Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

1960s Winter Atmospheric Research

The Murie Legacy

Is There Life in Well Y-7?

Bear on Bear Predation

Volume 10 Number 4

The wonder of the world,
the beauty and the power,
the shapes of things,
their colours, lights,
and shades; these I saw.
Look ye also while life lasts.

COURTESY THE MURIE CENTER, MOOSE, WYOMING

Legacy

In the 25 years I've lived and worked in Yellowstone, one of my fondest memories is a trip I took many years ago from Yellowstone Lake to Moose, Wyoming. The occasion was afternoon tea with Mardy Murie. A few other young seasonal naturalists and I had the opportunity to meet this extraordinary woman, who in partnership with her husband, Olaus, has done great things in her lifetime for the cause of wilderness preservation. At the time, I remember wondering how many scores, if not hundreds, of perfect strangers had made their way to her doorstep. For a moment on the drive south, I wondered how she tolerated it all. When we arrived, I found that the answer was simple—with hot tea served in china cups from a silver service accompanied by freshly baked cookies.

Never before had I met a person more grounded to the earth, nor nobler in her generosity. She did not carry herself like the "mother of wilderness" or the "grandmother of American conservation," regaling us with tales of her adventures with Olaus in the Arctic or of their efforts, in this very cabin, to create the Wilderness Act. In fact, we were hard-pressed to get her to speak of these accomplishments. Instead, we found a gracious host—a woman who lived simply and who held forth not about herself, but who seemed more interested in us. I remember that she asked more questions than she answered. She made us feel like we were the only ones who had ever thought to come to her door.

As the pages of this *Yellowstone Science* began to take shape, a common thread emerged, weaving its way from story to story: that of legacy. Yellowstone, itself, is a legacy. It is, if all goes well, a physical place preserved forever. It is also a testament of the importance of wildness to a people, and to their will to protect it for future generations. Yellowstone, the place and the idea, has brought many people to this corner of Wyoming, Idaho, and Montana. Some never left; others come back year after year. Vincent Schaefer found a winter home here for over a decade thirty years ago. In the first of a two part series, Dr. Thomas Brock chronicles Schaefer's pioneering atmospheric research and the legacy of his Yellowstone Winter Research Expeditions.

In this issue, we pay tribute to three friends of Yellowstone who we've recently lost—Jay Anderson, J. David Love, and Boyd Evison. We remember the dedication each of them brought to their work and what they leave us: Jay Anderson's passion for the Greater Yellowstone Ecosystem and equal love for sharing that knowledge with his students; Dave Love's interpretation of the Teton landscape and mentoring of this generation of geologists; and the NPS's Boyd Evison, who recognized the importance of science throughout his NPS career, and long championed its use in managing national parks. Their passing calls us to remember that research, too creates a legacy. It lays a foundation of knowledge on which those in the future may build; somehow, I'm certain that Vincent Schaefer would be pleased to know that he shares these pages with John Spear et al., as they carry on the tradition of investigation in a most unusual search for life "beneath" Yellowstone.

Reflecting on the lives and work of these people, the question arises, "What legacy will we leave?" As we mark Mardy Murie's 100th birthday, my thoughts are drawn back, as they often are, to that afternoon at the Murie Ranch. I now understand why she tolerated, even welcomed, so many intrusions into her life and her living room. She made us feel like fellow travelers, worthy colleagues who shared a common vision to preserve and protect the last best places. While her voice no longer speaks out in the name of wilderness as it once did, she has nurtured generations after her to do the same, just as she carried on for Olaus when he was no longer able. As much as anything, this is the Murie legacy, alive and well—cookies, tea, and hope. I smile when I think of Mardy who in 1998, journeyed to Washington, D.C. to be honored with the Presidential Medal of Freedom. As President Clinton leaned over her wheelchair to place the medal around her neck, this conservation matriarch in her late-nineties, never quitting, never missing an opportunity, whispered to the president, "We still have work to do."

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Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

Volume 10 Number 4 Fall 2002

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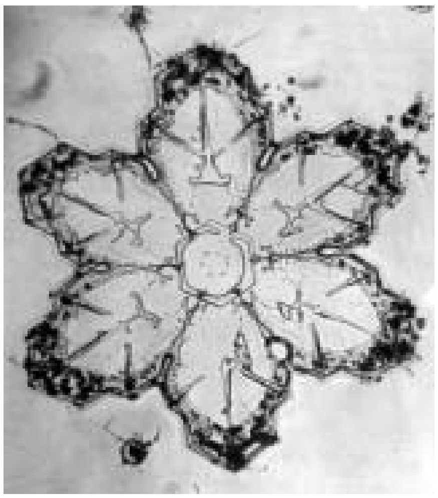

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Cover photo: Ice crystal cloud produced by throwing hot water into air with a temperature of -45°F.
Above: Photomicrograph taken from a replica snow crystal prepared by the 1962 Yellowstone Field Research Expedition. Both photos are from the Yellowstone National Park archives, courtesy Vincent Schaefer.
Left: Christmas at the Murie Ranch in Moose, Wyoming.
Accompanying quote: Denys James Watkins-Pitchford, as carved by Olaus

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The Yellowstone Field Research Expeditions

Winter Research in the Interior, Part I

by Thomas D. Brock

YNP ARCHIVES, COURTESY VINCENT SCHAEFER

Using a fist-sized chunk of dry ice fragments fastened to the end of a wire and swung in a circle overhead, a member of the 1962 Yellowstone Field Research Expedition (YFRE) seeds a supercooled cloud upwind of Old Faithful Geyser and along the road in front of the Old Faithful Inn.

During the 1960s, an extensive and pioneering series of field research expeditions was carried out in the Old Faithful area of Yellowstone National Park. These expeditions, under the leadership of atmospheric scientist Vincent J. Schaefer, brought into the park a wide variety of scientists interested in doing winter research. Although initially focused on ice crystal formation, cloud seeding, and related phenomena of atmospheric science, the expeditions soon broadened out into other areas, including biology, atmospheric chemistry, and geothermal phenomena. The expeditions provided an unparalleled opportunity for scientists to carry out research in a cold, clean, wilderness environment under nearly ideal conditions. Financial support for the whole operation was supported by National Science Foundation grants.

The Yellowstone Field Research Expeditions operated for 11 years, from 1961 through 1971, and brought hundreds of scientists to the park during winter. In the later years, the Old Faithful area became no longer suitable for this sort of research. Air pollution from snowmobiles became a serious factor, and the buildings used for the project had to be torn down to make way for the major road realignment and expansion that occurred in the early 1970s. The operation was moved to Norris Geyser Basin, where the last expedition was held in January and February of 1971.

I was privileged to participate in the Yellowstone Field Research Expeditions for two winters. It was my first opportunity to study microbial mats during the winter, and it also enabled me to study hot springs in the Old Faithful area that were not available in the regular season because they were so public. During my two winters, I was also able to observe the atmospheric scientists at work, and to appreciate the reasons why they were attracted to Yellowstone National Park and the Old Faithful area in particular.

Most people today are not aware of the pioneering work that Vincent J. Schaefer and his associates carried out in Yellowstone's winter. The research was extensive, innovative, and of broad scale. Much of it was published by the various scientists in their own scientific journals. The results of this winter research are summarized in Schaefer's 12 annual reports, which can be found in the vertical files of Yellowstone's library, under the heading "Climate and Weather."

Vincent J. Schaefer

The Yellowstone Field Research Expeditions were conceived and directed by Vincent J. Schaefer (1906–1993), of the Atmospheric Sciences Research Center of the State University of New York at Albany. Schaefer's career as a scientist was unusual. Although he eventually received honorary doctorate degrees from two universities, he had no real university education and, in fact, never completed high school.

Vincent J. Schaefer was born and raised in the Schenectady area of New York. Because his family was in financial difficulties, he was forced to begin work at an early age. He joined an apprentice machinist program at the General Electric Company, the major employer in Schenectady. Schaefer eventually became established in the machine shop of the research laboratory at General Electric, where he built equipment for scientists and engineers. Among the scientists for whom Schaefer built equipment was physicist Irving Langmuir (1881–1957), who won the Nobel Prize in 1932 for his research on surface chemistry. (The Langmuir absorption isotherm remains a widely used expression in physical chemistry.)

In 1932 Vincent J. Schaefer became the personal assistant of Irving Langmuir and from then on the two worked closely together for many years. Despite his lack of academic training, Schaefer proved to be an accomplished research scientist. Together, Schaefer and Langmuir published many research papers on such topics as surface chemistry, electron microscopy, the affinity of ice for surfaces, protein films, and submicroscopic particulates. Schaefer was promoted by General Electric to research associate in 1938. With the advent of World War II, Schaefer and Langmuir did extensive research for the military on gas mask filtration, submarine detection of sound, production of artificial fogs using smoke generators, aircraft icing, ice nuclei formation, and cloud physics. Some of this work was carried out at the Mount Washington Observatory in New Hampshire.

THOMAS J. HENDERSON, ATMOSPHERICS, INC.

Vincent Schaefer in the field near Old Faithful Geyser.

Throughout his life, Vincent Schaefer had an interest in the Adirondacks, archeology, natural history, and the outdoors. He was an enthusiast hiker and skier. In 1933 he began work on creating The Long Path, a hiking trail that begins near New York City and ends at Whiteface Mountain in the Adirondacks. During this period Schaefer also created adult education programs on natural history topics, and he spoke widely on these in the community.

In 1940 Vincent Schaefer developed a method for making replicas of individual snowflakes using a thin plastic coating on a microscope slide. This discovery brought him national publicity in popular magazines and through this he became known in his own right. It was this technique that made Schaefer's research at Old Faithful possible many years later. In the summer of 1946 Vincent Schaefer discovered a procedure for inducing snow formation by seeding supercooled water with dry ice. Although first developed as a laboratory procedure, in November 1946 Schaefer and Langmuir carried out a successful field test by seeding a natural cloud from an airplane. According to Schaefer's notes: "It seemed as though the cloud almost exploded." From the ground, Langmuir watched the snow fall through binoculars. Later, with associate Bernard Vonnegut, Schaefer and Langmuir discovered that silver iodide was a superior cloud seeding agent.

Within a few years, cloud seeding became an important area of research and practice. Many clouds are inefficient sources of moisture, retaining more than 90% of their water. Cloud seeding greatly increases the precipitation efficiency. Soon, many commercial cloud seeding operations began. Wintertime cloud seeding is done to increase snow pack in ski areas and in arid mountain areas in the west where snow melt is a principal source of water. In the summer, cloud seeding is used by water agencies and hydroelectric power companies.

The work of Schaefer, Langmuir, and Vonnegut lead to a very extensive development of cloud seeding research, both basic and applied. Despite the controversy that ensued about the appropriateness of tampering with the weather, cloud seeding has become extensively utilized, especially in the western part of the United

States. Because of the military implications, Schaefer became laboratory coordinator of Project Cirrus, a research project of the Air Force and Navy. Later, Schaefer worked in the Rocky Mountains with the U.S. Forest Service on the possible use of cloud seeding to prevent lightning-induced forest fires (Project Skyfire).

Vincent Schaefer did extensive consulting in atmospheric research for private industry, the U.S. government, and universities. For some years during the 1950s he was director of research for the Munitalp Foundation, a research organization with extensive work in meteorology. In 1960 Schaefer helped found the Atmospheric Sciences Research Center (ASRC) of the State University of New York at Albany. He served as Director of Research for ASRC until 1966, when he became director of the center. He spent the rest of his career at ASRC. He retired from ASRC in 1976 and died July 25, 1993, at the age of 87. Schaefer was the recipient of many honors, including honorary doctorates from the University of Notre Dame, Siena College, and York University. The Weather Modification Association has established a Vincent J. Schaefer Award for scientific and technical discoveries in the field of weather modification, and Schaefer himself was the first recipient of this award. According to his obituary in the *New York Times* (July 28, 1993), Schaefer published nearly 300 scientific papers and many books. Among other books, he was the author, with John Day, of the *Peterson Field Guide to the Atmosphere*.

Origins of the Yellowstone Field Research Expeditions

Schaefer had conceived the idea of doing cloud seeding research in Yellowstone National Park in the 1950s, probably during the years when he was involved with Project Skyfire. He anticipated that in combination with rich moisture sources from the geysers and hot springs, the cold weather would lead to the development of a wide variety of unique atmospheric phenomena. According to a report he wrote later, Schaefer had been attempting to visit Yellowstone Park in the winter for 10 years but had been unable to obtain permission. However, in the winter of 1959–1960, a park ranger was assigned to spend the winter at Old Faithful to monitor any changes in the hot springs and geysers that might have been caused by the Hebgen Lake earthquake of the previous summer.

