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Volcanism in National Parks: Summary of the Workshop Convened by the U.S. Geological Survey and National Park Service, 26-29 September 2000, Redding, California

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Table of Contents

<u>List of Tables</u>

Foreword
Volcanism's Broad Impact on Parks

Spectacular volcanic scenery and features were the inspiration for creating many of our national parks and monuments and continue to enhance the visitor experience today (Table 1). At the same time, several of these parks include active and potentially active volcanoes that could pose serious hazards – earthquakes, mudflows, and hydrothermal explosions, as well as eruptions – events that would profoundly affect park visitors, employees, and infrastructure. Although most parks are in relatively remote areas, those with high visitation have daily populations during the peak season equivalent to those of moderate-sized cities. For example, Yellowstone and Grand Teton national parks can have a combined daily population of 80,000 during the summer, with total annual visitation of 7 million. Nearly 3 million people enter Hawai`i Volcanoes National Park every year, where the on-going (since 1983) eruption of Kilauea presents the challenge of keeping visitors out of harm's way while still allowing them to enjoy the volcano's spellbinding activity.

Table 1. Primary national parks and monuments having volcanic resources

Katmai National Park and Preserve, Alaska
Aniakchak National Monument and Preserve, Alaska
Lake Clark National Park and Preserve, Alaska
Wrangell-St. Elias National Park and Preserve, Alaska
Bering Land Bridge National Preserve, Alaska
Sunset Crater Volcano National Monument, Arizona
Lassen Volcanic National Park, California
Lava Beds National Monument, California
Devils Postpile National Monument, California
Mojave National Preserve, California
Death Valley National Park, California
Hawai`i Volcanoes National Park, Hawaii
Haleakala National Park, Hawaii
Craters of the Moon National Monument, Idaho
Bandelier National Monument, New Mexico
Capulin Volcano National Monument, New Mexico
El Malpais National Monument, New Mexico
Crater Lake National Park, Oregon
Mount Rainier National Park, Washington
Mount St. Helens National Monument, Washington (managed by U.S. Forest Service)
Devils Tower National Monument, Wyoming
Yellowstone National Park, Wyoming

Eruptions also could affect people living and working in the areas surrounding parks, especially along rivers leading from active volcanoes. Mount Rainier, for example, has produced mudflows that have traveled far beyond the boundaries of the park, and both the monitoring strategy and response plans by the USGS and NPS have taken this aspect of the hazard into account. Moreover, a period of volcanic unrest in a park, even if an eruption did not result, would likely trigger an emergency response such as that specified by an incident command system and could lead to closure of the park and evacuation of nearby communities.

Still other national parks and monuments consist of striking volcanic features that present important resource protection issues for park managers. For example, Craters of the Moon National Monument in Idaho consists of a large lava field of more than 60 flows with spectacular flow features, eruptive fissures and cones, rafted blocks, and lava tubes. In heavily visited areas, significant damage has occurred to brittle and unstable pahoehoe flow surfaces, and there has been substantial impact from souvenir collecting. Many of these effects are localized, but the visual consequences are significant. To reduce further damage, certain areas have been closed and barriers created, and visitors are instructed to stay on trails.

In some parks, the great expanse of backcountry presents a different kind of resource-protection challenge. For example, in the fall of 2000, a group of motorcycle enthusiasts rode their dirt bikes into the Painted Dunes area of Lassen Volcanic National Park. This area is particularly fragile, and severe ruts were created in the soft, bare, and easily erodible volcanic ash. Evidence of this damage will persist for many years and without mitigation may be increased by natural erosion. Uninformed attempts to mitigate the damage may instead cause further degradation of the resource. NPS resource managers are developing a plan to minimize the long term impact to Painted Dunes by this act of vandalism in consultation with USGS geologists.

Volcanic processes can influence ecosystems in diverse and interesting ways. In California's Lava Beds National Monument, more than 400 caves in 12 lava-tube systems are home to 14 species of bats, including maternity colonies and hibernacula, and the largest concentration of Townsend's big-eared bats in California. About 70,000 visitors per year enter caves, most in about 5 percent of the caves. Visitor impacts to bats, archeological resources, flora in cave entrances, speleothems, ice features, and bacteria are a concern. About 1 percent of the caves are gated, and park interpreters guide many visitors through the Monument's lava tubes

Pioneering work by Dr. Thomas Brock in the 1960s revealed microbes thriving in the high temperatures and hostile chemistries of Yellowstone's thermal springs, previously thought to be sterile environments. Current research demonstrates that the thermal springs are complex ecosystems containing a rich array of specially adapted microbes. Similar environments are believed to have been abundant early in the Earth's history and may occur elsewhere in the solar system. Life in today's thermal springs therefore may be closely related to, and provide important information about, early life forms on the Earth and organisms that could inhabit other planets. Enzymes and segments of genetic code that allow microbes to survive in thermal springs also have important industrial, environmental, and pharmaceutical applications. The most successful to date has been TAQ Polymerase, an enzyme extracted from a research sample of the Yellowstone microbe *Thermus aquaticus* that is critical to efficiently replicating DNA through the polymerase chain reaction. Biotechnology company scientists continue to test small research samples of micro-organisms in search of additional valuable components. These must be synthesized or cultured in the laboratory, because Federal law prohibits sale or commercial use of materials removed from sites managed by the National Park Service.

