Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

A Lifetime of Geologic Discovery
Mammoth Hotel Strike
Fossil Beetles

Volume 5 Number 4

In Old Infancy

This year marks the 125th anniversary of Yellowstone, first national park in the world. I thought first how this issue presented stark contrasts in how researchers define and document the history of the "old" park. While we wonder today if the unceasing wetness of 1997 is an aberration or the start of a new trend—possibly the result of *El Niño* or global warming—Scott Elias reminds us that over "just" the last 125,000 years, conditions and plant and animal species were often quite different from those in Yellowstone's more "recent" climate history—the last 14,500 years—reconstructed through studies of fossil beetle data.

Changes in the park climate, and other things, come up again in our interview with geologist Irving Friedman, who discusses dating lava flows and monitoring geysers and hot springs. In a fortuitous accident, Dr. Friedman's geologic work turned out to also be of great value to cultural resource managers. But, thinking only of the contrast between the scale of geologic and human history in greater Yellowstone, I was surprised to find that the park archeologist was quite familiar with obsidian hydration dating and its applications in her field of study.

The scale of time in which scientists work ranges vastly, affecting each researcher's perspective. So also do the time frames within which humans view such things as the vegetation of the northern range, patterns in weather and geyser eruptions, and fluctuating numbers of animals that influence their attitudes about whether or how we should manage park resources.

Perhaps I had underestimated how strong the cultural-natural connections are, or should be, among our scientists and managers. How humans view their own role over time in relation to the environment also influences their attitudes about landscape management. National park policy is often portrayed as attempting to exclude human influence from the landscape. Too often, the park is described as a model (to emulate or not) for *natural* resource conservation. Only in recent years has it begun to gain widespread recognition for its role in *cultural* resource preservation. And organizationally, we still tend to view natural and cultural resource research and management efforts as separate (and sometimes conflicting). Yet, as we learn more about how prehistoric and historic humans used the lands and resources we continue to value, we hear more discussion about how to factor humans into our mission to conserve parks "unimpaired for future generations."

As Brit Fontenot points out in his article, Yellowstone is not—and, even in its infancy, was not—isolated from human influences and societal trends affecting the rest of our nation and other environments. This October, we celebrated the cultural-natural connections with our fourth biennial scientific conference. Historians, writers, ethnographers, archeologists, biologists, geologists, and others met to discuss *People and Place: the Human Experience in Greater Yellowstone*.

We are eager to present more articles on greater Yellowstone's cultural resources, and encourage relevant submissions, just as we continue to seek new information from natural scientists. And we encourage researchers and managers in both fields to discuss the connections between their disciplines. We know that it takes *time* to write such material. But, for students of greater Yellowstone, who operate on human, not geologic, time scales, we think it would be worth it. SCM

Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

Volume 5 Number 4 Fall 1997

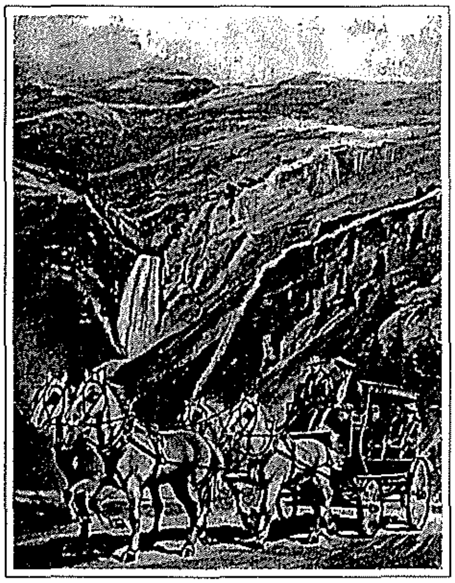


Table of Contents

Editor
Sue Consolo-Murphy
Art Director
Renée Evanoff
Associate Editor
Sarah Broadbent
Assistant Editor
Mary Ann Franke
Printing
Artcraft Inc.
Bozeman, Montana

On the cover: Autumn in the Boundary Creek thermal area in the southwest corner of Yellowstone. See related interview page 9. Photo by Jennifer Whipple. Above, the cover of an early Yellowstone Park Association Hotels brochure (1900s), see Historical Vignette page 15.

Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190.

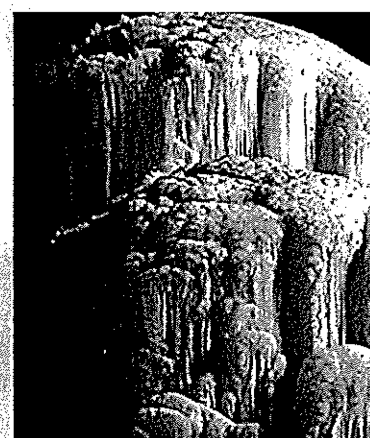
Support for *Yellowstone Science* is provided by the Yellowstone Association for Natural Science, History & Education, a non-profit educational organization dedicated to serving the park and its visitors. For more information about the Yellowstone Association, including membership, write to P.O. Box 117, Yellowstone National Park, WY 82190.

Yellowstone Science is printed on recycled paper with a linseed oil-based ink.

Reconstructing Yellowstone's Climate History

How Departing Glaciers, Flora, and Fauna Left Their Mark

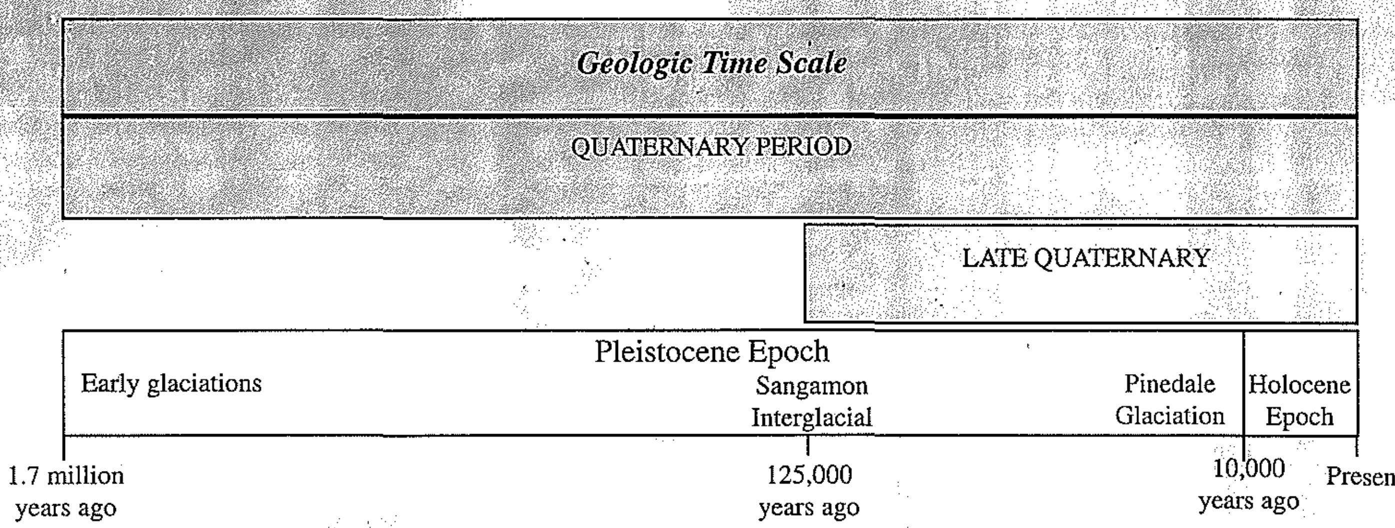
by Scott A. Elias



During the last 125,000 years, the glaciers of the last ice age moved southward to cover Canada and much of the northern United States, and then began to melt as the climate shifted again. This still unfolding period, referred to as the late Quaternary, bridges the interval between the ice-age world of prehistoric species, some of which are now extinct, and modern biotic communities. To try to understand how our present day ecosystems are responding to environmental changes without a knowledge of this history would be like trying to understand the plot of a long novel by reading only the last page.

The study of past ecosystems is a form of detective work, investigating the available evidence to reconstruct what, where, when, and how something happened. In trying to retrace the steps of the ice age, you might say that the trail of clues has grown exceedingly cold, with the suspects and witnesses all long dead. But the task is not impossible. While geological evidence helps us determine the timing of glacial events, the extent of the ice flow, and its impacts on regional landscapes, fossil remains can provide information about ice-age flora and fauna, and their response to environmental changes.

For about 25 years, geologists and paleontologists have been collecting these kinds of data to reconstruct how the Yellowstone area has been affected by climate shifts during the late Quaternary. The following article summarizes some of the research that has been done on the park's glacial and paleoecological history (adapted from my book, *Ice-Age History of National Parks in the Rocky Mountains*, 1996), and my own reconstruction of climate change based on beetle fossils.



Yellowstone's Last Glaciers

The most recent large-scale glaciations of the Rocky Mountain region are the Bull Lake and the Pinedale, both named for places in the Wind River Range of Wyoming. During the 1960s, the general consensus among geologists was that the Bull Lake ice advances were the first since the Sangamon Interglacial warming period, which would mean that the Bull Lake Glaciation began no more than about 110,000 years ago. But evidence from the Yellowstone area has suggested otherwise. Rapidly cooling lava forms obsidian, a natural glass such as that found at Obsidian Cliffs, where molten lava is thought to have encountered Bull Lake ice. The rhyolite flows (extruded, fine-grained volcanic rock) at Obsidian Cliffs have been dated by obsidian hydration at about 150,000 years old. On this basis, according to geologist Ken Pierce (1979), Bull Lake ice appears to have formed in Yellowstone before the Sangamon Interglacial.

In most Rocky Mountain regions, Bull Lake moraines extend farther down-valley than Pinedale moraines. In the western Yellowstone area, Bull Lake ice reached an average of 20 km (12.4 miles) farther than the subsequent Pinedale Glaciation. But on the north side of the park, Pinedale ice pushed beyond the Bull Lake limit, obliterating terminal moraines left by the previous glaciation, which appears to have occurred after the Sangamon Interglacial in some regions and before it in others. So Bull Lake Glaciation has not been clearly defined as an event in a single interval of time.

The Pinedale Glaciation brought an immense cover of ice centered along a north-south axis through Yellowstone Lake in a line about 150 km (93 miles) long, with ice flowing radially to the northeast, west, and southwest. Glaciers from the Absaroka and Gallatin ranges and the Beartooth Highlands in the north filled the Lamar and Yellowstone river valleys, then flowed northwest into Montana (Fig. 2), converging near Gardiner to drain ice from northern Yellowstone. Glaciers in the southern Absaroka Range flowed west into Yellowstone, occupying the depression now filled by Yellowstone Lake, and then down the Hayden Valley. The two ice masses came together and covered all but the southwestern edge of the park, burying its valleys and Central Plateau region under about 700 m (2,300 ft) of ice.

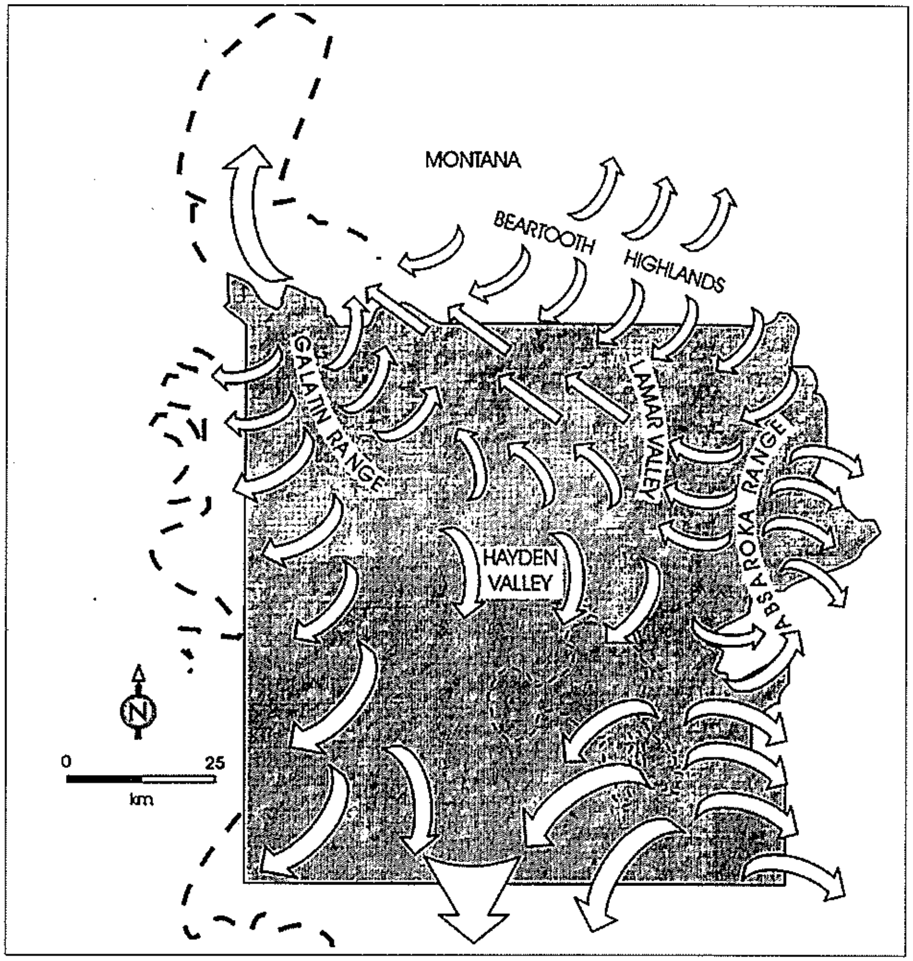


Fig. 2. Map of Yellowstone National Park, showing extent and patterns of movement of glacial ice during the last glaciation (from Elias, 1996).

