peaceful silence, rare beauty and complete solitude.

In this setting everday problems seemed so remote. I wondered about this planet Earth and the record of its past life written in the layers of rock. How were those layers, which tell the story of life from the first single-celled plants and animals to the living things of today, to be read? As I gazed at this arid landscape of sagebrush and flat-topped buttes, I tried to imagine Fossil Lake existing here, fifty million years ago. How did the fish I had just found live its life and how did it die? What other forms of life shared the waters of the ancient lake? Although I had a basic knowledge of geology, these were questions about which I could only speculate.

Decisive moments in one's life don't always occur in dramatic settings. Mine came here while kneeling on the rock ledge of that hot, dusty butte. I knew that I would be back; back next year and the year after and the year after that. Since then I have come to know and love this area, as well as its people. This, I had discovered, was a land of eternity and hostility— but not without islands of hospitality and much beauty.

Fossil Trail You can follow the path of old time fossil collectors to upper quarry sites on the butte. Some fossils may be seen on the ground, but they may NOT be removed. Wayside exhibits along the trail explain the geology here. A side trail into the Wasatch Formation exhibits some land fossils.

Visitor Center The story of Fossil Butte is told in exhibits which include some prepared fossils. Ask park rangers about hiking in the park and arrangements for guided walks. Lodging and meals are available in nearby Kemmerer and Cokeville.



Kemmerer The closest major town is 16 kilometers (10 miles) from Fossil Butte. Kemmerer has motels, restaurants, and commercial campground facilities. Camping is not allowed in the park.

Historic Townsite Fossil, which grew up and thrived briefly after the turn of the century, has been a ghost town for decades. The few decayed buildings remain in private ownership.

II. VISITING FOSSIL BUTTE

Sagebrush thrives in the high, arid country of southwestern Wyoming. The climate is ideal for scrub plant vegetation which also includes greasewood and many grasses. It is a country sparsely settled by people who are vastly outnumbered by sheep, antelope, and mosquitoes.

Kemmerer, Wyoming, just 16 kilometers (10 miles) from Fossil Butte, is 96 kilometers (60 miles) northwest of Rock Springs, and 160 kilometers (100 miles) northeast of Salt Lake City. The town is growing in leaps and bounds so that it is no longer small and quiet. But it is still friendly. The people who live here have a distinct advantage over many of us who live elsewhere. They can jump in a pickup truck or car and be near mountains in an hour. They can camp in clean air alongside a clear stream and fish for trout in uncontaminated waters. They can view wild animals in their natural habitat and feel a close relationship with nature.

June comes to Wyoming as a blessed interlude between stormy winter and hot summer. June skies are blue, the breezes warm, and the flowers abundant. This is the time to "fish for fossils." Any earlier than this and you are up to your waist in snow; any later and you will broil in the mid-summer sun.

Fossil Butte National Monument has no campgrounds, but Kemmerer has commercial camping facilities nearby. If you camp out, be prepared to take certain risks. Due to the thin atmosphere at a high elevation of 2100 meters, (7,000 feet), the Wyoming sun can burn your skin in only a few hours. At the campsite, the only patch of shade may be under a lowly picnic table. Even this is welcome. As evening approaches, hoardes of mosquitoes suddenly appear. They have voracious appetites and most certainly are related to vampire bats. The consolation is the fact that they only appear about three hours each day. In the evening when the sun disappears below the horizon, the temperature drops like a head-shot duck. One minute you are sitting clad only in short sleeved shirt, and the next, searching for a warm jacket and blankets and hurrying to build a fire for hot coffee.

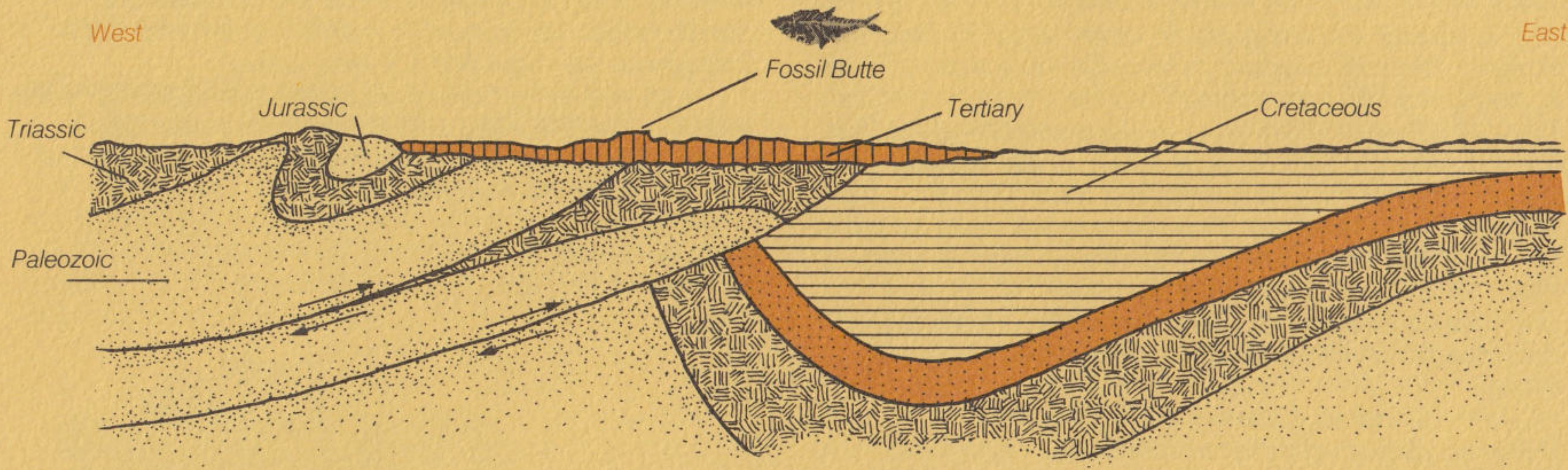
Summertime temperatures can reach the 30-40° C range (high 80s° F) during the day and drop to near freezing at night. Because of the low temperature, condensation forms quickly inside the tent and drips throughout the night like a spring shower.

