Yellowstone Science

volume 18 • issue 1 • 2010

Precontact Archeology in Yellowstone

Interview with Archeologist Ann Johnson

A New View of Yellowstone's Geyser Basins

Science in Brief

The value of Yellowstone National Park as a scientific laboratory as well as a public pleasuring ground is reflected in the fact that the park hosts more than 200 researchers from various agencies, universities, and organizations each year. They produce hundreds of papers, manuscripts, books, and book chapters on their work annually—a volume of information that is difficult to absorb. *Yellowstone Science* journal was started in 1992 to help report Yellowstone-based scientific research findings to researchers, park managers and staff, and the interested public. In each issue we feature articles written by researchers from many disciplines—from art history to microbiology—and distribute it to more than 3,500 readers as well as make it available online.

Since the inception of *Yellowstone Science* there have been few changes to the journal. Yet with advances in technology our audiences now receive even more information which is ever more widely available. With more demands on our time as readers, a shorter article has its advantages. In keeping with the times and our audiences' needs, *Yellowstone Science* is pleased to introduce a new department in this issue, "Shorts." This department will feature brief summaries of recent and important-to-Yellowstone projects and publications. Through Shorts, we will attempt to report on more of the projects and results that researchers provide us with. We hope you enjoy this new department.

I would also like to remind you of another forum for science in Yellowstone, the upcoming 10th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, "Questioning Greater Yellowstone's Future: Climate, Land Use, and Invasive Species." Information on the conference can be found on the Greater Yellowstone Science Learning Center website (www.greateryellowstonescience.org/gyesciconf2010). Registration will open in June.

In this issue, retired park archeologist Ann Johnson imparts what she learned over a long career in Yellowstone. Park geologist Cheryl Jaworowski shares new images of Yellowstone's geyser basins that can help us to better understand and protect these large thermal areas. We hope you enjoy the issue.

NPS/HFC COMMISSIONED ART COLLECTION, ARTIST GIL COHEN

Yellowstone Science

a periodical devoted to natural and cultural resources

volume 18 • issue 1 • May 2010

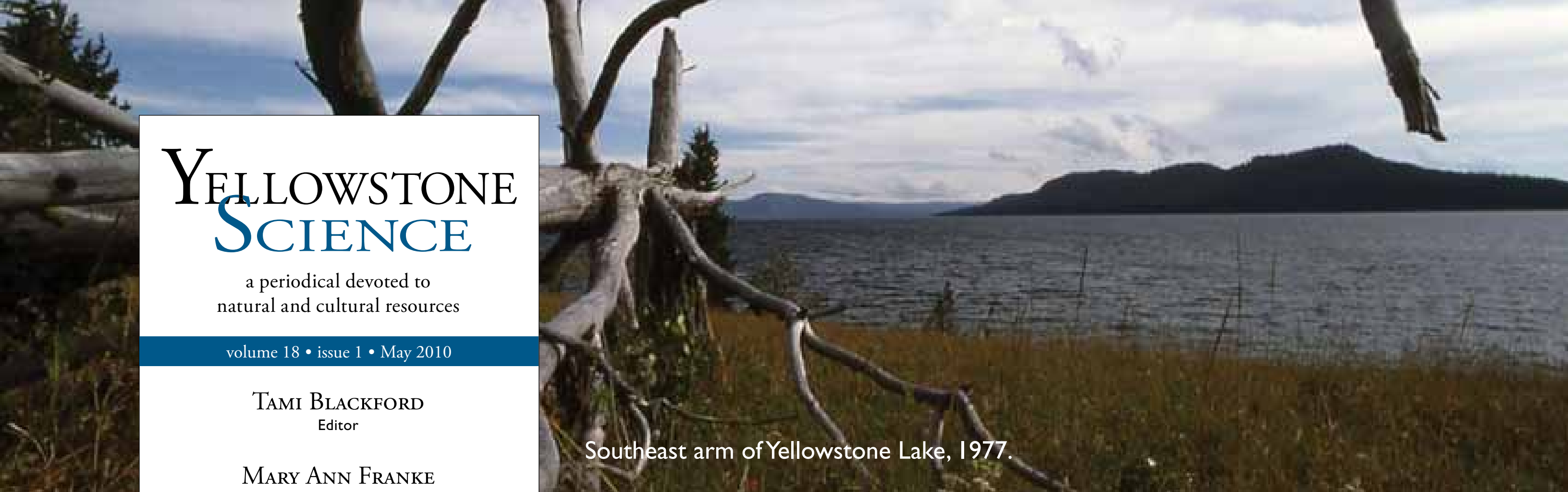
Tami Blackford
Editor

Mary Ann Franke
Associate Editor

Emily Yost
Graphic Designer
Assistant Editor

Janine Waller
Assistant Editor

Artcraft Printers, Inc.
Bozeman, Montana
Printer



Southeast arm of Yellowstone Lake, 1977.

NPS

FEATURES

DEPARTMENTS

Yellowstone Science is published periodically. Support for *Yellowstone Science* is provided by the Yellowstone Association, a nonprofit educational organization dedicated to serving the park and its visitors. For more information about the association, including membership, or to donate to the production of *Yellowstone Science*, visit www.yellowstoneassociation.org or write: Yellowstone Association, PO Box117, Yellowstone National Park, WY 82190. The opinions expressed in *Yellowstone Science* are the authors' and may not reflect either National Park Service policy or the views of the Yellowstone Center for Resources.

For back issues of *Yellowstone Science*, please see www.greateryellowstonescience.org/ys.

Submissions are welcome from all investigators conducting formal research in the Yellowstone area. To submit proposals for articles, to subscribe, or to send a letter to the editor, please write to the following address: Editor, *Yellowstone Science*, PO Box 168, Yellowstone National Park, WY 82190. You may also email: yell_science@nps.gov.

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

Cover photo:
Stone cairn site near Yellowstone Lake. Photo by NPS/Robin Park.

News & Notes

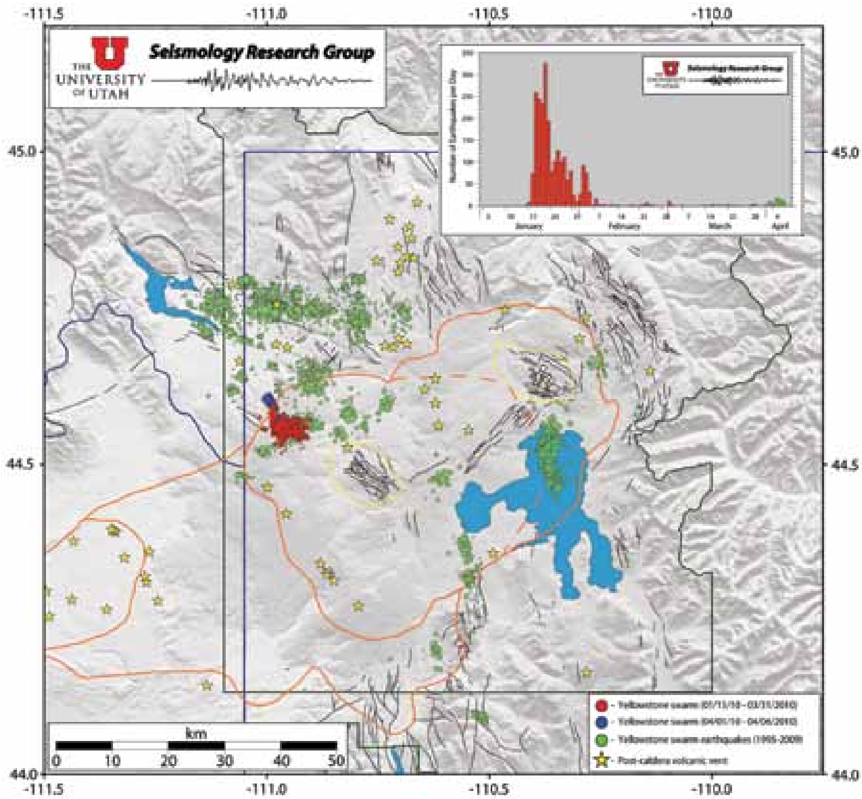
Summary of January–February 2010 Yellowstone Earthquake Swarm

Adapted from information available on the Yellowstone Volcano Observatory website (http://volcanoes.usgs.gov/yvo/)

An earthquake swarm that began on January 15, 2010, with a few small quakes picked up in intensity on January 17 (fig. 1), and by the end of February, earthquake activity at Yellowstone had returned to near-background levels, but seismic activity increased slightly in early April. The swarm was located about 10 miles (16 km) northwest of the Old Faithful area on the northwestern edge of the Yellowstone Caldera.

Swarms have occurred in this area several times over the past 30 years, but this swarm is the second largest recorded in the park. It lasted longer and included more earthquakes than last year's swarm beneath Yellowstone Lake (December '08/January '09). Calculations by the University of Utah Seismology Research Group of the total seismic energy released by all the swarm earthquakes corresponds to one earthquake with an approximate magnitude of 4.4. The largest recorded swarm at Yellowstone occurred in the fall of 1985 in a similar location, in the northwest corner of the Yellowstone Caldera.

As of April 6, 2010, a total of 2,357 earthquakes had been automatically located for the entire swarm, including 16 with a magnitude greater than 3.0; 141 with M2.0–2.9; 1,742 with M1.0–1.9; 1,361 with M0.0-0.9 and 97 with M<0.0. The largest events were a pair of earthquakes of magnitude 3.7 and 3.8 that occurred after 11 PM MST on January 20, 2010. Both events were felt throughout the park and in surrounding communities in Wyoming, Montana, and Idaho.



JAMIE FARRELL, ROBERT B. SMITH, AND CHRISTINE PUSKAS OF THE UNIVERSITY OF UTAH SEISMOLOGY RESEARCH GROUP

Figure 1. Map of Yellowstone National Park showing recent swarm earthquakes (*red*), previous swarms from 1995–2009 (*green*), volcanic vents (*yellow stars*), caldera boundaries (*orange*), Mallard Lake resurgent dome—to the southwest, and Sour Creek resurgent dome, to the northeast (*yellow lines*). Histogram shows the number of earthquakes per day from January 15 to April 6, 2010.

Many of the 19 M2.5-3.0 earthquakes were also felt in the region.

Michael Curtis Receives Wilderness Stewardship Award

In recognition of his role in furthering the safe use of low-impact methods for backcountry work, Yellowstone ranger Michael K. Curtis received the National Park Service's Intermountain Region Leader in Wilderness Stewardship Award.

Ranger Curtis started working for the National Park Service in Yellowstone as a Youth Conservation Corps (YCC) enrollee in 1990. After four summers he had advanced from youth leader to crew leader. He then worked on park trails for seven seasons, four as the leader of the South District trail crew. He spent one winter with the Lynx Project (2001–2002), then became the Shoshone Lake Ranger from summers 2002 through 2005. During those winters he did snowmobile patrol at South. Curtis also worked in Capitol Reef and Big Bend national parks and as a bio-aide for Idaho Fish and Game. Since May 2006, he has been the backcountry supervisor for the Snake River District.

As a backcountry supervisor, Curtis has shown a dedication to refining and implementing the minimum

COURTESY OF MICHAEL CURTIS

Yellowstone ranger Michael Curtis was recognized by the National Park Service's Intermountain Region for his leadership in wilderness stewardship.

requirement analysis process. When the Yellowstone Park Foundation (YPF) offered to provide funds for backcountry equipment, he proposed saws and axes, conducted the necessary research, found the appropriate vendors, and taught backcountry rangers how to use these tools. He has become known regionally for his advice on the acquisition and maintenance of crosscut saws and other primitive tools and is sought out for his expertise by other agencies and organizations.

One of the many hazardous jobs carried out by Yellowstone rangers is to put up cross timbers in trees so that campers can hang their food out of reach of bears. This is a lower-impact alternative to having large steel boxes flown into the backcountry for storage of food and other bear attractants. To make this work safer, Curtis researched the use of climbing and arborist equipment and primitive mechanical advantage techniques. To make the best use of a YPF grant to install metal roofs on two backcountry cabins at Shoshone Lake, which required moving more than a ton of steel 10 miles into the backcountry, Curtis chose the lowest impact, though most labor-intensive, transport method—canoes. When the manual construction methods became unfeasible, he adopted short-duration generator use and rechargeable electric tools as the appropriate solution.

In these ways, Curtis has served as a role model for the seasonal rangers who have worked with him and continues to impart these values, standards, and techniques servicewide.

Northern Elk Herd Winter Count

Under what were considered only fair survey conditions, the Northern Yellowstone Cooperative Wildlife Working Group counted 6,070 elk in the annual winter aerial survey of the northern Yellowstone elk herd. This year's survey was hampered by a lack of snow on the ground and some poor flying weather.

Although the population size has remained fairly stable since 2006, this year's count is down significantly from the 9,545 elk counted during the winter of 2004–2005, and elk numbers have declined 60% since wolf restoration began in the region in 1994. However, a significant reduction in both wolf numbers and wolf predation has been observed on the park's northern range in the last seven years. Biologists believe that fewer elk calves survive and elk numbers have decreased in areas where there are higher numbers of wolves and grizzly bears, but have stabilized or even increased in areas where there are fewer predators and only moderate population reduction from hunting. Montana Fish, Wildlife and Parks has issued only 100 antlerless elk permits per season in recent years and recommended closing the Gardiner late hunt for the next two years to increase the size of the elk herd.

The herd winters between the park's Northeast Entrance and Dome Mountain and Dailey Lake in Paradise Valley, Montana. In this year's survey, the number of elk observed in the park was about equal to those counted outside the park's north boundary.

The Northern Yellowstone Cooperative Wildlife Working Group, which includes biologists from Yellowstone National Park, Montana Fish, Wildlife and Parks, Gallatin National Forest, and the US Geological Survey, will continue to monitor trends of the northern Yellowstone elk population and evaluate the relative contribution of various components of mortality, including predation, environmental factors, and hunting. The Working Group was formed in 1974 to preserve and protect the long-term integrity of the northern Yellowstone winter range for wildlife species by increasing knowledge of the species and

USGS/STEVE ARD

Bull elk spotted during the 2009–2010 annual winter aerial survey.

(NEON), and was responsible for conducting a Greater Yellowstone Area Science Agenda Workshop that brought more than 100 scientists and managers together to analyze the need for research in three major ecological stressors: climate change, land use change, and invasive species.

Bison in Hayden Valley during the late winter bison survey, 2009–2010.

their habitats, promoting prudent land management activities, and encouraging an interagency approach to answering questions and solving problems.

Late Winter Bison Population Estimated at 3,000

Based on the findings of the late winter bison survey, park staff estimated the bison population size at about 3,000. Low snowpack and numerous bare patches of ground made the aerial survey difficult to conduct this year and likely resulted in an underestimate of the population by as much as ten percent. Last year's late winter population estimate was 2,900 bison.