The relationships between glacial and travertine deposits in northern Yellowstone, particularly around Mammoth Hot Springs, were analyzed by Neil Sturchio and other geologists (1994). They found that some of the travertine deposits are covered by Pinedale deposits, some overlie older glacial deposits, and others lie within pre-existing deposits. Their chronological reconstruction showed that an early ice advance occurred between 47,000 and 34,000 years before present (yr B.P.), and the

Years Before Present	Pinedale Glaciation in Yellowstone
47,000	
	Early ice advance
34,000	
	Interstadial interval
30,000	
	Extensive ice advance
22,500	
	Major ice recession
19,500	
	Minor readvance
15,500	
15,000	Ice margins retreat rapidly
14,000	Park lowlands free of ice

Fig. 3. Chronology based on travertine deposits near Mammoth Hot Springs.

lower areas of the park were probably completely free of ice by about 14,000 yr B.P. (Fig. 3).

Evidence of the Pinedale Glaciation abounds in the Yellowstone area. When blocks of ice were stranded during the ice retreat at the end of the Pinedale Glaciation, they became buried by glacial outwash and lake sediments. The depressions left behind when the blocks melted became kettle holes, now small ponds that dot the landscape in many park locations. Glacial deposits, characterized by their poorly sorted load of boulders, cobbles, sands, and silts, can be seen in Soda Butte Creek, the Lamar Valley, and Yellowstone Canyon. A glacial erratic boulder weighing about 500 tons was deposited near Inspiration Point. Between Geode and Oxbow creeks, west of Tower Junction, is an ancient stream deposit that formed when meltwater ran along the edge of a Pinedale glacier. A deep channel that carried glacial meltwater can be seen north of Gardiner, and Pinedale's terminal moraines can be seen several miles further north of the park, at Eightmile Creek and near Chico Hot Springs, Montana.

The Grand Canyon of the Yellowstone, however, was not marked by the flow of Pinedale ice. Geologic evidence indicates that the canyon was cut before the Pinedale Glaciation, by the Yellowstone River over many millennia. Ice from an earlier glaciation filled the canyon and protected its walls from scouring as a Pinedale glacier flowed across it. The bedrock source of the large glacial erratics perched on the rim of the canyon near Artist's Point (Fig. 4) lies to the northeast, in the Beartooth Mountains. Ice also dammed the Yellowstone River near Canyon Village, creating a lake in the Hayden Valley area whose sediments have been exposed in the bluffs cut by Elk Antler Creek and other streams.

Toward the end of the Pinedale Glaciation, as ice flowing from the Beartooth region receded to the Tower Falls area, its southwest margin dammed the Yellowstone River, forming a lake that reached a depth of about 180 m (590 ft) in the canyon. Called "Retreat Lake" because it was created by the retreat of regional ice, it nearly filled with silt before the ice stopped receding and the dam melted. Its initial outlet was near Lost Lake, at an elevation of about 2,100 m (6,890 ft). As the ice receded and this outlet channel was abandoned, new outlets formed at lower elevations near Tower Junction. The use of progressively lower outlets formed the canyon known as "The Narrows," and the sediments that had nearly filled Retreat Lake were cut through by the Yellowstone River, leaving many gravel-covered terraces along the canyon walls.

In Cold Terms

Glacial erratic — a boulder gouged out of bedrock by glacial ice, carried along with the ice flow, and then dropped as the ice recedes.

Glacial moraine — a mound or ridge of unsorted glacial debris, deposited by glacial ice in a variety of landforms.

Glacial outwash — a long interval between glaciations in which the climate warms to at least the present level.

Interstadial — a relatively warm climatic episode during a glaciation, marked by a temporary retreat of ice.

Terminal moraine — the end moraine that marks the farthest advance of a glacier or ice sheet.

When glacial lakes drain, the results are sometimes catastrophic. According to Ken Pierce, at least two floods that were 45-60 m (150-200 ft) deep rushed down the Lamar and Yellowstone drainages as Pinedale ice retreated. A flood deposit from the late Pinedale period can be seen between the road and the river about 5 km (3.1 miles) northwest of Gardiner. A river channel bar deposit 20 m (65 ft) high and 450 m (1475 ft) across, covered with giant ripples, extends for about a kilometer, along with other bars and boulder ridges. The downstream side of the ripple crests is littered with boulders up to 2 m (6.5 ft) in diameter. The floodwaters apparently swept up materials from moraines in the Deckard Flats region and carried them downstream. Elsewhere on the north side of the park, late Pinedale floods scoured landscapes and laid down flood deposits at the mouths of Reese Creek and Yankee Jim Canyon.

The Northern Yellowstone Outlet Glacier, which flowed north out of the park during the Pinedale Glaciation, exited the park at Gardiner, leaving behind well-preserved scour marks and deposits, especially where the topography and bedrock favor their development. On Dome Mountain divide above the Yellowstone River, ice scoured the bedrock to form

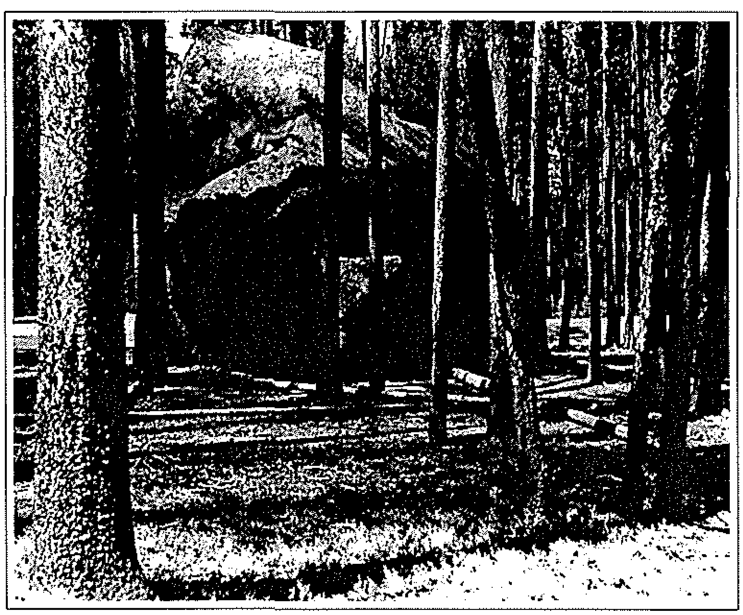
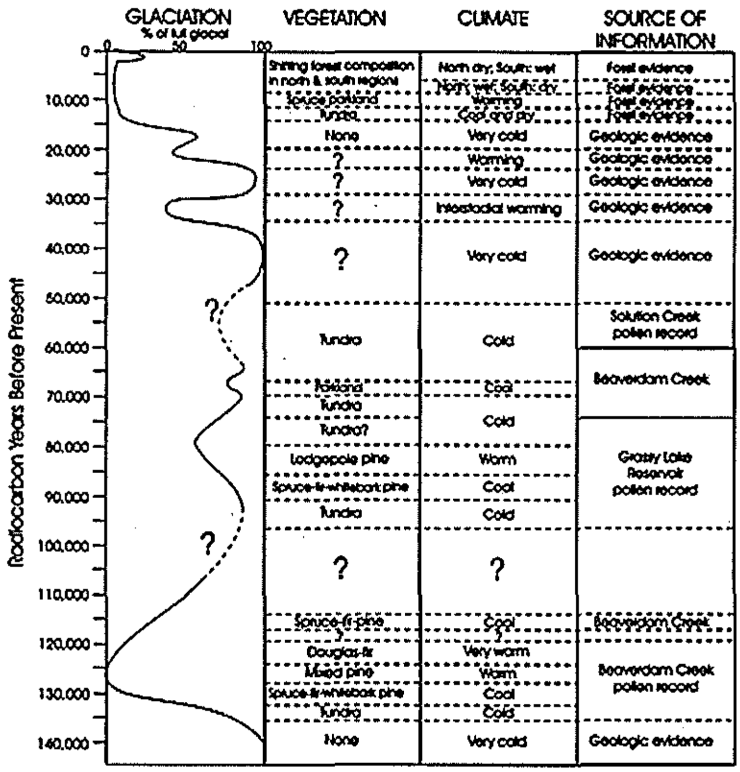
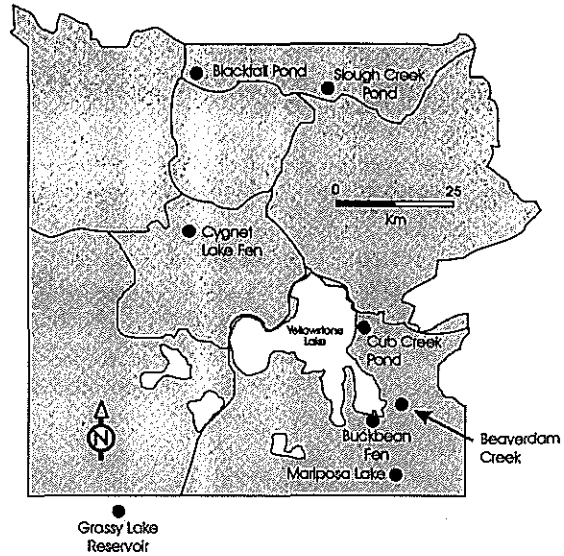


Fig. 4. A glacial boulder near Inspiration Point. Courtesy of the Yellowstone archives, reference YELL 35135-2.





Figures 5 and 6. Summary of environmental history of the Yellowstone region during the last 140,000 years, based on geologic and paleontological dates, and map showing location of fossil sites.

depressions and left mounds of debris in small ridges and hills. Exposed bedrock here was polished smooth by the glacier.

Elsewhere in the park, the interaction of receding ice and hot springs created interesting landscape features. In the Mammoth Hot Springs area, the late Pinedale glacier melted erratically, littering the landscape with large blocks of ice that were buried by sediments left by the receding ice margin. When the ice blocks finally melted, they left a series of alternating depressions and small hills, referred to as a "kettle and kame" landscape. This topography is common throughout the Yellowstone region, wherever blocks of ice were left stranded by receding glaciers. Just south of Mammoth, the cone-shaped Capitol Hill and other nearby features are probably glacial sediments left by ice that was melted by hot springs.

Late Pleistocene Vegetation

An important tool in researching Quarternary paleoecology in Yellowstone is palynology, the study of modern and fossil pollen. Many plants, especially wind-pollinated plants such as conifers, produce an abundance of pollen; a single lodgepole pine may produce 21 billion grains a year. With an extremely durable outer wall that resists decay, pollen may be preserved for thousands of years if it lands in a lake or bog.