In spite of these conditions, sleep comes quickly. In the morning, the Wyoming sun brings forth a new day—another day to climb the sheer buttes and to learn more of the story of Fossil Butte.

III. EOCENE MOUNTAINS AND LAKES

Escape from a time frame of minutes and hours and think in terms of eons, of land-forms chang-ing, of an immensity of geologic time. Once that picture is clear, if only for a moment, it sets the stage for a magnificent story of un-folding life.

Simplified structure section through present-day Fossil Basin



Structural details by Dr. D.L. Blackstone

The Green River Formation and its valuable fossil content reveal a series of events that began about 64 million years ago as the Age of the Dinosaurs, ended. The Cretaceous, as it is known, had been a period of relatively stable conditions throughout Western North America. Many of the changes that took place toward its end were not only responsible for the extinction of the remaining dinosaurs but transformed the western landscape as well.

During the Cretaceous a large inland sea extended from the Gulf of Mexico to Alaska. In places it was 1610-kilometers (1000-miles) wide. The sea diminished in size by the end of the Cretaceous, and it completely disappeared by the beginning of the Eocene, 55 million years ago.

The sea sediments, and older underlying rocks, were slowly buckled and folded to eventually form the Rocky Mountains. The Rockies did not suddenly appear in cataclysm, but were raised little by little each year. As the uplift continued, basins were created between the mountain ranges. Water collected in these basins to form lakes. Thus, the inland fresh-water lakes of the Green River Lake System were formed.

The Green River Lakes

The Green River Lake System was made up of three lakes: Lake Uinta, Lake Gosiute, and Fossil Lake. The first to form was Lake Uinta, which occupied a huge basin in Utah and Colorado. Later the other lakes formed, one being Lake Gosiute, which covered two basins primarily in Wyoming and the other, Fossil Lake, which was located in a small narrow depression west of the present day town of Kemmerer. Uinta and Gosiute Lakes were very large and relatively shallow, flooding nearly level basins. Fossil Lake was small and deep compared to the others.

Of all the lakes, Uinta was clearly the largest and perhaps the most stable. However, throughout their history, both Gosiute and Uinta expanded and contracted at various times. At certain other times these two lakes, despite their enormous area and slight depth, must have been quite stable. The presence of thick algae reefs, which required hundreds of years to form, indicate constant water levels. Any more than slight changes in water level would have registered in the growth layers of the reefs (Bradley 1929). Gosiute and Uinta were connected, at various times, by an outlet from Gosiute and it is possible that a connection existed with Fossil Lake because similar fossils have been found in all three lakes.

Evidence suggests that the lakes may have overflowed for long intervals, but the presence of sun-dried mud cracks, far out in the basins, indicates that at other times the lakes shrank drastically. One possible explanation would be the existence or lack of an outlet during these stages. It is clear that the lakes had rivers and streams that flowed into them.

Climate played an important part in the fluctuations in lake sizes. An increase or decrease in annual rainfall would cause lake levels to rise or fall. The fossil record seems to indicate a warm, temperate climate. Petrified wood specimens from the nearby Bridger Formation contain annual rings that suggest mild seasonal changes during that later period. The presence of fossilized crocodiles, palm leaves, and other types of tropical life, indicates a perennial supply of fresh water.

Then, toward the end of the lake's existence, the climate became more arid. Without outlets, Gosiute and Uinta Lakes became salty. Sediments carried by streams from the surrounding highlands gradually filled the lake basins.

The final disappearance of the lakes was caused by the continued uplift of the region. Rivers and streams, running faster from higher elevations, carried still larger amounts of material which covered the lake deposits with flood plain deposits. Fossil Lake was the first to disappear with Gosiute following later. Uinta persisted longer than the others, but it, too, eventually ceased to exist.

The Green River Formation

Today the accumulated lake sediments called the Green River Formation cover an area of 88,000 square kilometers (34,000 square miles) and in some areas are 610 meters (2,000 feet) thick. These rocks are exposed extensively in sections of Wyoming, Colorado, and Utah. The formation is famed for two reasons: oil shale and fossilized fish.

Oil shale is a sedimentary rock impregnated with oil derived from organic matter which accumulated on the bottoms of Gosiute and Uinta lakes. These deposits could prove to be of tremendous importance when it becomes economically feasible to extract oil from them. For example, it is reported (Schaeffer and Mangus 1965) that the Piceance Creek Basin in northwestern Colorado alone has a potential reserve of some 600 billion barrels. This is just a part of the total deposit.

Actually, the terms oil shale and Green River shale, which originated from early field studies, are commonly, but inaccurately used. The principal material, as we now know, is limestone. All are part of the Green River Formation, but the greatest abundance of fossil fish, for instance, comes from a layer of thinly laminated limestone.

IV. LIFE AND DEATH IN FOSSIL LAKE

Fossil Lake, known today as Fossil Basin, was appropriately named. Although fossils occur throughout the entire Green River Formation, the majority of the finest specimens came from Fossil Lake. The fish that lived and died here 50 million years ago are known and valued throughout the world.

The lake sediments in Fossil Basin are 60-90 meters (200-300 feet) thick and are seen exposed in the edges of the buttes. They are composed primarily of mudstones, siltstones, volcanic ash and, most important, the layer of laminated limestone, which is commonly referred to as Green River shale.

The Fossil-Bearing Layer

One unit of laminated limestone in particular has become famous for the fossil record it contains. This fossil layer varies in thickness from 35-50 cm (14-20 inches). Millions of fish representing perhaps many thousands of years are recorded in this layer. Skin and scales of the fish along with the bones are preserved in exceptionally fine detail. And, due to the uncommon circumstances under which this layer was deposited, the record can be read like a book.

Several other layers also yield many fish from later periods in the life of Fossil Lake. Though abundant, most specimens are not the quality of those in the lower, better preserved layer.

Conditions for Life

Of course, it is just a stroke of sheer luck that the story of this ancient lake can be told at all. A fish dies and eventually settles to the bottom. Buried in mud and subjected to great pressure, it is transformed into a fossil. Here it might well have lain, deeply buried for the rest of time, had not the elements eroded and exposed it. Considering the tremendous force nature exerts in raising these rock beds, it is amazing that fossils ever come to view intact. Fortunately, the fossil layers of Fossil Lake were raised hundreds of meters with very little of the tilting, heaving, and buckling usually associated with mountain building.