In the winter of 1959, through his contacts with Maynard Barrows (who was at that time the Chief Forester of the park), Schaefer was briefly able to study the winter conditions at Old Faithful, and did some preliminary seeding experiments using dry ice and silver iodide. Barrows and Schaefer then spent a week at Old Faithful in February 1960. The park superintendent's report for March 18, 1960, includes the following paragraph under the heading "Inspections: Forester Maynard Barrows...and Research Scientist Vincent Schaefer...were at Old Faithful from February 11 to 18th conducting experiments in the Upper Geyser Basin including seeding of steam clouds from geysers and hot pools with silver-iodide and studying geysers to see if they generate electricity when they erupt."

For this first trip, transportation was provided by the National Park Service. Schaefer and Barrows drove to West Yellowstone, where they were met by a park ranger who transported them by Weasel snow tractor to Madison Junction. Ranger Riley McClelland met them there and transported them the rest of the way to Old Faithful. "We arrived in time to deposit our gear in a very cold cabin which was to become our headquarters for the next eight days."

During this visit, Schaefer found that the air was of exceptional purity and that the extensive fogs that developed during the night and early morning were generally supercooled. Conditions were ideal for cloud seeding studies. In addition, a wide variety of other phenomena were observed, all related to the extremes of heat and cold.

Cloud seeding at Old Faithful permitted detailed observations on snow crystallization. One could test various seeding agents, and had the ability to "catch" the process at various stages. The air was so free of cloud condensation nuclei that it was possible to cause a cloud to form above a hot spring pool simply by lighting a match. Schaefer described the experience as like "walking in a cirrus cloud." To study such clouds in the atmosphere is difficult and expensive, requiring very sophisticated equipment, pressured cabins, and high-performance jet aircraft. Yet in Yellowstone they can easily be studied from the ground and, at modest expense, in the geyser basins.

COURTESY THOMAS J. HENDERSON, ATMOSPHERICS, INC.

On a very cold day, just a lighted match was able to cause a cloud to form above a hot spring pool, 1962.

ARCHIVES, STATE UNIVERSITY OF NEW YORK, ALBANY (SUNY ALBANY)

The mess hall, also used as a seminar room and makeshift office by YFRE scientists, 1968. It would soon be demolished.

After the 1960 exploratory visit, Schaefer determined to return the following year, bringing with him scientist friends who were also interested in cloud seeding and related phenomena. He received strong support and encouragement from the National Park Service and from Yellowstone's Superintendent Lemuel A. Garrison and Chief Naturalist Robert N. McIntyre. The National Science Foundation provided financial support for a nine day visit to the park. In addition to Schaefer, seven other scientists participated, as well as Maynard Barrows, who was by then Chief Forester of Grand Teton National Park. (In addition to his official oversight of the expedition, Barrows also assisted Schaefer with some of the field research.)

This first formal visit was quite successful, and from the experiences of this group Schaefer devised procedures that were then used for subsequent expeditions, which extended over the next decade. Although he originally called the program a "Seminar," after the second year he changed the title to "Expedition." In most of the reports, the title was given as Yellowstone Field Research Expedition.

According to Schaefer: "The great value of a program such as [this]...is the opportunity for the interdisciplinary attack on scientific problems in discussions and in field research. In addition, the experience provides a brief retreat from the pressures and diversions of the laboratory, college, or university, and thus permits the participant not only to get a better perspective of his current activities but by interplay of personalities with his colleagues he obtains new ideas and stimulation."

Yellowstone Field Research Expeditions Operations

Although in the early years the facilities were somewhat makeshift and primitive, by the time of the third expedition in 1963, substantial facilities were provided by the National Park Service. Two buildings were made available: a bunk house and a mess hall. These buildings were south of the Camper's Cabins, in an area called "Shackville." (I refer here to a 1949 detailed map of the Old Faithful area which shows every building present.) One building (building 162 on the park building inventory) was used as a mess hall. This was a double apartment that in summer provided temporary housing for visiting NPS employees. This building had a large room that had kitchen facilities where the cook worked, and where meals were taken. The cook did the cleanup after breakfast and lunch, but volunteers did the evening washing and drying. Since the kitchen was the only warm area in the complex, it served as the expedition's

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National Geographic photographer Paul Zahl set up a temporary microscopy laboratory next to his bed in the bunkhouse. 1967.

social area. After dinner, the nightly seminar was held in this same room. This building had an additional smaller room that served as its entry, and which could be used by participants for writing or reading. The nightly "Happy Hour" also took place in this smaller room. In the early years, Harold Gooding, a restaurant owner in West Yellowstone, did all the cooking. In later years, his business kept him in West Yellowstone but he hired the cook and continued to provide the food and all cooking and eating supplies.

The bunkhouse (building 163 on the park inventory) was a log cabin used in summer by single NPS employees. It was near the mess hall and easily accommodated 12 people. The expedition purchased high-quality sleeping bags filled with three pounds of goose down. A flannel sheet served as a liner. To freshen the bags for the next user, they were covered with snow and left outdoors for several hours. "When recovered it was like they had been dry cleaned." Although the bunk house was heated by a kerosene stove, the washroom part of the building, which contained indoor showers and toilet facilities, was not heated, and water had to be kept running at a constant drip to prevent the pipes from freezing. These two buildings had not been built for winter use, but served more or less adequately. One year, the bunkhouse was not available and participants slept in an upstairs room of the mess hall. A telephone was available at the mess hall, but incoming collect calls were not permitted and outgoing collect calls could not be charged. Incoming calls had to be restricted to those of an emergency nature, preferably person-to-person, and only during the hours 6–7 a.m. and 6–7 p.m.

After the first two years, Vincent Schaefer had refined the Yellowstone Field Research Expedition so that it operated smoothly on a four-week schedule. The group was limited to 12 individuals, which Schaefer considered the optimum number he could accommodate with the available bunk and mess facilities. A different group would be present each week, with occasional visitors who were there for one or two days. Schaefer made a concerted effort to bring together persons who had not known each other, except perhaps by reputation. He also tried to balance ages and experiences so that senior scientists and recent graduates were brought together.

Due to the potential rigors of the expedition, each participant had to submit a Medical History Form describing any potential health problems. Student participants were also required to submit a physician's statement certifying that "I am capable of participating and that I am up-to-date on tetanus booster, flu shots, a negative skin test for tuberculosis, or a chest x-ray."

En route to the park, the groups would rendezvous at Idaho Falls on a Monday. Most would have flown into Idaho Falls on the previous day and stayed overnight at the Bonneville Hotel. All travel costs for the round trip between Idaho Falls and Old Faithful, and all living expenses in the park, were paid by the expedition. Participants were expected to provide their own travel costs to and from Idaho Falls.

George Wehmann, a scientist at the Idaho Atomic Energy Commission facility and friend of Schaefer's, handled arrangements at Idaho Falls. (Wehmann himself participated in several of the expeditions. He also returned to Old Faithful after the snow was gone in the spring to retrieve the electrical line to the geyser basin as well as any materials or equipment that might have been lost in the snow.) Very early the next morning, the group would leave Idaho Falls in two rented cars for West Yellowstone, a distance of 110 miles. At West Yellowstone the group would transfer to snowmobiles for the 30-mile oversnow trip to Old Faithful. Depending on the weather and snow depth, the trip to Old Faithful would take from 1½ to 3 hours. In the early years, the snowmobile service was operated by Harold Young, a West Yellowstone resident who had pioneered commercial snowmobile service in the park, but about 1968 the NPS transferred the snowmobile franchise to the Yellowstone Park Company. Both services operated regularly-scheduled snowmobile service to Old Faithful and provided special runs for Schaefer's group. In addition to the run bringing in participants, there was usually one extra run per week bringing in commissary items.

After the incoming group had unloaded its gear, the outgoing group would load and leave immediately for West Yellowstone, arriving by early afternoon. The same rented cars that the incoming group had used were driven back to


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Guy Goyer of the National Center for Atmospheric Research leads an evening seminar in the mess hall, discussing the effects of high-pressure acoustical waves on supercooled water drops and hail. Fourth YFRE, 1964.

Idaho Falls. Some participants were able to make late afternoon plane connections to Salt Lake City.

Participants with projects that needed supercooled clouds would arise before sunrise, catch an early breakfast, and walk the half mile to the Upper Geyser Basin. (In some later years, one or two small snowmobiles were kept at the bunkhouse for occasional use, although most people walked, skied, or snowshoed to their study sites.)

For safety reasons, participants were required to travel in pairs whenever the temperature was colder than -40°F. Other times, participants were encouraged to travel in pairs or small groups "for mutual protection from animals and other possible dangers in the thermal areas." Over the decade of the research expeditions, no serious accidents occurred.

Lunch was at noon, but field lunches were available for those wishing them. Dinner was at 6:00 p.m., about an hour after sunset. After dinner and cleanup of the mess hall, a seminar was held each night. Vincent Schaefer placed great importance on the nightly seminar, because it encouraged interaction among the participants. He especially hoped for interdisciplinary attack on problems of mutual interest. The titles of the seminars are given in each year's annual report, and the range of topics is very wide.

In the expedition's first years, the participants were probably selected by Vincent Schaefer, from his wide circle of acquaintances. (Throughout the whole 11-year period, there was never a female participant.) As the expeditions became more widely known, an individual with a suitable project could apply for admission. The rule was that a first-year participant was automatically guaranteed a place for the next year. A few scientists with extensive need for the winter facilities attended more than twice. Schaefer made an effort to assemble each group so that it was well balanced, with as wide a variety of mutual interests as possible.

Researchers had to bring all their own equipment. There was electrical power in the bunkhouse and mess hall. There was also a temporary electric powerline extending past Old Faithful to Castle Geyser by way of the Firehole River, and outlets were available at a number of locations along this line. For field work in other locations, electrical equipment had to be battery-operated. Although the microprocessor had not yet been invented, there was a wide array of compact, battery-operated equipment that could be used in the field. The principal problem was that some equipment did not work well in the cold. The key to a successful research activity was to keep equipment simple, and to design simple experiments. This philosophy was an important part of Vincent Schaefer's lifelong approach to science.

COURTESY ROGER CHENG

Schaefer surveys the results of cloud seeding at Castle Geyser.

Every year Vincent Schaefer assembled an annual report of activities that had taken place at the Yellowstone Field Research Expedition. This served as a progress report to the National Science Foundation and also provided documentation of all research activities. Each participant was required to submit a report of activities carried out, with data and photographs if needed. They were usually only a few pages long, but occasionally were much longer. The annual report also contained a list of all participants, a schedule of all seminars, and a fairly detailed weather record. Any research papers that had been published based on research done during the expedition were listed at the end of the report. In the later years of the expedition, this publication list was often several pages long.

Because Schaefer was an atmospheric scientist, it was natural that weather observations were kept. A formal procedure was established for making weather observations, and these data were published in the annual reports. Temperature was recorded at 7 a.m., noon, 5 p.m., and 10 p.m., observations on snowfall, etc. made, and any unusual optical effects were noted. These observations probably provide some of the best winter data for the Old Faithful area.

An Overview of Research Conducted

First Expedition (February 12–26, 1961)

Most of the early research of the Yellowstone Field Research Expeditions dealt with atmospheric research, primarily cloud seeding. In the first expedition in 1961, Vincent Schaefer carried out three successful seeding experiments. More successful experiments would probably have been possible but the weather was unusually warm that year.

The first seeding experiment was carried out on February 18, 1961, when the outside temperature was 15°F. Using a fist-sized chunk of dry ice fastened to the end

YNP ARCHIVES, COURTESY VINCENT SCHAEFER

Basket of dry ice used for cloud seeding.

of a wire and swung in a circle overhead, seeding was carried out upwind of Old Faithful Geyser and along the road in front of the Old Faithful Inn (see page 2). The seeding was carried out for about 30 minutes. A faint bluish cloud of ice crystals could be seen forming in the wake of the dry ice. Before the seeding the air was quite clear, fewer than 100 particles of ice crystals per cubic meter. Within five minutes of the seeding, the concentration of crystals had increased a million times. The area of crystallization continued to grow until a snow shower of artificially-formed crystals extended all the way to Castle Geyser, about a kilometer downwind. One of Schaefer's colleagues, L.R. Koenig from the University of Chicago, used Schaefer's replica method to collect ice crystals. The crystals were mostly in hexagonal plates between 70 and 100 microns in diameter.

A second seeding, using silver iodide, was carried out February 23, when the temperature was 8°F. The silver iodide generator was a simple propane burner which ignited a mixture of silver iodide/sodium iodide dissolved in acetone that was burned in a flame holder. This generator was operated near a small steam vent east of Old Faithful. Within five minutes, dense clouds of ice crystals were found within 100 yards of the generator, with concentrations exceeding 1,000 per cubic centimeter. Within 30 minutes, the entire area was filled with ice crystals, creating a light snowfall that covered the bare ground. The behavior of particles in the air was observed with a small searchlight.

These seedings also produced spectacular optical effects. "A flashlight pointed overhead disclosed a bright spot at the zenith. A 22° halo and a vertical streak could be seen when looking toward a light source. The moon, which was at about half phase, produced a circumzenithal circle passing through the moon. Venus produced sufficient illumination to produce a striking vertical star streak."