Since the Bull Lake and Pinedale glaciers have largely obscured evidence more than 140,000 years old, paleoecology in Yellowstone begins at the last interglacial, the Sangamon. Geologist Richard Baker has studied pollen and plant macrofossils from lake sediments that were deposited at several sites during Sangamon and early Pinedale times (summarized in Fig. 5, with a map of the sites shown in Fig. 6). Sediments from Beaverdam Creek, near the east shore of Yellowstone Lake, yielded botanical evidence of a transition from late glacial to full interglacial environments, thought to represent the onset of Sangamon climate. A cold, pre-Sangamon climate supported tundra vegetation that gave way to forest typical of the subalpine zone today: spruce, fir, and whitebark pine. At the peak of the warm period, about 127,000 yr B.P., regional forests were dominated by Douglas-fir, with limber and ponderosa pine. These trees grew at sites above their modern elevational limits, suggesting a climate warmer than today's. When the climate cooled again, the subalpine spruce-fir forest became dominant once more, with a return to tündra as Pinedale glaciation began.

A gap in pollen-bearing lake sediments appears from the end of the Sangamon Interglacial through the early part of the Pinedale Glaciation. The first evidence of Pinedale environments comes from the pollen record of Grassy Lake Reservoir, just south of the park, which indicates an interstadial interval that progressed from cold to warm to cold again. This interstadial is stratigraphically above (and hence younger than) sediments containing pollen that indicate full-interglacial conditions, but below (older than) the Pitchstone Plateau rhyolite lava flow, which is dated at 70,000 yr B.P. The early Pinedale interstadial therefore probably began about 95,000 yr B.P., when the vegetation sequence of tundra to spruce-fir forest was repeated. However, the warming pulse was not strong enough to usher in full interglacial conditions; it culminated in the establishment of lodgepole pine forest in the Yellowstone region from about 85,000 to 80,000 yr B.P. Because the Central Plateau region of Yellowstone is underlain by rhyolite bedrock, which produces relatively infertile soils that are unfavorable to other regional tree species, it was essentially treeless during periods when the climate was unsuitable for lodgepole pine, even though spruce, fir, and whitebark pine were growing elsewhere in the region.

When colder conditions returned about 80,000 yr B.P., forests gave way to tundra again. Increased pine, spruce, and fir pollen at the Beaverdam Creek site indicate that another warming took place after 70,000 yr B.P., but lasted no more than a few thousand years. From about 68,000 until at least 50,000 yr B.P., the landscape was covered by tundra, based on pollen assemblages from a site at Solution Creek studied by geologists Gerry Richmond and J. Platt Bradbury. No pollen-bearing sediments have been found that date from 50,000 to 14,000 yr B.P. We do not know if glaciers were present before Pinedale ice arrived about 30,000 yr B.P., or if the climate was just too cold and dry for vegetation.

Several late Pinedale-age sites in the Yellowstone area have provided pollen assemblages that have been studied by Richard Baker and Cathy Whitlock. Blacktail Pond, which lies at just over 2,000 m (6,560 ft) near the northern park boundary, was deglaciated about 14,500 yr B.P., and the pond sediments began accumulating pollen about 14,000 yr B.P. The oldest pollen assemblages indicate that tundra vegetation gave way to spruce parkland by about 12,800 yr B.P. The Blacktail Pond region supported only spruce parkland in the early part of the late glacial warming, while the vegetation records from sites farther south, such as Buckbean Fen, show moisture-loving plants such as dwarf birch, and forests that included fir and poplar. The late-Pleistocene differences in climate and vegetation between north and south have become even more pronounced in recent times.

The Yellowstone area become forested about 12,000 yr B.P. Engelmann spruce was the first conifer to become established in most places, followed by whitebark pine and lodgepole pine. Pollen records from northwestern Wyoming suggest that Engelmann spruce migrated north as ice retreated, at a rate of about 200 m (656 ft) per year. All of the conifer species currently found in the park were apparently able to survive the last glaciation in ice-free regions of northwestern Wyoming.

As conditions warmed, Yellowstone's treeline climbed 450 m (1475 ft) in 300 years as conifer forests became established on higher ground. After 10,500 yr B.P., the southern region of the park was covered with forests typical of modern subalpine regions. Pollen assemblages from Cygnet Lake Fen show that by about 10,000 yr B.P. lodgepole pine had spread northward to the Central Plateau, where it has been the dominant species ever since.

Late Pleistocene Mammals

Because few deposits containing Pleistocene vertebrate remains have been found in Yellowstone, most of our knowledge of regional faunas comes from sites outside the park. Probably the most important of these is Natural Trap Cave (east of the park near the Montana-Wyoming border), where sediments have preserved bones characteristic of late Pinedale times, dated from 21,000 to 11,000 yr B.P. Among these remains, Miles Gilbert and Larry Martin (1984) have identified extinct animals (dire wolf, short-faced bear, American lion, American cheetah, mammoth, four kinds of North American horses, American camel, woodland musk-ox, and extinct species of bighorn sheep, bison, and pine marten); species no longer native to the area (collared lemming and Arctic hare); and many mammals still found in northwestern Wyoming (antelope, gray wolf, cottontail rabbit, chipmunk, pocket gopher, and several species of rodents). While most of the extinct species from these deposits are large mammals, all of the species still present today are small- to medium-sized animals. The region east of Yellowstone was probably grassland throughout the late Pleistocene, just as it is today, so it is not surprising to find many grazing animals in the fossil assemblages.

However, the variety of animal life seems to have been far richer in Pinedale times than it is now. Imagine the fauna of the African savannah transported to a cooler climate: North American cheetahs and lions in place of African ones. Columbian mammoths instead of African elephants. Short-faced bears, gray wolves, and dire wolves hunted camels, musk-oxen, and American horses, as well as antelope and bison. While their Old World relatives have managed to survive through the Holocene, many of these animals no longer existed here by 11,000 yr B.P.

Yet such comparisons can be misleading, because the modern climate of the African savannah is very different from the Pinedale climate of northern Wyoming, in which the faunas had a strong arctic-subarctic element. During the late Pleistocene, species that today are found only in Alaska and northern Canada—Arctic rodents, musk-oxen and caribou—ranged across the grasslands of Wyoming. So while the plains of Wyoming may have been as dry as the modern African savannah, they were certainly far colder.

Along with the extinction of large mammals in Wyoming at the end of the last glaciation, mammoths, mastodons, camels, giant sloths, and many other species became extinct throughout North America. Why did this happen? Although the obvious answer might be that these cold-adapted animals could not tolerate the warm climates of the Holocene, these same species and their ancestors had survived a dozen previous interglacial periods, at least one of which was probably substantially warmer than any Holocene climate.

Imagine the fauna of the African savannah transported to a cooler climate: North American cheetahs and lions in place of African ones. Columbian mammoths instead of African elephants. Short-faced bears, gray wolves, and dire wolves hunted camels, musk-oxen, and American horses, as well as antelope and bison.

So megafaunal mammals must have been affected by some other environmental factor, possibly the arrival of humans. Ecologist Paul Martin coined the phrase "Pleistocene overkill" to describe how hunting pressure combined with rapid climate change to wipe out most of the megafauna on this continent. This theory suggests that North American megafauna was especially vulnerable to late Pleistocene (Paleoindian) hunters because the animals had little natural fear of humans, who were newcomers on the continent then. Because the fossil evidence is spotty, we may never know if the overkill theory is right. But whatever the cause of the extinction, we are left with a collection of large animals that made it through the Holocene. If they wore T-shirts, they'd probably say, "We Survived the Pleistocene-Holocene Transition"!

Holocene Climates

During the last 10,000 years, changing climates in the Yellowstone region brought about some large-scale changes in regional vegetation (Fig. 5). Today the northern part of the park is considerably drier and warmer than the highlands to the south. This is easily appreciated in late spring, when the southern parts of the park are buried under meters of snow while the Mammoth region is often snow free—Yellowstone's "banana belt." But this has not always been so. Thanks in large part to the work of palynologist Cathy Whitlock, we have come to understand how topographic differences have affected regional environments. During the early Holocene (9500–7000 yr B.P.), northern Yellowstone's climate was wetter than today, while the southern region was warmer and drier.

Fluctuations in the amount of incoming solar radiation (insolation) have been the primary cause of large-scale changes in Earth's climate during the Quaternary Period. According to a theory developed in 1938 by Milutin Milankovitch, summer insolation (and consequently summer temperatures) peaked from about 11,000 to 9000 yr B.P., at the transition between the last glaciation and the early Holocene, a period when the Yellowstone region is estimated to have received 8.5 percent more insolation during the summer and 10 percent less during the winter than it does today.

Paleoclimate reconstructions suggest that this increased summer insolation created high pressure weather patterns in southern Yellowstone. Relatively warm and dry conditions tend to increase fire frequency in this region, and enabled fire-adapted species such as lodgepole pine, Douglas-fir, and aspen to outcompete other species. For example, lodgepole pine cones release their seeds when they are heated by forest fires, a characteristic that ensures a large crop of seedlings will sprout in recently burned landscapes, overwhelming those of other species. Consequently, southern Yellowstone forests were dominated by lodgepole pine and Douglas-fir from 9500 until 5000 yr B.P, when they began receiving increased moisture and the modern closed spruce-fir-pine forest became established.

The same atmospheric conditions that fostered a warm, dry climate in southern Yellowstone during the early Holocene increased the moisture further north, which supported forests of lodgepole pine, juniper, and birch from 9500 until 7000 yr B.P. This region, like parts of central and eastern Wyoming, apparently received more precipitation from summer monsoons that brought moisture from the Pacific. Then by about 1600 yr B.P., increasing aridity brought about the ecosystem we see today: broad parklands of grasses and sagebrush with Douglas-fir and lodgepole pines on moister hillsides.

Fossil Beetle Evidence

Beetles are the largest group of organisms on earth, with more than one million known species. Their hardened carapaces (exoskeletons) preserve well in lake sediments, peat bogs, and stream sediments. Studies of their fossil remains in the Rocky Mountain region and elsewhere have shown that beetles are reliable indicators of climate change because their ranges shift in response to regional temperature changes. While changes in regional vegetation may take centuries or thousands of years, wholesale changes in beetle species composition may occur in a given region within a few years. For the same reason, the beetles used in climate change studies are predators and scavengers; plant-feeding beetles respond more slowly to climate changes because they cannot become established in new regions until their host plants are present.

Using 74 beetles species from 20 fossil assemblages found in 11 sites from northern Montana to central Colorado, I have reconstructed a history of climate change in the Rocky Mountain region during the last 14,500 years, similar to studies I have done in the Midwest and the East. To determine the climatic tolerances of the beetles in the fossil assemblages, I used the mean July and mean January temperatures of the 3,186 North American locations where the species presently occur to developed a climate envelope for each species. Then I overlapped the climate envelopes of all the species found in a fossil assemblage to produce a mutual climatic range (MCR) that represents the climatic conditions suitable for the species in that assemblage. (This technique assumes that the present climatic tolerance range of a species can be applied to its Quaternary fossil record, so that fossil occurrences of a given species imply a paleoclimate within the same range.) The 20 fossil assemblages span the interval 14,500-400 yr B.P. Based on the MCR analysis, the oldest assemblage reflects full glacial conditions, with estimated mean January temperatures 27.7°C (50°F) colder than today, and mean July temperatures 9.7°C (17.5°F) colder. This climate is comparable to that estimated from an Illinois assemblage, which was dated at 21,500 yr B.P.

Assemblages dating 13,200 yr B.P. and 12,800 yr B.P. signaled that late Pleistocene warming in the Rocky Mountains was rapid and intense. The MCR reconstructions indicate summer temperatures well above full glacial levels and only 2.1°C (3.8°F) cooler than today, although winter temperatures remained extremely cold. The same increase in summer temperatures was found in MCR reconstructions of beetle assemblages from the eastern United States dated 12,800 yr B.P.

My MCR estimates show that mean July temperatures were approaching modern levels by 12,200 yr B.P., and by 10,000 yr B.P. several assemblages indicate warmer-than-modern mean summer and winter temperatures. The warmest mean July temperatures, which were 5.1°C (9.2°F) warmer than today, were found in an assemblage dated 9850 yr B.P. from La Poudre Pass, Colorado. Winter temperatures appear to have peaked slightly sooner.