State licensed and tribal hunters removed four bison from the population this year. No other bison have been captured or shipped to slaughter, or otherwise removed from the population this winter. The surveyed bison were observed in two herds; 56 percent on the northern range, and the remainder in the park interior.

The population estimate is used to inform adaptive management strategies under the Interagency Bison Management Plan (IBMP) as carried out by the National Park Service, the US Forest Service, the Animal and Plant Health Inspection Service, the Montana Department of Livestock, and the Montana Department of Fish, Wildlife and Parks. The IBMP is designed to conserve a viable, wild bison population while protecting Montana's brucellosis-free status. Specific management actions may be modified based on expected late winter population levels, as corroborated by the summer population estimate.

Olliff Wins Natural Resource Management Award

In January 2010, former Yellowstone Center for Resources Director Tom Olliff won the National Park Service's Regional Director's Award for Natural Resource Management. Now serving as the Greater Yellowstone Inventory and Monitoring Network Program Manager, Olliff has long championed science-informed resource management by building relationships between scientists and parks, as well as sponsoring scientists to conduct mission-critical research and making science accessible to managers.

His accomplishments have been built on years of dedication, long-term vision, and perseverance. In 2009, he published the first Superintendent's Report on Natural Resource Vital Signs, a capstone of almost a decade of efforts to develop, sustain, and engage three programs under the auspices of the Natural Resource Challenge: the Greater Yellowstone Inventory and Monitoring Network, the Greater Yellowstone Science Learning Center, and the Rocky Mountains Cooperative Ecosystem Studies Unit. He also served as a co-leader in developing the *NPS Servicewide Benefits-Sharing Environmental Impact Statement*, was integral to the selection of the Yellowstone National Park Northern Range Core Site as one of the 20 Domain sites of the National Ecological Observatory Network

10th Biennial Scientific Conference on the GYE Announces Keynote Speakers

The program committee of 10th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, "Questioning Greater Yellowstone's Future: Climate, Land Use, and Invasive Species," recently confirmed keynote speakers for the October event.

The opening keynote will be given by Dr. Marcia McNutt, director of the US Geological Survey. Keynotes for each of the primary themes of the conference will be given by: Dr. Stephen Gray, director of the Water Resources Data System and Wyoming State Climatologist; Dr. Robert Gresswell, US Geological Survey research biologist; and Dr. Andrew Hansen, director of the Montana State University Ecology Department.

Speakers also committed to the three traditional, named lectures for the conference series. Dr. Judith Meyer, associate professor at Missouri State University will deliver the Aubrey L. Haines Lecture. Dr. Mary Meagher, retired National Park Service ecologist, will deliver the A. Starker Leopold Lecture. Professor Göran Ericsson, Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, will deliver the Superintendent's International Lecture.

The conference will be held October 11–13, 2010, in Mammoth Hot Springs, Yellowstone National Park. Registration will be available in late spring via the conference website, www.greater yellowstonescience.org/gyesciconf.

YS

Passages

Linda L. Wallace


PAUL SCHULLERY

Dr. Linda Wallace at the Lamar River cable car during a day in the field in 1989.

Linda L. Wallace, a 58-year-old grassland ecologist who had conducted long-term research in Yellowstone, passed away on December 13, 2009, after a long battle with cancer. Born in Colorado, she received her BA in biological sciences from the University of Northern Colorado, her MS in botany from the University of Wyoming, and her PhD in botany from the University of Georgia. Her postdoctoral research at Syracuse University with professor Samuel McNaughton, and at the Serengeti Research Institute in Tanzania became the foundation for her ensuing work in grazing ecosystems. Subsequently, the Yellowstone grazing ecosystem became her passion, and was always at the forefront for her.

Her research in Yellowstone in the 1980s and 1990s focused on fire and northern range research. After the 1988 fires, she spearheaded an effort of scientists who had been working in the park to obtain National Science Foundation (NSF) funding for a large, integrative study of ecosystem responses to the fires, from soils to vegetation, wildlife, and stream ecology. According to Dr. Michael B. Coughenour, Senior Research Scientist at Colorado State University's Natural Resource Ecology Laboratory, even though the NSF did not fund the proposals, the exercise had long-lasting positive effects in stimulating many new ideas for research and fostering a "community of science" among Yellowstone ecologists. In addition to teaching at the University of Oklahoma, she was part of a team of collaborators that worked to reframe the "overgrazing" issue on the northern range in the context of wildland range ecology. The park's 1997 report *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem* cited six of her publications.

Retired Yellowstone writer-editor Paul Schullery, currently scholar-in-residence at Montana State University Library, remembers that for the 5th Biennial Scientific Conference on the Greater Yellowstone Ecosystem in 1999, "Exotic Organisms in Greater Yellowstone: Native Biodiversity Under Siege," Wallace served as the expert summarizer, immediately synthesizing the sessions into a presentation that was an amazing performance of scholarly breadth. She also edited the 2004 Yale University book *After the Fires: The Ecology of Change in Yellowstone National Park.* Within the last decade, her research interests had turned to examining the effects of global warming and climate change on grassland ecosystems, and she was part of a working group investigating the ecological consequences and sustainability of cellulosic ethanol. She will be missed at this year's 10th biennial conference, which will focus on climate change in the Greater Yellowstone Ecosystem.

"Linda was unusual among researchers in the park," former National Park Service ecologist Mary Meagher recently noted, "in her willingness to help the park's field people with resource issues. She made a five-day, south boundary horseback trip with rangers Jerry Mernin, Dave Phillips, Tom Olliff, and me, to assess methods for evaluating outfitter campsite impact, and a separate single day in to Heart Lake for the same purpose on which we were joined by ranger Ann Maria Chytra. If those trips didn't start her horse interest, they surely reinforced it. She pitched in and watched how things were done at cabins and went at it. Backcountry time has long been my setting for evaluating a person, and she passed with flying colors. Linda did not tell you what some would think you wanted to hear, she told you what she thought, but she was not a contentious person. She was a great sounding board. She always had ideas, but she also was a fine listener. She was the finest grassland ecologist I will know."

YS

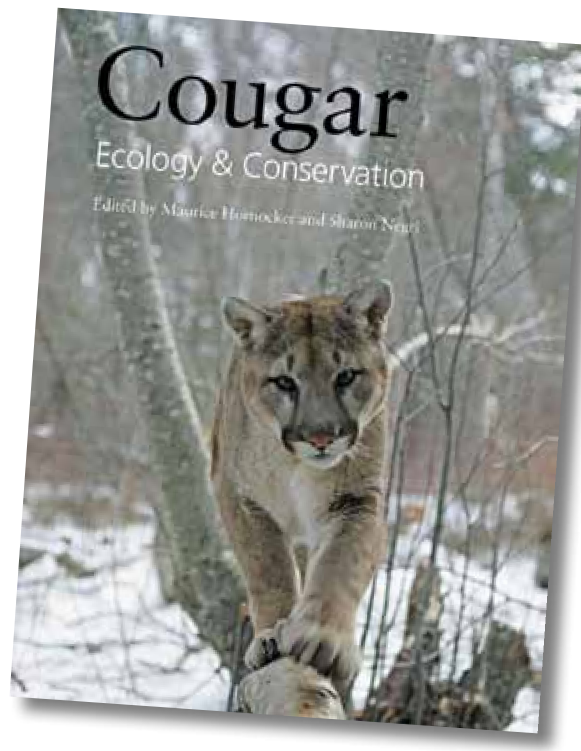
NPS/HFC COMMISSIONED ART COLLECTION, ARTIST GIL COHEN

Shorts

A new department featuring summaries of recent and important-to-Yellowstone research and publications.

Cougar: Ecology and Conservation

Hornocker, M., and S. Negri, eds. 2009. *Cougar: Ecology and conservation.* Chicago: University of Chicago Press.



UNIVERSITY OF CHICAGO PRESS

The cougar's range once extended from northern Canada to the tip of South America, and from the Pacific to the Atlantic, making it the most widespread animal in the western hemisphere. But overhunting and loss of habitat vastly reduced cougar numbers by the early twentieth century across much of its historical range, and today the cougar faces numerous threats as burgeoning human development encroaches on its remaining habitat.

When internationally renowned biologist Maurice Hornocker began the first long-term study of cougars in the Idaho wilderness in 1964, little was known about this large cat. Its secretive nature and rarity on the landscape made it difficult to study. But his groundbreaking research yielded major insights and was the prelude to further research on this controversial species. Hornocker joined with Sharon Negri, conservationist and director of WildFutures, a non-profit organization, and together they produced *Cougar: Ecology and Conservation*, a seminal resource for scientists, wildlife managers, biologists, conservationists, and anyone who has an interest in large carnivores. Hornocker and Negri invited 22 leading scientists, spanning the globe from Canada to Patagonia, to contribute to this rare anthology. The distinguished contributors have a wide range of experience and present personal perspectives and research results as diverse as the ecosystems cougars inhabit.

Among the contributing scientists are Yellowstone National Park researcher Toni Ruth of the Selway Institute and former park mid-sized carnivore biologist Kerry Murphy, who draw on more than 20 years of experience each working with cougars in Yellowstone. Combined, their Yellowstone studies span about 15 years and are focused on cougar ecology and predation before and during the reestablishment of wolves. Ruth and Murphy's chapters address adaptations that make the cougar the perfect predator. They also examine the cougar's diet across its range from North to South America and the affect of human factors, climate variations, and interactions with other carnivores such as wolves, bears, and coyotes on prey selection, frequency of kills, and, ultimately, prey populations.

Cougar: Ecology and Conservation is the first comprehensive review of cougar throughout the cat's enormous range. It includes such topics as taxonomy, genetics, history, behavior and social organization, predator-prey relationships, population dynamics, human dimensions, the role of government and citizens in conservation, and the future of research. This compilation of recent findings, stunning photographs, and firsthand accounts of field research woven throughout the book unravels the mysteries of this magnificent animal and emphasizes its importance in healthy ecosystem processes and in our lives. The book is 304 pages long and contains 16 pages of color photographs.

—University of Chicago Press, WildFutures, and Toni Ruth

Trumpeter Swan Abundance and Growth Rates in Yellowstone National Park

Proffitt, K.M., T.P. McEneaney, P.J. White, and R.A. Garrott. 2009. Trumpeter swan abundance and growth rates in Yellowstone National Park. *The Journal of Wildlife Management* 73(5):728–736.

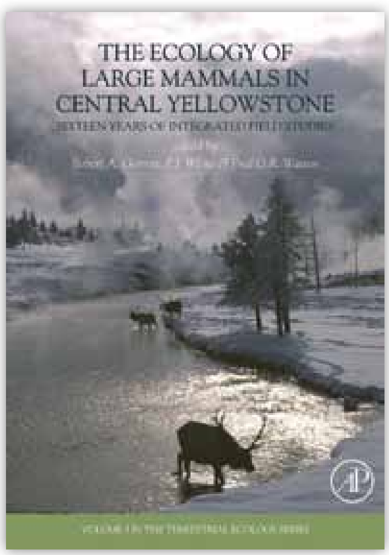
As a result of nationwide conservation measures, nearly extirpated trumpeter swan populations have grown dramatically over the past 40 years. However, in contrast to the increasing number of wintering trumpeter swans in Yellowstone National Park, most of them migrants from Canada, the park's resident population has declined steadily, with estimated abundance ranging from 59 in 1968 to 10 in 2007. This study found little evidence that the resident population's annual growth rate was affected by the number of migratory wintering swans, but the decline was more rapid following the draining of winter ponds and cessation of the winter feeding program at Red Rock Lakes National Wildlife Refuge in 1992–1993, and growth rates were lower following severe winters, wetter springs, and warmer summers. The authors conclude that the park provides marginal conditions for nesting and may be acting as a sink for swans dispersing from more productive areas. This effect has been compounded over the last several decades by habitat changes (e.g., decreased wetlands due to long-term drought or chronic warming) and recovery of predator populations. Thus, barring interventions that would conflict with National Park Service policy to minimize human intervention, trumpeter swan presence in Yellowstone may be primarily limited to occasional residents and wintering aggregations of migrants from outside the park.

NPS

The Ecology of Large Mammals in Central Yellowstone: Sixteen Years of Integrated Field Studies

Garrott, R.A., P.J. White, and F.G.R. Watson, eds. 2009. *The ecology of large mammals in central Yellowstone: Sixteen years of integrated field studies*. San Diego: Academic Press.

The Ecology of Large Mammals in Central Yellowstone: Sixteen Years of Integrated Field Studies is a comprehensive synthesis of extensive and interrelated research conducted to understand the influences of climate and landscape on the dynamics of the mammals in the interior of the world's first and most famous national park, Yellowstone. Central Yellowstone is home to a large migratory bison herd, elk, and wolves. It is largely free from development and hunting, which provides unique opportunities for researchers to better detect the ecological processes and mechanisms underlying ecological patterns. *The Ecology of Large Mammals in Central Yellowstone* is the third book in a terrestrial ecology series and includes contributions from 11 staff members of the Yellowstone Center for Resources.



ACADEMIC PRESS

Contributed chapters advance the theoretical understanding of population, community, ecosystem patterns and processes, and the ability of ecologists to effectively maintain assemblages of these large mammals and the ecological processes that they facilitate. Contributing authors include detailed descriptions of the central Yellowstone environment and present results of intensive field sampling, remote sensing, and modeling of important ecosystem components like snowpack, geothermal intensity, wind patterns, vegetation cover, and plant phenology. These results are merged with extensive demographic, spatial, and behavioral databases from the resident elk, migratory bison, and reintroduced wolf populations to address population-level ecological processes. The fortuitous reintroduction of wolves after the studies were well-established provided a rare field experiment that enabled the assessment of both the direct and indirect impacts of this top predator on its prey and the role of climate and landscape attributes in shaping these interactions.

The Ecology of Large Mammals in Central Yellowstone also includes the results of intensive field studies on wildlife-human interactions designed to provide objective scientific data to inform some of the contentious management and policy issues in Yellowstone. Finally, in an effort to provide a strong outlet for public science education, contributors present innovative and diverse educational products designed to communicate the ecological knowledge obtained from the research and conclude by addressing the role of science in Yellowstone. YS

NPS/YELL 36193

An 1871 photo by William H. Jackson of Crested Pool and Castle Geyser in the Upper Geyser Basin. The photo is part of the original album Jackson provided to the park from the US Geological Survey expedition. Jackson's photos were integral in the effort to establish Yellowstone National Park.