It can be assumed that Fossil Lake was an ideal place for fish to live, judging by the large numbers of fossilized specimens found here. Ultimately the quantity and diversity of a fish population depends on the amount of plant life a lake can support. This is determined by water temperature, water depth, and the availability of certain chemical elements including nitrogen, phosphorous, and calcium. Plants grow best in shallow waters. A lake that is deep throughout is a poor producer of plants, since sunlight, which is necessary to plant growth, cannot reach through great water depth. Fossil Lake was deeper than the other lakes, but the shallows along the shoreline must have supplied ample plant life to support fish.

Not only were the waters of Fossil Lake life-giving; on the land plants and animals thrived as well.

At the north and south ends of the lake marshes and flood plains with palms, cypress, willow, and fig trees thrived due to a perennial water source. Crocodiles, turtles, and snakes lay along the shores, soaking up sun on logs and in the shallow water. The abundant birds and mammals that lived here bore little resemblance to those of today. Beyond the marshlands the terrain was semi-arid. On the lower slopes grew oak, elm, maple, and beech. Higher, grew spruce and pine, suggesting elevations of from 1330 to 2430 meters (6,000 to 8,000 feet) (McGrew and Casilliano 1975).

The lake itself teemed with fish, millions of them. A Garden of Eden? Hardly. In the world of fish, many individuals eventually end up in another's maw. Coupled with that possibility is the fact that something killed these fish—killed them by the millions. Why did they die in such large numbers? What caused their unusually fine preservation?

Quite apart from their value as keys to the puzzle of life, fossils evoke wonderment and mystery, much the same way art does.

Conditions for Preservation

Special conditions must exist for plants and animals to fossilize. Organic matter decays by bacterial action, tissue is consumed and bones and cartilage disarticulate. As the bodies of creatures fall apart, they tend to be scattered by mechanical forces of wind and water currents, and the activity of scavenger animals. Consequently, to be preserved as a fossil, an organism usually must be buried during or immediately after death and be covered quickly with layers of sediment.

The limestones which formed in the deeper parts of Fossil Lake are laminated in sets which have been interpreted as varves representing annual sedimentation. Each varve consists of two separate layers. One layer, very light in color, contains large amounts of calcium carbonate. The other layer is darker and much thinner and is composed mainly of organic matter. It is believed that these two layers were deposited at different times and represent many thousands of years.

One explanation for why the fish were preserved comes from studies of lakes with similar chemistry.

The question with regard to Fossil Lake is: How were the dead fish buried so quickly and therefore preserved in a sediment of calcium carbonate which eventually consolidated to become limestone? The answer comes in part from observations of similar existing lakes.

Assuming a fairly constant calcium content, only at certain times of the year does it precipitate out of lake water and fall to the bottom as a fine "rain" of solid calcium carbonate. This happens during spring and early summer when algal blooms occur in the warming surface water. In photosynthesis, the process by which plants make food, algae consume carbon dioxide. The chemical result of algal blooms then, extraction of carbon dioxide, is to leave in the water the right combining form of carbonate (the carbonate ion) which raises the alkaline level allowing calcium carbonate to precipitate out of solution and fall to the bottom.

In fall, the algae die and carbonate production stops. Algae settle to the bottom along with other dead organic matter, which has been settling all summer. Now, however, it lies exposed to decay. Bacterial fermentation uses oxygen and releases carbon dioxide which tends to make the bottom water less alkaline—the reverse of what was happening on the surface.

Some of the calcium carbonate mud is, therefore, redissolved, but not enough to offset the heavy precipitation during spring and early summer. The layer of decayed organic matter accounts for the dark layers which alternate with light layers in the laminated limestones in which the fossils are found.

Thermal stratification, which has been observed in lakes of warm, temperate climates, also may have contributed to good fossilization in Fossil Lake. In such a lake, warm surface water forms a separate and distinct layer over colder, deeper water. Oxygen in the surface water is supplied by winds and surface plant life, but little mixing occurs with the bottom layer. Here any available oxygen is consumed in the decay of organic matter. The result is an oxygen-deficient bottom layer in which scavenger creatures that might disturb the bottom cannot live.

Why Mass Mortality?

It is clear that for some reason many of the fish of Fossil Lake were killed under catastrophic conditions. Several mass-death layers are found in certain sections of the lake. Two are composed almost entirely of fish known as **Priscacara** and several others seem to be made up exclusively of **Knightia**. One of the **Knightia** layers is composed of extremely large numbers of fish, suggesting that several groups may have been wiped out.

Many causes could be responsible for these fish kills. A few algae are toxic to fish. It is possible that annual, summer algal blooms of this type may have caused the mass-death layers. These algae blooms would normally have occurred during the annual deposition of calcium carbonate and any fish killed at that time soon would have been covered with a protecting film of sediment.

Logically, fish that died after deposition of the annual layer of calcium carbonate would lie unprotected on the lake bottom, their bodies subject to attack by bacteria. This would explain the presence of thousands of specimens which are found totally, or at least partially, decomposed. The extent of decay would depend primarily upon the length of time a fish lay on the bottom prior to the next period of deposition. Those fish that died just after the annual deposition of calcium carbonate would lie exposed for most of a year and would be almost completely decayed. Fish that died months later would be only partially decomposed and be fairly well preserved (McGrew and Casilliano 1975).

Each fish lived its own life, died its own death, was entombed in the layers of limestone and found eternity as a fossil. Their remains, little by little, were covered by a fine deposit which embraced every fin and scale so gently that every delicate outline was preserved. Each year the protecting blanket became a little thicker until eventually the layers became the solid stone of the Green River Formation.

Fossil Lake died, or did it? It is true that it was filled with sediments and dried up but, we can still see the fish that swam in its waters, the plants and animals that lived along its shores, and the birds that flew in its skies. What can be said of the beautiful fossils preserved here for ages past and future, but that this much of the lake certainly still lives.