The insect record is practically the only fossil data from the Rocky Mountain

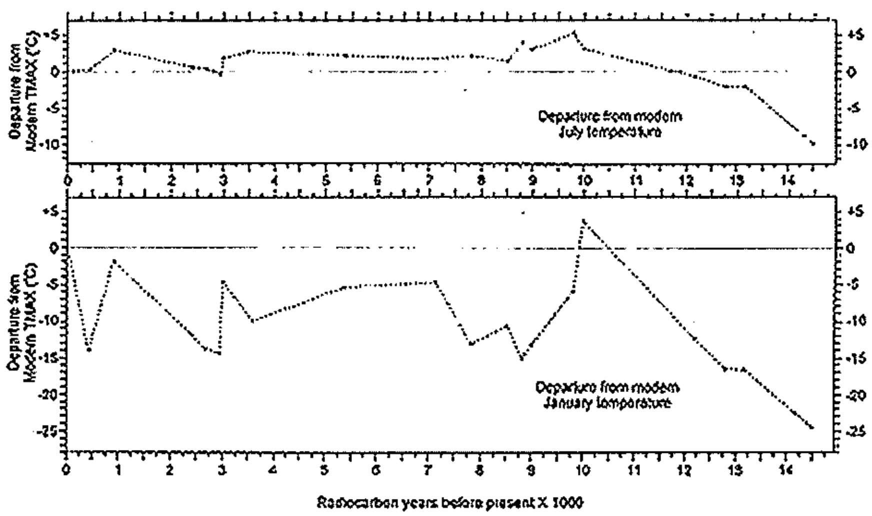


Figure 7. Reconstructions of mean July and mean January temperatures in the Rocky Mountain region. Shown as departures from modern temperatures at study sites. The estimates were derived from fossil beetle data, using mutual climatic range method.

region to show this degree of warming in early postglacial times. The pollen record, although not entirely consistent, indicates that regional vegetation lagged behind postglacial climate warming on the order of 1,500 to 2,000 years. S.K. Short (1985) found that the treeline at La Poudre Pass remained below its modern elevation as late as 6,800 yr B.P. Although I did not attempt to reconstruct past moisture regimes from the insect record, it is at least partly corroborated by regional glaciological data, as well as by the estimated period of maximum summer insolation. A study in northern Montana indicated extensive melting of regional glaciers before 12,000 yr B.P. The Yellowstone Plateau was apparently deglaciated before 14,000 yr B.P., and the Park Range of northern Colorado by about 13,800 yr B.P.

By 9,000 yr B.P., the fossil insect data indicate that summer temperatures, although still above modern parameters, were declining from their early Holocene peak (Fig. 7). I estimate that mean July temperatures were 2.9°C (5.2°F) warmer than modern, and mean January temperatures were well below modern levels.

The fossil assemblages indicate a gradual summer cooling trend from 7,800 to 3,000 yr B.P., with mean July temperatures reaching their current levels by about 7,000 yr B.P. After 3,000 yr B.P., a progression from warmer-than-modern to cooler-than-modern summers, and back to warm again is evident. Mean January temperatures remained below modern levels throughout the mid-Holocene and persisted in the study region until the last 1,000 years. A brief warming pulse in both summer and winter temperatures was inferred from a 900 yr B.P. assemblage. By 400 yr B.P. mean July temperatures had cooled to near-modern levels while winter temperatures had fallen below modern levels. Additional late Holocene insect assemblages are needed to clarify the timing and intensity of climate changes during the last few thousand years.

Regrettably, despite more than five years of searching I have yet to find a good Pleistocene insect assemblage in the park that could be used for a climate change reconstruction. However, Yellowstone has many lakes, ponds, bogs, and streams, so it is only a matter of time until the right sort of deposit is found.

Scott Elias is a fellow at the Institute of Arctic and Alpine Research at the University of Colorado at Boulder. His book, Ice-Age History of National Parks in the Rocky Mountains, *is the culmination of 12 years of research. Scott has dug Pleistocene fossils out of ancient lake beds above treeline in the San Juan Mountains of Colorado and in Glacier National Park, Montana, and from bogs and ponds in Rocky Mountain National Park.*

Suggested Reading

Baker, R.G. 1986. Sangamonian and Wisconsinan paleoenvironments of Yellowstone National Park. Geol. Soc. Amer. Bull. 97:717–736.

Elias, S.A. 1996. Ice-Age history of national parks in the Rocky Mountains. Washington D.C., Smithsonian Inst. Press. 170pp.

Elias, S.A. 1996. Late Pleistocene and Holocene seasonal temperatures reconstructed from fossil beetle assemblages in the Rocky Mountains. Quat. Res., 46:311-318.

Fritz, W.J. 1985. Roadside geology of the Yellowstone Country. Mountain Press, Missoula. 149pp.

Gilbert, B.M., and L.D. Martin. 1984. Late Pleistocene fossils of Natural Trap Cave, Wyoming, and the climatic model of extinction. Pages 138–147 *in* P.S. Martin and R.G. Klein, eds. Quaternary Extinctions: A Prehistoric Revolution. University Arizona Press, Tucson.

Pierce, K.L. 1979. History and dynamics of glaciation in the northern Yellowstone National Park area. U.S. Geol. Surv. Prof. Paper 729-F. 90pp.

Short, S.K. 1985. Palynology of Holocene sediments Colorado Front Range: vegetation and treeline changes in the subalpine forest. American Association of Stratigraphic Palynologists Contribution Series, 16, 7-30.

Sturchio, N.C., K.L. Pierce, M.T. Murrell, and M.L. Sorey. 1994. Uranium-series ages of travertines and timing of the last glaciation in the northern Yellowstone area, Wyoming-Montana. Quat. Res. 41:265–277.

Whitlock, C. 1993. Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks. Ecol. Monogr. 63:173–198.

Whitlock, C., and P.J. Bartlein. 1993. Spatial variations in Holocene climatic change in the Yellowstone region. Quat. Res. 39:231–238.

Yellowstone Seen Through Water and Glass

A Geologist Shares His Recollections of Discovery and His Concern for the Future of Yellowstone's Geysers

Photo courtesy Irving Friedman

Irving Friedman earned a Ph.D. in geochemistry at the University of Chicago. His doctoral research was on phase equilibria at high temperature and pressure; "in other words, things that make rocks." This was followed by a postdoctoral appointment to study the stable isotope abundance of natural materials in the laboratory of Dr. Harrold Urey in the Institute for Nuclear Studies. Hired by the U.S. Geologic Survey (USGS) in 1952, he worked on mass spectrometry and the stable isotopes of oxygen, hydrogen, and carbon to study geologic and hydrologic processes. He has a long association with Yellowstone's geothermal features and issues. Dr. Friedman was interviewed for Yellowstone Science *in March of 1997.*

YS: What was the purpose of your first work in the park?

IF: I was studying the deposition of calcium carbonate in Mammoth Hot Springs to determine whether the deposit was organically or inorganically deposited, or both, and under what conditions it was deposited. I was also dating some of the volcanic flows in the park as part of the Geological Survey's mapping effort. We were attempting to apply obsidian hydration dating to volcanic glass—obsidian—that is present in many of the flows.

YS: Tell me about the obsidian hydration dating technique. Was this method originally developed to date rocks?

IF: I and Robert. L. Smith of the Geological Survey developed the method because of our interest in obsidian—volcanic glass of rhyolitic composition—how it formed, and how it reacted with its environment. This was one of those serendipitous discoveries that we thought might be used as a dating tool, particularly in Yellowstone, where lava flows were thought to vary in age from less than a hundred thousand to perhaps half a million years but hadn't been precisely dated, and there was some question as to the validity of the dates.

YS: How is obsidian formed, and is it found in other places besides Yellowstone?

IF: When volcanic flows of rhyolitic composition—that is, magma enriched in silicon, sodium, and potassium compared to the more common basalt—is extruded onto the earth's surface, the outer surface of the flow is chilled, forming a glass called obsidian. The interior of the flow cools slowly, allowing time for individual crystals of various minerals such as quartz and feldspar to form, resulting in a rock called rhyolite, a fine-grained relative of granite. Obsidian is a glass that resembles bottle glass; it can be black, brown, and even red, and it contains very little water in its structure. Rhyolitic rocks are found in most places where there has been extensive volcanic activity—New Mexico, Utah, Nevada, Oregon, Arizona, California, as well as Mexico, Guatemala, Peru, Iceland, Turkey, New Zealand, and Russia.

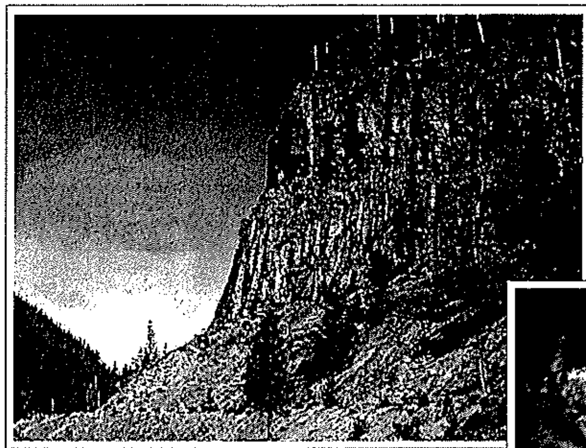
In many places (but not in Yellowstone), the obsidian is found in close association with another volcanic glass called perlite, which is mined in huge tonnages. Perlite sometimes encloses small pieces of obsidian. Both materials have the same chemical composition except that perlite has a much higher water content. Perlite is not as transparent as obsidian, and instead of being hard and strong, it is opaque and friable and made up of thin layers giving it a pearly luster, hence the name. Although obsidian typically has less than 0.3 percent water, perlite has something in the order of 3, 4, 5 percent water.

At one time it was thought that since obsidian was certainly a product of volcanism—it's just a super-cooled rock, if you will—perlite was similarly a primary product of volcanism. In this case, then, the magma that produced the perlite must have a high water content. But this was contrary to what Bob Smith and I thought, because other evidence indicated that these magmas did not have a high water content. Well, where did the water come from that is present in perlite?

We thought that there must be some explanation other than the fact that perlite is originally from a melt of high water content. The only other conclusion would be that the additional water arrived secondarily, after the rock cooled. And if that was so, it would indicate that water could penetrate into obsidian rather quickly, geologically speaking—in hundreds of years. This seemed unlikely, and I looked for proof.

YS: Does a geologist look for proof only in the rocks, or elsewhere?

IF: I remember visiting the Field Museum in Chicago and seeing obsidian artifacts recovered from earth mounds in Ohio—ceremonial blades and chipped obsidian—that had been manufactured by ancient people of the Mound Builder culture. These mounds had been dated as approximately 3,000 years old by carbon-14 dating of associated charcoal. It occurred to me that here is obsidian that had been chipped, creating new surfaces



Obsidian Cliff in Yellowstone National Park and a close-up of obsidian rock.

NPS Photos

3,000 years ago. If water would penetrate into obsidian at a significant rate, you should be able to detect it in these artifacts. I was able to convince the curator to let me take a few of these obsidian chips with me. We cut little slices of some of these chips, ground down the slices until they were thin enough to see through, and examined them under the microscope. Sure enough, there was evidence of water penetration into the obsidian. We measured the depth of penetration of water into the obsidian during the 3,000 years since the surface had been chipped. This allowed us to determine a rate at which water traveled by diffusion into these obsidian artifacts—a rate that proved that perlite was not a primary product of volcanism, as was obsidian, but that perlite might have been formed *from* obsidian. Also, we discovered that the rate of penetration of water was easily measured and might be used to date geological material, such as the Yellowstone rhyolite flows, as well as archeological material.

YS: Did you apply this new dating technique to Yellowstone?

IF: In cooperation with several geologists, I collected many obsidian samples, made thin sections, and examined them under the microscope. As I expected, they all contained hydration layers of various thicknesses, and from the hydration thickness we calculated ages of the volcanic flows. Most of these ages agreed with those derived by other techniques.

In addition, U.S. Geologic Survey geologist Kenneth Pierce and I discovered that in some localities, the samples contained several different hydration thicknesses, implying that multiple events produced the surfaces at different times in the past. For example, at Obsidian Cliff the obsidian has some very thick hydration rinds that correspond to the age of the flow, which is about 180,000 years old. But many samples also contained cracks having two different hydration thicknesses which yielded ages that corresponded to what we thought was the time of the Bull Lake Glaciation and the Pinedale Glaciation.