Using Thermal Infrared Imagery and LiDAR in Yellowstone Geyser Basins

Cheryl Jaworowski, Henry P. Heasler, Christopher M.U. Neale, and Saravanan Sivarajan

Yellowstone National Park's hydrothermal features were the main reason for the creation of the world's first national park. Over the years, many visitors, park staff, and scientists have viewed, sketched, and photographed Yellowstone's thermal features. Their protection is the primary focus of Yellowstone's peer-reviewed geothermal monitoring plan. Implementation of the monitoring plan has led to a new view of the hydrothermal systems in which a thermal area is more than the sum of its parts (thermal features, thermal deposits, altered ground, geothermal gases, thermal water, geology, and faults and fractures). It is a globally rare, composite natural resource that supports an array of recreational, economic, scientific, and cultural and natural heritage benefits.

In 2005, congress allocated funds to implement scientific monitoring of Yellowstone's hydrothermal systems. This paper highlights thermal infrared imaging results from a three-year collaborative study with the Remote Sensing Services Laboratory at Utah State University.

Yellowstone's Hydrothermal Areas

All of Yellowstone is listed as a significant thermal feature as defined by the congressionally enacted Geothermal Steam Act of 1970, amended in 1988 (*Federal Register*, vol. 52, 28795), that directs the Department of the Interior to monitor significant thermal features (*US Code* 30 § 1026, Mineral Lands and Mining). Thus, Yellowstone is required to monitor and protect its geothermal features from external threats such as those posed by geothermal development in Idaho (Island Park Known Geothermal Resource Area) and Montana (Corwin Springs Known Geothermal Resource

Area). Other potential threats to Yellowstone's geothermal systems include oil, gas, and groundwater development in Wyoming, Montana, and Idaho.

Yellowstone's earth-sourced heat (*geothermal*) can be found throughout the park. Often, visitors only see the water-sourced heat (*hydrothermal*) emanating from one of the thousands of hydrothermal features (geysers, hot springs, mudpots, and fumaroles) that make Yellowstone famous. In some places, Yellowstone's unusually high heat flow may be 60–120 meters (200–400 ft.) beneath a green, grassy meadow. Geothermal areas include both hot, dry rock and hydrothermal systems.

A key question underpinning the geology program's effort to monitor Yellowstone's heat is: *What is a thermal area?* The following working definitions may help to clarify this:

Thermal area: A contiguous geologic unit generally including one or more thermal features. Its boundary marks the maximum aerial extent of hydrothermally altered ground, thermal deposits, geothermal gas emissions, or heated ground. This is equivalent to terms such as Upper Geyser Basin, Midway Geyser Basin, Mud Volcano area, Smoke Jumper Hot Springs, or Hot Spring Basin (fig. 1A).

Thermal group: A subdivision of a thermal area that contains one or more hydrothermal features and can be isolated by physiographic, geochemical, or hydrographic parameters, though not on the basis of geologic materials (fig. 1B).

Thermal feature: A vent emitting steam or hot water, or several vents emitting steam or hot water that show an identifiable relationship. For example, Beehive Geyser has many smaller vents that erupt simultaneously to form the geyser plume.

Thermal drainage: A term referring to a physiographic/hydrologic drainage in which thermal areas are found. Examples include the Firehole, Yellowstone, or Gibbon drainages. Drainages also may be called basins, such as the Firehole Basin. Hydrologic unit parameters define a drainage.

Geology of the Upper, Midway, and Lower Geyser Basins

Yellowstone's hydrothermal areas are surface expressions of a complex system that reflects surficial sediments, bedrock geology, and faults and fractures. Numerous sediments and

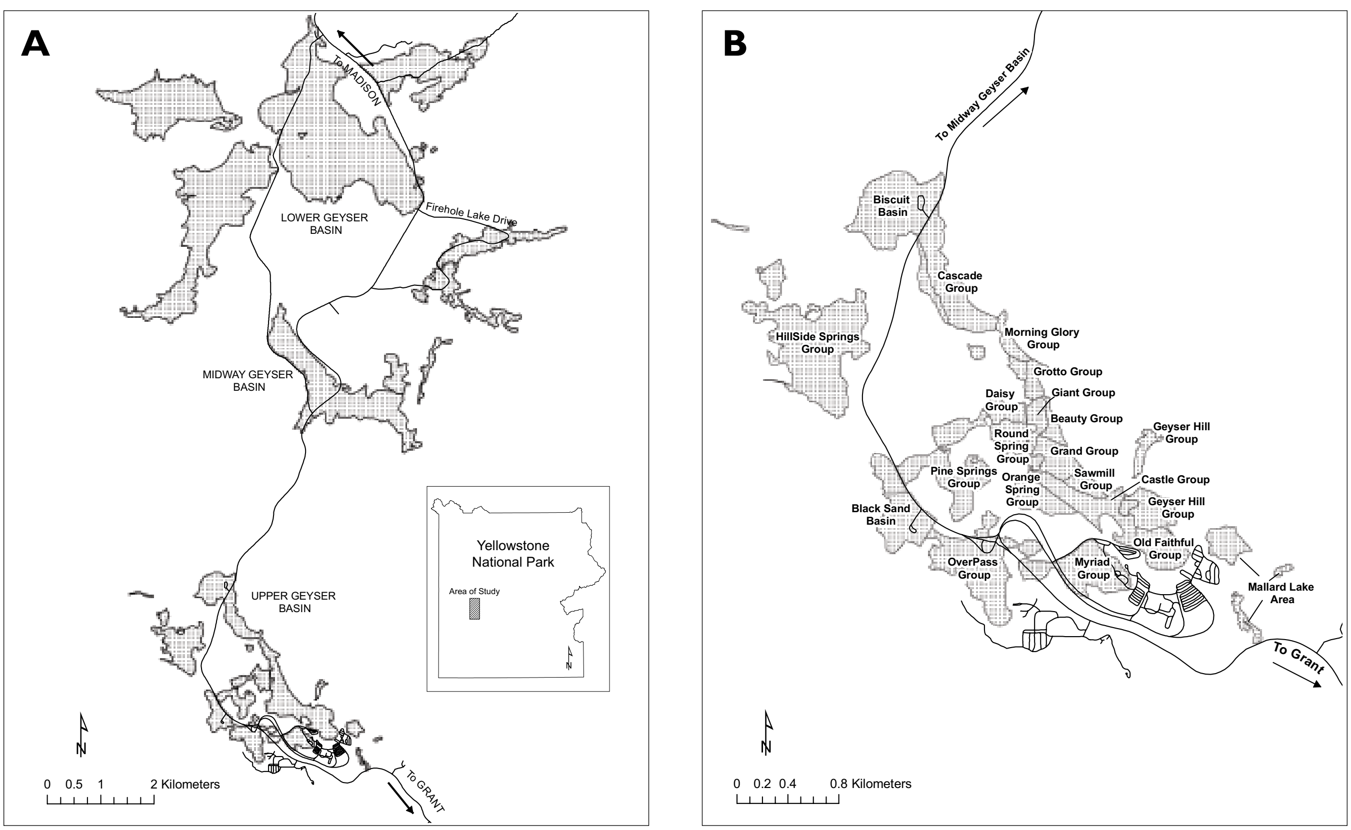


Figure 1. (*A*) Map showing the location of the Upper, Midway, and Lower geyser basins. (*B*) Map showing thermal groups of the Upper Geyser Basin. The late Rick Hutchinson, Yellowstone National Park geologist, mapped the spatial extent of these thermal areas. The Yellowstone Spatial Analysis Center converted his original mapping into a digital layer. See the NPS Data Store (http://science.nature.nps.gov/nrdata/) for a digital layer of Yellowstone's thermal groups.

Temperature and heat are two measures of Yellowstone's hydrothermal systems. Temperature is a relative measure of the "hotness" or "coldness" of an object. The temperature of a thermal spring can be measured easily but may not inform us about the hydrothermal system. In contrast, heat is a measure of energy that flows from a hot object to a cold object. Quantifying the heat from a large thermal pool at 65°C (149°F) versus a small pool at 65°C (149°F) provides important information about differences between these two hydrothermal systems. Degrees Fahrenheit (°F) or Celsius (°C) are the unit of temperature while calories or joules are the measure of heat.

episodic lava flows filled in the caldera that formed after the 640,000-year eruption of the Yellowstone Volcano (Christiansen and Blank 1974a, 1974b). Not long after this eruption, the 516,000-year-old (± 7,000 years) Biscuit Basin lava flow covered older volcanic rocks (figs. 2A and 2B). The 198,000-year-old Scaup Lake flow could represent the end of one volcanic episode (Christiansen 2001). As part of a new cycle of volcanic activity, the 153,000-year-old (± 2,000 years) Elephant Back flow and 165,000-year-old (± 4,000 years) Mallard Lake flows (Christiansen 2001; Christiansen et al. 2007) formed east of the current Upper, Midway, and Lower geyser basins. Another episode of volcanic activity involved the 112,000-year-old (± 2,000 years) Summit Lake and the 110,000-year-old (± 1,000 years) West Yellowstone lava flows (Christiansen 2001). These lava flows added new volcanic terrain along the park's western edge. Today, the Upper, Midway and Lower geyser basins occupy topographically low ground with volcanic plateaus surrounding them.

Faults and fractures have cracked rocks and allowed hydrothermal fluids to flow vertically and horizontally through the layers of rocks and sediments.

Various sediments (sand, silt, gravel, and clay) also filled in the low places and overlie the volcanic rocks. Rivers and glaciers deposited the variety of earth material, and hydrothermal fluids cemented these sediments with silica in places. The silica-rich hydrothermal deposits (sinter) form the light-colored thermal ground seen at Upper, Midway, and Lower geyser basins. In the Upper Geyser Basin, obsidian-rich, gravelly sand that is locally cemented can vary 5–150 feet (1.5–45.7 m) in thickness (Waldrop 1975). In other geyser basins, the earth materials deposited by melting glaciers are gray to brownish-gray sand and gravel.

Faults and fractures have cracked rocks and allowed hydrothermal fluids to flow vertically and horizontally through the layers of rocks and sediments. The mapped faults on the Mallard Lake resurgent dome (uplifted rock) show the expected trends of faults and fractures now hidden by sediments (fig. 2A). Northwest, north, and near east–west trends of faults and fractures probably affect the flow of hydrothermal fluids through the rocks in the Upper, Midway, and Lower geyser basins. Movement along these fractures during earthquakes may affect the hydrothermal system. Previous scientific work and observations indicate that these hydrothermal systems are affected by earthquakes (Marler 1964; Husen et al. 2004). Thus, temperature maps and LiDAR images of the Upper, Midway, and Lower geyser basins can show how subsurface faults and fractures localize the flow of hydrothermal fluids through rocks and overlying sediments.

Temperature Maps of the Upper, Midway, and Lower Geyser Basins

During September 2005, 2006, and 2007, Dr. Christopher Neale, a professor at Utah State University, and his graduate students collaborated with Yellowstone National Park geologists to acquire baseline temperature maps for the Upper, Midway, and Lower geyser basins (figs. 1A and 1B). In 2007, they used a temperature-sensing camera (a FLIR Thermocam SC640) in Utah State University's aircraft. Pilots flew over selected areas while the Remote Sensing Services Laboratory crew deployed ground-based instrumentation to document atmospheric conditions used for correction of the thermal imagery. Park geology program staff and volunteers deployed temperature loggers in select thermal pools for temperature calibration and validation of the airborne thermal imagery.

The Upper Geyser Basin is a 2.9-square-kilometer (1.1 mi^2) thermal area with numerous thermal groups and thermal features in the Firehole River drainage (fig. 1B). The September 2007 nighttime thermal infrared map of the Old Faithful area (1-m spatial resolution) shows high (40°C–70°C or 104°F–158°F), intermediate (15°C–30°C or 59°F–86°F), and low (5°C–15°C or 41°F–59°F) temperatures within the Old Faithful, Geyser Hill, and Myriad groups (fig. 3). Even the lowest temperatures on these maps show the elevated ground temperatures resulting from Yellowstone's hydrothermal system. Detailed topography from a 2008 LiDAR (light detection and ranging) sensor is the shaded, gray base for this temperature map (this LiDAR data is available at http://opentopography.org).

In the Old Faithful area, infrastructure (buildings, roadways, and water and sewer lines) obscures the natural temperature variations at the ground surface. Figure 3 shows the effects of park infrastructure directing the underground flow of heat and fluids. Low-temperatures (10°C–15°C or 50°F–59°F) around the south side of Old Faithful show the location of an abandoned sewer line. This abandoned sewer line conducts heat and steam around Old Faithful Geyser. A linear trend of elevated temperatures from an active water line parallels the road to the northeast of the Myriad Group. Ongoing field experiments and scientific investigations will provide additional information about the sources for the low temperatures on the nighttime thermal infrared maps.

In the Old Faithful area, infrastructure…obscures the natural temperature variations at the ground surface.

