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

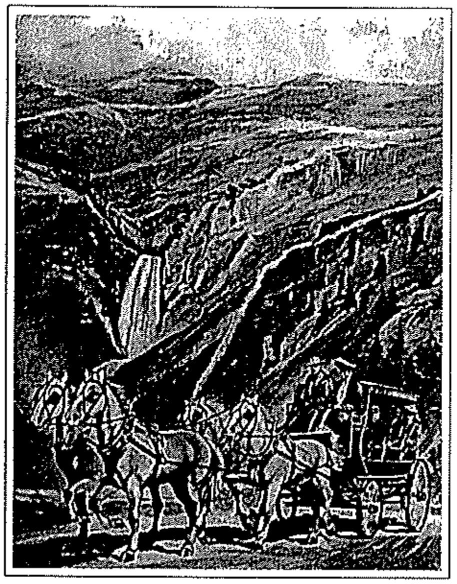


Table of Contents

Reconstructing Yellowstone's Climate History 2

Data from fossil beetle assemblages and a primer on geology remind us that Yellowstone's prehistoric environment ranged from glacial cold to summers hotter than the historic 1988, and that climate continues to influence which species thrive.
by Scott A. Elias

Yellowstone Seen Through Water and Glass 9

His studies of obsidian led to a technique used by archeologists to date cultural artifacts; through monitoring chloride in park rivers he hopes to help protect geysers from changes associated with development.
Interview with Irving Friedman

Striking Similarities: Labor Versus Capital in Yellowstone National Park 15

In the park's 125th anniversary year, a historian reminds us that Yellowstone, a cultural icon, was and is not a wilderness isolated from "outside" events.
by Brit T. Fontenot

News and Notes

• Yellowstone Signs Bioprospecting Agreement • Grizzly Bear Production, Mortalities Up Again in 1997 • Noted Limnologist Dies • MSU to Host Research Symposium • Decline in Spotted Frogs • Bison Exhibited, Mugged • And More 19

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.

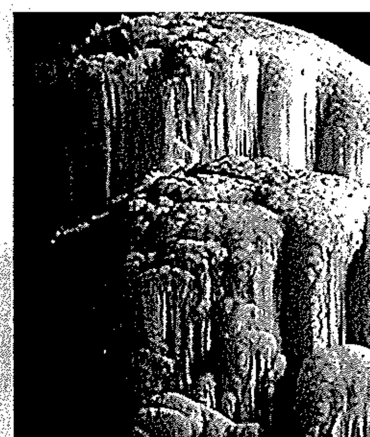
Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY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

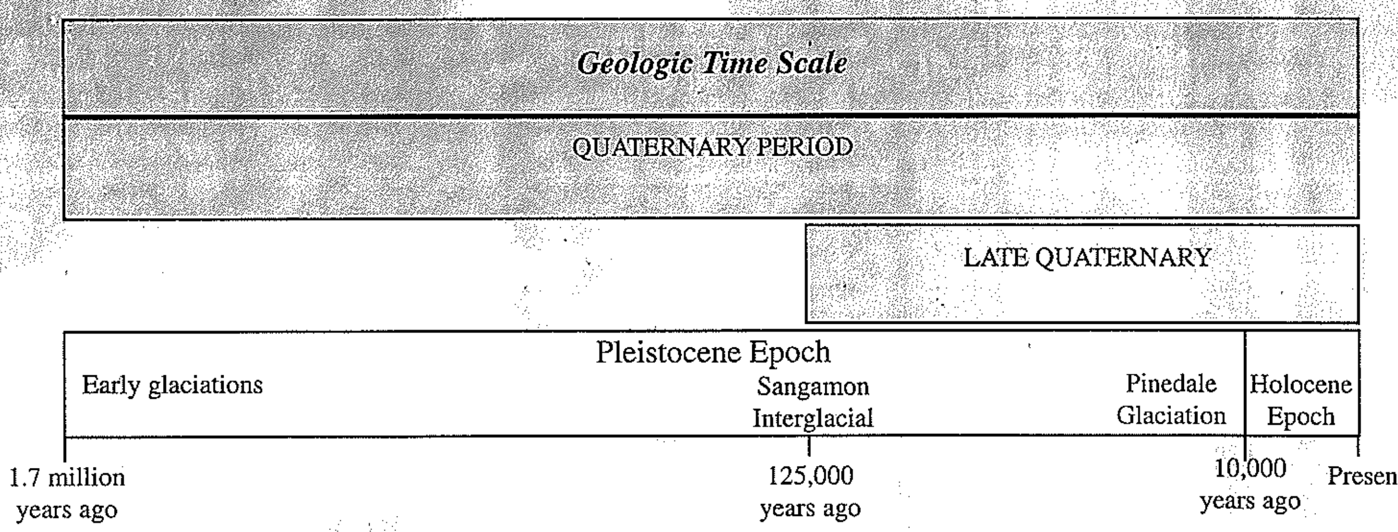
by Scott A. Elias



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.