We postulated that these cracks were created by the weight of ice—there was 3,000 feet of ice above the Obsidian Cliff flow during the Pinedale glacial advance and probably the same amount during the earlier Bull Lake advance. That's a lot of ice that resulted in lot of pressure on the obsidian, and it must have caused cracks to form. Well, as soon as you form a crack, water begins to penetrate the crack and to diffuse into the obsidian itself to form a hydrated surface. If you had cracks formed during the first glaciation (the Bull Lake) and 80,000 years later another similar event causing additional cracking, you'd see some cracks formed by one event and some by the second. And indeed, the dating of the cracks matched up with the previous estimates of the dates of Pinedale and Bull Lake glacial deposits. That was another interesting utilization in Yellowstone of obsidian hydration dating.

YS: Wasn't the cultural resource connection an important breakthrough, with the dating of obsidians quarried in Yellowstone and traded across the continent by Native Americans?

IF: At the very beginning we depended on archeologists to provide us with obsidian from sites dated by carbon-14 so we could get some idea of hydration rates. Later, when the obsidian hydration technique was developed, archeologists really seized on the technique because it's relatively cheap and in many parts of the world, particularly Central America, archeologists don't have any other datable material except obsidian artifacts—often obsidian chips that remain after the manufacture of knives or points. In the tropics, wood doesn't persist, and there isn't much to date except artifacts, and the artifacts in many cases are rocks. You can often date the time a rock was formed by geologic processes, but that's not what the archeologists want to date; they want to date the time the rock was fashioned by man, not the time that nature fashioned it. As a geologist, I'm interested in the latter, but the archeologist is interested in the former.

YS: I understand that you have been measuring ground temperature in Yellowstone. Is this connected with obsidian hydration dating?

IF: Yes. Early on we postulated and determined that the ground temperature—the temperature to which the obsidian had been exposed while buried in the ground— would have influenced the rate at which the obsidian hydrated. In the laboratory we hydrated obsidian at high temperature under controlled conditions, causing it to hydrate at temperatures from 95°C to as high as 200°C. In this way we determined the rate at which obsidian samples from Obsidian Cliff would hydrate at different temperatures. If we knew the temperature, we could determine at what rate it would hydrate, which then meant that you could actually date things more precisely. If you had an obsidian artifact that an Indian had created and left buried in the ground for 2,000 or 3,000 years, by measuring the present day temperature you'd have a good estimate of the temperature that existed during the past 3,000 years during which the obsidian hydrated.

One problem is that the present-day temperature may not be exactly the temperature it was in the past. However, in most places the temperature hasn't changed greatly for the past 5,000 years, and the small temperature changes that have occurred are not enough to affect our results. It's only where you're dealing in very ancient (>10,000 years) man-made objects or older geologic samples that you have to worry about what the past temperatures were. In any case, you have to start from some datum—usually present day—and then estimate what changes might have occurred in the past.

YS: And this complicates dating the human activity. Elaborate on the relationship between your geologic investigations and the archeological ones, if you will.

IF: My latest effort in the park was with NPS archeologist Ken Cannon, who collected obsidian artifacts from occupation sites along the shores of Yellowstone Lake in areas that may be disturbed because of road construction. There's a lot of geothermal activity along the lake shore—it's probably one reason the Indians occupied the sites. Obsidian found at these sites would have been exposed to higher temperature, and hydrated at a higher rate, than obsidian collected from sites where the ground was not heated geothermally.

Our ground temperature measurements will also be useful for archeological materials found in non-hydrothermal areas. In addition to their use in calculating obsidian hydration ages, ground temperature measurements are useful in other ways. For example, researchers who study soil formation; they need to know the rates of formation of soil—and this is temperature dependent. In biological studies temperatures are also a factor. Like all research, there are always other uses for data than the investigator realizes when he starts.

YS: Another piece of work that I know you've been involved in is chloride flux monitoring.

IF: Its original aim was to develop a data-base to help protect Yellowstone Park from oil and gas and geothermal development that could influence the thermal features in the park, particularly the geysers.

YS: Did this start back in the late 1970s or early 1980s when there was discussion about opening up the Island Park area for geothermal leasing?

IF: Yes. It was the time of the Arab oil boycott, oil prices were sky-high, energy companies were looking for alternate energy sources, and geothermal was a big thing at the time. As an aid to prospecting for geothermal resources, the U.S. Geological Survey was asked to issue a bulletin listing the world's geothermal resources. Well, it turns out that the Island Park area was listed as having the highest potential in the United States, which generated interest in geothermal exploration in this area. The Forest Service proposed to issue geothermal leases in the area adjacent to the west boundary of Yellowstone and issued an Environmental Impact Statement (EIS) as required by law before proceeding. At the time, officials in Yellowstone were unaware of these proceedings since notices were not sent to them. Just before it was too late to respond to the EIS, someone brought it to my attention, as well as to the attention of park officials. I don't know if it was done with malice and forethought or if it was just stupidity.

YS: And you got involved because of the park's concern?

IF: Yes. At about the same time, concern had been raised in Congress, and Congress asked the Geological Survey to comment on the possibility of damage to thermal resources by geothermal development. The request was passed to USGS geothermal experts who wrote a letter to the Secretary of Interior who then sent it to the Senate. The letter pointed out that in all cases where there had been geothermal development adjacent to active geysers—in New Zealand, Iceland, and Nevada—the geysers had permanently ceased erupting.

However, the letter concluded, they saw no problem with geothermal development adjacent to the park as long as it was properly monitored and controlled. The monitoring was to be carried out from two wells drilled close to the park boundary—between the park and the Island Park area—to measure the pressure in the wells as an indication of what was going on in the geothermal aquifer. If the pressure was to fall, further utilization of energy from the geothermal wells would be stopped.

Well, I saw the report to Congress and got mad (I was younger), and I wrote a letter to the Director and sent copies to a lot of other people, pointing out how impractical this was. I said that the Survey didn't have a very good record of being able to control development adjacent to anything.

YS: Who ever said government scientists couldn't disagree! What was the substance of your concerns?

IF: First, it is difficult to be sure that the aquifer being monitored by the two wells is the same aquifer being tapped for energy some miles away. Second, we don't know what degree of pressure drop would cause damage to Yellowstone's geysers. Third, we don't know if the natural aquifer pressure is a constant. It may vary from year to year, and in a seismically active area such as Yellowstone, quakes could cause episodic changes. The developers could claim that pressure changes, if observed, were not significant. Obviously, developers with perhaps a billion dollars invested in a geothermal field and power plant are not going to quietly fold their tents and walk away because of a small pressure change in a monitoring well. In short, we don't know what to monitor, and we can't control it, and therefore we shouldn't play Russian roulette with Yellowstone.

So I thought of what could done that would cost very little, and might give a database which would be useful in the future in determining that Yellowstone's geothermal system had been disturbed. The total heat flow from a geothermal system, or portion of it, is one important component in geyser activity (the plumbing system that supplies water is another). But it's very difficult to monitor heat flow. A number of people have suggested that monitoring be carried out with some constituent that comes up with the heat. Chloride is the one usually chosen because it is easy to measure cheaply and is a conservative constituent. In other words, it's something that does not disappear before you get to measure it. In Yellowstone all the chloride that leaves the park has to come through four major rivers that drain the park—the Falls, Madison, Snake, and Yellowstone. Therefore, if you just monitor the chloride in these four rivers you can at least determine if the whole system has been disturbed by geothermal or other development.

"...they saw no problem with geothermal development adjacent to the park as long as it was properly monitored and controlled...In short, we don't know what to monitor, and we can't control it, and therefore we shouldn't play Russian roulette with Yellowstone."

YS: By monitoring, do you mean river gauging?

IF: To measure the chloride *flux* you need two things. You want to end up with how many grams or pounds or whatever of chloride come out each year from each river. It is necessary to measure the water discharge by gauging streamflow on each river, and to sample the water for its chloride *concentration*—the amount of chloride in a given volume of water—periodically (about 30 times during the year). The amount of chloride that leaves per year—the chloride flux—can then be calculated for each river, and the sum of the fluxes from the four rivers is the total chloride flux from the park.

When USGS chemist Dan Norton and I began this project, the discharge from the Yellowstone and the Falls was being monitored by the Water Resources Division of the USGS. The Madison had been monitored, but measurements had stopped the year before. The Snake had been monitored for a few years in the 1930s and then stopped due to lack of funding. The park provided funding to reactivate stream gauges on the Snake and Madison. Later on we thought it'd be useful to monitor the Firehole and Gibbon, which separately drained the two most active thermal areas in the park.

I originally thought at least 20 years of baseline data would be necessary. This might not be finished in my lifetime, but the work could be continued by others.

YS: So, do we understand about the relationship between the surface waters in the streams, the ground water, the aquifer and what the disturbance effects might be?

IF: These are some of the things we are learning. The original concept of chloride flux monitoring was to protect the park, but also, it's for research. The variations in chloride flux over the years will allow a better understanding of the underground system and how it responds to magma movement beneath the park, earthquakes, and other tectonic-induced changes.

Because of the immediate concerns over potential development at Island Park, the first thing we did was to consider the thermal features in the Boundary Creek area close to Island Park and the southwestern border of the park. In the 1960s, I had taken a traverse across Boundary Creek to the Bechler River and discovered a thermal area—I'm sure people had seen it, but it was not on the maps. It's a small valley with boiling springs and other thermal features at the headwaters of Silver Scarf Falls, which are warm. We also discovered other thermal features; in fact, middle Boundary Creek is warm enough to bathe in. And I thought we should look at these thermal features, with the thought that if geothermal development in Island Park disturbed the Yellowstone system, the disturbance would first affect these nearby small thermal areas which are not very deep-seated.

We installed small weirs to measure discharge from several small hot springs in this very remote area. There's no easy way to get in except walking 8 or 10 miles. We equipped the weirs with newly developed electronic monitoring devices that we thought would be able to monitor these springs and store the information, so we would only have to go back every few months and retrieve the data. The system worked for eight months, and then, as usual, everything quit. It became expensive and impractical to send people several times a month, winter as well as summer, to service the equipment. It's a long hike in the summer, but it's a hell of a thing to do on skis. It's at least 30 miles round trip. There's nothing. No shelter.

We finally got a few thousand dollars to go in once a year, in the winter, by

One of the weirs in the Boundary Creek area of Yellowstone that was equipped with electronic monitoring devices to store information on chloride flux that could be retrieved every few months.

helicopter to make a single measurement at the time of minimum flow of 11 springs and streams. That continued for eight years and was quite successful. We had the usual close escapes—I almost got killed a few times!—but these things happen.

YS: And the results of what you found out from that work?

IF: We found that the chloride flux in these small hot springs changed seasonally in a surprising manner. The chloride flux went up in the spring and down in the fall. In the past it was assumed that the chloride *flux*, unlike concentration, would be constant; even in the springtime, though the hot spring discharge increased due to snowmelt, the snow contains little chloride, so the chloride flux would not change in spite of the increased discharge. If this was how the system worked, the chloride *concentration* in the hot spring discharge should decrease in the springtime, due to presumed dilution, and increase during low water in the fall. Well, it didn't. The chloride concentration remained constant; it *isn't* being diluted by snowmelt. And in the fall, what little water that came out had the same chloride concentration as the water that discharged during high flow following snowmelt. No matter how much water came out of the hot spring, the chloride concentration was the same. That threw us for a loop.

Our explanation was that these hot springs are tapping a groundwater layer that may be 1,000 feet thick and is mixing with chloride-rich volcanic steam. The rate of discharge of the spring is influenced by the height of the water table above the spring. During snowmelt the height of the water table increases, increasing the pressure, which causes an increased flow out of the hot spring. However, the *local* water table above the hot spring does not mix with the *deeper* water that feeds the spring, and therefore the chloride concentration in the hot spring does not change even as the discharge rises during the time of snowmelt.

We recognized a similar pattern in the chloride flux in the major rivers, where the chloride concentrations change a little because of snowmelt, but the changes were relatively small. Therefore the chloride flux in the rivers is also related to the height of the water table, which is seasonal, and it also varies from year to year. That's one reason that we need 20 years of records to establish a long-term, reliable, data baseline.

YS: So, subtle changes in groundwater levels and pressure caused by drilling might affect the park's thermal features.

IF: Yes. We believe this cannot help but affect geysers, which are very sensitive to changes in these things: heat, water, and pressure.