V. THE FISH

Compared to present-day fresh water lakes, the mixture of Eocene fish types in Fossil Lake and the other Green River lakes was curiously diverse. Many fish were strictly fresh water forms, but some were adapted to either fresh or salt water. Many fed primarily on plankton and were low on the food chain. Others were predators, feeding on smaller fish, and several were scavengers.

It is possible by studying the fossils closely to identify many individual species of fish. For a convenient sorting out of all of them, however, the more general name (the genus) is used. Plants and other animals were part of the Eocene lake and lakeside ecology, so some non-fish fossils are also mentioned in this chapter.

Many fascinating observations can be made about the ecology of Fossil Lake by looking at how each fish type was adapted for survival.

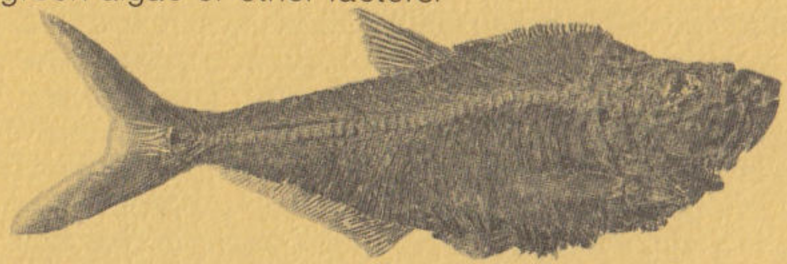
KNIGHTIA

By far the most abundant of the fishes from Fossil Lake is the genus known as **Knightia.** There are literally millions of them preserved. They were relatively small fish, 10-23 centimeters (4-9 inches) in length.

Knightia, now extinct are members of the family that includes modern herring. They formed large schools, much the same as the herring of today. Herring frequently enter rivers, adapting quickly to either fresh or salt water, and survive equally well in both.

Knightia apparently fed on plankton, and algae, and in turn were the main source of food for many of the larger, predatory fish. Eocene lake deposits in South America also contain fossil **Knightia,** so it appears that this genus was fairly widespread.

Towards the center of Fossil Basin, several death layers of **Knightia** can be found in a localized area. One of the layers is clearly a catastrophic mortality of several schools. This layer may show up in one quarry and be totally absent from another a short distance away. The obvious sudden death of so many fish could be explained by the presence of toxic substances produced by blue-green algae or other factors.



DIPLOMYSTUS

The second most common fish found in Fossil Basin is **Diplomystus**. They also belong to the herring family, although the larger ones, unlike their **Knightia** relatives, probably did not form large schools. It can be assumed that **Diplomystus** was a surface feeder because of its mouth structure. Smaller ones probably had a diet comparable to that of **Knightia.** However, it is evident that the larger ones included **Knightia** in their menu since partially digested remains are often found in their stomachs. Occasionally a specimen is found with a **Knightia** still lodged in its mouth, showing that it met its doom by choking on a morsel too large to swallow.

It appears that **Diplomystus** was even more widely distributed than **Knightia,** because the former are known from Cretaceous rocks from Brazil and Syria and also Tertiary deposits from Brazil and West Africa (Schaeffer and Mangus 1965).

Small **Diplomystus** are very common and larger specimens up to 56 centimeters (22 inches) in length are found frequently. A substantial percentage of the larger fish were damaged by decay before preservation, although perfect specimens are still plentiful.

Diplomystus had very thin skin and scales, which makes them by far the most difficult to prepare. Perfect preparation of a small specimen is almost impossible.

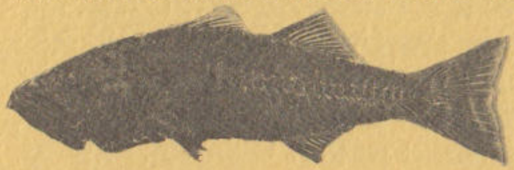
PRISCACARA

Priscacara is one of the most attractive fishes and is a favorite of collectors. They closely resemble present day sunfish, although the two are not in the same family. They were originally thought to be of the perch family, but it seems that they are more closely related to the basses (Schaeffer and Mangus, 1965).

Priscacara is the one genus that has no close living relatives. It is known only from the Eocene and may have become extinct shortly after that time (McGrew and Casilliano 1975).

The most striking feature of **Priscacara** is its long, thick anal and dorsal spines. These probably aided swimming and perhaps provided protection from predatory fish. Due to the similarity with sunfish, it can be speculated that **Priscacara** may have filled an ecological niche similar to contemporary sunfish.

Priscacara are found in much fewer numbers than **Knightia** or **Diplomystus,** but they are still common. They almost always range between 10 and 15 centimeters (4 and 6 inches) in length and 28 centimeters (11 inches) is considered to be gigantic and quite rare, although at least one 38 centimeter (15-inch) specimen is known. Curiously, this fish is almost never found as a juvenile.

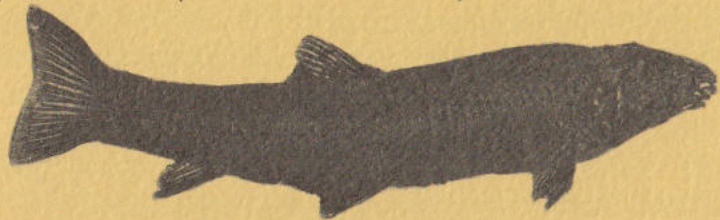


MIOPLOSUS

Although outnumbered about fifty to one by **Knightia,** **Mioplosus** is found in substantial numbers. **Mioplosus** is a perch and can be distinguished by its two separate and distinct dorsal fins. Contemporary forms usually frequent shallow water areas in large, clear lakes. Its jaws were equipped with many small, sharp teeth and its diet included smaller fish, such as **Knightia**.

Fossil **Mioplosus** normally are found measuring between 30 and 40 centimeters (12 and 16 inches) with larger individuals uncommon. Occasionally **Mioplosus** fry are found fossilized in groups and it would seem that schooling was common among juveniles. Larger fish were probably more solitary, venturing into deeper water frequently.

Of all the genera, **Mioplosus** is one of the easiest to prepare, due to its heavy bone structure and thick skin and scales. Damage frequently is present in the head region and bones are often shifted and out of place. Perfectly preserved specimens are not plentiful.