Park infrastructure also has adversely impacted hydrothermal features and groups in other areas. Figure 4 clearly shows the thermal signature of hot water diverted during the construction of the overpass. This area is warm enough that both lanes of the road are snow-free in the winter. This 3–5 meters (10–16 ft.) spatial resolution nighttime thermal infrared image of the Old Faithful overpass shows intermediate temperatures (15°C–30°C or 59°F–86°F) at the ground surface caused by hydrothermal fluids. The low temperatures in figure 4 (5°C–10°C or 41°F–50°F) show hydrothermally heated ground as well as vegetation and asphalt that have been heated by the sun. Similar to the overpass hydrothermal area, Black Sand Basin has a shallow

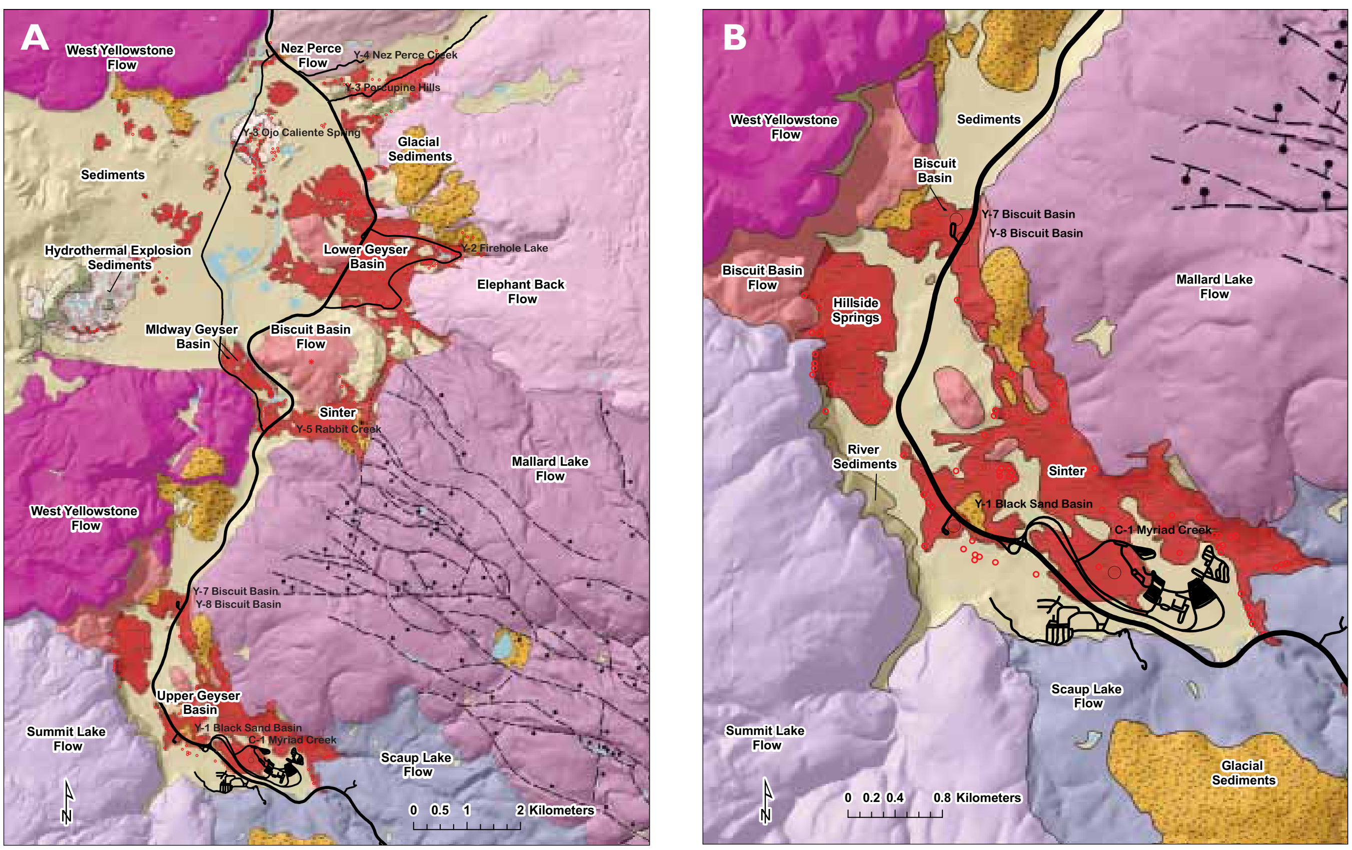


Figure 2. (*A*) Geologic map of the Upper, Midway, and Lower geyser basins over a digital elevation model. Lava flows, various sediments (glacial, hydrothermal explosion, and other) and hot spring deposits (sinter) are shown. Notice the major roads (*black solid lines*) and the faulted Mallard Lake resurgent dome (*black dashed lines*). (*B*) Geologic map of the Upper Geyser Basin over a digital elevation model. Lava flows surround the Upper Geyser Basin. The oldest lava flow, Biscuit Basin (*peach*), crops out in the river valley and along the valley sides. Younger lava flows covered the Biscuit Basin flow. Sediments deposited by ice and water occur in the river valley and on the lava flows. In places, hydrothermal water cemented the sediments and formed sinter (*red pattern*). Geologic maps are modified from Christiansen and Blank 1974 and 1974b. For a digital layer of Yellowstone's geology, see the NPS Data Store (http://science.nature.nps.gov/nrdata/).

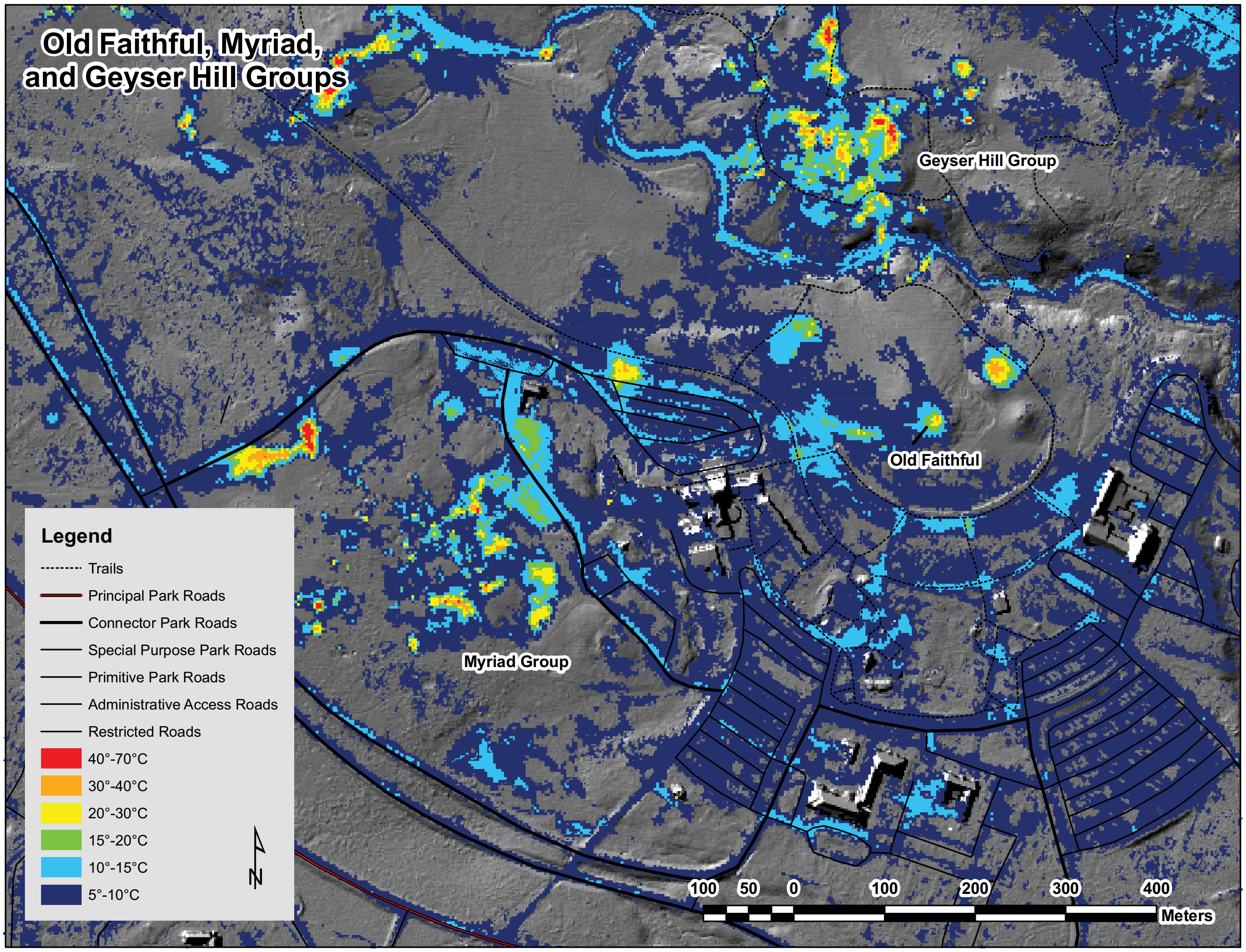


Figure 3. Map showing high (*red*), intermediate (*orange, yellow, and green*), and low (*light and dark blues*) temperatures surrounding Old Faithful Geyser, draped over a 2008 LiDAR image. Notice Old Faithful Geyser, the nearby circular area of warm ground, the Geyser Hill Group, and the Myriad Group. The arc of warm ground (10°C–15°C or 50°F–59°F) surrounding Old Faithful Geyser shows the influence of park infrastructure on the flow of heat and fluids. In contrast, the Geyser Hill Group displays the natural temperature variations (10°C–80°C or 50°F–176°F) of a hydrothermal system.

hydrothermal reservoir (Fournier et al. 1994). Thus, Black Sand Basin is a sensitive hydrothermal area that easily could be impacted by development.

Flowing north from the Old Faithful area, the Firehole River shows its hydrothermal character at 10°C–15°C (50°F–59°F) (figs. 5 and 6). At the time of the September 2007 flight, the FLIR Thermocam SC640 sensed Grotto Geyser, Radiator Geyser, Splendid Geyser, Morning Glory Pool, and other thermal features. Between Grotto Geyser and Morning Glory pools, the Firehole River flows between faulted or fractured outcrops of the Biscuit Basin lava flow and the Mallard Lake dome (fig. 5). These fractures or faults (north–northwest and east–northeast trending linear features) may fragment the hydrothermal system into subsurface blocks that move independently with earthquakes.

Not far from Biscuit Basin, the Cascade Group raises the temperature of the Firehole River (fig. 6) from a range of 10°C–15°C (50°F–59°F) to a range of 15°C–20°C (59°F–68°F). Here, the Firehole River flows between rhyolitic lava flows on the east and river terraces on the west. The LiDAR clearly shows how glaciers smoothed and cut deep glacial grooves into the hillside above the Cascade Group. It is interesting that low-temperature thermal signatures (5°C–10°C or 41°F–50°F) occur at a bedrock contact between the faulted and glaciated Mallard Lake flow and the underlying Biscuit Basin flow (fig. 6 and fig. 1A). These low ground temperatures on the east hillside may be due to vegetation, different rock types, or groundwater. Ongoing studies will help determine the causes of these low ground temperatures near the front of the Mallard Lake lava flow.

In Biscuit Basin (fig. 7), the hot thermal features (red and orange areas) near the Firehole River have been sporadically

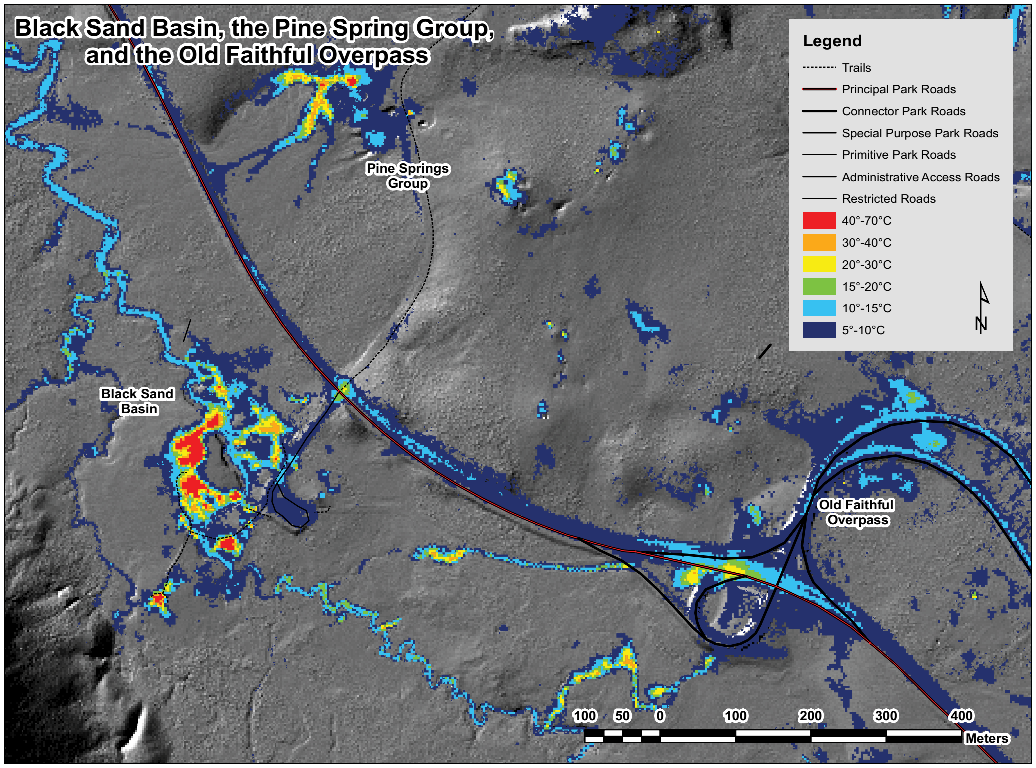


Figure 4. Map showing high (*red*), intermediate (*orange, yellow, and green*), and low (*light and dark blues*) temperatures near the Old Faithful overpass, draped over a 2008 LiDAR image. The Old Faithful overpass adversely impacted the hydrothermal system. Note the natural variation in temperatures at Black Sand Basin and the thermal character of the Little Firehole River.