YS: Will chloride flux monitoring allow us to be able to detect small changes due to extracting hot water or steam from a geothermal well, and not only detect them, but do so in time to do something about it?

IF: That we don't know. There's some doubt that it might. My original thought was that we having nothing to lose. It doesn't cost much, and it gives us a base from which to assess changes caused by earthquakes and the movement of magma. It may or may not have use as a warning tool, but in any case, it tells us more about what's going on in the natural system. So from several points of view it should be continued.

YS: What do you think is the biggest threat to Yellowstone's geologic resources, and what is the biggest geologic research need?

IF: A big threat could still be geothermal, but the biggest threat is gas and oil extraction. Gas and oil extraction is worse than geothermal energy utilization, because during geothermal development, normally what you take out of the system is the heat; the extracted water is usually pumped back into the ground. But in the case of gas and oil, you're removing more; you're removing the gas and oil. Historically this extraction of material in oil fields has caused earthquakes and subsidence. Normally, these effects haven't been serious enough to cause serious concern, particularly in view of the large monetary gains associated with oil development.

It has been proven that a series of earthquakes about 35 years ago in Denver were caused by pumping liquid waste down a deep well at the Rocky Mountain Arsenal near the old airport. Denver had been a seismically quiet area until the pumping began, which coincided with the occurrence of swarms of earthquakes—the largest was, I believe, 4.2—strong enough to rattle the bed and shake the house. A geologist pointed out the perfect correlation between the amount of pumping and the earthquake incidence. To confirm the relationship between addition or removal of subsurface material

"We don't even know the extent of the geothermal resource here...Where are the thermal features? How big are they? How do they change with time, and how are they affected by tectonic events in and near the park?"

and earthquakes, a test was carried out in the recently abandoned Rangely oil field in central Colorado. When pumping was instigated, local earthquakes were generated; the more they pumped, the greater the earthquakes.

Earthquakes are known to be some of the events that cause changes in Yellowstone. We can't control those that occur naturally, but we don't want to generate shallow earthquakes close to the major geysers of Yellowstone.

YS: The biggest research need, then, is?

IF: We don't even know the extent of the geothermal resource here. Rick Hutchinson was inventorying these resources. He did a damn good job, but he's not around to continue it. Where are the thermal features? How big are they? How do they change with time, and how are they affected by tectonic events in and near the park? The inventory needs to be continued and expanded.

We need to have a system in place to do continual and better monitoring, not just for geothermal resources but for other components of the Yellowstone system. For example, the fluxes of heavy metals is not known. How much contamination of the park is caused by adjacent mines? We should be looking at many constituents—copper, zinc, lead, arsenic, to name a few. We need to know more about what's happening—are the fluxes of these and other components increasing, or changing in various ways? There should be more geochemical monitoring, other than just chloride flux.

A serious problem in attempting to protect the park is the lack of basic detailed geologic knowledge of areas surrounding the park. Geologic mapping should be initiated to fill the gaps.

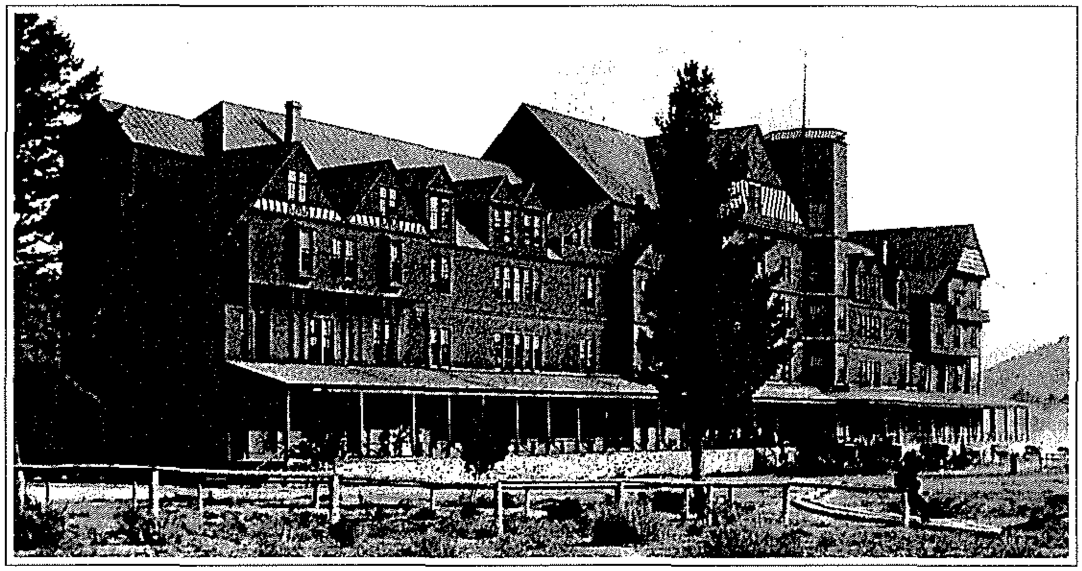
YS: Geologists bemoan the fact that Yellowstone's geothermal curiosities were the major reason the park was created, but because they don't stand up and move across the boundaries and don't cause many legal problems, they tend to receive less attention than do animals, which have more vocal constituencies.

IF: That's right. I believe there should be more discussion of the geologic resource issues. I'm sure that this has been done in the biologic sphere, but there needs to be more consideration given to the geologic aspects. The New World mine situation did one good thing: it did mobilize interest and the realization among people that you can affect the park's resources in many ways, not just by killing off the buffalo or the elk or whatever, but by contaminating them with the residue from mining and by ruining the geothermal features. And that's the only good thing about the New World situation. But we need to take advantage of the public concern and not let the momentum created by this real danger to the park be dissipated without action.

"The New World mine situation did one good thing: it did mobilize interest and the realization among people that you can affect the park's resources in many ways, not just by killing off the buffalo or the elk...but by contaminating them with the residue from mining and by ruining the geothermal features."

Above top: Boundary Creek thermal area. Lower photo: Silver Scarf Falls. Photos courtesy Jennifer Whipple.

Striking Similarities: Labor Versus Capital in Yellowstone National Park



The Mammoth Hotel in 1884 after the controversial labor strike. Photo by F. Jay Haynes, NPS archives.

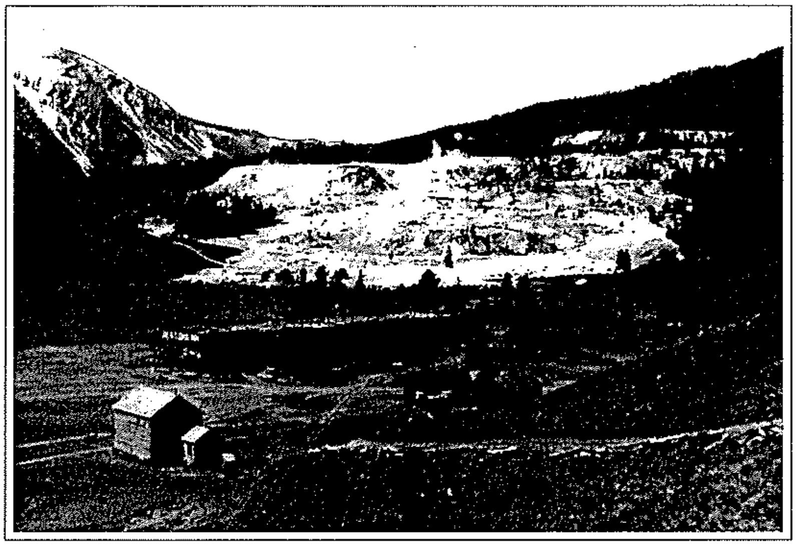
by Brit T. Fontenot

By the 1880s, Yellowstone National Park was well known to most Americans as a vacation wonderland, representing a place where the visitor could experience the strange, exciting, and exotic. Early park visitors, mostly eastern elites, regarded a trip through "Wonderland" as a welcome respite from the grit and grime accompanying late nineteenth-century urbanization and industrialization. Travelers envisioned Yellowstone as an island sheltered from the surge of American incorporation, an escape from negative aspects of change.

Growing urban populations, increasing corporate monopolization of industry, and recurring labor disputes symbolized the growing pains associated with late nineteenth century industrializing America. Preferred retreats like Yellowstone represented idealized and romanticized natural places, a refuge from humans and their aforementioned ills. Far from its idealized representation as an untouched wilderness, Yellowstone, even in its infancy, mirrored many cultural and industrial trends simultaneously occurring in Victorian America.

In the fall of 1882, attempts to blur the lines between wilderness and civilization began in earnest. In the name of comfort and accessibility, park boosters Carroll T. Hobart, Henry F. Douglass, and Rufus Hatch of the Yellowstone Park Improvement Company, began construction of the 250-room National Park Hotel at Mammoth Hot Springs.[1] An ensuing labor strike by carpenters working on the structure at Mammoth serves as but one example of parallels between Yellowstone National Park and industrializing America. The example buttresses the notion that the park was not, and is not, a sheltered and isolated wilderness standing alone and resisting change. Yellowstone is deeply woven into the complex cultural fabric of our nation and its people.

[1] Richard Bartlett, *Yellowstone: A Wilderness Besieged*, Tucson, University of Arizona Press, p.129-130.



Building of the National Hotel, 1883. The Yellowstone Park Improvement Company began construction of the first Mammoth Hot Springs Hotel in 1883, on the site of the present Mammoth Hotel. Designed by L. F. Buffington ("the father of the modern skyscraper"), this hostelry boasted electric lights, quite a coup for a hotel located so far into the wilderness. It was initially called the "National Hotel," but the name "Mammoth Hot Springs Hotel" was also in use by the late 1880s. Built in Queen Anne style, it was 414 feet long and 54 feet wide with three to four stories and several wings behind it. One construction workman died after a fall from a scaffold there, and other workmen took physical possession of the hotel when they were not paid and held it hostage for many months. President Arthur ate a meal in the new hotel that first year with its roof half-finished and open to the sky. Note the "old Gardiner road," visible at bottom center and right. Photo courtesy the Haynes Foundation Collection, Montana Historical Society, Helena, Montana.

Strife between labor and capital was a hallmark of American industrial progress in the late nineteenth and early twentieth centuries. Yellowstone, however, represented a seemingly unlikely place to find labor disputes much less qualities of industrialization. This is partly due to where we feel comfortable looking for characteristics of modernization. Attention to these issues is more often directed to densely populated, highly monopolized, and industrialized urban areas. Typically, Yellowstone embodies the antithesis of such places and imagining Yellowstone National Park associated with American trends of industrialization seems absurd. The challenge, therefore, is to peer beneath the surface where the reality is far different from the illusion. By 1884, the world's first national park exhibited characteristics of American incorporation, i.e., labor struggles in the National Park Hotel strike—something all too familiar to the remainder of the nation.

The significance of the strike was two fold. First, it established intersections between Yellowstone Park and the remainder of America, dispelling myths of wilderness isolated and unaffected by national trends. During the decade of the 1880s thousands of industrial workers throughout America declared authority over the processes of production by protesting, sometimes violently, the condition of their working-class lives. During this decade alone, America witnessed almost ten thousand strikes and lockouts.[2] Yellowstone, too, was affected. Generally, strikes broke out in response to tightening managerial control by corporate interests. Workers, anxious about autonomy, wage rates, work hours, conditions, and increasing mechanization, communicated their discontent by striking. For these Americans, strikes "signified an expression of working-class life."[3] Similar issues confronted workers participating in the National Park Hotel strike in 1884.

Second, the strike identified a distinct working-class culture living and laboring within the boundaries of the park. Manual laborers erected Yellowstone's infrastructures. They toiled in order that others might experience comfort and leisure. Problems confronting early park tourism—accessibility and accommodations—were solved through the sweat of the workers. Yellowstone's laborers built the lodgings, graded the roads, tended to the animals, cleaned, cooked, and performed countless other duties for park visitors. The park's working class represented a culture ignored by most people—one that park promoters like Hobart, Douglas, and Hatch attempted to hide from view in their efforts to maintain the illusion of an untouched, unspoiled, natural wonderland. For park promoters, the notion of laboring in Yellowstone contradicted the very intent of the park; "for the benefit and enjoyment of the people."[4]

Employing this logic, concessionaires and other park boosters planned for completion of the National Park Hotel *before* the arrival of the first guests in the summer of 1884. Single-minded concerns for the comfort of Yellowstone guests proved disastrous for the Yellowstone National Park Improvement Company (Y.N.P.I.C.). Failures to recognize the carpenters' plight resulted in severe tensions between the laborers constructing the hotel and Y.N.P.I.C. management in Yellowstone.