Volcanic parks and monuments continue to offer exciting opportunities for collaborative research. For example, in the summer of 2000 at Crater Lake National Park, Oregon, the NPS, USGS, and University of New Hampshire jointly conducted a bathymetric survey of the lake bottom to improve understanding of aquatic biology and geochemistry, as well as volcanic processes and hazards. The survey used a high-resolution multi-beam mapping system to determine lake-floor elevations to within 50 cm (1.5 ft), far more accurately than the previous 1959 survey. The new data provided stunningly clear pictures of the lake bottom and permitted new interpretations of the volcanic and landslide activity since the cataclysmic eruption of Mount Mazama 7,700 years ago. During that event, an enormous volume of magma (~60 km^3) was explosively erupted, and the roof of the magma chamber collapsed to form a deep bowl-shaped depression or caldera, 8 km by 10 km across, that now holds Crater Lake.

In recognition of the importance of volcanism to diverse park issues, the Geologic Resources Division of the National Park Service and the Volcano Hazards Program of the USGS convened a workshop to bring together USGS and NPS scientists, managers, and interpreters. The purpose of the gathering was to lay the groundwork for improving scientific input to park management (operations, resource management, interpretation, and planning) and for facilitating volcano research and hazard monitoring in parks. Lassen Volcanic National Park served as an excellent host for the workshop which was held in nearby Redding, California. Lassen Volcanic National Park was established by Congress in 1916, inspired by the 1914-1917 eruption of Lassen Peak. A field trip to the park included many stops near striking volcanic features and deposits so that participants could learn about the natural history of the area and develop an appreciation for the scope of the potential volcanic hazards and emergency-response issues that scientists and park managers would face during a future period of volcanic unrest and eruption in the park.

A bi-agency steering committee provided insightful guidance in planning the workshop. NPS members were Sid Covington, Marsha Davis, Bob Higgins, Louise Johnson, Lindsay McClelland, and Judy Rocchio. USGS members were Steve Brantley, Michael Clynne, Marianne Guffanti, Terry Keith, and Bonnie Murchey. The steering committee gratefully acknowledges the help and support of Superintendent Marilyn Parris and the staff of Lassen Volcanic National Park in making the park a memorable and valuable part of the workshop. Emily Fiala of the George Wright Society contributed greatly to the success of the workshop by her thorough management of workshop logistics.

Examples of Recent Volcanic Activity in National Parks and Monuments

As evidenced by these examples, volcanic activity is not merely an exotic novelty in certain parks but rather a real phenomenon to be reckoned with by park management, scientists, visitors, and surrounding communities.

California

- **Lassen Peak** erupted from 1914 to 1917 and inspired establishment by Congress of Lassen Volcanic National Park in 1916. The eruption involved explosions that destroyed a new summit lava dome and produced large eruption clouds, pyroclastic flows, and mudflows. Much of the park is within USGS-delineated hazard zones at risk for volcanic activity similar to the 1914-1917 eruption. About 25 years ago, the historic Manzanita Lake Lodge and other facilities were removed because of concerns about the potential for additional rockfalls from Chaos Crags, steep-sided, young lava domes that generated the Chaos Jumbles rockfall about 350-400 years ago. Many of the Manzanita Lake facilities have since reopened. Heat from the volcanic system is responsible for sustaining Lassen's vigorous hydrothermal system, notable for its numerous springs, fumaroles, and mud pots.