NOTOGONEUS

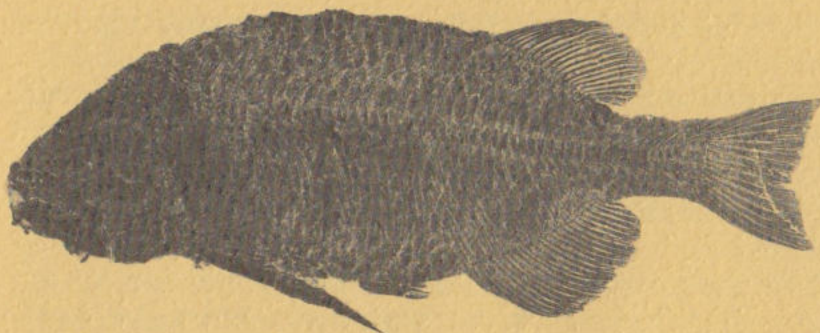
One of the most unusual fish occurrences in the sediments of Fossil Lake is **Notogoneus**. It had a long, slender body and was not an attractive fish. Its sucker-like mouth indicates that it was a bottom-feeding scavenger.

Partial remains of **Notogoneus** can be found in channel sandstone deposits, which were formed in stream beds, but complete specimens only appear in what was the center area of the lake. But if Fossil Lake was stratified most of the year, the lower layer was devoid of oxygen. What explanation would account for the presence of a bottom-feeder in such an inhospitable environment? It appears that dead specimens of **Notogoneus** must have floated in from other areas of the lake to sink in deep water.

Some of the fish have passed into extinction, but others like the gar have changed little since prehistoric times.

Discovery of a fossil **Notogoneus** is an uncommon occurrence, and they are considered to be one of the lake's uncommon fish. Eocene relatives of **Notogoneus** inhabited fresh water in France. One living species of the family still lives in western Pacific coastal waters.

Predator fish high in the food chain reproduce in smaller numbers than the fish they eat. This explains why some fossil types, such as Phareodus, are found infrequently. Other instances of rarity, however, are not so easily explained.



PHAREODUS

A large prepared **Phareodus** looks powerful with robust body, large fins and strong jaws set with numerous large teeth. **Phareodus** can approach 91 centimeters (3 feet) in length, and, because they were high on the food chain, are not abundant. Specimens discovered during a digging season can be counted on one hand, and small examples of this genus are even more scarce. The majority of discovered fossil specimens have been damaged, due to decay before preservation. A complete undamaged **Phareodus** is a treasure.

Phareodus possessed a long pectoral fin, which is one third the total length of its body. It was believed by some that this fin was used to scavenge on the bottom in shallow water and that this fish was primarily a scavenger. This may be partially correct, but it is obvious that **Phareodus** was a most efficient predator. Taking into account its stout body, it is clear that this fish was a very capable swimmer with excellent maneuverability. The tail structure and fin placement indicate that **Phareodus** could attack swiftly and pivot in an instant, giving prey little chance for escape.

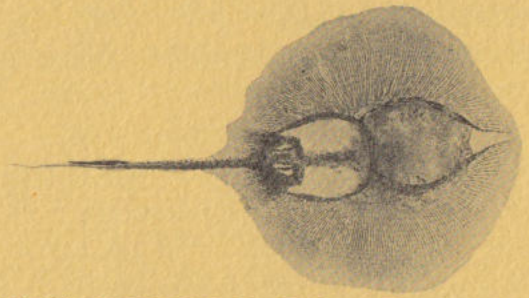
Poorly preserved remains are frequently found in channel sandstone deposits in the Bridger Formation, indicating a possible shallow water preference. Today, **Phareodus** appears to be most closely related to a genus which is restricted to rivers and lakes in tropical regions throughout the world (Schaeffer and Mangus 1965).

LEPISOSTEUS (gar)

Gars have been efficient and successful predators since the late Cretaceous and have changed little since that time. They are rare in the "fossil-bearing layer," but are found more frequently in channel sandstones formed in streams. Even today, gars favor river and stream environments. Several years ago a specimen over 1.5 meters (5 feet) long was discovered in Fossil Basin.

The gar's long jaws are equipped with many sharp teeth, which are used for catching prey. Gars are sluggish by nature and spend endless hours cruising close to the surface in a continuous search for prey. When a meal is sighted, the gar approaches very slowly until the morsel is positioned alongside its long snout. The fish then explodes into violent action and attacks with a lightning swift sideward sweep of its jaws, seldom missing. Due to its slow approach, the unsuspecting prey thinks the gar is not interested and the swift attack comes as a complete surprise. Gars are voracious eaters and will attack any moving thing that can fall into the category of food. Any creature too large to swallow is left unmolested.

Gars possess an air bladder with an open passage to the throat which they can use as a lung to supplement gill respiration. They rise to the surface periodically to discharge waste air and gulp in a fresh supply. This ability to breathe air directly enables them to survive in polluted water unfit for other types of fish. Today gars are common, especially along the Mississippi River drainage system.



XIPHOTRYGON (Sting Ray)

Of all the genera mentioned so far, the sting ray is by far the most rare. Each year only a few specimens are found in Fossil Basin. This would be expected because sting rays live strictly on the bottom in shallow water. This again brings up the mystery of their presence in the deep, stratified center area of the lake.

Fossilized sting rays are extremely rare in the "fossil-bearing layer" quarries, but they seem to be more common in the split-fish quarries higher up in the formation. It is possible that sting rays were more common in Fossil Lake at the time those split-fish sediments were deposited and were not as successful at the time the "fossil-bearing layer" was laid down, or the split-fish deposits may have originated closer to shallow water.

Its small backbone makes the outline of a fossil sting ray difficult to detect in the rock. Because of this, it is probable that many specimens have been thrown away and lost forever. It is remarkable that these creatures were fossilized at all. Sting rays are not bony fish, but are related to sharks. Their skeletons are composed of cartilage, which usually does not preserve as well as bone. On the tail a stinger is present, which can prove lethal to many creatures. Even with this weaponry, a sting ray is a most docile and defenseless creature and can in no sense be called aggressive. Present sting rays live mostly in marine water, although several freshwater forms still exist.