To observe these optical phenomena, Schaefer mounted a silvered garden sphere at a bend in the Firehole River about a half mile downstream from Old Faithful. This sphere provided an excellent full-sky view and sometimes revealed phenomena that were too faint to see when looking directly at the sky. Schaefer reflected later: "Although I have watched the sky in the north country more than 60 years, I have never seen displays such as we observed frequently at Yellowstone." Schaefer concluded that valuable information could be obtained on the effectiveness of different kinds of cloud seeding techniques using the atmosphere surrounding Old Faithful and other geysers.

A number of other natural phenomena were studied during this first expedition. These included: natural electrification phenomena at Old Faithful; radiation and heat balance of a hot spring; cold air entrainment in a geyser plume; infrared radiation of clear and cloudy skies around geyser and hot spring areas; air movements in the Old Faithful area; growth of ice crystal particles in the electrified plume of Old Faithful; study of rime ice formation near hot springs; time-lapse and high-speed photos of convective motions in geyser clouds; radioactivity in the vicinity of geysers and hot springs; electrical potential measurements in the Upper Geyser Basin; and optical and other physical properties of subcooled mist.

One result of the extreme cold and rich supply of moisture was the coating almost every night of trees, bushes, and other objects with frost crystals. Even the elk and bison became coated. The trees were often turned into grotesque shapes, which Schaefer called Ghost Trees. "When seen against a deep blue sky or by moonlight they provide a unique experience."

Some of the research other than cloud seeding should be noted. David Gates, whose field was micrometeorology, carried out extensive measurements on thermal radiation from objects and organisms in the Upper Geyser Basin. This work was published in *Science* in 1961. Bernard

YNP ARCHIVES, COURTESY VINCENT SCHAEFER

"Ghost trees" coated with frost crystals at Old Faithful.

Vonnegut, a long-time colleague of Schaefer (and brother of author Kurt Vonnegut), used sensitive electrical recording instruments to measure the electrical potential of the air in the geyser area. Although he expected the geyser eruption to be electrified, he found that this was not so. Vonnegut also measured radioactivity in the air and near the ground. He found that the air was extremely low in radioactivity, much lower than is found in urban areas.

Second Expedition (January 9–February 6, 1962)

The 1962 expedition was the first supported by a three-year grant from the National Science Foundation. Because of this assured funding, Schaefer developed more formal procedures for how the expedition would operate. The second expedition was much longer than the first, 28 days, and had a total of 21 different scientists. Because the weather had not been consistently cold enough for efficient cloud seeding in the first expedition, the second expedition was moved to early January. This was a wise decision, and the first two weeks of the second expedition experienced plenty of cold weather. In fact, two cold weather records were established, -44°F on January 10 and -45°F on January 22. Parts of 25 days were 13°F and colder, and parts of 10 days were 0°F or colder. In addition to Schaefer, four scientists from the first expedition returned again, and there were several new disciplines.

COURTESY ROGER CHENG

Thomas Brock and Vincent Schaefer (from left) observe brine flies at a spring, 1968.

Boeing Company research. Another expansion of the expedition involved a group of engineers from the Boeing Company of Seattle. A group of six engineers at Boeing's Aero-Space Division, under leader Richard McDonald, became interested in using the Old Faithful area as a study site after Schaefer gave a seminar at the Boeing Scientific Research Laboratory. Their interest was in the scattering of infrared radiation by ice crystals. Although their research was independent, they participated in all joint activities of the expedition and shared the cooking and living quarters. Also, they shared some of their equipment with the regular expedition members.

The Boeing engineers established their own field headquarters in the Upper Geyser Basin near the Old Faithful Inn. Their research concerned optical effects of ice crystal clouds. According to an onlooker, most of the observed effects had already been described in the literature but were based upon theoretical calculations rather than direct observation. The advantage of Yellowstone was that it was possible to generate at will different kinds of situations by use of the cloud seeding techniques. Presumably, there was an aeronautical or military significance to this research.

Atmospheric science research. Schaefer continued his cloud seeding research, with an emphasis on optical phenomena generated by dry ice and silver iodide seeding. On February 3, Schaefer was able to generate a complex halo phenomenon with silver iodide seeding that rivaled some of the most spectacular displays in the scientific literature, including the St. Petersburg, Russia, halo complex of the year 1790 (see cover). Seventeen different effects were recorded during a single period from 8:45 to 9:30 a.m., and many were photographed. Examples of these phenomena include halos, parhelia, crosses with sun in the center, parhelic circles, circumzenithal arcs, antisuns, antihelion arcs, fuzzy sun discs, and sun streaks.

A variety of other research was carried out in 1962: specific gravity of ice samples from the Yellowstone area; computation of the velocity of discharge of Old Faithful, its peak water volume flow, peak mass discharge rate, peak rate of work done above ground, and the estimated gallons of water discharged during a single average eruption; temperature measurements of trees and snow surfaces; microscopic studies of various snow crystal structures; growth of snow crystals from the soil near Old Faithful Geyser; infrared transmission of snow and hot spring surfaces; physical structure of rime and snow crystals forming near geysers; light diffraction studies on clouds forming near Old Faithful and Castle Geysers; testing of a continuous recording particulate sampler; measurement of the concentration of condensation and freezing nuclei in the atmosphere using portable particle detectors; testing the suitability of commercial refrigerants as cloud seeding agents; measurement of temperatures of tree trunks; and measurement of snow depths around hot pools as a way of measuring heat flow.

Brine flies. In addition to the physical studies, Vincent Schafer noted the presence of brine flies upon the microbial mats at a number of hot springs in the Upper Geyser Basin. Although brine flies had been known for many years to be associated with hot springs, their existence in winter conditions had apparently never been recorded. Schaefer noted that the flies were living in a unique microclimate. He observed pink areas on the surfaces of microbial mats that he determined to be high densities of brine fly egg masses.

Schaefer concluded that "a very intensive life cycle existed among the brine flies *(Ephydra brusei)* and that their environment consisted of a highly restricted microclimate during extended periods in the wintertime having the dimensions of not more than two or three meters by one-half meter by 10 centimeters. Thus their entire 'world' consists of a volume of air of less than a cubic meter…Many fascinating details of the life cycle of these creatures included their feeding on algae under water having a temperature of 100–140°F protected by a surrounding air bubble... It is likely that studies in genetics would be very fruitful because of the winter isolation of each colony."

As far as I know, winter observations on brine flies had never been reported before these studies. Schaefer's approach, using the tools of an atmospheric scientist, were unique. He identified the hot spring as a tiny tropical environment completely surrounded by the depths of winter. His insights here have been followed up by a number of biologists in the later 1960s and 1970s. We now know quite a bit about these tiny ecosystems.

Third Expedition
(January 8–February 5, 1963)

When the third expedition began in early January 1963, there was insufficient snow on the ground for snowmobile travel. A four-wheel drive vehicle of the Atmospheric Sciences Research Center was used to transport gear from Albany and to reach Old Faithful during the first week of the expedition. The snow was one third less than the previous year, although the temperature regime was similar. On January 12, a record low temperature of -47°F was reached. At the other extreme, a spectacular warm Chinook wind began on January 21 and removed most of the remaining snow. On February 4 the temperature on Geyser Hill reached +53°F. Thus, within a three-week period the temperature ranged 100°F! Despite these wide variations in temperature and snow, the researchers managed to keep busy.

YNP ARCHIVES, COURTESY VINCENT SCHAEFER

Portable, battery-operated equipment was used extensively in the YFREs. Vincent Schaefer in center. 1962.

New facilities were provided by the NPS that year. The building was insulated, which eliminated the pipe-freezing problems experienced in past years. Also, the mess hall had new equipment for food storage and preparation. These facilities were apparently used for the expedition each year until the late 1960s. The park also provided a small auxiliary building for use as a cold room, and loaned the expedition a small library of reference volumes that proved of great use to the scientists. This was the first year that students were participants. There were two undergraduate students and two graduate students who worked as research assistants.

Further research on ice crystal formation was carried out, confirming results of earlier years. Schaefer continued his observations on the microclimatic environment of brine flies. He used a Questar Telescope, which permitted focus as close as seven feet, to observe brine flies feeding underwater. This confirmed his discovery of the previous year that the fly was able to feed under water encased in a bubble of air, which probably provided short-term insulation. Preliminary work was made on films that develop on the surfaces of most hot springs.

An interesting phenomenon observed was the hissing sound that could be heard when hot water was thrown into air that was colder than -40°F (or -40°C, since both scales are the same at this low temperature). The sound was most pronounced when the water temperature was above 100°F. It was uncertain whether this sound was due to a change in phase from water to ice, an electrical effect, or was due to some mechanical friction. Extensive electrical studies were performed on the eruptions of Old Faithful. At temperatures below -40°F a striking electrical discharge was measured. Studies on other kinds of chemicals that could induce cloud seeding were carried out. Observations were made on the mechanism that controlled the ejection of mud droplets from mud pots.

Although not part of the expedition, bear researchers John Craighead and Maurice Hornocker visited the expedition and carried out some hibernation studies on a black bear. This was the first year that John Craighead and/or his brother Frank was associated with the expedition, beginning a relationship that continued through the 11th and last expedition. (I believe Vincent Schaefer had known the Craighead twins since their childhood years growing up on the east coast.) At the conclusion of the third expedition, Schaefer entered into an agreement with the National Park Service and the Department of the Interior that gave the Atmospheric Sciences Research Center the authority to "head and coordinate winter research activity at Yellowstone for the next five years."

Fourth Expedition (January 7–February 4, 1964)

In the Fourth Expedition there were 46 individuals representing 27 separate organizations. Nineteen were from universities, 10 from private research institutions, 9 from public research institutions, and 8 from governmental units. Although the disciplines represented were primarily in atmospheric science, several biologists participated.

Publicity and media activities. Schaefer was always mindful of his goal of communicating science to the public. During the spring of 1963, Schaefer and three other scientists who had participated in that expedition made a one-hour television program for national distribution on WNETV, on the American Association for the Advancement of Science (AAAS) Engineering Series. Even greater public media access was provided during the 1964 expedition, when Schaefer arranged for a film crew from the National Film Board of Canada to join the expedition and prepare an educational film. This was a color film, sponsored by the American Meteorological Society and supported by the National Science Foundation. In addition, NBC Radio, through its Monitor program, visited the expedition and recorded a series of tapes that were later broadcast nationwide. Additionally, Raymond Falconer of the Atmospheric Sciences Research Center presented daily broadcasts by telephone to a group of radio stations in New York State. These broadcasts were also carried by the local Idaho Falls radio station. Schaefer also gave a number of noontime talks to groups of visitors who came to the Old Faithful area with Harold Young's snowmobile service.

Also, several regional newspapers (Idaho, Utah, Montana, and Colorado) wrote articles on the expedition and were given photographs. According to Schaefer: "We made the effort to assist in all of these matters, since I believe it is the duty of scientific groups supported by public monies to attempt to present to the interested public reliable information of an informative nature pertaining to research efforts. We invariably found a most attentive and seemingly appreciative audience." Several park officials visited the expedition this winter, including Lemuel A. Garrison, superintendent of the park (and soon to become Regional Director of the Midwest Region), Assistant Superintendent Richard A. Nelson, Chief Naturalist John M. Good, and several district naturalists. These officials were able to observe experiments in progress.

Atmospheric research. This year, apparently for the first time, arrangements had been made with the Yellowstone Park Company for access to the "Captain's Walk" at the top of Old Faithful Inn, permitting observations and research experiments from this point high above Old Faithful. The winterkeepers at the inn, Mr. and Mrs. Don Sun, gave eager cooperation to this venture.

The winter of 1964 was another mild winter, and the lack of extreme cold prevented some types of research observations. Only twice did the temperature drop below -20°F and the maximum temperature was mostly above +25°F, occasionally even above freezing. However, there were enough cold mornings for certain kinds of cloud seeding studies to be done. A method was devised for producing a line of silver iodide nuclei for ice crystal formation. This was done by impregnating 100 feet of primacord with silver iodide and detonating it almost instantaneously. Samples of ice crystals resulting from this seeding were collected about a half mile away. A new type of seeding procedure using a pyrotechnic road flare containing silver iodate was developed and tested. In another study, a 200-foot lightweight sampling boom was tested in the vicinity of Castle Geyser. In findings that may have anticipated air pollution studies, evidence was obtained of organic residues present in the clean atmosphere of Yellowstone.

ARCHIVES, SUNY ALBANY

A Canadian film crew visits the YFRE site in 1964.

Participants of the Second YFRE on the final day of the expedition, along with their cook and driver. Vincent Schaefer is on far right. February 6, 1962.

Frank C. Craighead. In his first participation in the Yellowstone Field Research Expeditions, biologist Frank C. Craighead tested a device he had constructed for telemetering temperature readings from remote sites. At this time, Craighead was on the staff of the Environmental Research Institute at Carlisle, Pennsylvania. Later, he became a staff member of the Atmospheric Sciences Research Center in Albany.