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

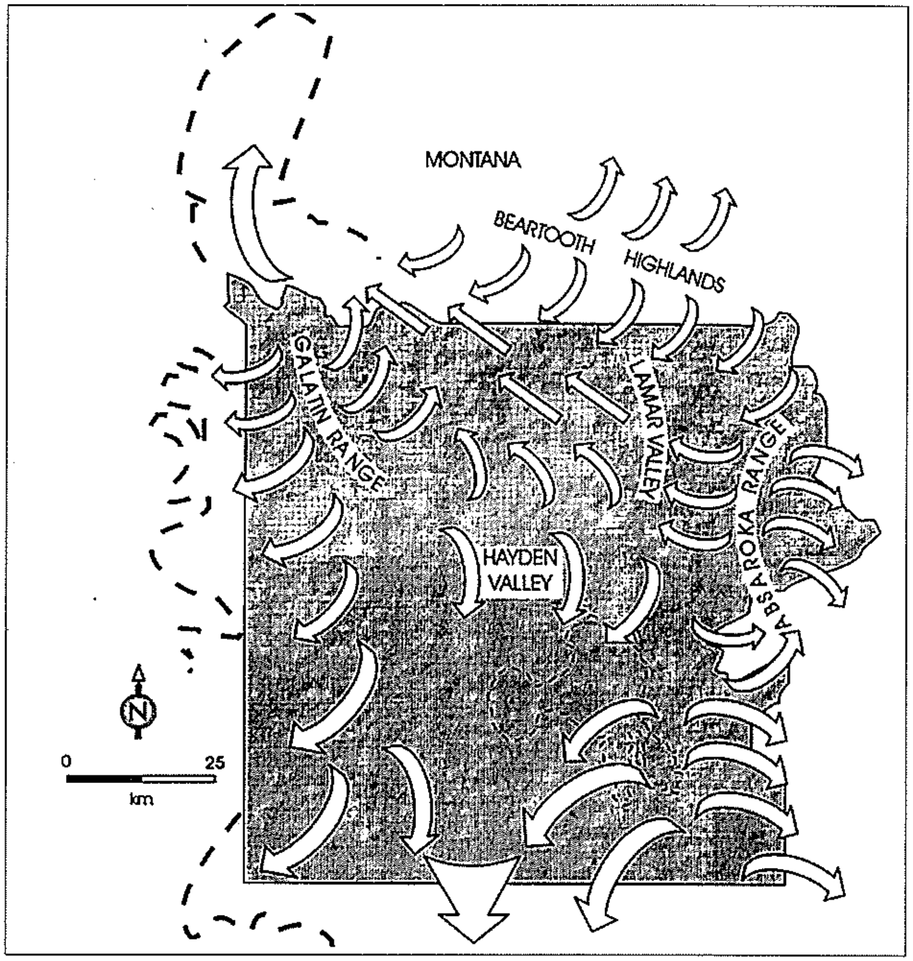


Fig. 2. Map of Yellowstone National Park, showing extent and patterns of movement of glacial ice during the last glaciation (from Elias, 1996).

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.

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

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.