Hawai`i

- **Kilauea Volcano**, in Hawai`i Volcanoes National Park, ranks among the world's most active volcanoes. It erupted continuously from its summit crater in the 19th early 20th centuries. Since 1952, Kilauea has erupted 34 times. The current eruption, now in its nineteenth year, is the most voluminous outpouring of lava on the volcano's east rift zone in the past five centuries. By January 2001, lava flows had destroyed 187 structures (including a park visitor center), covered 13 km of highway with lava as thick as 25 m, and added 207 hectares to Kilauea's southern shore. The Pu`u `O`o vent releases between 1,000 and 2,000 tonnes of sulfur dioxide gas per day, a very large amount that leads to volcanic air pollution (vog) on the island of Hawai`i and in the park. Recent geologic studies have determined that, in addition to producing lava flows, the volcano also has a history of explosive eruptions. Kilauea generated large explosive eruptions several times in the 16th–18th centuries, most recently in 1790 when many Hawaiian warriors were killed. Three large explosive events also occurred 1000–2800 years ago. Kilauea also is the source for many of Hawai`i's largest earthquakes, including a magnitude 7.2 event on November 29, 1975, which triggered tsunami as high as 14.6 m that killed 2 campers.
- **Mauna Loa Volcano** is the world's largest volcano, and its enormous bulk forms half the surface area of the island of Hawai`i. Mauna Loa has erupted 33 times since its first well-documented historical eruption in 1843. Most of these eruptions began near the volcano's summit within Hawai`i Volcanoes National Park, then about half quickly developed into flank eruptions both within and outside the park. Eruptions from the northeast rift zone of Mauna Loa can send flows toward Hilo, a community of about 40,000 people; land now within the city limits was covered by lava in 1880-81, and in 1984 a lava flow reached to within 6.5 km of the city. Eruptions along the southwest rift zone, however, present the greater threat to life and property, because several newly built residential areas lie immediately downslope of potential vents. Mauna Loa is certain to erupt again, but

monitoring data suggest that very little or no molten rock has risen into the volcano's magma reservoir since about 1993.

Alaska

- **<u>Redoubt Volcano</u>**: The 1989-1990 activity of Redoubt, which lies within Lake Clark National Park and Preserve, demonstrated the broad impact that an eruption can have beyond park boundaries. Repeated lahars (mudflows) disrupted operation of the Drift River oil terminal facility on the edge of Cook Inlet, far downstream from the eruptive vent. Ninety minutes after an explosive eruption began on 15 December 1989, a 747 jet with 231 passengers encountered the resulting eruption cloud about 240 km downwind from the volcano. The jet lost power in all four engines for about five minutes, losing 4,500 m (14,600 ft) before the pilots were able to restart the engines and land safely in Anchorage. This barely averted tragedy brought into horrifying focus the potential threat to aviation from volcanic-ash clouds dispersed at high altitudes. Since that time, the USGS, NOAA, and the FAA have coordinated operations to better disseminate information to air carriers about the status of eruptive activity and the extent of ash clouds along air routes over the North Pacific's many active volcanoes. The Alaska Volcano Observatory also has installed seismic instruments on ~20 additional Alaskan volcanoes, so that more information about eruptive hazards can rapidly be conveyed both to communities on the ground and to aircraft.
- **<u>Katmai</u>**: The planet's largest eruption of the 20^{th} century occurred at the site of Novarupta dome, part of the Katmai cluster of volcanoes on the Alaska Peninsula. The eruption created Katmai Caldera and the Valley of Ten Thousand Smokes and expelled about 35 km^3 of pumice and ash, much of which spread beyond Alaska. At the end of the three-day eruption, the ash cloud shrouded southern Alaska and western Canada, and sulfurous ash was falling on Vancouver, British Columbia, and Seattle, Washington. Radio communications and shipping were disrupted, villages were permanently abandoned, and animal and plant life was decimated in southern Alaska. In 1916, Robert Griggs led a National Geographic Society expedition to the Katmai area, and his report of the spectacular eruptive features helped persuade President Woodrow Wilson to create Katmai National Monument (now Park) in 1918.

Washington

- **<u>Mount Rainier</u>** is an active volcano that had a small pumice-producing eruption in the first half of the 19th century and reportedly produced ash-laden steam clouds in 1894. Mount Rainer is potentially very dangerous because of the size and frequency of lahars (mudflows) and debris avalanches during the past several thousand years. With an elevation of 4,392 m, Mount Rainier contains more ice and snow than all other Cascade volcanoes combined. Modest-sized eruptions can melt sufficient snow and ice to send a meltwater torrent down the flanks of Rainier and form lahars that travel beyond the base of the volcano to areas now densely populated. The most recent large lahar occurred about 500 years ago when a debris avalanche from Sunset Amphitheater on the volcano's west side swept down the Puyallup River valley all the way to Puget Sound. Where the valley meets the Puget Sound lowland near the town of Orting, the lahar was at least 5 m deep.
- **<u>Mount St. Helens</u>** is the most active and youngest volcano in the Cascade Range. The awesome explosive eruption on May 18, 1980, captivated the nation as it blasted down the forest as far as 27 km from the vent, triggered the largest landslide in historic time, sent

destructive lahars down river valleys more than 80 km from the volcano, and killed 57 people. This event was followed by five smaller explosive eruptions through 1981 and sixteen non-explosive extrusions of viscous lava (1981-1986) that built a lava dome nearly 270 m tall in the volcano's new crater. One of the most enduring geological consequences of the 1980 eruption, and the most costly single element in the overall recovery effort, has been the persistent downstream sedimentation caused by the erosion of loose volcanic debris deposited around the volcano. In August 1982, President Ronald Reagan signed a measure establishing the Mount St. Helens National Volcanic Monument, which is managed by the U.S. Forest Service.