AMIA

Amia is one of the rarest fish found in Fossil Basin. Only a few complete specimens are known to have been discovered during the hundred years the site has been worked. Amia is a predator and therefore high on the food chain, so it is understandable that they would be uncommon, but, on the other hand, they are usually very successful in areas where they have become established. Their extreme rarity in Fossil Basin is a mystery. Fossil Amia can be found in many rock formations in Europe and they have been fairly widespread in this country.

The Amia of today is commonly known as bowfin. It is a nocturnal predator, a strictly fresh-water fish, as were its predecessors.

Amia is a primitive fish. With the exception of the loss of ganoid scales, it has changed little since its introduction during the late Cretaceous. Amia possesses an air bladder like the gar, and can rise to the surface every few minutes to take on a fresh supply of oxygen. They can live in water containing too low an oxygen supply for most other species. For this reason, they are tough fish, and specimens kept out of water for 24 hours often survive without apparent harm.

POLYDON (Paddlefish)

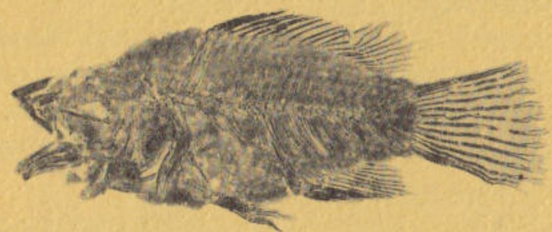
The paddlefish is extremely rare in Fossil Basin, and so far, fossils have been incomplete. Paddlefish of today

Collectors who remove fossils under Wyoming permit from quarries outside the monument are required to turn over rare finds for scientific study.

prefer river habitat, and those found in the sediments of Fossil Lake may have accidentally strayed into the lake while searching for food. Paddlefish feed by straining plankton out of the water with their long gil rakers. Similar forms still survive in the rivers of China and the Mississippi River in the United States.

ICTALURUS (Catfish)

Catfish are extremely rare in Fossil Basin. Only a few specimens are known. Catfish are shallow water scavengers, and, although they are not commonly present in the sediments of Fossil Lake, they are occasionally found in the stream channel deposits of the Green River System. Catfish appear to be found most frequently in the deposits of Lake Gosiute.



ASINEOPS

Asineops is seldom found in the sediments of Fossil Lake, but several other localities occasionally produce an excellent example. Here again, Lake Gosiute seems to be the primary source of known specimens. This genus may seem to be more scarce than it actually is. Insufficient research has been conducted in the split-fish quarries above the "fossil-bearing layer" where it is likely that Asineops may occur more frequently.

ERISMATOPTERUS & AMPHIPLAGA

Small, rather nondescript, plain-looking, these trout perches have living relatives in North America. They are both known from the deposits of Lake Gosiute, but only Amphiplaga has been found in Fossil Basin. Erismatopterus has not yet been documented from Fossil Basin, but it could possibly be here. Both these fish probably fed on a combination of insects and small crustaceans.

OTHER FOSSILS

Fossils other than fish can be found entombed in the sediments of Fossil Lake. Fossil leaves commonly display every minute detail that was present when they settled to the bottom. Beautifully fossilized insects are also plentiful, but only from certain layers. Complete palm fronds, some over 1.8 meters (6 feet) across, are occasionally found.

Although fossil fish are common, other vertebrates are extremely rare. During the hundred or more years the site has been worked, only a handful of birds have been uncovered, although individual feathers are frequently found in the lake sediments. In another area of the Green River Formation, bird trackways are fossilized in Eocene mud flats. Many of these tracks were made by flamingoes, showing not only footprints, but also beak marks, created by the side to side motion of feeding.

A few turtles are known among the deposits of Fossil Lake, but only one of large size. Fossilized bats have been found and one beautifully preserved snake. A large crocodile was discovered close to Fossil Lake and at least one small specimen is known from the sediments of the lake itself.

At the quarry, collectors raise limestone in large, heavy slabs so that individual specimens are less likely to be broken.

VI. THE FOSSIL HUNTERS

It is not difficult to project the possibility of discovery of Green River fossil fish by Indians long before Europeans arrived in North America. Imagine the amazement and confusion such a discovery would bring—a fish transformed into rock when fish were only known to be swimming full of life in rivers and streams!

Of course, there is no record of such a first find, but arrowheads left near Fossil Butte show that Indians perhaps were the first fossil hunters in the area. More recently, science, with its convincing explanation of what fossils are, stimulated the search which has come to involve professional geologists and paleontologists in addition to non-scientist collectors. Most of those who collect and prepare fossils commercially appreciate the scientific importance of their activity.

In a frontier west filled with enterprising individuals, the geologist's hero is Ferdinand Vandiveer Hayden, whose fossil collecting expeditions laid the foundation for the government's geological and geographical surveys of the territories.

The Professionals

The first recorded Green River fossil fish were collected in 1865 by a geologist named John Evans. Then, during the summer of 1868, Ferdinand Hayden, soon to become Director of the newly established Geological and Geographical Survey of the Territories, conducted a geological reconnaissance of the Wyoming Territory. In the area of present-day Rock Springs and Green River, he observed a distinctive sequence of rocks and went on to forecast lasting scientific interest in the area in his annual report of 1869.

In this first published notice of the Green River shales, Hayden states: "A little east of Rock Spring station a new group commences, composed of thinly laminated chalky shales, which I have called the Green River shales, because they are best displayed along Green River. They are evidently of purely fresh-water origin. . . . When carefully studied, these shales will form one of the most interesting groups in the West. . . . The fauna consists of . . . vast quantities of freshwater fishes, preserved in much the same way as those in the Solenhofen slates of Germany.

One of the marked features of this group is the great amount of combustible or petroleum shales, some portions of which burn with great readiness, and have been used for fuel in stoves." (Schaeffer and Mangus 1965).

When Hayden compared the similarity of the Green River fossils to those of Solenhofen, he most likely was referring to the quality of preservation rather than the way the fossils were formed. The lithographic limestones of the world famous Solenhofen site were deposited in a salt water lagoon, unlike the fresh water sediments of the Green River Formation.