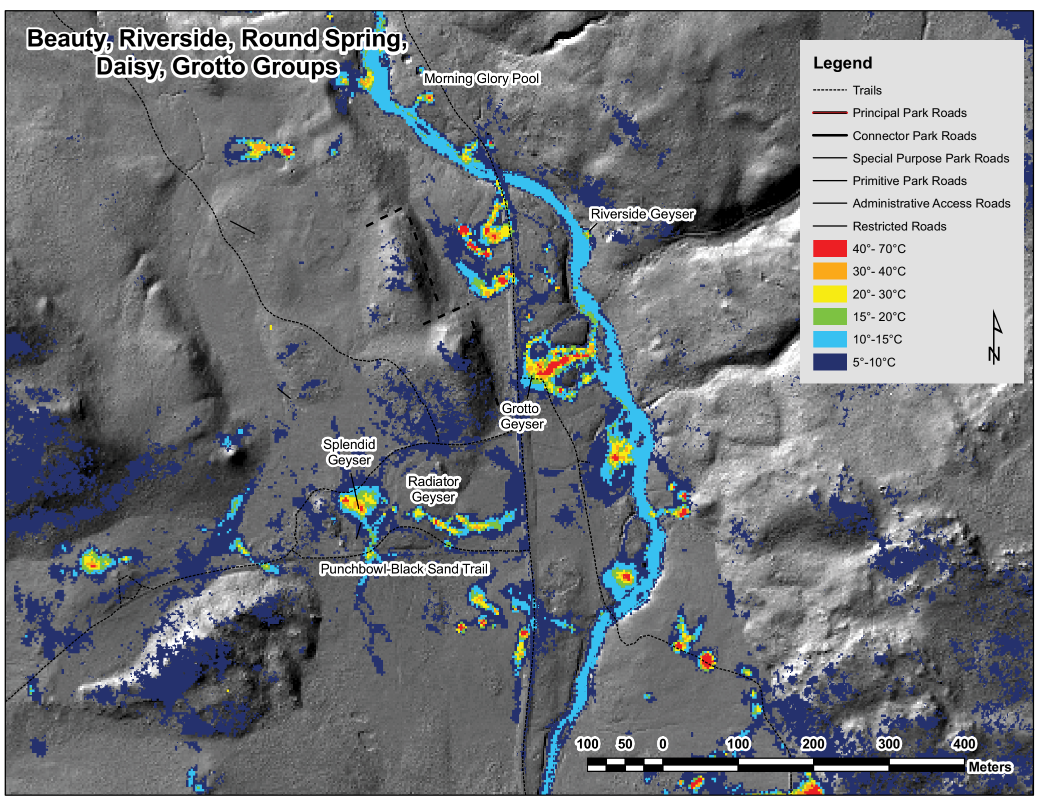
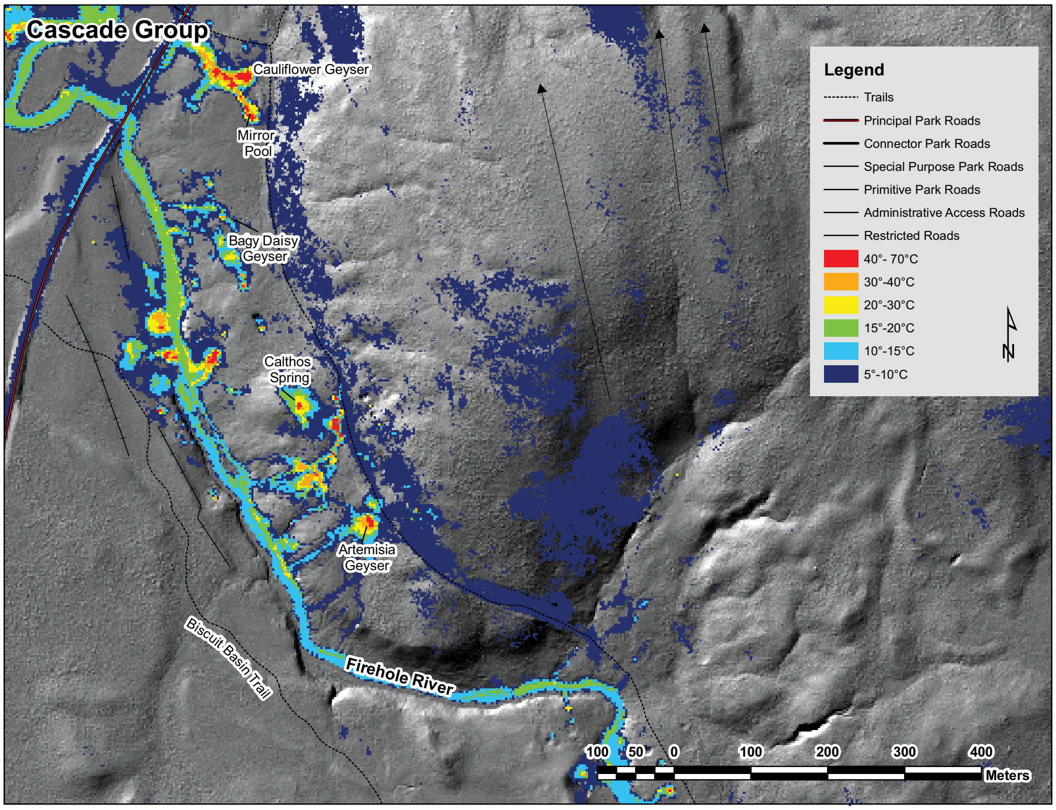


Figure 5. Map showing high (*red*), intermediate (*orange, yellow, and green*), and low (*light blue and dark blue*) temperatures along trails in the Upper Geyser Basin, draped over a 2008 LiDAR image. North–northwest and east–northeast-trending fractures (black dashed lines) may affect some thermal groups and thermal features. The old asphalt roadway, now used as a bike path, is barely visible at 5°C–10°C (41°F–50°F). The 10°C–15°C (50°F–59°F) Firehole River shows the influence of hot outflow from nearby thermal features and thermal features within the river.

Figure 6. Map showing high (*red*), intermediate (*orange, yellow, and green*), and low (*light and dark blues*) temperatures along trails in the Upper Geyser Basin, draped over a 2008 LiDAR image. Terraces (*hatched lines*) occur west of the Firehole River. Glaciers smoothed the hillside and cut deep grooves (*black arrows*) above Artemisia Geyser. The contact between the Mallard Lake and Biscuit Basin lava flows occurs near the unlabeled trail.



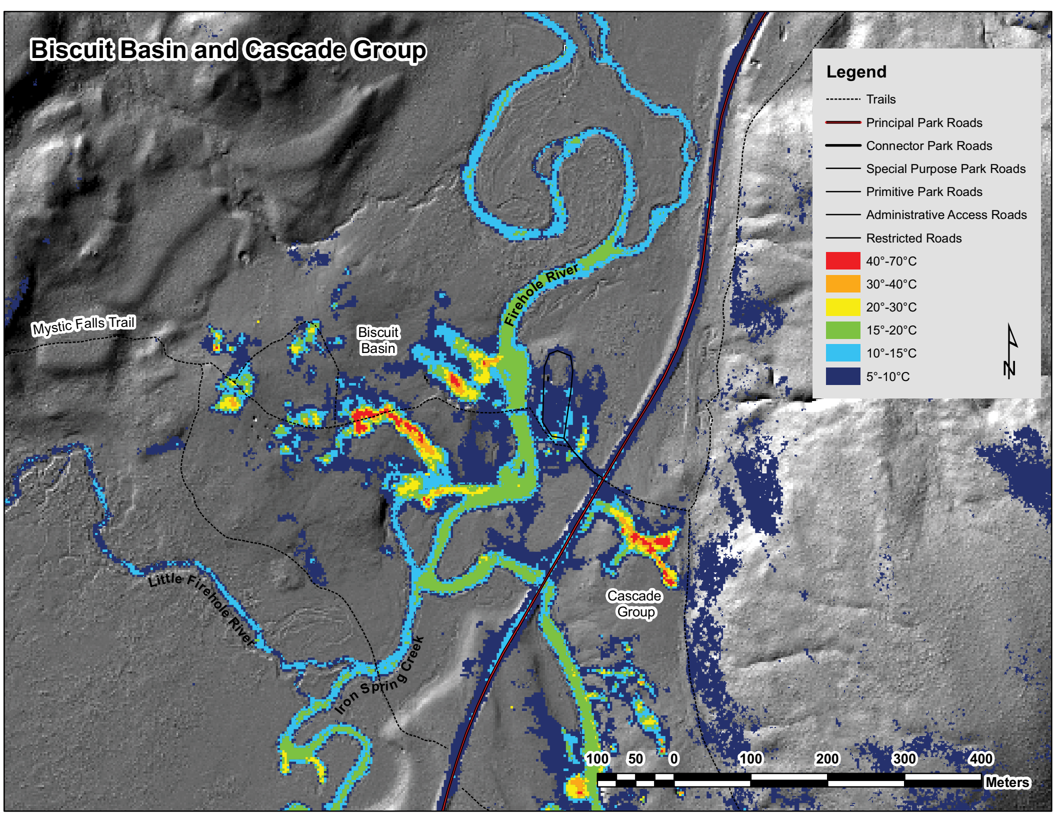


Figure 7. Map showing high (*red*), intermediate (*orange, yellow, and green*) and low (*light and dark blues*) temperatures at Biscuit Basin, draped over a 2008 LiDAR image. Beginning in 2006, the hot (40°C–80°C or 104°F–176°F) area near the Firehole River boardwalk erupts steam, water, and rock debris. Notice that only small areas of warm ground temperatures (at 5°C [41°F]) and greater are visible at the ground surface. To map the entire Biscuit Basin thermal area, elevated ground temperature, hot springs deposits, hydrothermally altered ground, and geothermal gases are necessary.

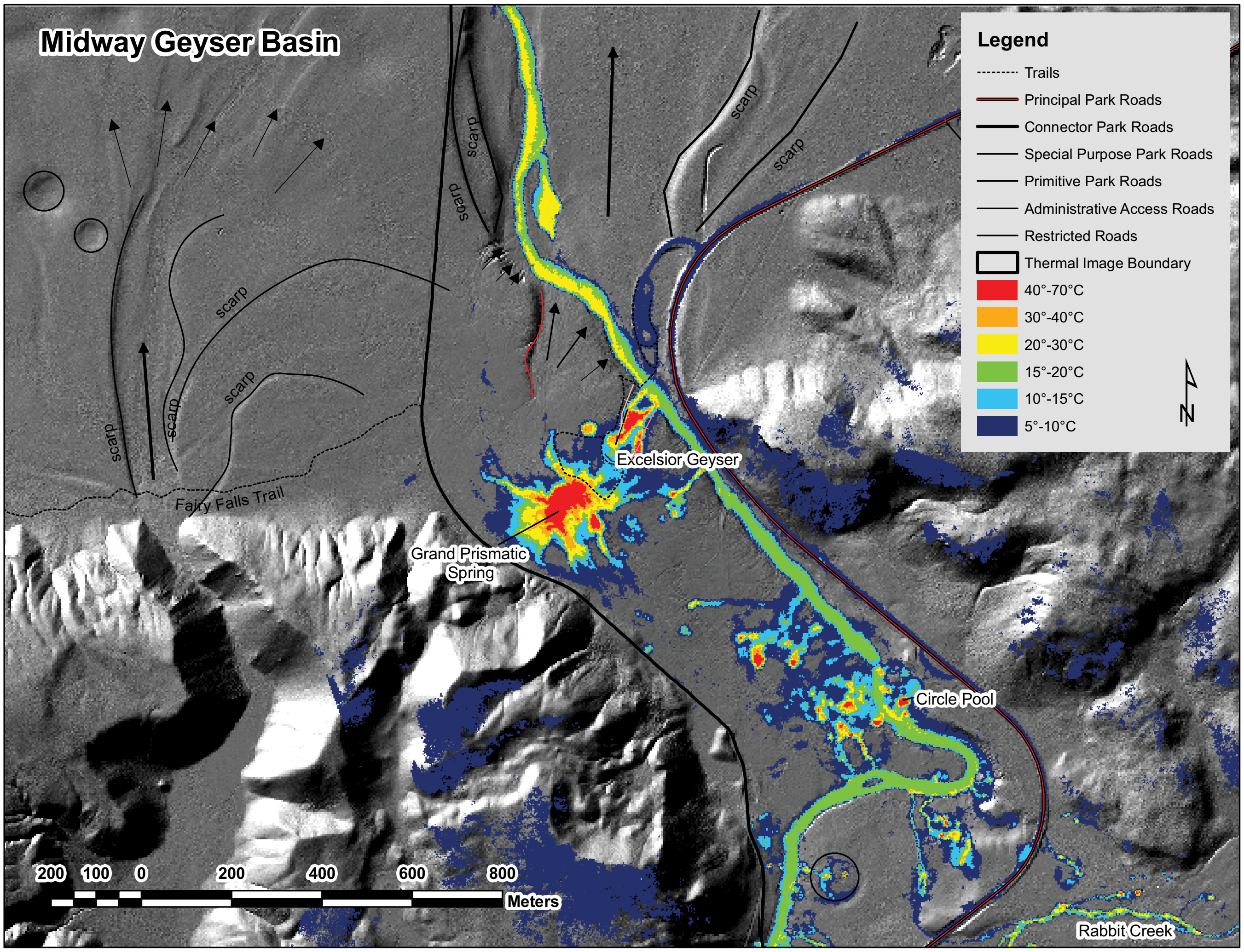


Figure 8. Map showing high (*red*), intermediate (*orange, yellow, and green*) and low (*light and dark blues*) temperatures at Midway Geyser Basin, draped over a 2008 LiDAR image. The sinuous, solid black lines near Grand Prismatic Spring indicate the boundary of the 3–5 meter nighttime thermal infrared imagery. The LiDAR allows preliminary interpretation of flood scarps (*solid black lines*), flood channels (*large arrows*), possible hydrothermal explosion features (*black circles*), and lateral debris flow deposits (*small black arrows and red hatched lines*) from Grand Prismatic Spring and Excelsior Geyser.

erupting obsidian sand, mud, and water since 2006. In July 2006 and May 2009, the authors observed these “dirty,” forceful geyser eruptions, hydrothermal eruptions, or hydrothermal explosions ejecting hot water and debris both vertically and laterally. In July 2006, the laterally flowing, hydrothermal water deposited a rocky debris apron (at least 14 meters [46 ft.] wide, 11 meters [36 ft.] long, and 4.5 centimeters [1.8 in.] thick). These events provide small, modern-day analogs for the large, paleo-hydrothermal explosions in Midway and Lower geyser basins. These eruptions of obsidian sand and mud make sense when the underlying geology is considered. About 55 meters (180 ft.) of obsidian-rich sand and gravel overlie the Biscuit Basin lava flow (Fournier et al. 1994). These thermal pools that forcefully erupt are aligned along a northwest trend and may reflect subsurface fractures in the Biscuit Basin lava flow. Near the road and the Biscuit Basin parking lot, the low ground temperatures show the interaction of the low-temperature component of the hydrothermal system with the park infrastructure.

At Midway Geyser Basin (fig. 8), the Firehole River flows between the Biscuit Basin lava flow and the West Yellowstone flow (fig. 2A). Previous geologists (Muffler et al. 1982b) described and mapped the gravel and sand of the outwash plain. The 2008 LiDAR image of the area shows the terrace scarps and flood channels of the late glacial outwash plain. The Firehole River is visible as an underfit stream (too small to have eroded the valley it occupies) within a late glacial flood channel. In this reach of the river, thermal outflow increases the temperature of the Firehole River from 15°C to 30°C (59°F–86°F). The LiDAR topography also enables a preliminary interpretation of lateral debris flows (small arrows and hatched lines on fig. 8) from

An Exceptional Day at Biscuit Basin

Henry P. Heasler

On May 17, 2009, a group of scientists visited Biscuit Basin as part of a two-day Earthscope field trip. The group was standing by Wall Pool, discussing hydrothermal explosions. Just as the discussion finished at 11:17 AM, Wall Pool surged, then erupted, expelling foot-sized ejecta (figs. 1 and 2). There was a sensation of heat associated with the eruption, which lasted for an estimated 10 to 15 seconds.

Was the May 17 event a hydrothermal explosion or a geyser eruption? A hydrothermal explosion is caused by a depressurization of a column of boiling water, much like the forces that cause a geyser eruption. The difference between a small hydrothermal explosion and a geyser eruption is that a hydrothermal explosion results in the fragmentation and ejection of overlying strata. Rocks are expelled, either creating a new depression or enlarging an existing vent. The expelled rocks form a debris pattern of ejecta around the explosion.