Wyoming

- **Yellowstone** National Park, Wyoming, encompasses the largest active magmatic system in North America, which produces major seismicity, ground deformation (uplift and subsidence), and thermal activity. The Yellowstone system is centered on a huge 45 km x 75 km caldera characterized by geologically infrequent but very large and destructive eruptions. The caldera was formed by collapse of the ground surface during an enormous eruption -- one of the largest known in the world -- approximately 630,000 years ago. The most recent magmatic eruptions at Yellowstone occurred about 70,000 and 150,000 years ago and produced extensive lava flows as thick as 300 m that have filled in the much of the caldera. The Yellowstone system has not erupted in historic time, but its great abundance of spectacular hot springs, geysers, and fumarole fields are vivid reminders of its potent volcanic past. An explosion of heated ground water occurred ~7400 years ago, forming Mary Bay in Yellowstone Lake; although very small compared to the previous magmatic eruptions, similar future events nonetheless would pose a significant hazard within the park. The Yellowstone region also is very active seismically. The 1959 magnitude-7.5 Hebgen Lake earthquake centered just outside the park's northwestern boundary was the largest historic earthquake in the western US interior. Landslides triggered by the earthquake swept into and dammed the Madison River, causing 28 fatalities.

Key Points and Recommendations of the Workshop

Shared Responsibility

The value of scientific information to park planning, resource management, and interpretation was clearly demonstrated by the numerous issues discussed at the workshop. Because there are typically very few or no staff geologists at national parks, the responsibility for communicating geologic research results to park managers usually falls directly upon the scientists performing the research. Geoscientists must be willing to undertake direct communication with park managers and interpreters and put extra work into creating non-traditional products of their research. Park personnel share in the responsibility of effectively using scientific information in that they must be receptive (both individually and organizationally) to scientists' input and find ways (both individually and organizationally) to apply it to their real situations.

Volcano Hazards and Monitoring within Park Boundaries – and Beyond

Park managers have discretion when deciding whether to operate facilities in areas of potential geologic hazards, but they must clearly inform the public of those hazards. Furthermore, hazards that originate from volcanic sites within a park may affect facilities and communities outside the park, and the requirements of designing an effective volcano-monitoring network are such that instruments installed within a park may be part of a larger array that extends outside the jurisdiction of the park. NPS and USGS personnel are urged to develop a shared perspective about the importance of monitoring needs and public safety that looks both within and beyond park boundaries for the broader community benefit.

Hazard-Response Planning

Every park subject to significant volcanic hazards that could adversely affect park operations or visitor and staff safety should examine its need for both an internal plan for its own response actions and an interagency plan for a coordinated, comprehensive response. There is no one-size-fits-all response plan for national parks; each park must develop plans that address its specific situation and relationships with other agencies.

Interagency volcano response plans typically define the (1) responsibilities of various government agencies and departments in dealing with a restless or active volcano; (2) specific alert-level scheme (if any) that USGS scientists will use during a period of volcanic unrest and eruption; and (3) procedures by which the various elements of the plan will be put into effect when required. Each organization represented in the plan prepares its own plan for action in response to alert levels defined in the more comprehensive interagency plan. An example of a very robust plan that involves a national park is the one developed for Mount Rainier. The intense planning and education efforts of the NPS, USGS, and other federal agencies, and state and local jurisdictions and organizations led to a new volcano emergency-response plan for the area and a much-better informed public. The plan was completed in July 1999. Organizations involved include the National Park Service, Pierce County Department of Emergency Management, King County Emergency Management, Washington State Emergency Management, Washington Division of Veterans Affairs, University of Washington, U.S. Forest Service, National Weather Service, U.S. Army at Fort Lewis, Federal Emergency Management Agency, and the cities of Tacoma, Puyallup, Sumner, Orting, and others. The plan is available online at http://www.co.pierce.wa.us/abtus/ourorg/dem/EMDiv/Planning.htm

Interpretation

The geology of most parks is under-interpreted, and this is particularly unfortunate for volcanic parks with their fascinating landforms and active natural processes. Much work lies ahead to create new and more effective interpretive products and services in order to enhance the public's appreciation of the important role of volcanism in creating the landscapes and ecosystems of national parks. The challenge is compounded because few park interpreters understand volcanic geology or feel confident in communicating it to the public. Thus, scientists must work closely with the interpretive staff of national parks in planning and generating a variety of interpretive products. Additional park interpreters, both seasonal and permanent, with experience or training in the geologic and earth sciences would help improve interpretive services for visitors. USGS and NPS Web sites will be increasingly important interpretive products that warrant further collaboration. Additional recommendations about interpretive products are given below.