The temperature probe Craighead used was able to transmit temperature data from the winter environment of brine flies feeding on microbial mats in hot springs. He was able to show that the temperature of a brine fly egg mass about one inch above the water varied from 63°F to 86°F over a 40-minute period. The report includes a photograph of Frank Craighead measuring the temperature of the brine fly microenvironment. Presumably, Craighead had chosen the brine fly habitat for testing this equipment because of Schaefer's interest in these animals. Craighead also reported the first stages of a radio-tracking program for large animal research in the park. This was a cooperative program involving the National Park Service, the Montana Cooperative Wildlife Research Unit, and the Environmental Research Institute of Carlisle, Pennsylvania. Involved in this research as guests of the expedition were John J. Craighead and Maurice G. Hornocker of the Wildlife Management Institute of Montana State University.

The 1964 expedition was the final of a three-year series supported by the National Science Foundation. Schaefer applied for and received a grant for an additional three years, thus supporting the expedition through 1967. ✪

To Be Continued

Thomas D. Brock began researching the microorganisms of Yellowstone hot springs in 1964. With his students and associates, he carried out a wide-ranging research program in the park in the 1960s and 1970s. He participated in the Yellowstone Field Research Expeditions in the winters of 1967 and 1968. Since his retirement from the University of Wisconsin at Madison he has continued to maintain his interest in Yellowstone. He is on the Board of the Yellowstone Association, and is a member of its Educational Services and Educational Products Committees.

Honoring the Murie Legacy

Mardy Murie turns 100

by Paul Schullery

ALL PHOTOGRAPHS COURTESY THE MURIE CENTER, MOOSE, WYOMING

Mardy and Olaus Murie at their Teton ranch home, 1953. The Murie name and ranch have been synonymous with the cause of wilderness preservation and pathbreaking research in greater Yellowstone for more than a half century.

The 100th birthday of Margaret "Mardy" Murie, of Moose, Wyoming, on August 18, 2002, has brought well-deserved attention to the legacy of the Murie family in this region and beyond. Sharing that attention with Mardy—and leading the celebration—on this occasion was the recently established Murie Center, of Moose, Wyoming, which seeks to honor the Murie legacy by serving as a "voice for the value of wild nature and its connection to the human spirit."

The Murie legacy is a rich one, in greater Yellowstone and internationally. Mardy and her husband, Olaus, one of the past century's most influential wildlife biologists and conservationists, arrived in Jackson Hole in 1927, so Olaus could study its already controversial elk herd. In 1945, Mardy and Olaus, along with Mardy's younger sister Louise and her husband Adolph Murie (Olaus's half brother), purchased a small but magnificently situated guest ranch near Moose, and converted it into the family home. Olaus and Adolph used the ranch as their home bases for research and conservation work the rest of their lives.

Olaus died in 1963, and Mardy has continued to live at the Murie Ranch. Adolph died in 1974, and Louise, who celebrated her 90th birthday in March, now lives in Jackson and is still very active in regional conservation, including work with the Teton Science School and membership on the boards of directors of both the Jackson Hole Conservation Alliance and the Murie Center.

Among their contributions to greater Yellowstone, the Muries may be best known for several literary and scientific classics. Adolph's *Ecology of the Coyote in the Yellowstone* (1940), a milestone study of the role of predators in a wild ecosystem, was one of the most influential works in the history of national park wildlife management. Olaus's study of the Jackson Hole elk served as the foundation for his equally influential *The Elk of North America* (1951). Olaus and Mardy co-wrote one of the most popular and powerful memoirs of life in this region, *Wapiti Wilderness* (1966).

The passion for wild places that these works display was equally evident in many other Murie works, the best-known being their books and monographs: Mardy's *Two in the Far North* (1962) and *Island Between* (1977); Olaus's *Alaska-Yukon Caribou* (1935), *Field Guide to Animal Tracks* (1954), *Fauna of the Aleutian Islands and Alaska Peninsula* (1959), and *Journeys to the Far North* (1973); and Adolph's *The Wolves of Mount McKinley* (1944), *A Naturalist in Alaska* (1961), and *The Grizzlies of Mount McKinley* (1981).

All of these works, and many more shorter papers, reports, and publications, were and are important in the evolution of federal land-management direction.

Though Olaus was the one with an official leadership position in The Wilderness Society (he served as its president beginning in 1945), both Mardy and Olaus were universally recognized as a team in the campaigns for wilderness protection. The ranch functioned as the headquarters for The Wilderness Society, and the Muries continued to host society meetings there into the 1960s. Aldo Leopold, Sigurd Olson, Howard Zahniser, and many other of the nation's (and the world's) leading figures in ecology and conservation took part in important meetings at the ranch. Momentous legislation that grew from the energies mobilized at the ranch included the designation of the Arctic National Wildlife Refuge (1960) and the Wilderness Act (1964).

Lyndon Johnson signs the Wilderness Act. Mardy Murie and Alice Zahniser stand left.

Following Olaus's death, Mardy carried on with their work, speaking, writing, and continuing to host the foremost conservationists of the time at the Murie Ranch. Raised in Alaska and the first female graduate of the Alaska Agricultural College and School of Mines (1924), she was well-suited to be perhaps the most eloquent and effective voice on behalf of the protection of Alaskan lands during that great national debate in the 1970s. Widely and frequently honored as the matriarchal figure of the conservation movement, most recently Mardy was awarded the Presidential Medal of Freedom by President Clinton in 1998, and the National Wildlife Federation's J.N. Ding Darling Conservationist of the Year Award in 2002. Her life has been celebrated in a superbly produced video narrated by Harrison Ford, *Arctic Dance: The Mardy Murie Story*, and an equally memorable companion volume by the same name written by Charles Craighead and Bonnie Kreps. Both are available from the Murie Center bookstore at the web site address given below.

Olaus and Mardy Murie later in life.

The Murie Ranch's role as a center of conservation thinking and action has been continued by The Murie Center, created in 1997, the same year that the Murie property was designated a National Historic District. A non-profit organization working in partnership with Grand Teton National Park, the center is based at the ranch and has recently launched a campaign to restore the historic structures, establish additional facilities, and endow a long-range program to honor and promote the Murie legacy. Much like the Leopold family "shack" near Baraboo, Wisconsin, from which came Leopold's classic work of natural history and conservation, *A Sand County Almanac* (1949), the Murie Ranch has become a symbol of the accumulated wisdom it sheltered and the ideas it helped inspire.

Olaus and Mardy Murie in their trail furs while on their Alaskan dogsled honeymoon.

This year, Murie Center activities included a variety of workshops and "conversations," as well as a symposium, "Wild Nature and the Human Spirit," held August 24–27. The center has already earned the involvement of many conservation and literary luminaries, including Peter Matthiessen, George Schaller, Terry Tempest Williams, and Barry Lopez. Former Yellowstone Superintendent Bob Barbee currently serves as vice chair of the center's board of directors. For more information on Murie Center programs, contact them at The Murie Center, P.O. Box 399, Moose, WY 83012, (307) 739-2246, *development@muriecenter.org*, or visit their web site at *www.muriecenter.org*.

Fireplace at the Murie Ranch, which has become a symbol of the ideas it helped inspire.

Paul Schullery, a former editor of Yellowstone Science, *works part-time in the Yellowstone Center for Resources as a writer-editor. His most recent book is* Lewis and Clark Among the Grizzlies *(Falcon/Globe Pequot, 2002).*

A Search for Life in Yellowstone's Well Y-7

Portal to the Subsurface

by John R. Spear, Jeffrey J. Walker, Susan M. Barns, and Norman R. Pace

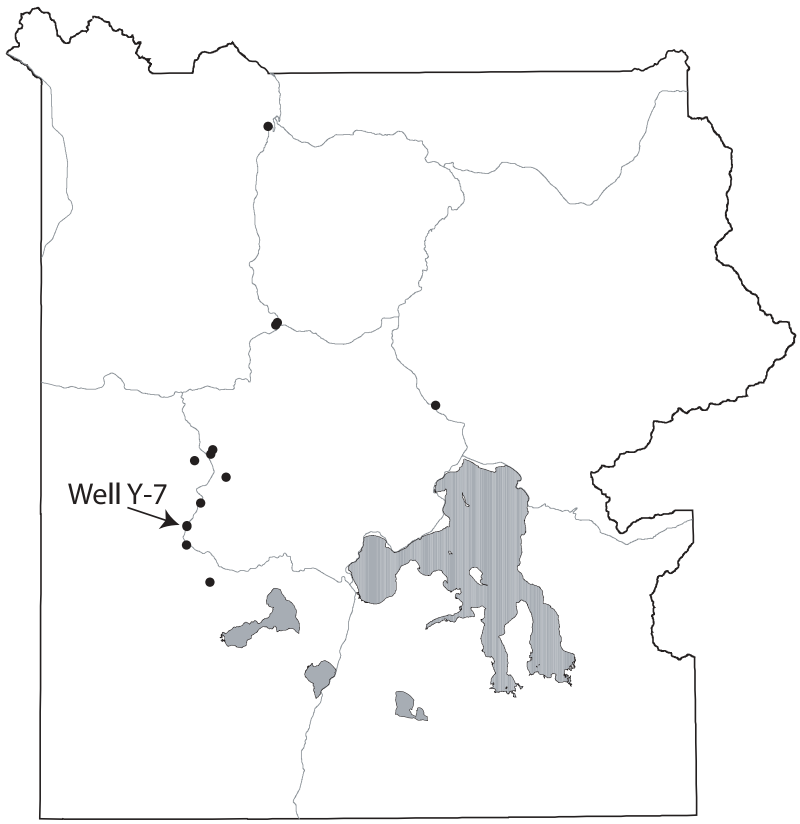
COURTESY JOHN SPEAR

An in situ *growth vial, designed to detect the presence of subsurface microbiota, is attached to a stainless steel cable for deployment into Yellowstone's Well Y-7.*

Background

In the 1960s, Don White and colleagues from the U.S. Geological Survey in Menlo Park, California, drilled a series of experimental wells in Yellowstone National Park to study groundwater chemistry, heat flow below the surface, and subsurface mineral composition (White 1975, 1988). At the time, few people suspected that the Earth's subsurface might be shot through with life. Scientists have since discovered that microorganisms inhabit much of the subsurface to depths of several kilometers, suggesting that a significant portion of the Earth's biomass may occur underground in the form of microorganisms that inhabit soil, groundwater, and the pore spaces within rocks. Microorganisms have been observed as deep as seven kilometers below the Earth's surface in Sweden's Siljan Ring, a granitic region northwest of Stockholm where oil and gas have been found within granite; and in submarine hydrothermal vent flows from below the deep sea floor. Such organisms are of interest due to their unique ecology and potentially large impact on chemical processes in the subsurface.

Most of the wells drilled by the USGS in Yellowstone were under high pressure and required special fittings to prevent eruption. Later, some of these wells did erupt as man-made geysers that had to be capped with tons of concrete. The wells were drilled prior to the implementation of the National Environmental Policy Act (NEPA) that requires analysis of environmental impacts of given actions requiring a federal permit. To do this kind of work today would require, at the least, an Environmental Assessment (EA), more likely an Environmental Impact Statement (EIS). Of the 13 wells that were originally drilled to depths ranging from 215 to over 1,000 feet, only two, Well Y-7 in Biscuit Basin and Well Y-10 on the Mammoth Terrace, remain uncapped and as such, provide for research opportunity. Well Y-7 plunges 75 m (245 ft) down into the aquifer of Biscuit Basin. This makes the well a unique portal into the potential subsurface biosphere of the Yellowstone geothermal system. The well is unpressurized, with standing water one meter below a valve at the surface, and is lined with steel casing to 32m (102 ft.). A natural thermal gradient exists in the well, from about 50°C at the surface to 141°C at the bottom, which does not boil due to hydrostatic pressure. Thus, in principle, the well is a good location to seek potential life at the highest temperatures, above the normal boiling point of water of 100°C at sea level (about 94°C at the alti-



Locations of exploratory wells drilled in Yellowstone by the USGS during the 1960s. White, Fournier, & Truesdell, 1975.

tude of the Yellowstone area). Well Y-7 spans the thermal range where "thermophiles" (heat-loving microorganisms) and even "hyperthermophiles," can live (above 50°C and 80°C, respectively). Currently, the known upper temperature limit for life is 113°C, a record held by *Pyrolobus fumarii*, a member of the domain of life *Archaea*, that lives in hydrothermal vents on the floor of the Atlantic Ocean.

Microbial life has recently been discovered in several unique environments previously considered inhospitable for life. Because such organisms thrive in environments humans would consider extreme, they are known as "extremeophiles." In addition to high temperature and subsurface environments, microbes are found to thrive in environments with high salt concentrations, high radiation, high pressure, low water availability, and very low temperatures. In order to accommodate these chemical and physical environments, such organisms have evolved enzymes (proteins that catalyze important biochemical reactions) that function well under the conditions (Pace, 2001). Enzymes isolated from extremeophiles have spawned a billion-dollar industry in biotechnology and biomedicine. For example, the recently completed human genome sequence project was made possible by the discovery of the thermostable Taq DNA polymerase, isolated from *Thermus aquaticus*, a bacterium originally found and studied in Yellowstone National Park.