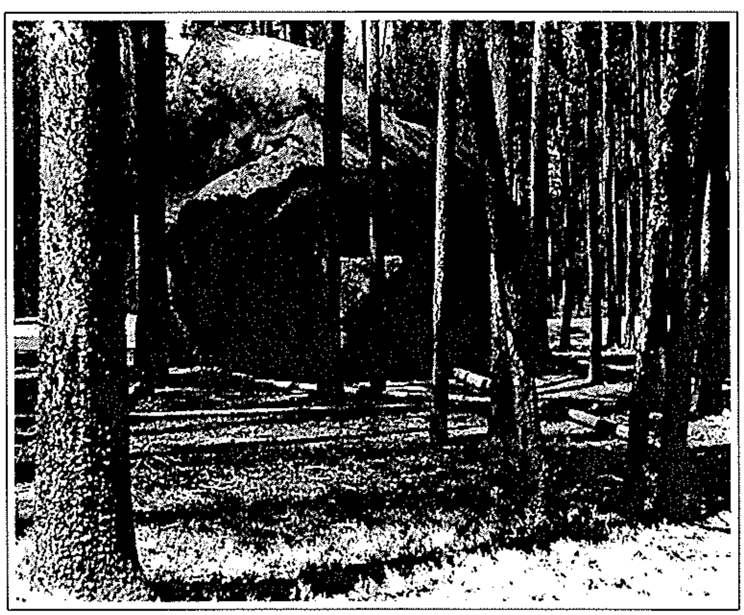
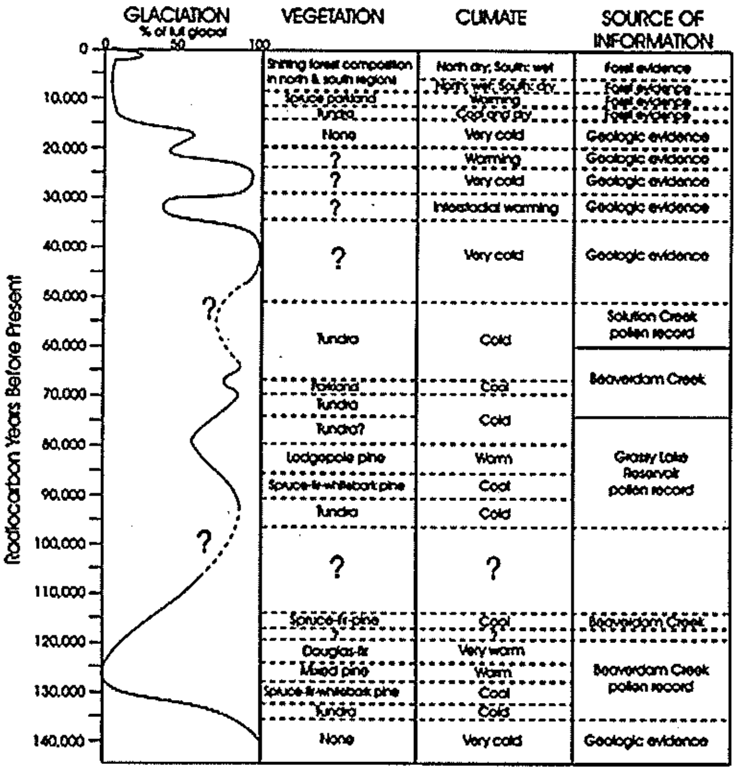
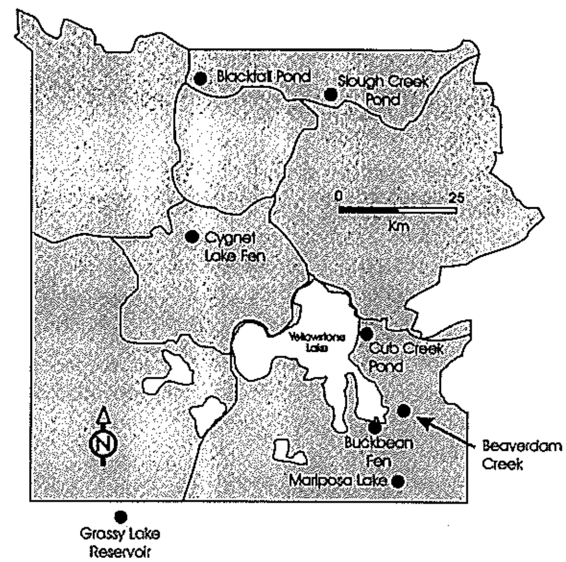


Fig. 4. A glacial boulder near Inspiration Point. Courtesy of the Yellowstone archives, reference YELL 35135-2.





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 tundra 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

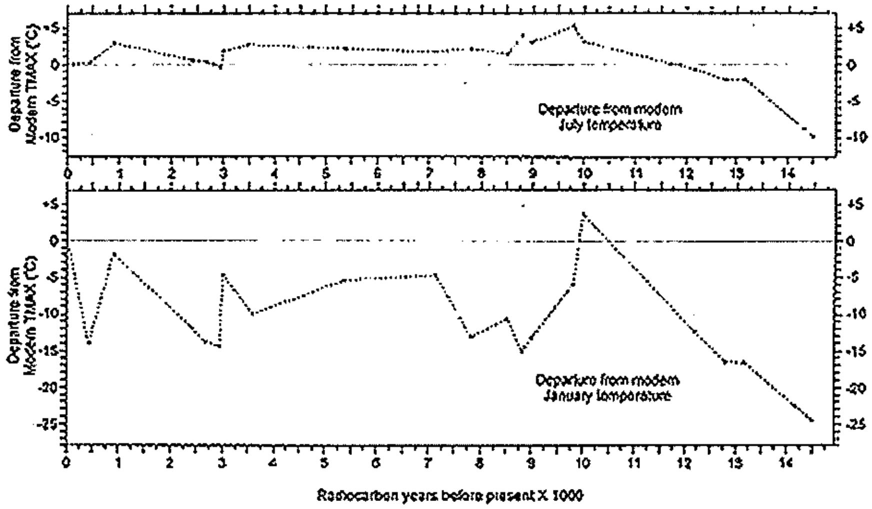


Figure 7. Reconstructions of mean July and mean January temperatures in the Rocky Mountain region. Shown as departures from modern temperatures at study sites. The estimates were derived from fossil beetle data, using mutual climatic range method.

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.