The National Park Service Geoscientists-in-the-Parks program, managed by the Geologic Resources Division with significant funding from the Geological Society of America and other partners, has placed about 50 geological interns, volunteers, and seasonal employees in national parks for each of the past several years. Some of these geologists have moved into seasonal and permanent positions in parks. This program could help locate well-qualified candidates for interpretive and resource-management positions targeted toward strengthening geologic interpretation.

Research

Park managers increasingly understand the need for scientific information to ensure that they are prepared to make the best possible decisions. Congress recognized the value of research for parks in the National Parks Omnibus Management Act of 1998 (P.L.105-391), which for the first time provided an explicit research mandate for the National Park Service. The Act instructs the Secretary to "assure that management of units of the National Park System is enhanced by the availability and utilization of a broad program of the highest quality science and information" and to "take such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions." Newly revised NPS Management Policies reflect the Act's mandates by encouraging parks to welcome appropriate research and integrate scientific data into the management process.

Scientific research needs and opportunities vary substantially between the national parks, but baseline geologic information (especially geologic mapping) is needed for all national parks and monuments. Efforts are underway to systematically compile existing geologic information and data and identify gaps in baseline data for most parks. With support from the NPS Inventory and Monitoring Program, the Geologic Resources Division is leading the effort in cooperation with park staff and scientists from the USGS, state geological surveys, and universities. The long-term goals of this work are to provide digital geologic maps, detailed bibliographies of geologic publications, and geologic reports for each park and monument.

To facilitate scientific research in national parks, the National Park Service is implementing a streamlined and uniform research and collecting permit process through a new Web site, http://science.nature.nps.gov/research. Current information about ongoing research projects will be provided directly to park managers based on a required Investigator's Annual Report, which scientists can submit via the Web site.

Balancing Scientific, Public Safety and Wilderness Values

Wilderness areas comprise about half of park acreage nationwide. The NPS increasingly understands the value of research, including in wilderness. Scientific research has high inherent value because it benefits humankind and is an expression of human curiosity. However, accommodating research with wilderness values remains challenging. For example, there is tension between the need for hazard monitoring to protect public safety and the need to protect wilderness from mechanical encroachments such as conspicuous installations of geophysical instrumentation.

Wherever a wilderness area is designated within a park, the preservation of wilderness character and resources becomes an additional statutory purpose of the park. NPS Management Policies (section 6.3.6) state that "The statutory purposes of wilderness include scientific activities, and these activities are encouraged and permitted when consistent with the Service's responsibilities to preserve and manage wilderness." Also, NPS Director's Order 41 states "The increase of scientific knowledge, even if it serves no immediate wilderness management purpose, may be an appropriate wilderness research objective when it does not compromise wilderness resources and character."

Scientific activities in wilderness must be consistent with the minimum-tool concept. The park superintendent, in accordance with the wilderness management plan, selects the minimum tool or administrative practice necessary to successfully and safely accomplish the management objective with the least adverse impact on wilderness character and resources. Administrative use of motorized equipment or mechanical transport, including motorboats and aircraft, will be authorized in accordance with the park's wilderness management plan only (1) if determined by the superintendent to be the minimum tool needed by management to achieve the purposes of the area, or (2) in emergency situations involving human health or safety or the protection of wilderness values. Such management activities will be conducted in accordance with all applicable regulations, policies, and guidelines and, where practicable, will be scheduled to avoid creating adverse resource impacts or conflicts with visitor use.

For a discussion of the NPS general policy for Wilderness Management, see http://www.nps.gov/refdesk/mp/chapter6.htm

Yellowstone Volcano Observatory

The workshop stimulated an unexpected outcome, as several participants realized during the gathering that it was time to formally establish the Yellowstone Volcano Observatory (YVO). The Yellowstone National Park region encompasses the largest active magmatic system in North America, which produces major seismicity, deformation, and thermal activity. The system is centered on an enormous caldera that is characterized by geologically infrequent but very large and destructive eruptions. A monitoring effort has been underway in Yellowstone National Park and vicinity for many years, primarily involving a seismic network operated by the University of Utah under a cooperative funding agreement with the USGS and with additional support from the NPS. Recognizing the need to (1) provide a stable long-term basis for ongoing monitoring, hazard-assessment, and research activities, (2) communicate more effectively the results of these efforts to responsible authorities and to the public, and (3) better coordinate various other relevant projects, the concept of YVO was proposed to the USGS, NPS, and University of Utah by a group of workshop participants. In May 2001, the USGS, University of Utah, and Yellowstone National Park signed an interagency Memorandum of Understanding, adding YVO to the ranks of the Alaska, Cascades, Hawaiian, and Long Valley volcano observatories. More information about the operations of YVO is available at its new tri-agency website http://volcanoes.usgs.gov/yvo/.