Since the 1960s, when Tom Brock and colleagues began to study Yellowstone's thermal pools and discovered bacterial residents such as *T. aquaticus*, scientists have wondered about the upper temperature limit for life (Brock 1978). The occurrence of life at near-boiling temperatures raises the question: What is the upper temperature limit at which an organism, or a community of organisms can thrive? Biochemists theorize that the molecules that constitute life could function at temperatures perhaps up to 150°C. Indeed, current theories suggest that life may have originated in a hydrothermal environment, in the absence of oxygen, about four billion years ago. An expansion in our knowledge of the diversity of terrestrial life may tell us where life is possible elsewhere in the universe. Since most planets have heated cores, a geothermally-warmed planetary subsurface could potentially harbor communities of microbial organisms protected from a harsh, outer world. Life in Earth's own warm subsurface may be a model for life on other planets, where temperature, pressure and radiation on the surface may exceed the limits for life.

We know remarkably little about the natural microbial world even on Earth. Until recently it was usually impossible to identify most microbes in the environment. It has been estimated that more than 99% of the microorganisms in the environment are incapable of being cultured using standard techniques (Amman et al. 1995). Microbiologists have traditionally relied on cultivation techniques (growth of organisms in the laboratory) to identify and compare microbes. This involves the growth of organisms in "pure" culture, free of other organisms. This, however, is a highly unnatural state, because most organisms in the environment live in communities, the composition of which can vary with the local geochemistry and environmental conditions, time of day and night or season, etc. To be sure, traditional culture techniques have revealed much about microorganisms. However, duplication of the environmental requirements of an organism in the laboratory is virtually impossible. Consequently, naturally-occurring microorganisms are seldom captured in culture.

However, modern molecular methods allow microbes to be identified without the need to culture them. DNA gene sequences extracted directly from organisms allow us to compare their similarities and differences, and can be used to make maps of the evolutionary relatedness of organisms. Such phylogenetic studies of the small subunit of the ribosomal RNA (rRNA) gene have opened a new, molecular view of microbial diversity, and indeed all biodiversity. The ribosome is the component in all cells responsible for the production of proteins (the molecules that allow cells to metabolize and function). It is made up of different sub-units, some of which are ribonucleic acid (RNA). For a number of reasons, the gene rDNA, that codes for the small subunit of the ribosomal ribonucleic acid (RNA), is particularly useful for phylogenetic analyses (Woese 1987). The molecular identification, by means of 16S rRNA of organisms comprising communities provides insight into communal function, and the physiology of naturally-occurring organisms often can be inferred based upon the physiology of cultivated organisms to which the molecularly identified organisms may be closely related. At this time, the use of these molecular methods is the only way to identify most microbial organisms *in situ* in the environment.

The molecular identification of microbes is based on a relatedness framework that includes all life. The molecular sequence-based view of life's diversity shows that there are three large relatedness groups, "domains" of life: *Bacteria, Archaea,* and *Eukarya,* of which we humans are representative (see Pace 1997 for review). Figure 1 shows a phylogenetic tree, or evolutionary map, containing 64 species of organisms based upon their 16S (or 18S for the *Eukarya*) rDNA sequences. The more separated different species are along the line segments in this tree, the more distantly related they are.

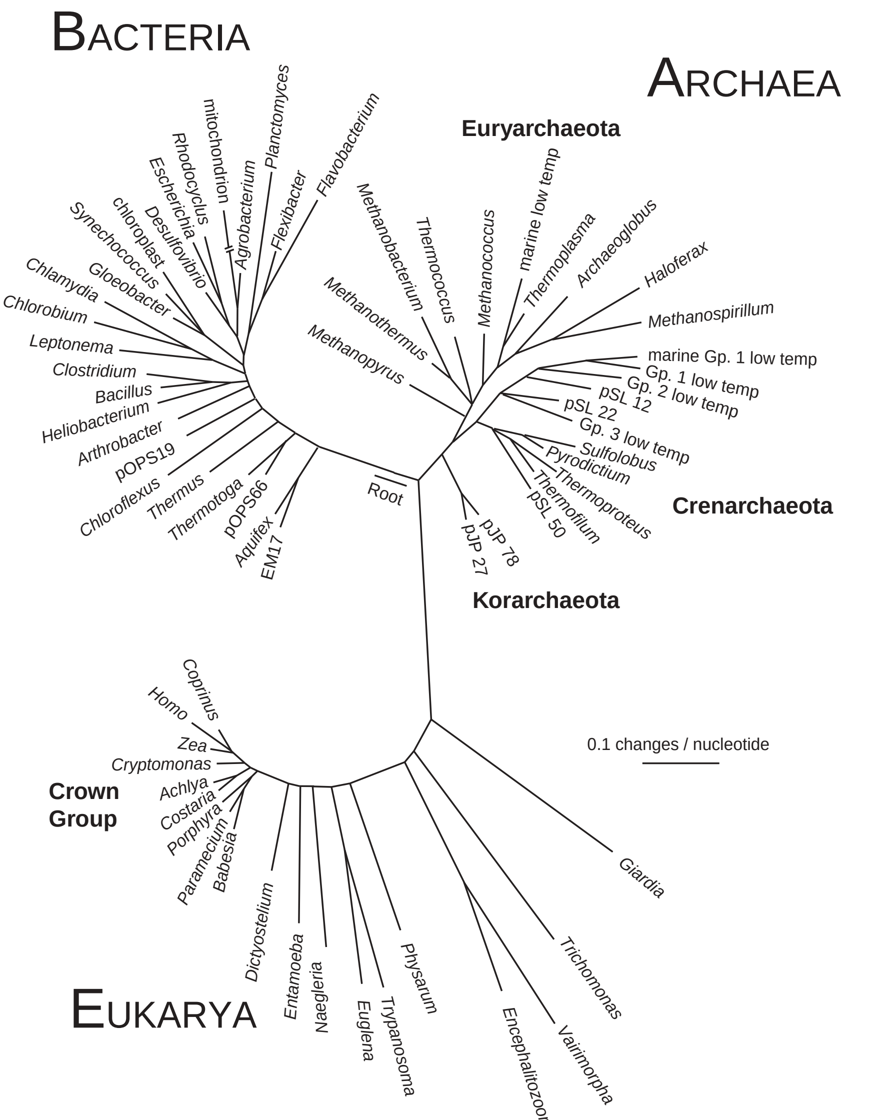


Figure 1: A universal phylogenetic tree based on small sub-unit ribosomal RNA sequences. The scale bar represents 0.1 changes per nucleotide. Humans are represented by the Homo grouping within the crown group of Eukarya. *Adapted from Pace, 1997.*

Molecular studies of Yellowstone's hot springs have revealed hundreds of new bacterial and archaeal species. Particularly intriguing are the thermophilic microorganisms. Some of the *Bacteria* that are visually conspicuous in Yellowstone hot springs are shown in the phylogenetic tree of Figure 1. "EM-17," a close relative of the cultivated *Aquifex,* is the main organism that makes up pink filamentous material that can be seen in several of the near-boiling springs in the park. OPS66, a relative of *Thermatoga,* is another abundant constituent of high-temperature biofilms. JP27 and JP78 are cloned rRNA genes that represent new kinds of archaeons, deeply divergent from known kinds of life and not yet cultured, that were first discovered in Yellowstone's Obsidian Pool. Organisms such as these high-temperature Yellowstone microbes exhibit particularly short lines from the original common ancestor in Figure 1, the "root" of the tree of life. Thus, these Yellowstone microbes may be among the most closely related of any modern organisms to the earliest life. This is one reason for the idea that life formed under hot conditions on the early Earth.

Methodology

Any documentation of life in Well Y-7 would require microscopic analysis to detect organisms, and DNA sequence analysis to identify them. Thus, our strategy for seeking microbial life in well Y-7 has been to suspend in the well a cable with attached glass slides, upon which microbial biofilms can develop. The slides can be retrieved at different times for microscopic inspection. Any developed biofilm can be scraped from the slide for rDNA analysis. We have successfully used this method in several surface hot springs in the park.

During the course of this study, we surveyed the temperature profile of Well Y-7 at different times of the year over a several year period, and conducted a chemical analysis of the well water at the surface. The temperature profile of the well is depicted in Figure 2. The year-round temperature of the well at the surface is approximately the same, at 47°C ± 2°C. The bottom temperature, however, ranged

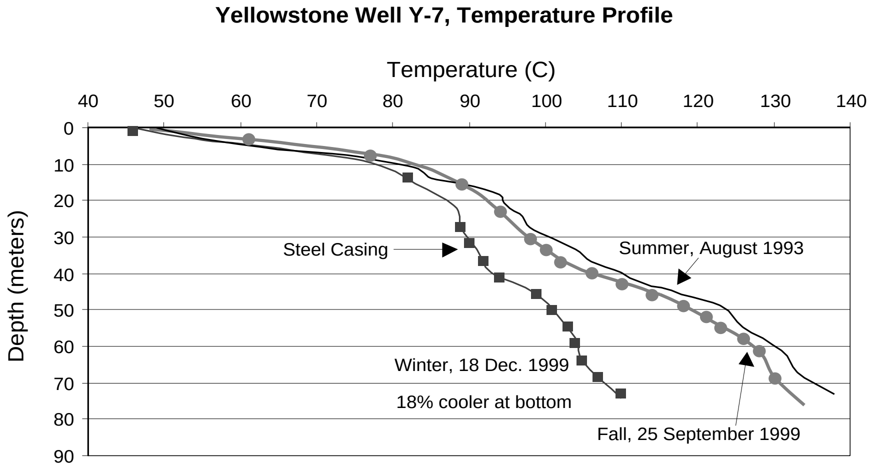


Figure 2. Well Y-7 temperature/depth profile.

from 135°C in September 1999 to 110°C in December 1999. By late spring 2000, the temperature at the bottom was back to 135°C. Thus, any experiments in Well Y-7 that may depend on temperature require close monitoring of the temperature gradient. Such extreme seasonal temperature variation in the deep portion of the well was completely unexpected, and will continue to be monitored.

The chemistry of the surface water of Well Y-7 was determined with an ion coupled plasma analyzer for inorganic elements in the water, a total organic carbon analyzer (TOC) for carbon in the water, and an ion chromatograph (IC) for anions in the water (Table 1). Particularly noteworthy is the absence of sulfate, even in the presence of readily detectable (3 mg/L) total sulfur. This indicates that the Well Y-7 water is highly reduced and contains very little oxygen. The non-sulfate sulfur presumably occurs as hydrogen sulfide. The chemistry of the water at the bottom of the well was not determined, nor was the extent of groundwater flow through the lower well.

Compound	Concentration (milligrams/liter)
Arsenic	0.66
Boron	2.05
Calcium	0.40
Copper	0.53
Iron	3.38
Lithium	1.13
Phosphorus	1.02
Potassium	22.21
Silicon	103.76
Sodium	265.05
Sulfur	3.05
Zinc	0.27
Total Organic Carbon	39.0
Fluoride	0.50
Chloride	106.0
Phosphate	7.0
Nitrates	no detect
Sulfates	no detect
Oxygen	no detect

Table 1. Chemistry of Well Y-7 surface water. The chemistry of water from the bottom of the well was not determined.

On several occasions over the six-year period of the study we suspended plain glass slides along the length of the well for times from a few weeks to several months. Any evidence for the development of microbial biofilms was meager, however. Only isolated cells were detected. It appeared that if there was life in Well Y-7, there was not much of it, and that any growth was slow. This led us to postulate that some important nutrient might be absent from the well, and that we might be able to encourage faster growth of any organisms present by adding appropriate nutrients. We designed an *in situ* growth chamber vial (see Figure 3) that could be suspended from the cable (Figure 4) that contained a glass slide bathed in a timed-release growth medium. The growth chamber was perforated to allow exchange of well water with the inside, and consequently, inoculation by indigenous microbes. Based on the chemistry of the well water, we designed a simple medium to provide a carbon and energy source (lactate and formate), and an electron acceptor (sulfate) that many microbes can use in respiration. The timed-release of growth medium was achieved by infusing the pores of a balsa wood plug, on which the glass growth surface is supported, with the growth medium. Laboratory tests with colored dyes showed that the medium

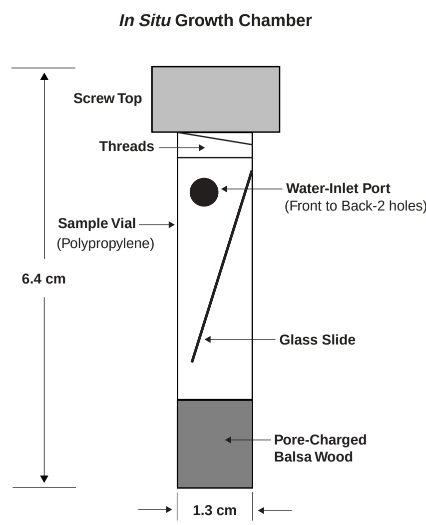


Figure 3. In situ *growth chamber.*

continued to diffuse out of the balsa wood for more than a week. We put cotton batting in some of the vials to provide an organic growth surface for potential microbes, as well as to restrict the diffusion of the medium in the flux of well water. We attached the autoclaved-sterile vials and lowered the cable down the well, where the growth vials were allowed to hang for one to six months.