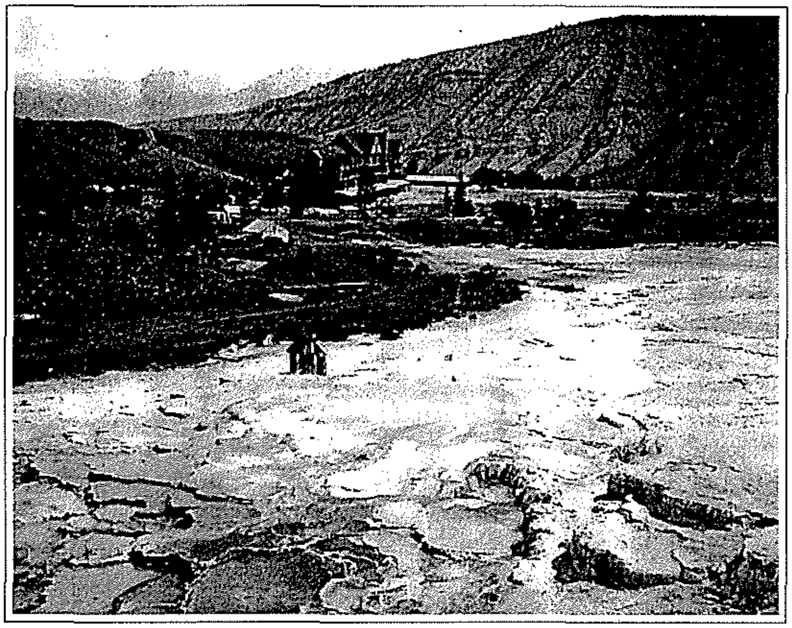
In late February 1884, 35 carpenters employed by the Y.N.P.I.C. seized possession of the incomplete National Park Hotel, located at park headquarters in Mammoth Hot Springs. "The carpenters," reported the *Livingston Enterprise*, "asserted their rights to the building on the ground that the work was incomplete and had never been turned over to the com-

[2] Alan Trachtenberg, *The Incorporation of America: Culture and Society in the Gilded Age*, New York, Hill and Wang, 1984, p. 89.
[3] Ibid.
[4] Bartlett, *Yellowstone*, p. 2.

pany."[5] Furthermore, the workers adamantly refused to relinquish possession until the Y.N.P.I.C. paid each man, in full, several months worth of back wages. In a March 1884 letter, labor spokesman E.C. Kelly complained to Interior Secretary Henry M. Teller of the difficulties faced by the striking men. Until they struck, according to Kelly, the carpenters labored faithfully for eight months without compensation.[6] In addition to their economic woes, cold temperatures and food scarcity exacerbated the workers' problems.

Despite initial financial backing from the Northern Pacific Railroad, the Y.N.P.I.C.'s coffers were depleted; the company was bankrupt. The concessionaire operated with a budget deficit for almost an entire year prior to the strike, since June 1883. By striking, the carpenters claimed the means of production from a company devoid of any working capital. Under these conditions, conflict resolution appeared hopeless. Kelly urged Secretary Teller to intervene on the worker's behalf. He pled to Teller for a speedy settlement to the labor dispute, described by historian Richard Bartlett as "one of the first sit-down strikes in American history."[7]

For over four months the bereft workers occupied the shell that was the National Park Hotel. Reports from the *Livingston Enterprise* described the workers as "destitute, being without proper clothing to protect them from the cold weather and all are without money . . . half naked and half starved."[8] Conditions worsened. Threats of violence and destruction by both parties ensued. Company representatives threatened to remove the strikers by force with help from the U.S. military. Strikers countered with promises of complete destruction of the wooden structure by fire if molested in any way. Each side maintained 24-hour armed vigils, but neither fired shots.



Bath house on Hymen Terrace showing National Hotel and Assistant Superintendent G.L. Henderson's house and barn, circa 1884. The long building in the background to the right of the hotel was the headquarters of the earliest in-park stagecoach company, established by Wakefield and Hoffman in 1883. Note the horse at the hitching post and the carriage above and to the right of the bath house, both of which probably belonged to G.L. Henderson. Bathing in the hot springs at Mammoth was among the first uses of the waters at Mammoth and began as early as 1871, during the days when hot soaking relief for the tired and long dirty was considered more important that preservation of a few hot springs. Hymen Terrace, on which stands the bath house here, was an active hot springs area until the 1930s and the site of a number of early bathhouses. Bathing in Yellowstone's hot springs has been prohibited for many years to prevent damage to delicate thermal features and as a safety consideration for visitors. Photo courtesy the Haynes Foundation Collection, Montana Historical Society, Helena, Montana.

The inability to resolve the conflict quickly lay mostly in confusions relating to proper park jurisdiction. Neither party knew exactly where to turn for action or advice. The disorganized and financially unstable Y.N.P.I.C., chartered under the laws of New Jersey, began to crumble. In the midst of this confusion, Hobart and Douglas combined their efforts against their former partner, Hatch, for the power to appoint the new company receiver. Hatch argued that the New Jersey district court should appoint the receiver; Hobart and Douglas contended that since the company was located in Wyoming Territory, a Wyoming territorial court should make the decision.[9] The strikers, too, were confounded. To emphasize the desperate nature of their situation, striker W. H. Briggle composed a letter to the Presi-

[5] *Livingston Enterprise*, (Livingston, Montana), Feb. 25, 1884.

[6] Letter from E.C. Kelly to Secretary of the Interior Henry M. Teller, March 12, 1884. File microcopies of the records housed in the National Archives of the Office of the Secretary of the Interior Relating to the Yellowstone National Park, 1872-1886; 1883-1884 Letters Received: No. 62, Roll 2. Yellowstone National Park Archives, Mammoth Hot Springs, Wyoming.

[7] Bartlett, *Yellowstone*, p. 146-147.

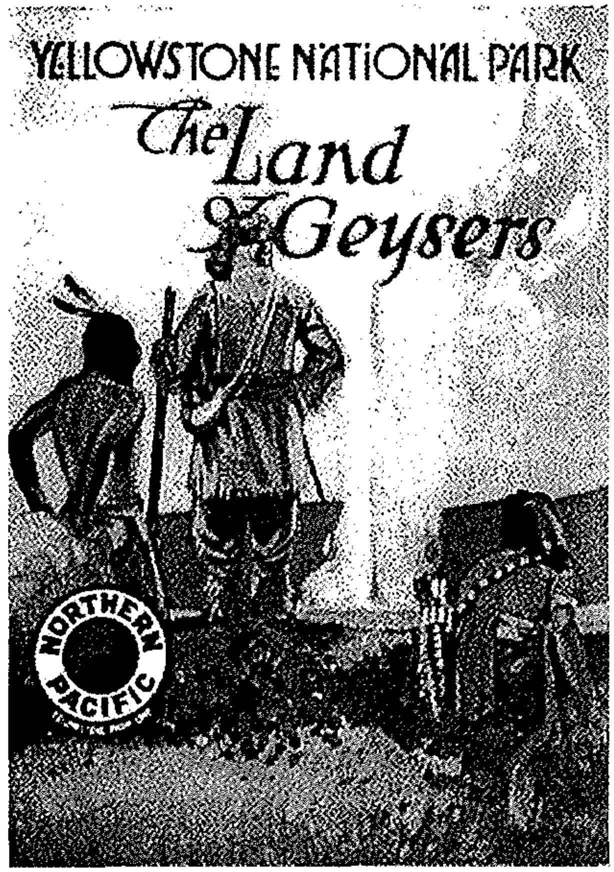
[8] *Livingston Enterprise*, (Livingston, Montana), March 11, 1884; *Livingston Enterprise*, (Livingston, Montana), March 17, 1884.

[9] Bartlett, Yellowstone, p. 149.

[10] Letter from W. H. Briggle to the President of the United States Chester Arthur, March 24, 1884. File microcopies of records housed in the National Archives of the Office of the Secretary of the Interior Relating to the Yellowstone National Park, 1872-1886; 1883-1884 Letters Received.: No. 62., Roll 2. Yellowstone National Park Archives, Mammoth Hot Springs, Wyoming.

dent of the United States, Chester A. Arthur. Briggle wrote, "Where can we get jurisdiction to force the company into a settlement—for the employees are in very needy circumstances."[10] No company official singlehandedly held the power to end the protest, and park regulations concerning issues of jurisdiction were extremely vague. No one knew who held the authority to arbitrate the strike. Finally, in June 1884, a Wyoming territorial court appointed the new receiver who took into their custody the property of the struggling Y.N.P.I.C., effectively ending the strike. Under this new management scheme the carpenters received their back pay, and on July 3, 1884, they peacefully returned the hotel to the company. The National Park Hotel opened and received tourists in a state of partial completion.[11] The men held out for their wages for a little over four months, from February 24, 1884, through July 3, 1884. For the carpenters, the first sit-down strike in American history and the first organized labor resistance in Yellowstone National Park was successful. Identification of a strike in Yellowstone Park is extremely telling. Conditions surrounding the National Park Hotel strike are exceedingly familiar to other struggles in other, more urban locations throughout America in the late nineteenth and early twentieth centuries. This evidence hardly points toward a Yellowstone isolated from American trends of incorporation and industrialization—quite the opposite. For a brief moment, the National Park Hotel strike highlighted what was once obscured: similarities between Yellowstone and urban America. This evidence declares that the park was home not only to elk, bison, eagles, and trout, but also to working-class men and women. The National Park Hotel strike distinguishes Yellowstone's working-class culture, one not unlike those of the working-class elsewhere in the United States.

The Northern Pacific Railroad heavily promoted Yellowstone National Park (as this old poster shows) and was the initial financial backer for the building of the National Hotel, but the Yellowstone National Park Improvement Company soon depleted those resources and the company eventually went bankrupt after operating in the red for an entire year prior to the strike.



What begs contemporary recognition and further study is that Yellowstone Park is a part of shifting national and cultural trends, and to what extent. Yellowstone was not, and is not, an isolated, silent observer of social and cultural change in America. It is, in fact, a dynamic, active, and willing participant in the continual evolution of American culture. The identification of a labor dispute is but one example bespeaking the relationships between the park, its workers, and American culture. American's exclusive ideas of nature were summed up by British literary critic Raymond Williams when he wrote, "The idea of nature contains, though often unnoticed, an extraordinary amount of human history."[12]

The occurrence of the National Park Hotel strike firmly sews the patch that is Yellowstone into the great American quilt, but for reasons other than simply symbolism. The strike establishes important intersection points between Yellowstone and the remainder of America and exposes the myth of an isolated wilderness. The strike also positively identifies a working-class culture in the park similar to others in urban America, in essence tying Yellowstone into the flow of the cultural current.

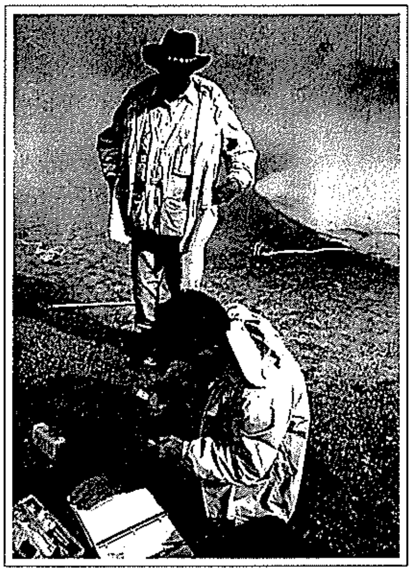
Fire and ice shaped the physical characteristics of Yellowstone, but people created "Wonderland." The mystique of Yellowstone was constructed and marketed by those who would use tourism to make a profit. From the beginning, our culture marked the parameters for Yellowstone based on their expectations of the "Yellowstone Experience." Since then, Yellowstone set the standard by which all other parks are judged. Yellowstone is indeed the "Crown Jewel" of America's National Park System. Let us not forget those who polish the facets, and why.

Brit Fontenot is a second-year graduate student in the Department of History at Montana State University-Bozeman. This article is part of his current master's thesis research on Yellowstone's working class.