Before long other geologists joined Hayden in the area and it soon became apparent that the Green River Formation was quite extensive. Vertebrate paleontologist E.D. Cope, a new member of the survey in 1870, investigated a large number of fossil fish discovered earlier by railroad workers during excavation of a cut two miles west of Green River. Cope's description of the fish from the "petrified fish cut" on the Union Pacific Railroad appears in Hayden's 1871 report.

Later in 1884, Cope published "The Vertebrata of the Tertiary Formations of the West", which described 25 to 30 species of Green River fish. "Cope's Bible," as it is called, takes a certain amount of strength to carry, since he filled it with thousands of fossil descriptions including drawings.

A. C. Peale was the first to mention fish quarrying at the famed Twin Creek location in the vicinity of Fossil Butte. Cope may have collected there a little earlier, but he does not specifically describe the site. In the early days, Fossil Butte and Fossil Ridge to the south were collectively referred to as the Twin Creek site. That title was used until only very recently.

Since those early days, very little work has been done on the Green River fossil fish, although extensive research has been directed towards the geology of the area. From the 1920s to the 1960s, W. H. Bradley devoted much of his life towards research on the geology of the region. He also studied and reported the climatic and environmental conditions that existed at the time these sediments were deposited during the Eocene. Much of the present knowledge about the Green River Formation is due to his dedicated work.

Recently Dr. Paul McGrew, of the University of Wyoming, has been researching the Green River Formation. The difference between McGrew's work and that of many of his predecessors is the fact that much of it has been in Fossil Basin itself, the home of Fossil Butte.

Many other devoted scientists have contributed research on the Green River Formation, among them Leidy, Marsh, Brown, Schaeffer and Mangus.

The Collectors

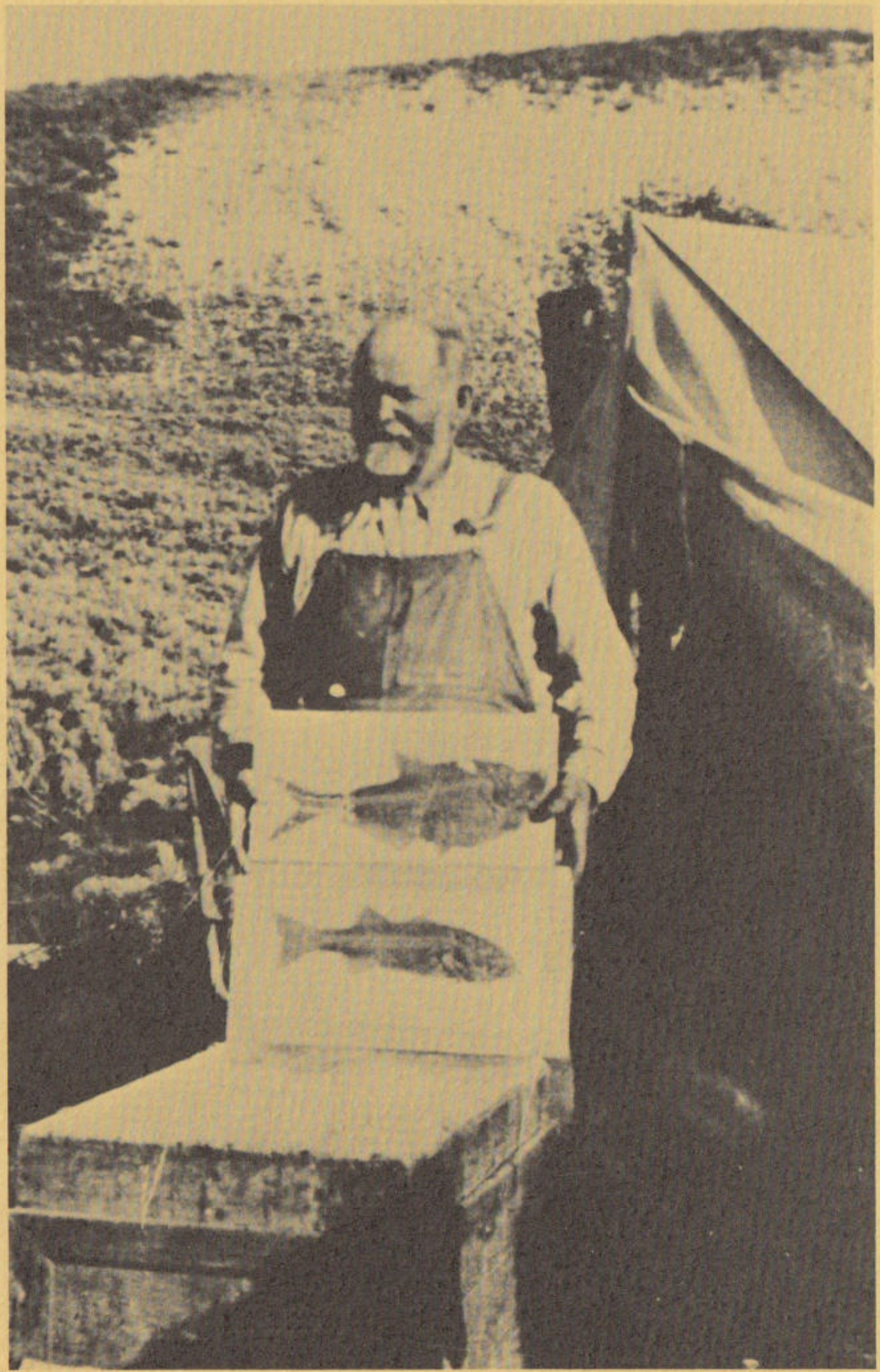
Discovery of the "petrified fish cut" during construction on the Union Pacific Railroad, focused attention on the Green River shales and marked the beginning of continuous collecting to this day. Exactly when collecting may have started at the famous Twin Creek site is not certain, but here is where the best specimens were found.

Little is known about the early collectors. Photographs attest to their presence but their names are unknown. Some were local coal miners who quarried the fossils for part time income. Most of them probably came and went through the now-defunct town of Fossil, west of Kemmerer.