After these deployments, we winched the cable up and collected the growth chambers for analysis. Vials with glass slides testing for microbial growth were suspended in 4% paraformaldehyde for both light and scanning electron microscopy (SEM). Vials with a cotton growth surface for DNA extraction were suspended in tubes with 70% ethanol. Samples were held at 4°C until analysis. Glass slides were visualized on a microscope with light, phase contrast, and epifluorescence (cells stained with the DNA stain DAPI). Slides for SEM were prepared by standard protocols (Gerhardt, et al. 1994) and visualized with an SEM microscope. Cotton growth surfaces analyzed for DNA content were prepared as described by Hugenholz (1998a, b) with the addition of a desiccation step to remove the 70% ethanol.

COURTESY JOHN SPEAR

Figure 4. Cable with attached vials is lowered into the well.

Observations of the glass slides indicated only a few bacterial cells present at 27 m (90 feet) and 89°C. No slides developed the lush bacterial biofilms observed in other Yellowstone locations like Octopus Spring in the White Creek Region of the Midway Geyser Basin (Figure 5). Instead, we saw, as with glass slides alone, only a few cells, attached sporadically. The greatest number of cells was obtained on slides hung just below the surface at 47°C (Figure 6a). Below 27 m and 90°C, we found no cell-like structures on the glass slides. Instead, we found a crystal-like precipitation formed on the surface of the slide, increasing in density the farther down the well that the slide was suspended (Figure 6b). No cells were found below the steel casing of the well that extends to 32 m below the surface. It appears that any biomass that may be present is extremely low in concentration throughout the length of the well. Additionally, DNA extractions performed on cotton growth surface samples hung at various depths were negative, due to very low cell numbers, if any. Thus, we conclude that the Well Y-7 component of Yellowstone's subsurface is essentially devoid of growing organisms.

COURTESY JOHN SPEAR

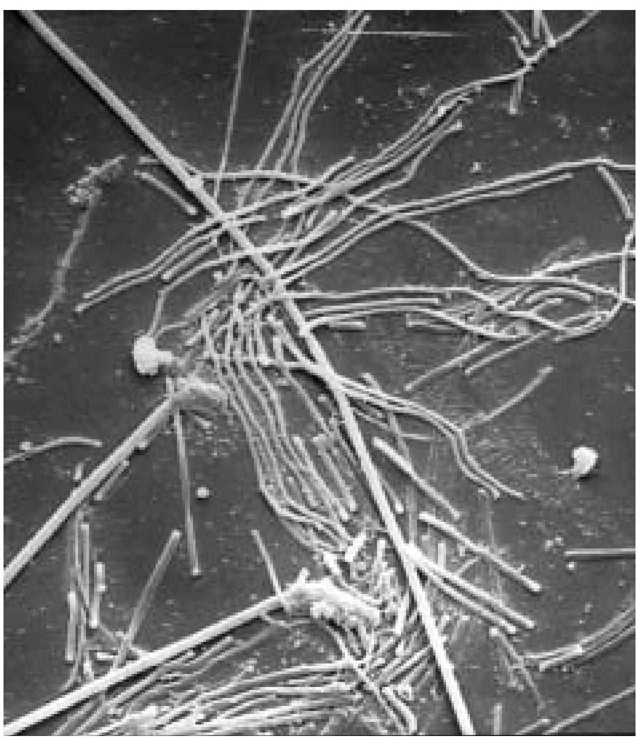


Figure 5. Scanning electron micrograph of a glass slide suspended in Octopus Spring. Biofilm containing a variety of cell types is visible.

Discussion

The detection of cells only in the upper 27 m of the well, to a temperature of 89°C, is unequivocal. However, the sporadic occurrence of only one or a few cells suggests that they did not grow on the slides. In the absence of biofilm-formation, it seems most likely that observed cells came from somewhere higher in the well, perhaps dislodged during operations. It is also possible, since the few cells found were only in the region of the steel casing, not below the casing, that either iron concentration or groundwater flow plays a role in where cells can survive here.

Overall, it seems most likely that the lack of microorganisms along the length of Well Y-7 is due to thermodynamically unfavorable conditions for life. That is, the well water is sufficiently chemically reduced that life cannot occur. Life processes require both an energy source (food) and an "electron-acceptor" (something for cells to breathe). The reduced state found by the water chemistry analysis discussed earlier indicates that the potential electron-acceptors sulfate, nitrate, and oxygen are absent. Although our experimental apparatus supplied an electron acceptor for cells to use, it seems likely that no cells were available in the subsurface system surrounding Y-7 to act as innocula. This situation contrasts with the surface hot springs, where the reduced, sub-surface waters emerge into an environment rich in those electron acceptors, such as oxygen, where life can flourish. We suppose that this essentially lifeless state of Well Y-7 extends throughout the reduced subsurface Yellowstone

COURTESY JOHN SPEAR

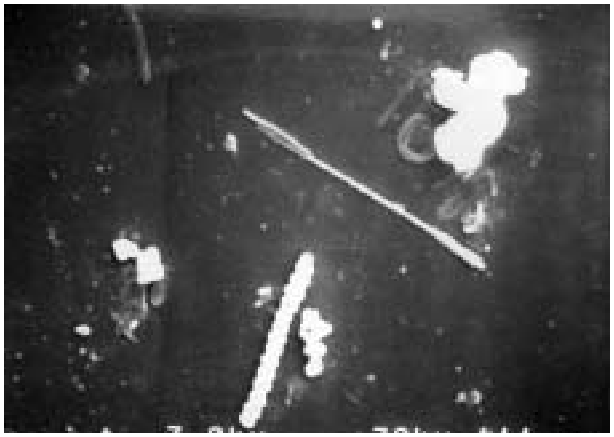


Figure 6a. Scanning electron micrograph of a glass slide suspended just under the surface of the water in Well Y-7. A couple of cell types are apparent, but no biofilm is visible.

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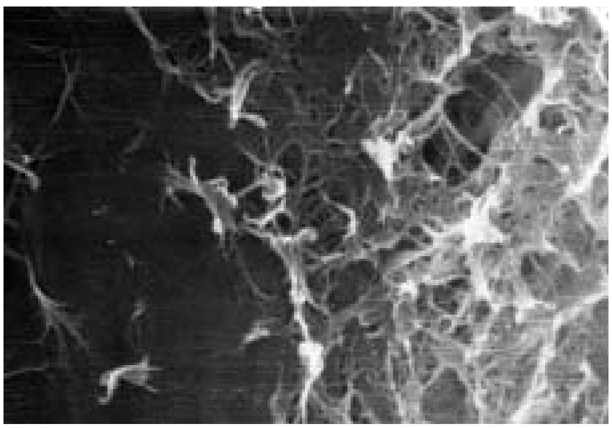

Figure 6b. Crystal-like structures observed on glass slides from the 50 m depth of Well Y-7, at approximately 110°C. No cell-like structures are observable.

hydrothermal system, and probably other hydrothermal systems worldwide.

Conclusions

We believe that these *in situ* experiments show that Well Y-7 is probably devoid of metabolically active life. The well remains a valuable research tool, however, as a portal for other probes into the hydrothermal system of Biscuit Basin. Only the upper one-third of the well's length is cased, so the lower well is in contact with the local hydrothermal flow. Well Y-7 is an excellent location to study and monitor groundwater properties such as temperature, chemical, and isotopic contents. Variations in the properties of the subsurface waters probably drive variation in the behavior of the Biscuit Basin thermal features.

The Yellowstone high-temperature microbial ecosystem has long been considered by researchers to be supported mainly by sulfur-metabolism. In such a system, hydrogen sulfide (food), is utilized along with oxygen (electron-acceptor). However, recent research shows that that kind of metabolism, however, is probably only a minor component of the productive metabolism of the Yellowstone ecosystem. Sulfides and other sulfur compounds are certainly conspicuous, both in measurements and in the rich odor of hydrogen sulfide that emanates from several thermal features, but another element, hydrogen, is likely to be the dominant energy source in the Yellowstone system. Hydrogen is the strongest electron donor (energy source) available to microbiota, and preliminary results indicate that Yellowstone's hot springs are rich in hydrogen (Spear, 2001). The biological observations in hot springs are consistent with the notion of hydrogen as a dominant energy source. The *Aquifex*-like and *Thermatoga*-like organisms that dominate both high-sulfur (e.g. Norris Geyser Basin) and low-sulfur (e.g. Midway Geyser Basin) hot springs, although not studied in culture, are close relatives of hydrogen-metabolizing organisms that respire with oxygen or sulfate. Molecular hydrogen, a potential energy source for microbes, probably is common in all ground waters (Stevens and McKinley 1995). The mechanism by which hydrogen is formed in groundwaters is not entirely clear. One main reaction between water and iron-bearing rock is the oxidation of reduced iron (Fe^{2+}), to form oxidized iron (Fe^{3+}) and hydrogen. Determinations of hydrogen in Yellowstone hot springs and correlated molecular phylogenetic surveys for microbial species are ongoing in our laboratory in order to explore relationships between geochemistry and microbial diversity.

NORMAN PACE

Well Y-7 is uncapped for researchers John Spear, Jeff Walker, and Kirk Harris.

Acknowledgements

We thank Ann Deutch at the Yellowstone Center for Resources, who allowed this research project to proceed smoothly, and the several rangers and volunteers of Yellowstone National Park who helped with access to the well and provided public interpretation for visitors to the project. In addition, we thank Richard Harnish, Environmental Science and Engineering Division at the Colorado School of Mines, for assistance with the water chemistry analysis. Tom Moses (USGS, Menlo Park, CA) provided some early temperature data. Brett Goebel (Australian Mining Company) conducted early tests with *in situ* growth chambers. Contributions from Mary Bateson, Montana State University, Anna-Louise Reysenbach, Portland State University, and Robert Fournier, retired from USGS, are appreciated. Funds for this work were provided by the National Science Foundation's Life in Extreme Environments program.

KIRK HARRIS

John Spear (right) is a postdoctoral fellow in Dr. Norman Pace's laboratory in the Department of Molecular, Cellular and Developmental Biology at the University of Colorado at Boulder. He earned degrees (M.S. and Ph.D.) in Environmental Science and Engineering from the Colorado School of Mines in Golden, Colorado, studying the reduction of soluble uranium by sulfate reducing bacteria. In his current position, he is looking for microbiota in and around Yellowstone with consideration for how that microbiota is related to various environmental chemistries.

Jeff Walker (left) is a graduate student at the University of Colorado at Boulder in the laboratory of Norman Pace. In his doctoral research, Jeff studies endolithic microbial ecosystems—communities of microorganisms that live in the pore space of rocks. Jeff is also involved in studying the microbiology of Yellowstone National Park.

Sue Barns (not pictured) was an undergraduate and graduate student in the laboratory of Norman Pace, and focused her doctoral research on high temperature microorganisms in Yellowstone. She is currently a researcher at Los Alamos National Laboratory, Los Alamos, New Mexico, using DNA-based techniques to study bacterial diversity in soils.

Norman Pace (top) is a Professor in the Department of Molecular, Cellular and Developmental Biology at the University of Colorado at Boulder. His laboratory has long been involved in molecular studies of microbes in extreme environments. Pace is a member of the National Academy of Sciences and a Fellow of the MacArthur Foundation. He is also a Fellow and Bicking Award recipient of the National Speleological Society.

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Evidence of grizzly bear predation on a black bear in Hayden Valley

by Kerry A. Gunther and Mark J. Biel

Both grizzly and black bears live in Yellowstone National Park. In this and other areas where grizzly bears and black bears are sympatric (share habitat), temporal isolation and behavioral differences tend to reduce direct competition between the two species. In the Greater Yellowstone Ecosystem, grizzly bears are generally most active from dusk until dawn, while black bears are most active during the daytime. Grizzly bears evolved to forage in open meadow habitats, whereas black bears are primarily adapted to living in forests. Grizzlies also have longer claws and larger shoulder musculature than black bears, making them more efficient at foraging roots and ground-dwelling small mammals abundant in open meadows. Grizzlies are generally larger than black bears, and are much more aggressive in defending themselves and their offspring from predators, including other grizzlies. Black bears typically escape predators by running into forest cover or climbing trees.