The Wall Pool event, however, had characteristics of both a hydrothermal explosion and a geyser eruption. Debris were ejected and formed a pattern around the pool (fig. 3). The current turbidity of the pool's water makes it difficult to determine if there was any change in the vent. Sometimes the pool erupts many times in a season, much like geysers. Dick Powell and Ralph Taylor, park volunteers, documented nine eruptions of the pool between June 29 and September 21, 2009. Thus, the eruption of Wall Pool can be considered on a continuum between a geyser eruption and a hydrothermal explosion. Perhaps the best term to use is an unusually forceful geyser eruption.

The name of the feature erupting also is unclear. US Geological Survey maps of the area from 1974 clearly label Black Opal Pool and Wall Pool. However, other investigations indicate that the area of the eruption may be named Black Diamond Pool.

YS

NPS

Figure 1. Beginning of the hydrothermal explosion/forceful eruption in Wall Pool on May 17, 2009, looking north northwest.

NPS

Figure 2. Continuation of the hydrothermal explosion/forceful eruption in Wall Pool. Note the debris being ejected by the explosion/eruption.

NPS

Figure 3. A park geologist and volunteer analyze ejected debris after a 2006 explosion/eruption of Wall Pool.

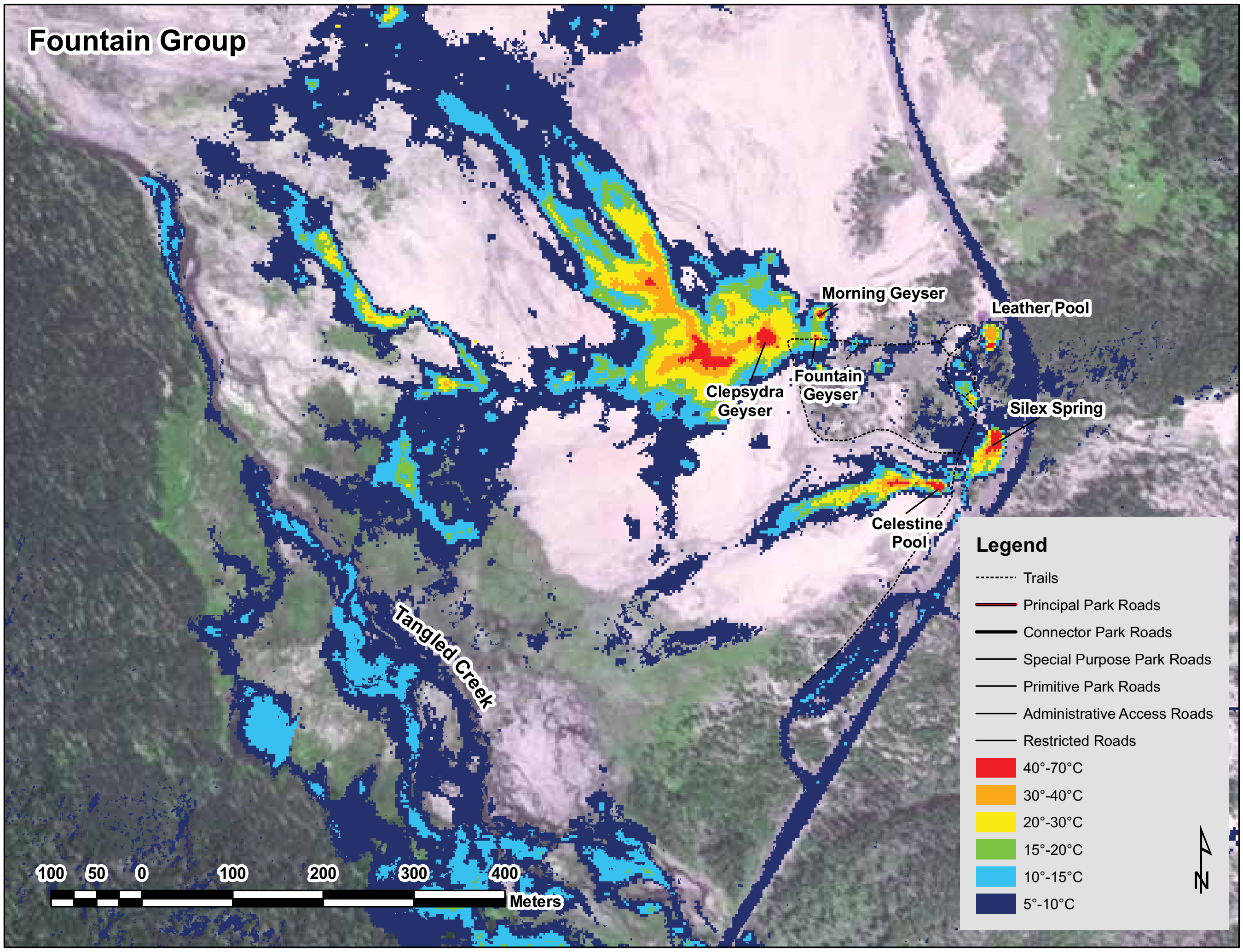


Figure 9. Map showing high (*red*), intermediate (*orange, yellow, and green*) and low (*light blue and dark blue*) temperatures of the Fountain Group, draped over a color infrared image. Notice the thermal outflows from Clepsydra Geyser, Celestine Pool, and Silex Spring. Fountain Geyser, Morning Geyser, and Leather Pool are hot to intermediate thermal spots. Tangled Creek (*lower left*) also shows an influence from hydrothermal features. The main road crosses the vegetated Elephant Back lava flow.

hydrothermal explosions at Grand Prismatic Spring and Excelsior Geyser. On the LiDAR, these lateral debris flow deposits appear to cross-cut the scarps of the late glacial flood terraces. Thus, the hydrothermal explosion events appear to be younger geologic events than late glacial floods. Other potential hydrothermal explosion craters are circular depressions in the late glacial sediments. Field investigations may confirm these initial interpretations of the 2008 LiDAR imagery at Midway Geyser Basin.

A tributary to the Firehole River, Tangled Creek flows by the Fountain Group at Fountain Flats (fig. 9). Hydrothermal features raise the temperature of Tangled Creek to 10°C–15°C (50°F–59°F). A ground surface temperature above 10°C (50°F) is a clear hydrothermal signature. Within the Fountain Group, the highest temperatures (30°C–70°C or 86°F–158°F) come from Clepsydra Geyser, Silex Spring, and Celestine Pool. Figure 9 shows that only some areas of the white sinter emit high surface ground temperatures detectable by airborne thermal infrared sensors.

At Pocket Basin (fig. 10), the presence of thermal features, heated ground, hot springs deposits, and chemically altered ground shows why the definition of a hydrothermal area is inclusive. In the Lower Geyser Basin, the LiDAR and thermal infrared imagery shows the Firehole River cutting through Pocket Basin's debris apron. Muffler et al. (1982a) described the apron as "unconsolidated breccias… with blocks of tough cemented yellow-stained sandstone, siltstone and conglomerate…." The LiDAR imagery shows radial flow lines (fig. 8) in this debris apron that could be associated with a lateral wave from the hydrothermal explosion at Pocket Basin. Here, the entire Firehole River has temperatures greater than 15°C (59°F), indicating that it is part of the hydrothermal system.

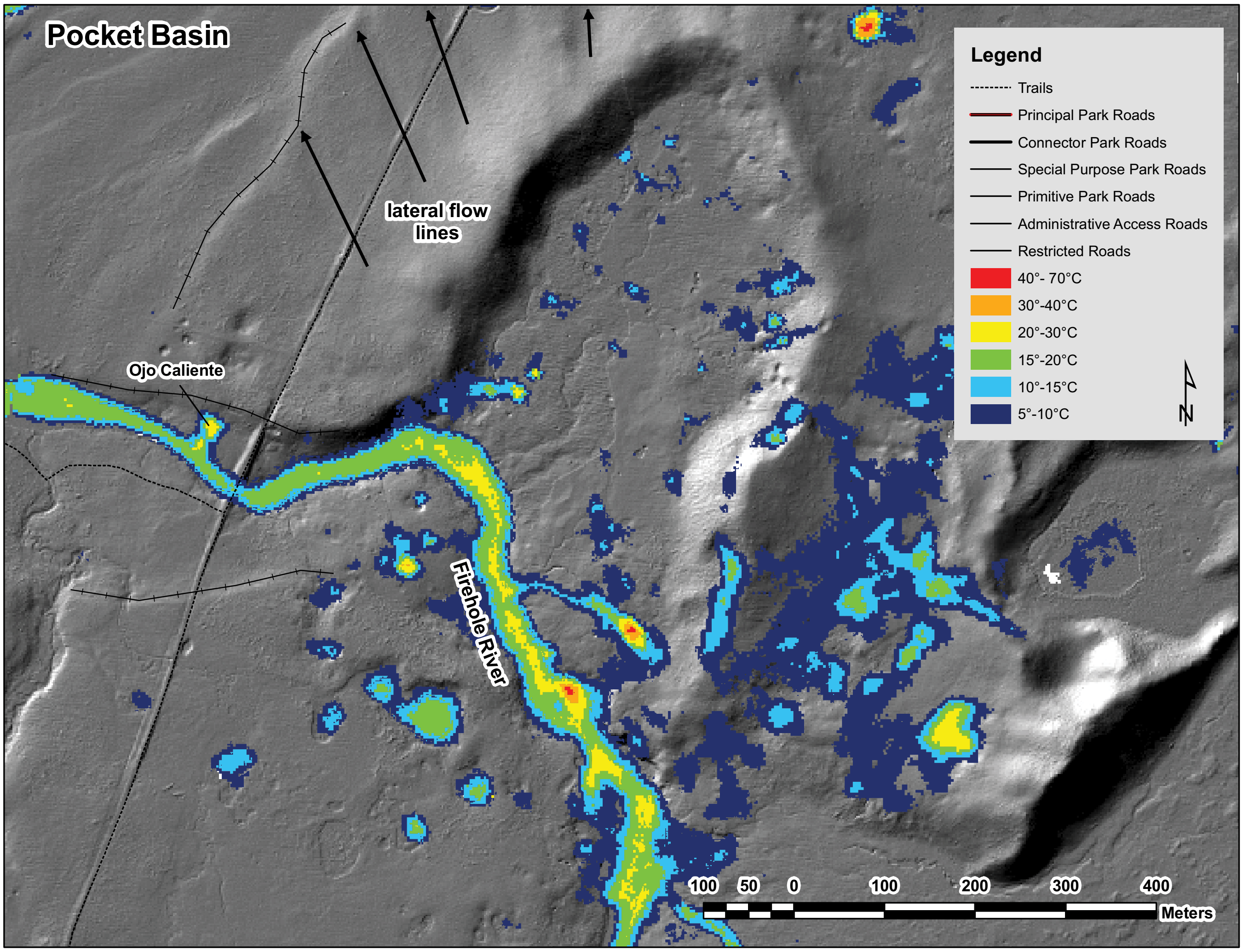


Figure 10. Map showing high (*red*), intermediate (*orange, yellow, and green*), and low (*light and dark blues*) temperatures at Pocket Basin, draped over a 2008 LiDAR image. Notice the lateral debris flow lines (*arrows*) in the debris apron and scarps (*black hatched lines*).

Discussion

In the late 1800s Nathaniel Langford, first superintendent of Yellowstone National Park, investigated one of Jim Bridger's stories about the Firehole River. According to Chittenden (1895), Langford described

> *…the stream as flowing over the smooth surface of a rock, and reasoned that, as two sticks rubbed together produced heat by friction, so the water rubbing over the rock became hot… Mr Langford found a partial confirmation of the fact, but not of the theory, in fording the Firehole River in 1870. He passed over the smooth deposit of an active hot spring in the bed of the stream, and found that the stream bottom and the water in contact with it were hot.*

Today, the thermal infrared maps of the Upper, Midway, and Lower geyser basins show that the Firehole River is an integral part of the hydrothermal system. Although people still feel the warmth of the Firehole River and its thermal springs, current-day visitors and scientists can understand that the heat beneath our feet ultimately comes from Yellowstone's active volcano, not from the friction of the water flowing over the riverbed.

Summary

The airborne thermal infrared images presented in this report show the vast size and interconnectedness of thermal areas. The figures and geologic discussions emphasize that thermal areas are much more than isolated thermal features or groups of thermal features. The entire Upper Geyser Basin is clearly one large contiguous geologic unit defined by altered hydrothermally altered ground, thermal deposits, heated ground, and geothermal gases. Thus, the entire Upper Geyser Basin is a thermal area. The perspective that thermal areas are more

NPS

Old Faithful Geyser erupting as seen from Castle Geyser in 1952.

than just the thermal vents in an area is a critical realization necessary for the protection of Yellowstone's unique hydrothermal resources.

YS

Acknowledgements

Many people contributed to the success of this collaborative research. Former Utah State University graduate students, Deepak Lal and Osama Akashesh, participated in the image acquisitions and image processing during 2005 and 2006. Dr Bayanai Cardenas, professor at the University of Texas, provided a FLIR Thermocam SC640 in 2007. Geology program volunteers Ralph Taylor, Dick Powell, and Karin Horrigan placed temperature loggers in thermal features before the anticipated flights. Conversations with park botanist, Jennifer Whipple, aided our understanding of vegetation in the thermal areas. Yellowstone National Park law enforcement rangers at Old Faithful allowed the temporary deployment of a station for calibrating airborne imagery. The Research Office at the Yellowstone Center for Resources reviewed and permitted this project. The Fire Cache approved the flight plans and contacted the pilots while they gathered imagery. Dr. Bob Smith of the University of Utah advocated for funding the GeoEarthScope airborne LiDAR group. In addition, David Phillips and his team (UNAVCO) and Christopher Crosby's team (University of California, San Diego) acquired and processed the 2008 LiDAR imagery. The Technical Oversight Committee of the Water Rights Compact between Montana and the United States also provided critical external support for this effort. Finally, Yellowstone National Park's geothermal monitoring plan would not have been possible without the late Irving Friedman. His passion for Yellowstone and belief in protecting its hydrothermal features resulted in the funding of the park's geothermal monitoring plan.

NPS

Cheryl Jaworowski is a geologist at Yellowstone National Park. She earned her doctorate in geology from the University of Wyoming and specializes in Quaternary geology and applying remote sensing to geologic mapping. **Hank Heasler** is the park geologist for Yellowstone National Park. **Christopher Neale** is a professor of biological and irrigation engineering and Director of the at Utah State University. **Saravanan Sivarajan** is a research assistant in the Remote Sensing Services Laboratory at Utah State University.

References

Chittenden, H.M. 1898. *The Yellowstone National Park*. Repr., Norman, OK:University of Oklahoma Press, 1964.

Christiansen, R.L. 2001. The Quaternary and Pliocene Yellowstone Plateau volcanic field of Wyoming, Idaho, and Montana. U.S. Geological Survey Professional Paper 729-G.