After the early days a series of semi-official caretakers worked the Twin Creek site commercially. At the turn of the century, Robert Lee Craig discovered his fossil hill and life's work when passing through the area. Before that he worked with Fred Brown, leader of the expeditions which contributed dinosaurs to the Smithsonian Institution collection.

Craig was a remarkable man. He spent about forty years quarrying fish, despite the fact that he had only one leg. He made the long hike and climbed the sheer buttes using a gnarled stick which served as a cane.

Using only a pocket knife, Robert Lee "Pegleg" Craig prepared many of the fossils that are still on display in museums in this country and abroad. He quarried in the summertime, living alone in a tent, and prepared his "catch" in winter, working in a small shelter adjoining the hotel in the town of Fossil where he sold his fish to passersby.



During the 1930s and until the start of World War II, the Haddenham family dug the fish in the summer, prepared them in the winter and sold enough to make a living. After the war, the elder Grandad, David C. Haddenham returned to the diggings and devoted the rest of his life to working the buttes. During those years he provided some of the leading museums and universities of the world with unusual fossil specimens.

Objects of Antiquity

The wisdom of preserving fossils for educational purposes has been recognized in law since the Antiquities Act of 1906. This legislation made it illegal to remove or injure "objects of antiquity" found on federal land. Today fossil collecting on government property is allowed by permit only when it is for the increase of knowledge.

For many years the famed Twin Creek area has been closed to collecting under the protection of the Antiquities Act. Fossil Butte, included in this area, was protected further in 1972 when it became a national monument. Outside the monument, commercial quarrying and collecting activities continue at quarries on Wyoming State land. Fossil fish not of the six main genera, along with any other vertebrate fossils, must be turned over to the State of Wyoming for research and study.

Present collecting methods are totally different than those of early days. Instead of pick, shovel, and wheelbarrow, the time-consuming operations of stripping overburden and removing debris are done with bulldozer and scoop. This makes more time for splitting the laminated limestone and removing the fossils.

Although pick and shovel are still necessary, the most important and delicate operation of splitting is done with fine bladed knives. The limestone is split again and again so that every possible specimen is recovered. Any carelessness or excess speed may damage the specimens. Even with extreme care, many are lost. A slab of limestone so thin that it cannot be resplit may contain small specimens still hidden from sight. Many other fish cannot be salvaged because they lie near natural seams in the rock which have allowed stray weathering elements free entry.

It takes the discipline of an artist to prepare Green River fossil fish. The methods and skills for fossil preparation are not that difficult to learn, but they require patience. Several hours are needed to prepare even a small fish, and a large one can take a hundred hours or more. Chisels, knives, files, and sandpaper can be used to remove the layers of limestone which cover a fossil specimen. However, upon reaching the fish itself, the final layers must be removed with needle sharp points. Using light pressure, the limestone is slowly turned into powder and blown away. Although this method is time consuming, it is the only preparation technique that will leave the specimen intact.

Nostalgia glimmers in an old snapshot of friends at the tavern. Sheepherders, railroad workers, and travelers mingled with the local fossil "fishermen" telling tall stories.

The town of Fossil grew to its greatest size about 1930. Even though the reputation of the fish was becoming international, it was not enough to support a local economy that died with the loss of the railroad.

VII. TOWN AND MONUMENT

Today's view of Fossil is only a reminiscence. But the ruins quietly flavor the scene with a definite taste of the past.

Early pictures of Fossil Butte show that its face was covered with beautiful cathedral-like rock spires. They are gone now, consumed by the picks and hammers of the early fossil collectors. Even so Fossil Butte is a spectacular landmark. Creation of Fossil Butte National Monument in 1972 recognized the importance of preserving this famous site by making it a part of the National Park System.

Now during the summer months, park rangers answer visitors' questions and point out interesting natural features. Many visitors climb to the top of the butte, along a trail with wayside interpretive exhibits. Collecting is prohibited, of course, everywhere in the monument.

At the base of Fossil Butte, not far from where the rangers run a small museum and visitor station, is the townsite of Fossil. It always starts my imagination when I think of this old ghost town. In the past, you could wander about what was left of the place.

The first townsite was established in 1882 east of here towards Kemmerer. It consisted of a railroad enginehouse and depot along with section and maintenance houses. At first its only purpose was to service the trains, but in 1884 people began to settle, and the town became headquarters for local sheep ranching outfits. Due to the steep grade, westbound trains could not slow down soon enough to stop at the original site, so in 1902 the railroad company moved its buildings a mile west, a short distance from Fossil Butte. The townspeople followed, and soon a tavern, hotel, and church were built.

The town was relatively short lived. Its recorded population reached 151, and then declined during the 1930s. In 1945, the post office was moved to Kemmerer when the town died.

The hotel had deteriorated badly when I was there. The tavern, only a few feet away, was weathered and worn, the years having taken their toll on this former oasis in the sagebrush. The depot was still standing, but the railroad tracks had been taken up long ago. The roof of the tavern would have leaked like a sieve in a rain. The windows were smashed, allowing storms free entry, and any semblance of paint had long since disappeared. But the basic structure was sound. New owners have plans to restore the hotel and tavern.

The interior of the tavern was faded but little changed from the old days. The long wooden bar was stained from leaking rainwater and covered with a thick layer of dust. Behind it was a huge mirror, with glasses and stacked poker chips still decorating the shelves below. In the corner stood an old piano covered with mounds of outdated newspapers.

Gone were the miners, sheepherders and railroad workers who came here to escape the heat of the day and share a drink with friends. Gone were the old fossil fishermen who would join them, after a hard day's work, to discuss the day's "catch" and talk about the one that got away. It was quiet now, peaceful and cool away from the glare of the sun outside the swinging doors. The aroma of sagebrush drifted in, carried by the wandering winds.

I sat down, relaxed and listened. Far in the distance I heard it. A piano was playing a quick and catchy tune. Vague shadows moved about the room. The sounds of muted conversation and laughter mixed with the clatter of bar glasses, the clink of poker chips and the scraping of chairs across the wood floor. An odor consisting of a curious combination of tobacco smoke, sweat and stale beer permeated the air. I was there. In my imagination I was surely there.