On August 2, 1998, park visitors looking for grizzly bears from Grizzly Overlook in Hayden Valley observed some ravens on a carcass on the northeast side of the Yellowstone River. Upon focusing their spotting scope on the carcass, they could clearly see the partially consumed remains of a black bear in the tall grass next to the river. The visitors reported the presence of the carcass to Canyon area rangers, who immediately forwarded the report to the park's Bear Management Office. We received permission from the rangers to canoe across the Yellowstone River to examine and retrieve the carcass. Accompanied by biological technician Christie Hendrix and park ranger Keith Gad, we canoed across the river to the carcass. Although the dead bear was not visible to motorists along the road, a large number of park visitors immediately pulled over to watch as we launched the canoe, creating a large canoe-jam. We paddled downstream and across the river and pulled the canoe up onto the bank next to the black bear's carcass to examine it. The carcass was that of an adult male weighing (minus the eaten tissue) 171 pounds. Prior to being consumed, the bear had likely weighed over 200 pounds. The bear had canine puncture wounds to the head and nose, as well as a crushed skull and left eye socket.

The wounds were consistent with those that would have been inflicted by a bear or other large predator. When fighting, bears will often bite each other on the nose in an effort to neutralize their opponents' weapons (teeth). We also found two bear scats containing vegetation next to the carcass. The predator that had killed and partially consumed the black bear had likely defecated these scats while feeding on its carcass. We collected the scats for DNA analysis to aid in determining the species of the predator that had killed the black bear, then loaded the carcass and two scats into the canoe and ferried upstream back across the river to the large aggregation of people that had congregated to watch. After letting the visitors see the bear, and explaining possible scenarios of what may have happened, we loaded the carcass into our truck, covered it with a tarp, and headed back to Mammoth.


YNP BEAR MANAGEMENT OFFICE

Black bear as found by river.

We took the bear's carcass to Neil Anderson at the Montana Fish, Wildlife and Parks Wildlife Laboratory in Boze-


YNP BISON MANAGEMENT OFFICE

Hayden Valley landscape, a couple of miles upriver from where the black bear was found.

man, Montana, for necropsy. Neil was able to measure one set of canine puncture marks he believed were caused by the lower canines of the predator that killed the black bear. The center-to-center distance of these canine puncture marks measured 59 mm, too large to have been from an adult wolf, mountain lion, or average-sized black bear. Measurements taken from reference skulls show that canine widths in that range are typical of average size, adult male grizzly bears in the GYE, although we could not completely rule out a very large adult male black bear as the predator. The identification of the predator that killed the black bear as a grizzly (based on the canine width of wounds found on the black bear's head) was later supported through laboratory analysis of DNA extracted from the bear scats collected at the kill site. We sent the scats to Dr. Lisette Waits at the University of Idaho for analysis, and DNA extracted from the scats indicated that they were, in fact, from a grizzly bear.

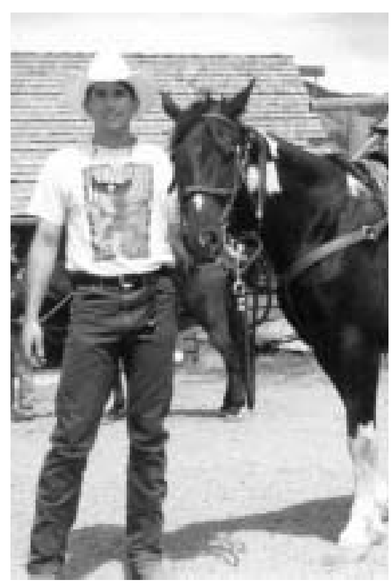
YNP BEAR MANAGEMENT OFFICE

Head of mauled black bear.

When threatened, black bears typically run to forest cover or climb a tree. In this case, the nearest climbable tree to the site where the black bear was killed was a single dead snag on a small island in the middle of the Yellowstone River over 70 meters away. The nearest climbable live trees were approximately 130 meters away on the opposite shore from the bank where the black bear was killed. The nearest climbable trees that could be reached without swimming were almost 1,000 meters northeast of the kill site. This observation lends insight into what can happen to black bears that wander too far from forest cover in areas occupied by grizzly bears, and why we rarely see black bears in the large, non-forested areas of YNP such as Pelican and Hayden Valleys, where grizzly bears are common. ✪

Kerry Gunther is Yellowstone National Park's Bear Management Biologist. He oversees bear-human conflict resolution and bear research and monitoring throughout the park, and has worked in YNP for 19 years. He has also worked in grizzly and black bear research and management for the U.S. Forest Service and the U.S. Fish and Wildlife Service. Kerry holds a B.S. in biology with minor studies in earth sciences from Northland College in Wisconsin, and an M.S. in Fish and Wildlife Management from Montana State University. He has published papers on bear management, bear-human conflicts, bear-inflicted human injuries, impacts of recreation on grizzly bears, and grizzly bear predation. He is the recipient of the 1997 Sigurd Olsen Environmental Achievement Award. In his spare time he enjoys photographing polar bears in the arctic and sea kayaking in Baja.

Mark Biel is the Field Biologist for Yellowstone National Park's Bison Management Office. He assists in coordinating bison research and monitoring in and around the park and is overseeing the vaccination approach study for the eventual implementation of a bison brucellosis vaccination program within the park. Mark has worked for the National Park Service since 1993 in the Bear and then Bison Management Offices. He received his B.S. in Animal Science with minor studies in animal nutrition and equine management from Michigan State University and his M.S. in animal nutrition and equine exercise physiology from the University of Illinois at Champaign–Urbana. In his spare time, Mark enjoys horseback riding, woodworking, hiking, and fishing. He and his fiance, Alice, live in Gardiner, Montana.



Passages

Jay Anderson, ecologist and teacher

by Nancy Huntly

The Greater Yellowstone Ecosystem lost a friend, supporter, and scientific leader this summer, when Jay E. Anderson, Professor Emeritus of Ecology at Idaho State University and a resident of Driggs, Idaho, died suddenly and unexpectedly of a stroke on July 4, 2002. Jay was born in Logan, Utah, and grew up on a ranch in the Big Hole Valley of Montana. He studied agriculture and education at Montana State University (B.S. Agricultural Education), taught high school for four years, then studied plant physiology and ecology at Syracuse University (M.S., Ph.D. Plant Ecology). He joined the Biology Department of Idaho State University in 1975 and was a faculty member there for 26 years, retiring in June 2001.

Jay was active in research, education, and scientific advisement for and in the greater Yellowstone, Intermountain, and Pacific Northwest regions. He conducted research primarily in the sage steppe, shrubland, grassland, and forest ecosystems of Western North America, and also spent three sabbaticals collaborating with Australian colleagues on the ecology of Australian deserts and forests. His main research areas were plant physiological ecology, vegetation dynamics, and fire ecology. He worked extensively within the sage-steppe ecosystems of the Idaho National Engineering and Environmental Laboratory, where his research included physiological ecology of plants' use of water and nitrogen in photosynthesis; patterns and causes of long-term vegetation dynamics; and pioneering applications of these basic sciences to waste management. He also co-edited a book on physiological ecology of North American desert plants, and conducted several studies within Yellowstone National Park, including research of the grazing ecosystem of the northern range and of the regeneration of Yellowstone's forests following the fires of 1988.

Jay was committed to making scientific information widely available to the public, so that ecological understanding could inform land use decisions. He served on many advisory panels for resource management, including the Birds of Prey Technical Review Committee, the Resource Advisory Council for the Upper Snake River Districts, and the Advisory Committee to the Idaho Falls District of the Bureau of Land Management, and he was a member of the Greater Yellowstone Coalition's Science Council for many years. Jay received ISU's Distinguished Researcher Award in 1998 and, in 2001, he received the Outstanding Scientist award from the Northwest Scientific Association in recognition of the importance of his scientific accomplishments to the Pacific Northwest

Jay Anderson discusses ecology and land use with students atop Sawtelle Peak in Idaho. Photo courtesy Nancy Huntly.

Jay was widely recognized as an exceptional teacher. He not only advised and taught many undergraduate and graduate students and post-doctoral researchers, but also was generous in providing advice and support to colleagues, especially the many younger scientists that he encouraged. He received the Master Teacher award from Idaho State University, as well as the Jerome Bigelow Award for his involvement of students in research. He made many presentations to school classes and civic organizations on the Yellowstone fires and on vegetation dynamics and grazing.

Jay will be remembered as a man who loved his family and friends, enjoyed his life and work, and both worked hard and played hard. He was an avid and accomplished skier, kayaker, cyclist, back packer, and fly fisherman, and many much younger colleagues aspired to meet Jay's standards of physical and professional accomplishment, as well as his enjoyment of life.

The Ecological Society of America has established the Jay E. Anderson Endowment, which will honor Jay through sponsorship of programs and projects that further his interests in and love of the ecosystems of the West and Pacific Northwest. Contributions to the Jay Anderson Endowment, which are tax-deductible, can be sent to: Ecological Society of America, 1707 H Street, NW, Suite 400, Washington, D.C. 20006.

Nancy Huntly is a professor of ecology at Idaho State University.

Dave Love, "grand old man of Rocky Mountain geology"

J. David Love, geologist, died August 23 in Laramie, Wyoming. He was born in Riverton on April 17, 1913, and lived in Lander and then in Laramie, where in 1933 he earned his bachelor's degree in geology and chemistry from the University of Wyoming, followed by a Master's degree in 1934. After working for the Wyoming State Geological Survey for two years, he was accepted as a graduate student at Yale University, where he received his doctorate in 1938.

David Love called his teacher, University of Wyoming geologist "Doc" Knight, "the great man of geology and the finest kind of human being." The student proved worthy of his teacher. He was employed by the USGS and Shell Oil until 1940, when he returned to the USGS until his 1987 retirement as USGS scientist emeritus after directing the USGS's Wyoming office for 44 years. His work encompassed research on strategic minerals during and after World War II, established the USGS Wyoming Fuels Branch, compiled the 1955 and 1985 editions of Wyoming's geologic map and was chief author of the 1992 Grand Teton National Park geologic map and the 1993 chart correlating all Wyoming geologic formations. Love authored more than 250 geologic publications, articles, and lectures as well as family-oriented stories and vignettes of his childhood.

> ***His breadth of knowledge on all manner of natural history—geology, botany, wildlife, archeology, and history—was inspiring.***
>
> *–former student Dr. Cathy Whitlock*

Love received a wide array of honors throughout his career as a geologist and humanitarian. In 1981, the University of Wyoming recognized Love as a Distinguished Alumnus. The Wyoming Geological Survey gave him honorary membership as well as its Distinguished Service Award, and established a field geology fellowship in his name. He won the Interior Department's Meritorious and Distinguished Service Awards, and the American Association of Professional Geologists' Public Service Award. He recently received the Rungius Medal from the National Museum of Wildlife Art for his collective studies of geologic formations and their influence on the habitats of animals in the wild. With his wife, Jane, he was awarded the Silver Medal from the Jackson Hole Medal Association for their gift of land to Teton County for affordable housing.

CATHY WHITLOCK

Dave and Jane Love.

Dave Love, however, was more than the sum of his publications and awards. He was a friend and mentor to geologists (as the advisor for 140 Master's theses and 50 doctoral dissertations), writers, and young people from around the world. The story of his life was provocative enough as to have captured the imagination of John McPhee, who made Love, his ancestors, and their Wyoming ranch the subject of his *Rising From the Plains* (1986). In that work, McPhee called Love "an autochthonous geologist. The term refers to a rock that has not moved…To be sure, experience had come to him beyond the borders—a Yale Ph.D., explorations for oil in the southern Appalachians and the mid-continent—but his career had been accomplished almost wholly in his home terrain. For several decades now, he had been regarded by colleagues as one of the two or three most influential field geologists in the Survey, and, in recent time, inevitably, as 'the grand old man of Rocky Mountain geology.'"

Dr. Love is survived by his wife, four children, seven grandchildren, and the enduring landscape to which he devoted his professional life. Memorial gifts may be made to any of the following: The J. David Love Field Scholarship, Wyoming Geological Association, c/o Kent Sundell, 5034 Alcova Rte. Box 12, Casper, WY 82604; The Museum of the American West, 636 Lincoln, Lander, WY 82520; The University of Wyoming Geological Museum, Box 3006, Laramie, WY 82071; or the Laramie Plains Museum, 603 Ivinson Ave., Laramie, WY 82070.

Passages

Boyd Evison, beloved NPS leader

Boyd Evison, beloved National Park Service leader for more than 40 years and, more recently, the Executive Director of the Grand Teton Natural History Association, died in California on October 4. Evison was one of the greatest and most influential leaders of the modern NPS. He dedicated his career to conservation, environmental education, and courageous leadership in the field of natural resource protection, touched the lives of thousands of NPS employees, and influenced the overall management of the entire national park system.

Evison, a native of Washington, D.C., earned his B.S. in forestry and wildlife management from Colorado A&M in 1954. In 1968, he earned a Master's degree in environmental communications from the University of Wisconsin at Madison. He began working seasonally with the National Park Service in 1952 as a fire control aide in Grand Teton National Park.