[11] Bartlett, *Yellowstone*, p. 149.
[12] William Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature*, New York, W. W. Norton and Company, 1996, p. 25.

Yellowstone Signs Bioprospecting Agreement

Photo Bob Lindstrom



Yellowstone National Park signed an agreement on the nation's first "bioprospecting" arrangement with the Diversa Corporation (a company specializing in the industrial application of biocatalysts, which is headquartered in San Diego, California) on August 17, 1997, after a 125th-anniversary ceremony at Mammoth Hot Springs.

Scientific interest in the park's hot spring microbes has increased steadily since the development of DNA fingerprinting technology in the late 1980s involving a microorganism called *Thermus aquaticus*. Revenues in excess of several hundred million dollars have been generated from the use of that technology, none of which has benefitted Yellowstone National Park.

The new agreement changes that, and allows the Diversa Corporation to conduct research on microorganisms sampled at Yellowstone while pledging a portion of the company's future profits from such research for conservation and the park's related scientific and public education activities. The agreement was reached with the assistance of World Foundation for Environment and Development (WFED), an independent non-governmental organization established to facilitate negotiations in the field of environment and development.

At a special workshop on "Biodiversity and Bioprospecting in the National Parks: The Yellowstone Experience," held on October 15, 1997, panelists from the park, WFED, and conservation organizations joined in discussion of issues with a University of Utah law professor and a representative of the American Type Culture Collection, repository for microbiological samples taken from Yellowstone and elsewhere.

Yellowstone is home to approximately 10,000 hot springs and other geothermal features, more than the rest of the world combined. To date, less than one percent of these thermophiles have been scientifically described. Funds and/or data generated from research activities that result from this new agreement will benefit the park's program to inventory and conserve Yellowstone's diverse resources.

Grizzly Bear Production, Mortalities Up Again in 1997

The greater Yellowstone grizzly bear population once again experienced a high year for both cub production and mortalities in 1997. As of October 10, biologists had documented 13 known grizzly bear deaths, 3 of which were natural and 10 of which were human-caused. The latter include one human-food-conditioned bear removed by managers and one bear killed illegally. The rest of the bear mortalities came, as is often the case, during the autumn hunting season. This year hunters killed eight grizzly bears, and may have killed two others, during surprise encounters during both archery and regular big game seasons in Montana and Wyoming. While some of these encounters are inevitable, education can help people avoid encounters that may be injurious to both humans and bears. Information presented at workshops on *Living in Bear Country* and available in print from national forest, park, and game and fish offices alerts people to recognize bear sign and behavior. In close encounters, non-lethal bear repellent has been very effective in deterring the animals away from hunters and other recreationists during surprise encounters. In October, Yellowstone ecosystem grizzly bear managers endorsed a campaign to encourage people to carry bear spray while working and recreating in bear country.

Human-caused grizzly mortalities continue to exceed recovery goals set for the ecosystem's threatened bear population. But in other ways, it was a good year for bears in the park due to continued sanitation measures and abundant natural bear foods. There were two bear-caused human injuries reported in the park in 1997, but both were relatively minor. There was only one incident of bear-caused property damage, and two incidents of bears obtaining human food or unsecured garbage. One black bear was trapped and moved away from a park road or development; another grizzly sow and her cubs frequented park roadways during early summer, requiring rangers to spend a significant amount of time monitoring the bears and associated traffic. However, no bears were removed from Yellowstone National Park in 1997.

Ironically, biologists believe that more bear mortalities and human-bear conflicts are partly a result of an increase in the grizzly bear population. In 1996, a record 33 sows produced 70 cubs. In 1997, biologists confirmed that at least 31 unduplicated female bears produced 62 cubs. Family groups include five sows with one cub each, 21 sows with the average two-cub litter, and five sows with three-cub litters. This year, 42 percent of the mother grizzlies were seen inside Yellowstone National Park.

The high production and good survivability among Yellowstone grizzly bears have been sufficient to offset mortality levels and result in a gradual increase in the bear population since 1986, according to published research.

Limnologist Brian Shero Dies

Dr. Brian R. Shero, limnologist and professor of biology at Medaille College in Buffalo, New York, died on December 10, 1996, after a year-long illness. Brian had been studying the effects of the 1988 wildfires on the diatoms of Yellowstone Lake for several years prior to his death, and was due to have spent 1996-1997 on sabbatical completing this important research. He had also been involved in research on the physical, chemical, and biological properties and features of the

Great Lakes and the Buffalo River. Brian was a strong advocate of environmental education, and organized aquatic ecology workshops for schoolchildren in his home state of New York. Dr. Shero received his Ph.D. in limnology from the University of Wyoming in 1977, and spent considerable time in Yellowstone pursuing his interest in the biology and geology of the park's aquatic resources.

Brian Shero is survived by his wife, Marlene, two children, his parents, and two brothers. Donations in his memory can be made to the Dr. Brian R. Shero Memorial Fund, Medaille College, 18 Agassiz Circle, Buffalo, NY 14214. Condolences and kind words of support may be sent to Mrs. Shero and family at 163 Crescent Ave., Buffalo, NY 14214-2330.

Researchers Document Decline in Spotted Frogs

Photo Renée Evanoff

Since 1991, Deb Patla and Dr. Chuck Peterson of Idaho State University have been studying a population of spotted frogs in the forest and meadows near the Lake developed area. Based on data about population size and habitat conditions from an intensive study conducted in the 1950s, it appears that the population has declined sharply, from about 1,600-2,000 frogs to fewer than 300 frogs in 1995. This long-term decline may be attributed largely to human-caused factors, especially water development at the headwater springs that has caused wetland loss and possible hydrological changes in areas important to the frog population. In addition, the highway relocation project disrupted a migration route between breeding and winter habitat that was heavily used by frogs in the 1950s. More recently, the Lodge Creek frog population, which breeds in a pool in a park horse corral, has had a series of reproductive failures due to unfavorable weather conditions and two years of high water levels at the mouth of the tributary to Yellowstone Lake. The frogs and their breeding pond also appear to be affected when horses trampled and disturbing the natural pool-terrestrial interface that is crucial to the metamorphosing frogs as they emerge from the pool. The researchers fear that this population faces local extinction and cannot continue to exist without successful reproduction and/or immigration. In July, park rangers worked with Patla to construct a protective fence around the frogs' breeding pool.

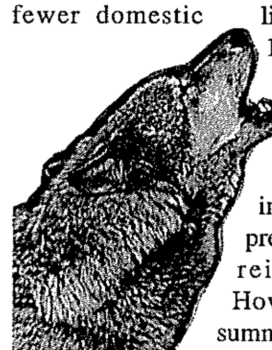
New Bison Exhibit Attracts Visitors

A new interpretive exhibit, *Where the Buffalo Roam,* opened to the public on August 1, 1997, at the Canyon Visitor Center. The exhibit, which contains two large dioramas of bison, explores the history and natural history of bison in Yellowstone as well as controversial bison management issues. The exhibit is a result of a unique new partnership between the Buffalo Bill Historical Center in Cody, Wyoming, and the park's Division of Interpretation. Although the long-term plan for the Canyon Visitor Center is to host a geology exhibit, the bison exhibit should be on display for at least 3 to 5 years. The area supervisor reported a significant increase in visitors following the opening of the exhibit, which was designed with assistance from park resource staff.

Bison "Mugged" for Research

Wildlife handlers from Helicopter Wildlife Management in Salt Lake City, Utah, recently used helicopters to approach and net-gun bison from the air for a new study begun in the park. Specially trained "muggers" subdued the bison without the use of chemical immobilization agents and placed radio collars on the captured bovines. The marking of 45 bull and cow bison is aimed at increasing the knowledge about seasonal movements of bison throughout the park. The five-year research project is being funded by the Biological Resources Division of the U.S. Geologic Survey and supervised by Dr. Peter Gogan.

Livestock-Killing Wolves Removed



In the first two years of their return to the Yellowstone ecosystem, wolves killed fewer domestic livestock—10 to 12 sheep— than biologists had predicted in the plan and environmental impact statement prepared for wolf reintroduction. However, in late summer and fall of 1997, several wolves were responsible for killing higher numbers of sheep, as well as the first cattle depredations. Although managers attempt to give wolves one chance at relocation away from livestock grazing areas after a reported depredation, additional depredations are cause for the offending animal's removal from the population. And, under the special rules for managing restored wolves, livestock owners or managers may take immediate action against a wolf caught in the act of stock depredation.

Two yearling wolves, who had belonged to the Sawtooth pack transferred to Yellowstone from northwestern Montana in 1996, were legally shot in separate incidents of stock depredation in Idaho and Montana during June and July. In early September, another female Sawtooth yearling was removed after killhead of Wyoming's Green River. The rancher who owned the sheep received $4,580 from the Defenders of Wildlife to compensate him for his lost livestock.

In October, the original alpha female from the Nez Perce pack, #27, was eliminated after killing two cows west of the park. Six younger wolves who had been roaming with her were trapped and placed temporarily back in a holding pen within Yellowstone National Park. In separate incidents, the alpha male of the seven-member Washakie pack near Dubois, Wyoming, was removed for killing cattle in late October, and another former Sawtooth wolf was killed for preying on sheep near Nye, Montana.

Despite these and other mortalities, the wolf population numbered around 85 wolves by late October, including 42 to 45 adults and 43 pups born into nine packs this past spring.

Abandoned Gravel Quarries Reclaimed

NPS resource management guidelines call for eliminating adverse impacts associated with abandoned mineral lands whenever possible. Yellowstone National Park, with funding and support from the Wyoming Department of Environmental Quality's Abandoned Mineral Lands Division, recently completed reclamation of two abandoned gravel quarries formerly used to provide construction materials in the park. After several years of planning and discussion involving park and state personnel, contractors recontoured the Dry Creek and Little Thumb Creek gravel pits to correct drainage problems and minimize erosion from the former quarries. Workers also tore up, decompacted, and removed asphalt roads to the quarries, enabling the restoration of wetlands at the Dry Creek site, located north of Craig Pass, and hastening the restoration of native cutthroat trout spawning habitat in Little Thumb Creek, north of Grant Village. Native trees and grasses were planted in the disturbed earth to discourage exotic vegetation infestations. With time, park resource managers expect these sites to return to their natural appearance. The state of Wyoming is interested in continuing the cooperative work to help restore additional abandoned rock and gravel quarries inside Yellowstone's boundaries.

MSU to Host Research Symposium for Yellowstone Anniversary

Yellowstone, long an outdoor laboratory for researchers, celebrates its 125th anniversary in 1997-1998 with a series of special events. These include a two-week symposium, to be held May 11-24, 1998, at Montana State University-Bozeman to commemorate the park's influence on scholarly research and creative activities. Offering a wide range of activities, the symposium will consist of four scientific conferences and three workshops, as well as a Greater Yellowstone Film Series, art show, and photographic exhibit. Scientific conferences will run two or three days each and deal with such topics as fire ecology, life in extreme environments, the human role in the park's ecosystem, and the interplay of geology and ecology. Workshops will discuss the greening of Yellowstone, future biological research, and information resources such as computerized data clearinghouses and linkages between federal and local governments. For more information, contact Carolyn Manley at (406) 994-5145.

New Lake Trout Spawning Areas Discovered

During the summer of 1997, approximately 1,050 non-native lake trout were caught in Yellowstone Lake, compared to 786 in 1996. Anglers caught 240 of the recorded lake trout, and NPS fisheries personnel caught another 806 in gill nets. More than 450 of the netted fish were spawners; 235 lakers were found at Carrington Island, 168 came from Breeze Channel between West Thumb and the main body of the lake, and 80 were caught along the southeast shore of West Thumb. Of the six "Judas fish" radio-tagged and released during 1996, three have been recovered or monitored in West Thumb, and two of these were in previously discovered lake trout spawning areas. None of the lake trout radio-tagged and released in 1997 have reappeared yet.

The discovery of spawning lake trout in Breeze Channel and along the southeast shore has biologists concerned, but the number of lake trout, especially spawners, being caught continues to reduce the overall population by a sizeable though undetermined amount. Unfortunately, biologists still lack a reliable estimate of the number of lake trout that have become established in Yellowstone Lake. Biologists from the Idaho Department of Fish and Game are working on a population estimate through the use of hydroacoustics; their report is expected by early 1998.

Lake Trout Angler Catches