Christiansen, R.L., and H.R. Blank, Jr. 1974a. Geologic map of the Madison Junction quadrangle, Yellowstone National Park, Wyoming. US Geological Survey Geologic Quadrangle Map GQ-1190, Scale 1:62,500.

———. 1974b. Geologic map of the Old Faithful quadrangle, Yellowstone National Park, Wyoming. US Geological Survey Geologic Quadrangle Map GQ-1189, Scale 1:62,500.

Christiansen, R.L., J.B. Lowenstern, R.B. Smith, H. Heasler, L.A. Morgan, M. Nathenson, L.G. Mastin, L.J.P. Muffler, and J.E. Robinson. 2007. Preliminary assessment of volcanic and hydrothermal hazards in Yellowstone National Park and vicinity. US Geological Survey Open-File Report 2007-1071.

Fournier, R.O., R.L. Christiansen, R.A. Hutchinson, and K.L. Pierce. 1994. A field-trip guide to Yellowstone National Park, Wyoming, Montana, and Idaho: Volcanic, hydrothermal, and glacial activity in the region. US Geological Survey Bulletin 2099. Washington: United States Government Printing Office.

Husen, S., R. Taylor, R.B. Smith, and H. Heasler. 2004. Changes in geyser eruption behavior and remotely triggered seismicity in Yellowstone National Park produced by the 2002 M 7.9 Denali fault earthquake, Alaska. *Geology* 32(6):537–540.

Marler, G.D. 1964. Effects of the Hebgen Lake earthquake of August 17, 1959, on the hot springs of the Firehole Geyser Basins, Yellowstone National Park in US Geological Survey Professional Paper 435, 185–197.

Muffler, L.J.P., D.E. White, M.H. Beeson, and R.O. Fournier. 1982a. Geologic map of the Lower Geyser Basin, Yellowstone National Park, Wyoming. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1373, Scale 1: 24,000.

Muffler, L.J.P., D.E. White, M.H. Beeson, and A.H. Truesdell. 1982b. Geologic map of the Upper Geyser Basin, Yellowstone National Park, Wyoming. US Geological Survey Miscellaneous Geologic Investigations Map I-1371, Scale 1:4,800.

Waldrop, H.A. 1975. Surficial geologic map of the Old Faithful quadrangle Yellowstone National Park, Wyoming. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-649, Scale 1: 62,500.

The Groundwork for a Career in Yellowstone's Past

A *Yellowstone Science* interview with archeologist Dr. Ann Johnson


NPS

On December 9, 2008, then Yellowstone Center for Resources Chief Tom Olliff and Yellowstone Science *editor Tami Blackford sat down with archeologist Dr. Ann Johnson to interview her prior to her retirement in December 2008 after almost 32 years of government service. In 1994, Dr. Johnson became Yellowstone National Park's first archeologist. During her tenure she authored more than 20 reports and managed, directed, and contributed to more than 60 reports produced under contract by teams of professional archeologists. These reports greatly enhanced the understanding of archeology in the park and resulted in a number of professional articles, several published in* Yellowstone Science, *in addition to papers presented at professional conferences throughout the Rocky Mountain Region.*

When Dr. Johnson arrived in Yellowstone, roughly 400 archeological sites had been recorded, many in such vague terms that they barely merited consideration. Along with other park staff, contractors, and volunteers, she upgraded the descriptions of many of these early finds to meet today's standards, and some 1,200 additional sites were added—a 200 percent increase in the number of documented archeological sites that serve as a foundation to increase scientific knowledge. During her career, the archeology program upgraded or defined 80–90 percent of all the documented sites in the park.

She also volunteered for the park's emergency medical services and served twice as acting Chief of Cultural Resources, for six months in 2000 and approximately two years in 2007 and 2008, and she volunteered for the archeology program in summer 2009. Dr. Johnson retired to Kalispell, Montana, where she is pursuing an education in nursing.

***Yellowstone Science* (YS):** What led to your becoming an archeologist for the National Park Service?

Ann Johnson (AJ): When I was 11, I took the train from Kalispell to Havre to visit my grandmother, and across the street was a kid my age whose father was in the local archeological society, an amateur group. That really set me up for forever. These people were doing things they loved on their own time, buying their own gasoline, investing in something that I thought was worthwhile. They were documenting not only archeology, but historic homesteads, oral histories, and the whole realm of local history and prehistory.

I went to the University of Montana, got a double major in zoology and anthropology. After getting a master's degree in anthropology, I went to the University of Missouri–Columbia and studied under W. Raymond Wood. At that time, the University of Missouri was very strong in northern plains archeology, which is what I had always wanted to study. I was never into painted pottery or architecture of the Southwest or Egypt or any of these other places—I was curious about them, but my passion was for the northern plains. I wanted to make some contributions in an area that hadn't received enough attention.

I always thought I would teach. All my classmates at the University of Missouri the year before I left school got teaching positions. But when I got out, in 1976, nobody could get a teaching job. You know how it is, teaching slots open up, fill, and then they're full for years. But people were starting to make a living doing cultural resource inventories, and I got an offer from the Colorado State Archaeologist to run a program doing inventories on national forest land. At the time, the US Forest Service didn't have cultural resource staff in Colorado, so they paid the Colorado State Archaeologist to do the work. It was a great beginning job and I learned much. But it was clearly temporary, and as the Forest Service staffed up, my job dried up.

I then became the district archeologist for the Bureau of Land Management in Casper, Wyoming. The Casper district was just being pounded for uranium, coal, gas, and oil, trona, and bentonite. I never was able to get resources adequately considered and I wasn't very happy there. After two years with the BLM, I got a job with the National Park Service in Denver. Two weeks later, we were moved administratively into the new Heritage Conservation Recreation Service, where the National Register activities, the National Historic Landmark activities, the Bureau of Outdoor Recreation, and the activities the National Park Service had been doing for other federal agencies were combined. My work was similar to what I had been doing for the Colorado State Archaeologist—federal agencies would say they needed an inventory and transfer us money, and we arranged for private contractors to do the inventory. I did a lot of contracting and learned skills that I continued to put to use.

From my first NPS performance evaluation, I said what I really wanted to do was work in a park. They thought I was crazy—you want to leave a nice big city and go to a remote park? It only took me, what, 16 years to do that. I had opportunities to go back East, but that isn't what I wanted to do. I wanted to be in the Rocky Mountain time zone. And after about two years I walked across the aisle and became part of the Rocky Mountain Regional Office in-park program. There were two archeologists—Adrienne Anderson and me. It was good because we split in terms of our backgrounds and interests, both topical and geographic. Adrienne took the Southwest, and the historic and Paleoindian archeology, and I took the northern plains and the prehistoric resources.


NPS/YELL 166630-7

Ann Johnson and Wayne Brewster, then deputy director of the Yellowstone Center for Resources, visit a wickiup at Lava Creek.

And we cooperated on many projects. My experience in the regional office was very beneficial because I got to see different resources in many parks and got to work with park staffs. I also worked closely with the other regional cultural resource specialists and absorbed much about history, historic architecture, ethnography, and curation.

In looking back, I was happy working for the National Park Service and feel fortunate that I ended up at Yellowstone. I never dreamed this was a possibility.

YS: How did you get the archeology program started in Yellowstone?

AJ: Despite the first professional archeological inventory in 1958, archeology received little consideration until the late '70s. The cultural resource laws requiring inventories prior to ground disturbance were increasing, the pressure to consider archeological resources was increasing, and the older managers were retiring and being replaced by people who were more flexible about these new ideas. When cultural resource compliance got started in Yellowstone, about '79, it was just a trickle at first, with inventories for road reconstruction and one or two compliance projects a year. Big projects were done by contractors and, most summers, I was coming up from the regional office for one or two weeks a year to do specific projects related to compliance activities. I was trying to make sense out of the increasing mass of site data and our growing obsidian sourcing database. I expected that most of the northern plains cultures would be represented in Yellowstone and that time depth would go back 12,000 years.


NPS/YELL 180401-4

Ann Johnson and Amy Hammermeister work at a roasting pit in site 48YE380.

In the summer of '89, I spent three months in Yellowstone doing post-fire inventories. I also continued to be involved in the federal highway program in Yellowstone. On Friday afternoons at about four o'clock, Tim Hudson [Chief of Maintenance] and Nancy Ward [Assistant Chief of Maintenance] would call Adrienne and me at the regional


NPS/YELL 180308-1

Dr. Mary Meagher, here with Ray Rathnell and Bob Flather, continues to contribute her knowledge as a biologist and a backcountry user to Yellowstone's archeology work.

office and we would talk about how each project was going, what we needed in terms of budgets, and so on. We found that having those conference calls made the federal highway projects go much more smoothly than they had before. (Elaine Hale later took over that role, first as park cultural resources technician and then as cultural resources specialist.) I also participated in some Yellowstone National Park planning projects. So I was a known quantity to the park staff.

I continued to state that I wanted to be assigned to a park, and I really wanted to be north of Denver. In 1994, there was a program to reduce the regional and central offices, and many people in those offices moved to parks. Yellowstone advertised for an archeologist and I was the only applicant. Apparently other possible candidates considered the park to be too remote for them.

From the beginning, I was conscious of being the first permanent park archeologist and I worked hard to set the bar high for anyone who would come later. I made it a priority to answer questions and respond to staff inquires and requests. I also tried to answer all visitor requests and to email or write everyone who turned in an artifact. The archeology program actively sought funding for inventories and to carry out salvage projects for sites that were being lost through erosion. Networking with park staff in all areas and at all levels was an important activity.

Then, as now, there was no substitute for getting out in the park to understand how the resources may have been used. Defining use patterns frequently becomes apparent only through documented studies over a period of time. Having Mary [Dr. Mary Meagher, a distinguished wildlife biologist who spent most of her career in Yellowstone] as a volunteer was especially beneficial to me—it made the corral operations staff more comfortable knowing that I wasn't out there on horseback by myself, and I eagerly tapped into her backcountry knowledge. It's all very well to intellectually understand what's on the other side of Mount Everts, but to actually be up there is invaluable—I could see the terrain, and Mary and I talked about how people would have used the land, how animals used it, and how people might have preyed on those animals. Without Mary's time and help, I would have understood less.

No one is successful standing alone. A great deal of the work was done under contract, but much of the program's accomplishments are due to the cooperation of park staff and the work of volunteers. The park staff were always very helpful. Volunteers helped accomplish fieldwork, cataloging, worked on site forms, and did everything asked of them.

YS: What do you regard as some of the high points of your career at Yellowstone?

AJ: As I look back, I'm pleased with the progress the archeology program has made, in developing an inventory and lists of source data for obsidian artifacts, compiling park radiocarbon dates, identifying resources, and so on. I'm also aware that a tremendous amount of work needs to be done in order to understand and protect archeology, but we have brought some clarification to several archeological problems and increased the number of documented sites. The most important achievement has been raising awareness for archeological resources among park staff and the public. Most of what we do is management and a little research happens along the way. We do research as a way of evaluating sites, as a way of understanding whether we need to preserve this site as compared with that site. You have to keep the research questions in the back of your mind—not every site has information that's going to help answer the questions in which you have the greatest interest. Sometimes it's a simple accumulation of evidence.


NPS

Obsidian core from Obsidian Cliff source.

A major advancement in Yellowstone archeology has been the recognition of the wide variety of stone suitable for the manufacture of tools that occurs in the park. Initially, we thought all the stone for tools was brought into the park except maybe some petrified wood and Obsidian Cliff obsidian. Now we know about a large area where chert was collected known as the Crescent Hill Formation (also called Robin's Quarry, see *Yellowstone Science* 15[1]), several other stone sources, and five additional obsidian sources. We have learned that Yellowstone is a much richer area for stone materials than we thought. Obsidian sourcing also enabled us to extend back the earliest presence of humans in the Yellowstone area. A Clovis point and a Folsom point found north of the park were both identified as having been made from Obsidian Cliff obsidian—people had to have come to the park because there's no place else you could get that type of obsidian. We recognize half a dozen obsidian sources used by Native Americans, but some were strictly local use and others were widely distributed. Future work will continue to increase the number of known obsidian sources and explicate their use and will build on what we learned.

In the late 1980s, a major study of Obsidian Cliff was conducted, and through that work the scale of Obsidian Cliff as an archeological site was realized. Getting it designated a national historic landmark was important. Although Obsidian Cliff had been known to exist for over 100 years, little was actually known about the physical remains. The rhyolite flow had been mapped by Robert Christiansen [of the US Geological Survey] and some other geologists, but Obsidian Cliff was not inventoried by an archeologist until 1988–1989, when we contracted with Dr. Leslie B. Davis, a professor at Montana State University whose expertise was on prehistoric use of obsidian in the northern plains.

Over my time here, the sequence of cultures who visited the park has become clearer. Future work will elaborate the details and clarify when people came to the park, especially from the west and south.

NPS

The archeology lab in the Heritage and Research Center is used for artifact processing, research space, and storage for maps, site files, and other references.

NPS

Horses must be used to access some sites in Yellowstone's backcountry and are often an asset to field work.

There are several instances where interdisciplinary research and cooperation advanced what we know about the park. One was at Osprey Beach on Yellowstone Lake where we have gained a clearer understanding of the terraces of different ages around the lake. A second example came about through archeological excavations of an eroding site on the Yellowstone River. The excavation extended down to deep deposits that were different from those above. The park geologists said they were lake deposits, and a sediment particle analysis confirmed this. The deposits indicate that a lake covered Gardiner, Montana, in 12,000 years before present. Lake deposits then were found near Stephens Creek at the same elevation. That would suggest that there had probably been a natural dam at Yankee Jim Canyon or maybe Corwin Springs, and it backed up water above Gardiner.

Another example of interdisciplinary work was an archeological effort at Hellroaring Creek, where our research determined that bison were present about 9,500 years ago. This was quite valuable to people working on bison because this was an early, if not the earliest, documentation of bison presence in the park.

A major step forward for the archeology program has been the improvement in the infrastructure. When I came to Yellowstone, I had a regular-sized office where I met with visitors and staff and tried to carry out cataloging, analysis, writing, and any other activities. In 2004 the Heritage and Research Center opened, and now there is an archeology lab with office, library, and work space that anyone would be glad to have. This happened during my time here although I had little to do with its planning and development, and this facility will benefit the archeology program for decades to come.

YS

The rounded serrated blade edges of this obsidian dart point found in Yellowstone are uncharacteristic of points usually found in the Greater Yellowstone Ecosystem and in the Plains. This point was likely hafted to the end of a wooden dart shaft, and used with an atlatl, a handheld extension of the shaft that allowed people to throw darts much greater distances and with greater accuracy.