Evison moved into the permanent ranks in 1960 as a park ranger in Petrified Forest National Park. He subsequently served in Lake Mead National Recreation Area and Hot Springs National Park before being accepted into the Department of the Interior's Management Development Program in Washington D.C.

In 1971, he returned to Grand Teton as assistant superintendent, but was too impressive a voice for conservation to remain undiscovered in one place. In the coming years he was tapped to be superintendent of Saguaro National Monument and the Horace Albright Training Center in Grand Canyon National Park.

In 1975, Evison was named superintendent of Great Smoky Mountains National Park, where the European wild boar, a non-native species living in the park, was multiplying in such great numbers that the damage to resources was extensive. Evison boldly contracted for out-of-state hog hunters to come in and control the problem, which set off a furor of local opposition. His refusal to back down resulted in the ongoing reduction program that continues to this day. He also

COURTESY JACKSON HOLE NEWS, JACKSON, WYOMING

Boyd Evison.

led a cutting-edge science program that began his career-long efforts to promote the use of parks as laboratories for study.

In 1978 Evison became Assistant Director for Park Operations in Washington D.C. He was then offered the position of NPS Director, but chose instead to go to Sequoia and Kings Canyon National Parks as superintendent in 1980. In 1985, Evison moved to Alaska where he became regional director and faced the biggest challenge of his career when the Exxon Valdez oil spill occurred. His heroic and steadfast support for his superintendents during the cleanup and for years afterward as resources damage assessments went through the legal process distinguish him in the annals of NPS history. In 1991 Evison left for Denver to serve as deputy regional director in the Rocky Mountain Region until he was asked to serve as interim superintendent of Grand Canyon National Park during a period crucial to the completion of the general management plan from 1993 to November 1994. During this time he was instrumental in developing a rationale for setting the use numbers within the Colorado River Management Plan—numbers that continue to set the standard to this day. He also became personally involved in the issue of air quality and soundscape management, an interest that continued as he participated after retirement in the National Parks Overflight Working Group.

Evison retired from the National Park Service in 1994, providing time for him and his wife, Barbara to do the traveling they always enjoyed. But in 1999 the Tetons beckoned yet again, when Evison became Executive Director of the Grand Teton Natural History Association. He is credited with expanding scientific and educational outreach opportunities through the work of the association as well as enhancing the long-standing partnership with the NPS, the U.S. Fish and Wildlife Service, and the U.S. Forest Service.

Evison received many accolades and prestigious awards throughout his NPS career and professional life, including the Department of the Interior's highest award, the Distinguished Service Award; the National Parks Conservation Association's Mather Award; and the National Park Foundation's Pugsley Award. He was recently awarded the George Melendez Wright Award for lifetime achievement by the George Wright Society.

Boyd is survived by his beloved wife, Barbara, who has shared his career as a true partner, along with their son, Chris, and daughter, Kathy. The family also includes son-in-law Randy Katz and daughter-in-law Lauren. During the last few years, one of Boyd's greatest joys has been being a grandfather to Joe and Sarah Katz.

In honor of Boyd, the family and the Grand Teton Natural History Association have established a Boyd Evison Graduate Fellowship to encourage scientific and conservation research in the national parks. Memorial donations may be made to the Boyd Evison Graduate Fellowship, c/o Grand Teton Natural History Association, P.O. Box 170, Moose WY, 83012. Cards may be sent to Barbara Evison, c/o Randy and Kathy Katz, 615 Walden Drive, Beverly Hills, CA 90210.

NEWS & notes

Experimental Animal Detection Driver Warning System Installed

An experimental animal detection system that warns travelers about wildlife approaching a roadway was recently installed on a section of U.S. Highway 191 (between mileposts 28–29 in the Black Butte area) in Yellowstone National Park. The system was designed by the Western Transportation Institute (Montana State University) and Sensor Technologies and Systems, Inc. This is part of a two-year study funded by 15 state Departments of Transportation, including the Montana Department of Transportation, to look at ways to reduce and mitigate the impacts associated with animal-vehicle collisions (e.g., human injuries/fatalities, wildlife injuries/fatalities, property damage).

As wildlife approach the roadway in the study area, a continuous radar beam is broken, and flashing lights on warning signs are activated, warning drivers of the possible presence of wildlife. The system is only activated by large wildlife like bison, elk, deer, and moose.

Alaska Quake Seems to Trigger Yellowstone Jolts

The magnitude 7.9 earthquake that rocked Alaska on November 4 apparently triggered scores of earthquakes here in Yellowstone, some 2,000 miles away. By 8:30 a.m. on that day, about 17 hours after the Alaskan quake, more than 200 small earthquakes had been detected occurring in clusters throughout the Yellowstone area. The quakes were recorded by the Yellowstone seismic network operated by the University of Utah Seismograph Stations.

Clusters of small earthquakes in time and space are common in Yellowstone. However, the clusters of Yellowstone earthquakes following the Alaskan mainshock extended across much of the park and were not concentrated in a single location.

The smallest events were of magnitude less than 0, and the largest of about magnitude 2.5. NPS rangers at Old Faithful and Canyon Village reported feeling some of the earthquakes.

COURTESY MARCEL HUIJSER

The animal detection system should be operational in December 2002.

While the data are preliminary, they suggest that the Yellowstone earthquakes may have been triggered by the passage of large seismic waves generated by the Alaskan earthquake. The apparent triggering is suggested by the fact the Yellowstone activity began within a half hour of the Alaska earthquake, which hit at 3:12 p.m. MST Nov. 3 (1:12 p.m. local time in Alaska).

Scientists once believed that an earthquake at one location could not trigger earthquakes at distant sites. But that belief was shattered in 1992 when the magnitude 7.3 Landers earthquake in California's Mojave Desert triggered a swarm of quakes more than 800 miles away at Yellowstone, as well as other jolts near Mammoth Lakes, California, and Yucca Mountain, Nevada.

2003 GWS Conference Announced

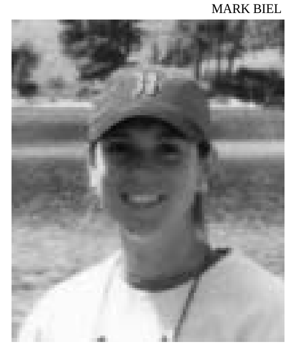
On April 14–18, 2003, the George Wright Society and National Park Service will co-sponsor "Protecting Our Diverse Heritage: The Role of Parks, Protected Areas, and Cultural Sites" in San Diego, California. This meeting will incorporate two of the country's leading conferences on parks and cultural sites: The George Wright Society Biennial Conference and Cultural Resources 2003, the National Park Service's flagship cultural resources conference.

The conference is scheduled to include four plenary sessions, 90 concurrent sessions, and a poster/computer demo/exhibit session, as well as workshops, special events, and field trips. The conference proceedings will be published. For information on attending the conference, go to *www.georgewright.org/2003.html* or contact The George Wright Society, P.O. Box 65, Hancock, Michigan 49930-0065 USA; 1-(906)-487-9722; fax 1-(906)-487-9405; *conferences@georgewright.org*.

Wondrak Wins MHS Award

The Montana Historical Society and *Montana: The Magazine of Western History* named YCR's Alice Wondrak the winner of this year's Burlingame-Toole award, given each year to the author of the best article submitted by a graduate student. The award was presented at the annual meeting of the Montana Historical Society in Havre on October 25. Alice's winning submission, "Wrestling with Horace Albright: Edmund Rogers, Visitors, and Bears in Yellowstone," is being published in *Montana: The Magazine of Western History* in two parts, beginning in Autumn 2002.

MARK BIEL

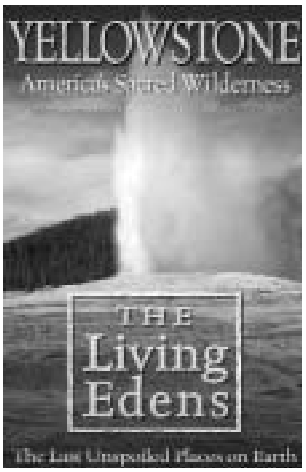


Alice Wondrak.

Yellowstone Film Earns High Honors for Locals

"Yellowstone: America's Sacred Wilderness," a one-hour film first broadcast on PBS in January 2001, has brought important recognition to three people in the Yellowstone region. The film, part of

PBS's "The Living Edens" series, was co-produced by filmmakers Hugh Miles, of Wimborne, Dorset, England, and Shane Moore, of Jackson, Wyoming, with additional filming done by veteran Yellowstone filmmaker Bob Landis, of Gardiner, Montana. YCR writer Paul Schullery wrote the script and narrated the film.



The award-winning video.

In September 2001, the film won the Best Cinematography award at the Jackson Hole Wildlife Film Festival in Jackson, Wyoming, where it outcompeted 650 other films. In November 2001, the film won the Grand Prize at the Banff Mountain Film Festival in Banff, Alberta, Canada, as the best of the 250 films competing. In October 2002, at the biennial Wildscreen 2002 Film Festival in Bristol, England, Paul Schullery won the "panda" (as Wildscreen's awards are known) award for best script. "Yellowstone's" co-producer, Hugh Miles, was awarded the Wildscreen festival's highest award, the panda for Outstanding Achievement. The Wildscreen competition is regarded as the most prestigious in the nature film world; its pandas are often referred to as the "green Oscars."

"Yellowstone: America's Sacred Wilderness" is still occasionally rebroadcast on PBS. Copies of the film may be ordered from the Yellowstone Association through their web site at *www.YellowstoneAssociation.org*.

FSEIS Released to Cooperators

On November 12, 2002, the Internal Review Draft of the Supplemental Winter Use EIS was released to the States and Counties serving as Cooperating Agencies with the National Park Service. Details of the preferred alternative will be presented to the public in the Final SEIS on February 19, 2003. The framework, as well as the details, are a package, with all components inextricably linked. The principal components of the package are: reducing numbers of snowmobiles through daily limits; implementing Best Available Technology requirements; implementing an adaptive management program; requiring that access is guided; ensuring that phase-in is reasonable and shared with the communities; developing a new generation of snowcoaches as a key to winter transportation; and ensuring that funding is available for implementation.

Daily Limits: Snowmobile numbers could increase or decrease slightly over the existing historic average. Peak use would be dramatically reduced, and some use would be directed away from the heavily impacted West Yellowstone to Old Faithful corridor. Total actual average daily use would be capped at the historical average for West Entrance and allow for minor growth and redistribution of use at the other entrances. Initial snowmobile daily limits are: North Entrance (Mammoth Terraces),50; West Entrance, 550; East Entrance, 100; South Entrance, 250; Continental Snowmobile Divide Trail, 75; and Grassy Lake Road, 75. Total: 1,100.

Best Available Technology: Best Available Technology (BAT) would ensure that oversnow vehicles are the cleanest and quietest possible under today's technology. For the winter of 2003/2004 NPS would set BAT as any snowmobile that is capable of reducing hydrocarbon emissions by 90% and carbon monoxide emissions by 70%.

Adaptive Management: Specific standards would be set for each winter management zone. The SEIS will prescribe monitoring standards, methods and management actions for critical resources in winter management Zone 3, (where snowmobiles and snowcoaches will travel). For each indicator, a standard either exists or is hypothesized (for adaptive management). Each indicator and monitoring method and intensity is prescribed. Management actions are implemented if the standards are exceeded. The NPS will establish an "open forum" strategy for the dissemination of monitoring results, technical expertise, monitoring techniques and results of peer review.

Guided Access: Training will be required for both commercial and non-commercial guides. Guides will be trained to avoid conflict with wildlife. The model will be tested during the phase-in period starting with 20% non-commercially guided use, including a training program for certification. Adaptive management techniques would be applied as experience is gained to adjust numbers within the limits as appropriate.

Phase-in: These components would be implemented over the course of two to three winter use seasons to allow communities, permittees, visitors, and concessioners time to adapt.

Year 1 (2003/2004): Implement daily limits; begin comprehensive monitoring program; require commercially-guided operations to be BAT; encourage rentals and private snowmobiles to be BAT; complete concession contracting for commercially guided operations; establish training program for non-commercial guides; propose changes for following winter.

Year 2 (2004/2005): Retain daily limits; continue comprehensive monitoring program; require all snowmobile entries to be guided (80%/20%); require all snowmobile entries to be BAT; propose changes for following winter.

Year 3 (2005/2006): Implement changes, if required with regard to guiding, BAT, limits, monitoring program, hours of operation, etc.

Snowcoach Development: Continue to support and help fund the current research and development for new snowcoach technology; support exploration of ways to fund purchase of an initial fleet of new snowcoach vehicles through DOE, DOT, and FHWA grants; require all snowcoaches must meet BAT standards.

Funding: The National Park Service is seeking operational funding as well as one-time funds to focus on enhanced winter operations, to implement a comprehensive monitoring program, to replace equipment, and to continue with research and development of the next generation of snowcoaches.

NPS PHOTO

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