Guidance to Develop Effective Interpretive Products and Programs

The field trip to Lassen Volcanic National Park was an excellent demonstration of the enormous potential that exists for park interpreters to help visitors appreciate the changing nature of volcanic landscapes and potential hazards during future eruptions. The trip was led by Michael Clynne and Robert Christiansen, geologists with the U.S. Geological Survey. Based on their recent geologic studies of the area, a detailed story of Lassen's volcanic activity has emerged. The field trip stimulated discussion about strategies for improving interpretive products and programs for park visitors so that they too could learn to discern volcanic features and to imagine volcanic processes more fully. After the field trip, two questions were posed to the participants in order to capture effective methods and strategies for interpreting park resources to visitors. The resulting advice summarized here is broadly germane to scientific activities in parks besides volcanology.

What can scientists (from the USGS, state geological surveys, and universities) do to help the National Park Service provide better interpretive products?

What can NPS managers and interpreters do to help scientists translate and share the results of their work?

Role of Scientists

- For each appropriate research proposal, include an outreach/interpretive element that can be developed in collaboration with the National Park Service. Develop relationships with National Park Service interpretive staffs to promote the transfer and translation of specific project work, including objectives, methods, and results.

- When considering a new idea or project for an interpretive product or service, engage the park interpretive staff throughout the effort. Ask the interpretive staff: how can I help you deliver effective interpretive products and services? The answer may not be the same for each park.

- For the park in question, identify geologic processes and geologic themes that might be used by interpretive staff. These might include a list of geologic features and landforms visible from specific locations and an overall description of how the landscape was formed and changed.

- Engage one or more interpreters to discuss research results and geology in the park. For example, take interpreters into the field during field work to various sites so that they may observe some of the activities involved in research, assist as appropriate in the project, ask questions related to the investigation (objectives, methods, progress and results thus far) and photograph the activity.

- Develop videotape presentations about basic geologic topics and processes or about geologic activity that has occurred in a specific national park – e.g., short video sequences of a scientist describing landforms, geologic features, and changes that have occurred over geologic time from noteworthy locations in the park. Scripts should be developed in cooperation with park interpreters to ensure effective communication with a non-geologist audience.

- Encourage students in earth science to apply for seasonal jobs as interpreters for the National Park Service.

- Learn about interpretive techniques and strategies promoted by the National Park Service interpretive programs. Attend meetings involving National Park Service interpreters such as the annual meeting of the National Association of Interpreters

- Minimize the use of scientific jargon and highly technical terms.

- Share the results of research with interpreters and the national park as many times as possible over many years, especially new results as they unfold. For example, provide copies of "poster presentations" to NPS interpreters and resource managers with examples of preliminary or final results of research in a park.

- Encourage earth science graduate students to develop training materials about geologic processes and landscape evolution in national parks.

- Submit the required investigators annual reports as specified in the National Park Service research permit and provide summaries of research progress, highlights, and results.

- Spend time with park visitors to develop an appreciation for the great diversity of interests, questions, and knowledge of people faced by interpreters every day. Offer to give one or more "walks and talks" or other presentations to park visitors as a model for interpreters.

Role of Park Staff

- Develop a strategy to archive materials provided by scientists to the interpretive program so that they are available over the long term as resource material for present and future staff.

- Develop a strategy for improving the training of seasonal interpreters that optimizes the time of scientists, including advance scheduling (months rather than weeks ahead) for annual training and intermittent seminars during seasonal field work.

- Send a letter of appreciation to senior managers of the scientists' organization (for example, USGS Director or Regional Director, college dean or department chair).

- Help provide ideas and metaphors for concepts, facts, and numbers (volume, size, distance, and rates) often used by scientists to explain research results and geologic history.

- Ask scientists to assist; don't hesitate to call or send e-mail to request assistance and discuss issues and objectives; requests are usually well received if made with plenty of lead time.

- Use the research-permit application system to encourage scientists to share and interpret information about their research with NPS.

- In collaboration with scientists, identify and organize venues for scientists to talk about their research with interpretive staff.

- Learn about ongoing research projects, identify those that could provide good interpretive topics, and actively work with scientists involved with those projects to develop interpretive programs.

- Regularly communicate interesting new research findings to the public.

- Work with science teachers on education outreach, and for advice on how best to communicate earth science topics to the public.

NPS Action Plans for Visitor-Use Impacts and Geologic Database

The National Park Service uses action plans to propose specific projects in response to resource-management issues. A consistent format facilitates incorporation into broader planning and budget processes. A plan for visitor-use impacts and one for geologic mapping were developed as a result of the workshop.

I. Action Plan for Visitor Use Impacts

Title:
Development of Assessment Method to Measure Visitor Use Impacts to Nonrenewable Geologic Features

Problem Statement:
Currently, methods to quantify the condition and vulnerability of nonrenewable geologic resources are lacking. Public use has impacted a wide variety of geologic features through intentional theft and unintentional trampling. The NPS has a legislated mandate to protect resources from impairment. The loss of geologic features significantly impairs the ability of the public to understand and appreciate the geologic meaning of parks. Specific examples of vulnerable features are found at lava tube caves, lava low surfaces, cinder cone slopes, and "collectable" volcanic rocks.