An Overview of Precontact Archeology in Yellowstone

Ann Johnson, adapted from a Yellowstone Science *interview*

Archeology is a group of methods and techniques that are applied to the study of people in the past. The goal is to understand what people did and what factors influenced their decisions (for example, which sources of stone were selected for tool making). In this article I will summarize what we think we know about the human past in Yellowstone at this time.

The archeology program is directed by generalized research topics in order to understand and interpret the archeological information that is collected. We need to know the sequence of different groups who used the park through time: who was in the park and when; how they subsisted: which plants and animals were eaten; which obsidian and other kinds of stone materials they used. Another big question is seasonality: what time of the year the sites were occupied. Prehistoric people were camping on Yellowstone Lake, but were they staying there in the winter? Settlement patterns are also important and more work needs to be done to understand settlement patterns within the park. Archeological information can be used to understand the environment at the different times the sites were occupied, which is called paleoenvironmental reconstruction.

Reconstruction of Yellowstone's past human environment has been based on limited information developed from several specific sites. The need for inventory continues even though more than 1,700 sites have been recorded because only a fraction of the park has been looked at for archeological resources and the inventory has been very unevenly distributed. Trails, backcountry campsites, and powerline corridors have barely been touched, even though resources in those areas receive repeated impacts. Only about 10 inventory days have been devoted to high-altitude areas since Aubrey Haines's manuscripts on the topic in 1963 and 1965. When the inventory is so unevenly distributed, extrapolation from inventoried to uninventoried areas of the park may lead to incorrect conclusions. An exercise done about 10 years ago using records that existed at that time suggested there might be 300,000 prehistoric and historic sites in the park. We think this number is high, but we have no better data with which to revise it. My guess is that the park may have about 80,000 prehistoric and historic sites.

Culture History

As the sequence of different cultures is better understood, questions can be formulated about individual cultures. What were these people doing here and how do those activities differ between earlier and later groups? We know that the interior valleys of Yellowstone were ice-free by about 15,000 years before the present (ybp), and people could have come into the area to hunt and collect material for tools. To date, we haven't found any sites that old in the park. However, obsidian tools from Clovis and Folsom cultures (the two oldest in western North America) were found a few miles north of the park and these were sourced to Obsidian Cliff, confirming that early people visited the park as the ice receded.

The largest numbers of sites discovered so far relate to groups that were here between about 5500 ybp and

1700 ybp. We also have the most radiocarbon dates from this period, which gives us additional confidence that sites from that period are the most numerous in the park. The question is, why was the park a relatively good place to be then, especially in comparison to earlier and later times? We have just begun to ask questions of our data, although we recognize that our sample size is small.

One hypothesis is that the much smaller number of sites after 850 ybp indicate less intense use of the park; work parties still came to obtain obsidian, but family groups were rare and camp locations that had been used by many groups for thousands of years were abandoned. Factors such as epidemics, the Little Ice Age (500–150 ybp), and the acquisition of horses contributed to changing patterns of human use. We do know that during the Little Ice Age, it was snowier with colder summers, and it would follow that occupation was limited during this period.


NPS/ROBIN PARK

Stone cairns are some of the features recorded throughout Yellowstone. They typically mark trail routes.

Archeology at Yellowstone Lake

With less than three percent of the park inventoried, we can rarely do more than document surface remains. An exception is the Osprey Beach site on Yellowstone Lake. It was eroding in 1958 when a University of Montana survey flagged it as being of significant interest, and although it was still eroding when we investigated it in 2000, we could determine that it was very rich and very old. Funding from the Yellowstone Park Foundation, which has been very supportive of archeology, made it possible for us to contract for the salvage of eroding deposits and illuminate human activities there years ago that have regional implications.

We recovered a wide variety of tools at Osprey Beach: points, knives, scrapers, sandstone shaft abraders, and other tools that indicated quite intensive camping activity that dates to about 9,300 years ago. We analyzed the obsidian artifacts to determine the sources of the material. With enough stone artifacts from different sources, we can model the route people were taking in their seasonal round. It's a useful way to visualize what these early people may have been doing. Based on a sophisticated blood residue analysis of these tools, we could determine that they had been used on bighorn sheep, bear, deer, and rabbit. Residue from unidentified feline and canine species was also present. Evidence suggests that some tools may have been attached to a shaft using rabbit sinew. The model proposed at the time suggested that these people were summering on Yellowstone Lake, moving in the fall to Jackson Hole, wintering in eastern Idaho, and returning in the spring past Obsidian Cliff. However, new models for more recent cultures suggest later people had different patterns of movement through the park and surrounding areas. Osprey Beach is a remarkable site that is helping to change the Paleoindian's use of obsidian. More obsidian tools and shaft abraders have been found at Osprey Beach than at any other known site of Paleoindian culture.


NPS

The excavation at the Osprey Beach site on Yellowstone Lake was supported by the Yellowstone Park Foundation.

With additional funding from the Yellowstone Park Foundation, we were able to inventory part of the Yellowstone Lake shoreline and found about 100 sites. We did not find another site from the same period as the Osprey Beach site, but several slightly younger sites might be worth investigating. Using National Park Service funds, more than 300 additional sites have since been located along the lakeshore and inventories are continuing.

Seasonality

Determining the season when the site was occupied depends primarily on finding specific animal remains (ungulate bones that mark fetal development or juvenile mandibles with teeth that erupt on a predictable schedule). Finding the right kind of bones can be a challenge, however, due to the generally poor preservation of organic materials in the park's acidic soil. Only half a dozen sites with these seasonal indicators have been identified in the past 14 years. Each showed occupation between March and the beginning of June and, in general, they are interpreted as showing that groups were using the northern winter range from late winter through spring. So far, we have no seasonal data for sites in the park interior. Because the needed data are rare, one must be patient and take a long view when studying when people used the park. Much remains to be done.

Obsidian Analysis Possibilities

Obsidian is important because it was a clearly preferred material for the manufacture of stone tools, there are numerous


LIFEWAYS OF CANADA/BRIAN VIVIAN

More backcountry inventories are required to identify the unknown sources of obsidian artifacts found in Yellowstone.


LIFEWAYS OF CANADA/BRIAN VIVIAN

A researcher uncovers a hearth at the Donner Site on the shore of Yellowstone Lake. A total of 137 obsidian artifacts were excavated, of which approximately 50 are sourced.

sources, and each specimen has a unique combination of trace elements that enables us to identify the geological source of an artifact. Irving Friedman, a USGS geophysicist (see *Yellowstone Science* 5[4]) developed techniques for both obsidian sourcing and establishing the age of an artifact based on the hydration rate (the rate at which water is absorbed by a fresh obsidian surface). When a newly exposed surface chunk of obsidian absorbs moisture from the air, the water molecules go into the chemical lattice with silica and other trace elements such as zinc and niobium. By examining a thin slice of the obsidian under a geological microscope with a polarized light, it is possible to measure how far water has penetrated the obsidian. Because of their slightly different chemical formulae, each obsidian source absorbs moisture at a different rate. It follows then, that if its geological source is known, the age of the obsidian artifact can be calculated.

While I was the head of the archeology program at Yellowstone (1995–2008), the number of obsidian sources in the park that were documented as having been used by early people increased from four to six; there are another six in Jackson Hole and in Idaho, and several in southwestern Montana. In addition, each year we come across several archeological specimens that do not match any of the known sources. To identify their sources would require more backcountry inventory. Robin Park, who recently completed her master's thesis at the University of Saskatchewan, examined differences in obsidian source usage between the southern part of the park and the area of the Yellowstone River upstream from Gardiner, Montana, from about 6,000 to 1,750 ybp. Her research provides evidence that different groups of the same people had different circulation patterns (seasonal rounds) during the same period. These groups had the same access to all the resources in Yellowstone and they probably

NPS/ROBIN PARK

Some sites with rock structures are hunting pits, others are probably vision quest structures or eagle catching pits, and the functions of some are unknown. Although some rock structures are uniformly weathered and appear to be old, we do not know when or by whom they were constructed.

interacted with each other. Nobody controlled the highly desired and most frequently used Obsidian Cliff source.

In Yellowstone, Obsidian Cliff obsidian is the most popular choice of obsidian tool stone throughout the pre-contact period. Bear Gulch is the other most frequently found obsidian. Because Obsidian Cliff is so well known, it is often incorrectly assumed that all obsidian came from there. For example, about half of the several thousand obsidian objects in the Hopewell mounds in Ohio came from Obsidian Cliff; the remainder are from the Bear Gulch source in Idaho. Similarly, in western Montana, nine out of ten samples have been identified as coming from Bear Gulch and only 10% from Obsidian Cliff. The pattern changes in eastern Montana. More data are needed to understand how the use of different obsidian sources varied through time, space, and culture.

Indian Use of Plants and Animals in Yellowstone

Most of our knowledge of early cultures comes from stone artifacts. Nonetheless, we have learned a great deal from burned and butchered bones left in archeological sites. We know that people were hunting animals, especially bison, bighorn sheep, deer, antelope, and beaver. Elk were also hunted but apparently less frequently. The only archeological evidence for fishing comes from half a dozen sites dating to about 3,000–1,250 ybp with net weights (see page 29) and one site with archeological fish bone. We simply do not have enough evidence to say what role fishing played in the subsistence patterns of people here.

There is almost no archeological evidence of the prehistoric use of plants in Yellowstone. Evidence of plants in the diet could be charred seeds and other plant remains (e.g., charred cactus pads) in archeological sites, or specialized tools or features to process the plants. People undoubtedly used plants to add variety to their diets and some plant products such as rose hips and various berries were likely to have been eaten raw. If plant remains are not charred, however, they will not be preserved for more than about 150 years, and uncharred seeds are assumed to be modern intrusions into the site. Tools used to grind plant material are rare, but have been found at both the Osprey Beach and Malin Creek sites, two sites in the park at which data recovery excavations were conducted. Charred prickly pear cactus has been found in a hearth on the lakeshore.

Many of the starchy roots used by Native Americans elsewhere are found in the park, but they have to be cooked in order for people to digest the carbohydrates, much as we cook potatoes before eating them today. If native peoples were using these starchy plants, we would expect to find these plant materials in cooking pits as are found elsewhere for camas. However, we have analyzed the contents of many roasting pits and hearths without finding plants of economic value. The function of these features remains a mystery, and we may have erred in assuming that they are roasting pits. It appears Native Americans were primarily hunting, and what they gathered was not preserved archeologically.


NPS

Initially the archeology program focused on site inventories. We are only beginning to understand Yellowstone's precontact archeology.

The Search for Native People's Trails

In the last few decades, professional archeologists have tried to identify a trail on the Blacktail Plateau, up the Indian Creek drainage, and north of West Yellowstone where Wayne Replogle, a park employee who researched the trail in the 1950s, believed he had found evidence that it entered the park. Despite considerable effort, we found none of the ruts or cairns that are known to mark other aboriginal trails, but Replogle also recorded a trail between Mammoth and Tower. I am convinced that park volunteer Bob Flather's work refutes it. The ruts that Replogle mapped are exactly the same width as wagon wheels, because he was actually recording the former Cooke City Miners' road.

If an aboriginal trail were to be discovered, it would be challenging to determine which groups of people used it to move through this area and it would have to be assumed that all groups used various trails at various times. The Bannocks and other tribes traversed the park, but as yet no one route has been identified as a recognizable trail, rather, continual use of a system of trails seems more likely—the choice of exact route probably varied from year to year. The lack of evidence to support a route through the mountains has undermined confidence in Replogle's identification of the Bannock Trail and indicates that further work is needed. Katie White, a University of Montana graduate student, is currently researching the Bannock Trail and her work may shed more light on the trail.

The Sheepeaters

Despite much public interest in the Sheepeater band of Shoshone Indians, we don't have any solid archeological evidence of Sheepeaters in the park to date. There is little to distinguish a Sheepeater site from that of other early visitors to the area. An archeological site with butchered bighorn sheep is not in and of itself an indication of Sheepeater presence because other groups used sheep and it is difficult to determine the ethnicity of prehistoric archeological sites.

There is only one historical written reference to the Sheepeaters in the park, Osborne Russell's 1835 journal of his trip through the Lamar Valley. Sheep skulls hung in trees have been occasionally reported in other places, but have not been recorded in Yellowstone to date. One of the defining characteristics of the prehistoric Shoshone is a type of pottery called "Intermountain Ware," a few pieces of which have been found in the park.

Retrospective

We are only beginning to understand the park's precontact archeology. Initially, the goal of our archeology program was to simply find and inventory sites—any sites—after which analyses at different levels can begin to make some sense of the mass of data. In this new phase, we can look at the site data for patterning and ask at least initial questions about how the park was used in the past, using information and research questions from both within and outside park boundaries. We are also beginning to collect information on the distribution of several site types, which helps an archeologist make recommendations to management regarding a particular site. With the data and analytical tools currently available, I look forward to future discoveries about Yellowstone's past. YS

From the Archives

NPS

This modified stone dates to precontact times and was used to weigh down fishing nets in the Yellowstone River. Archeologists hypothesize that the notches carved into the sides of this stone had the ends of a net wrapped around them. This net weight is one of a few recovered in Yellowstone National Park and is evidence for precontact people engaging in fishing activities. Net weights recovered in the park are the earliest evidence of fishing in Yellowstone. This net weight was found within a site in a level dating to 4,500–1,800 years ago. Other evidence for fishing, such as fish bones in cooking hearths, is not easy to come by because the acidic soils in Yellowstone quickly disintegrate delicate fish bones.

YELLOWSTONE ASSOCIATION

YELLOWSTONE PARK FOUNDATION

Canon

The printing of *Yellowstone Science* is made possible through a generous annual grant from the nonprofit Yellowstone Association, which supports education and research in the park. Learn more about science in Yellowstone through courses offered by the Yellowstone Association Institute and books available by visiting www.yellowstoneassociation.org.

The production of *Yellowstone Science* is made possible, in part, by a generous grant to the Yellowstone Park Foundation from Canon U.S.A., Inc., through *Eyes on Yellowstone* is made possible by Canon. This program represents the largest corporate donation for wildlife conservation in the park.

Yellowstone Science
Yellowstone Center for Resources
PO Box 168
Yellowstone National Park, WY 82190

Change Service Requested

PRSRT STD AUTO
US POSTAGE PAID
National Park Service
Dept. of the Interior
Permit No. G-83

Questioning Greater Yellowstone's Future
Climate, Land Use, and Invasive Species

The 10th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

October 11–13, 2010
Mammoth Hot Springs Hotel
Yellowstone National Park, Wyoming

www.greateryellowstonescience.org/gyesciconf2010

Yellowstone Science is available electronically at www.greateryellowstonescience.org/ys and in print. Readers may subscribe to the print and/or the electronic version. To update your subscription, email yell_science@nps.gov.