Management needs an objective process to assess the success or failure of various practices intended to reduce visitor use impacts (interpretation, trail improvements, ranger patrols, etc.). Information also is needed to assess which areas are particularly vulnerable to public use impacts and therefore should be avoided in future development planning.

Description of Recommended Actions:
Select a pilot park and develop protocols and methods to (1) identify features vulnerable to visitor impacts, (2) assess conditions relative to visitor impact, and (3) monitor changes over time on a site-specific basis. Develop a prioritized list of management activities in response to the completed assessments and monitoring.

Potential Partners:
National Park Foundation, U.S. Geological Survey, Association of American State Geologists, National Speleological Society, National Cave and Karst Research Institute, Cave Research Foundation, American Cave Conservation Association, and the NPS Geoscientists in the Parks Program (with supporters including the Geological Society of America, Association for Women Geoscientists, the National Association of Black Geologists and Geophysicists, the Keck Geology Consortium, The Newkirk Engler and May Foundation, and the Environmental Alliance for Senior Involvement).

Budget and Timing:

Year 1 – Develop and test protocols:	$25,000
Year 2 – Complete field assessment park-wide:	$25,000

II. Action Plan for Geologic Database

Title

Guideline to develop a park-specific geologic database - Understanding the ecosystem from the bottom up.

Problem Statement

Maps of bedrock geology, surficial geology, and soils form the backbone of many resource management programs. These maps describe the underlying physical habitat of many natural systems and are an integral component of the physical resource inventories stipulated by the National Park Service in its Natural Resources Inventory and Monitoring Guideline (NPS-75) and the 1997 NPS Strategic Plan. While bedrock maps are available in paper format for many National Parks, the information on some of these maps may represent outdated ideas that were prevalent at the time of mapping. Several other parks have no bedrock geologic map coverage. In addition, information on surficial geology and soils lags far behind information on bedrock geology. Bedrock and surficial geology are the medium that geologic processes work upon to create landforms. Landforms are readily identified components of landscapes in most physiographic provinces, and they provide important information on geologic, hydrologic and ecological disturbances, habitat, fire frequency and distribution patterns, archeology, cultural landscapes and many other applications. Maps depicting bedrock and surficial geology, soils, and landforms have much to contribute toward understanding dynamic processes and environmental hazards, effective long-term ecological monitoring, stewardship and interpretation of resources, and long-range park planning. Lack of this information leaves a gap in our knowledge that can lead to fundamental adverse implications for park operations with resulting long-range consequences. Indeed, parks already experience adverse consequences from management actions made in the absence of geologic information.

Background Information on Geologic Maps and Digital Representation

Geologic maps are typically complicated documents containing a variety of information that is both spatial and descriptive. Geologic maps depict two types of spatial information: observed objects and interpreted objects. Observed geologic objects consist of things that are actually observed or measured in the field, such as lithologic map units, structural features (faults, folds), structural measurements (strike and dip), mineralogy, petrology, topography, geomorphology and hydrography. Interpreted geologic objects are often inferred from the observational data. Examples are map units defined by observations of noncontiguous outcrops, and fault traces defined from evidence observed in several outcrops. Real geology is usually too complex to be precisely depicted at the scale at which geologic maps are normally published. Generally, geologic maps are interpretive products that emphasize one or more geologic characteristics and minimize others, depending on the purpose for which they were made. For example, a bedrock geologic map ignores or minimizes surficial deposits in most areas in favor of inferred bedrock units.

A geologic map is four-dimensional. Time is an important element of any map and is generally denoted by coded map-unit symbols. The time element can be either observed - such as one map unit overlying another or an historical deposit observed to have formed - or interpreted indirectly from map relations, isotopic dates, fossils, or other means.

Descriptive geologic information includes map unit symbols (formation name and time period symbols, structural symbols such as strike and dip, relative movement of fault blocks, fold axes and angle of plunge) and map legends. A map legend establishes an association between geologic objects and their geometric, spatial, semantic, and symbolic representation on a particular map. Thus, a geologic map is a representation of selected geologic objects symbolized and described for some specific purpose. Typical objects depicted on geologic maps include bedrock geology, surficial geology and geomorphology.

The exact representation of these objects as map entities is scale dependent, and the geometry may vary between point, line, polygon, surface and volumetric objects. This information can be digitally captured, stored in a geologic object data archive, and geometrically manipulated and analyzed in a GIS. It can be input and stored as points for features at specific locations (e.g. lithologic units), to produce a *digital* geologic map. There are two fundamentally different conceptual uses for digital geologic maps: cartography and analysis. Cartographers are generally concerned with using the digital representation of the geologic map to produce one or more publishable geologic maps, usually on paper. Analysts, on the other hand, are usually more interested in the representation of the geology in its digital form. Their interest is in combining the digital geology with other types of digital data in an attempt to model natural systems or to solve problems related to natural systems. The analyst needs to represent his products on paper also, so the analyst's needs include those of the cartographer.

The multi-layer GIS approach to digitally capturing, managing and visualizing geological map information has advantages over single-layer geological maps in extracting information and relating it to other research questions, resource management issues, interpretation and planning applications. For example, geological data and other information, such as fossil burial environments, archeological sites, ground-water vulnerability, slope stability, areas susceptible to erosion if disturbed, or geologic features providing unique habitat settings, can be presented in a thematic form to produce interpreted derivative maps. Derivative map themes may be numerous in scope, are site-specific and can even be unique to a park. They have the user, such as the resource manager, park planner, interpreter or resource protection ranger, in mind.

Elements of a Park Geologic Database

Four elements have been identified as foundational components of baseline geologic data for parks and have become the focus of the NPS Geologic Resource Inventory (GRI) funded through the Inventory and Monitoring (I&M) Program. These are: (1) digital bedrock and surficial geologic maps (GIS); (2) bibliography of geologic literature and maps (GRBIB/NRBIB); (3) on-site (park) scoping meeting; and (4) a Geologic Inventory Report (documentation of GRI outcomes). These elements are described in detail in an NPS-Natural Resource Information Division (NRID) Fact Sheet titled *Geologic Resource Inventory.*

Description of Recommended Actions

Part of the GRI process is to identify existing geologic maps in and around NPS areas, and where maps exist, evaluate their quality, coverage, and utility in park management applications. This establishes the known or existing condition. Currently the GRI process focuses on bedrock geology, and to a lesser degree surficial geology, and initiates identifying future mapping needs for a park. Steps a park can take are as follows:

Establish existing condition: Identify and inventory what is known of a park's geology

- Bibliography of park's geology - GRBIB (compiled from Georef and Geoindex databases)
- Lists of geologic map references
- Index map of associated geologic maps

Convene a park GRI workshop to review the four inventory elements

- Participants include park managers, I&M and GRD staff and/or regional representatives, geologists with intimate geologic knowledge of the park and area (from the USGS, state geological surveys, and universities), representatives of neighboring agencies and other cooperating institutions
- Scoping meetings last 1 to 3 days, depending on size of park and existing information base
- Objective: Assess quality and extent of known geologic information (maps and publications)

Determine the park's geologic information needs based on what is available as well as unknown

- If needed, educate park managers on what geologic maps can provide. A geologic map is a specific means of representing information. As author John McPhee describes it, a geologic map is a textbook on one page. Another wise geologist once said that a geologic map is a progress report, not a cut and dried product. Thus, no map is final, and all maps will need to be redone in the future as knowledge, techniques, or goals change.
- Discuss inventory needs and deliverable products, including GIS
- Identify and prioritize mapping needs based on park management issues and legal requirements (e.g., 1998 NPS Omnibus Act); discuss park-specific value of a variety of geologic map types, scales, and costs; parks that already have or are on their way to having complete bedrock and surficial geologic maps should scope the next level of geologic mapping and applications during the workshop
- Identify cooperators to provide technical support for new mapping
- Identify components to be covered in the park's Geologic Inventory Report

Prepare project statements to acquire products identified in the GRI

- Consult NRID for examples of funded digitizing proposals or completed projects of existing geologic maps
- Collaborate with identified cooperating geologist(s) to draft project statements/proposals for various funding calls; if working with a non-NPS geologist, then consult with GRD or support office geologist so that proposal conforms to NPS mapping standards, or call-for-proposal criteria if the funding source is internal

Overview of Activities of USGS Volcano Hazards Program in Parks and Monuments

Volcano Monitoring

Through its system of five volcano observatories, the USGS Volcano Hazards Program currently monitors 43 volcanic centers in the U.S. with various combinations of seismic, geodetic, geochemical, hydrological, and visual methods; 22 of these lie within or adjacent to national parks or monuments in six states (Table 2).

Volcano monitoring methods are designed to detect and measure signals caused by magma movement beneath the volcano. Rising magma typically will (1) trigger swarms of earthquakes and other types of seismic events; (2) cause deformation (swelling or subsidence) of a volcano's summit or flanks; and (3) lead to the release of volcanic gases from the ground and vents. By monitoring changes in the state of a volcano, scientists are sometimes able to anticipate an eruption days to weeks ahead of time and to detect remotely the occurrence of certain related events like explosive eruptions and lahars (mudflows). For general explanations of monitoring techniques, see http://volcanoes.usgs.gov/About/What/Monitor/monitor.html

Table 2. National parks and monuments in or near which volcano monitoring is conducted by the USGS Volcano Hazards Program, as of Oct. 2001. For more information about monitoring operations at a particular volcano, contact the appropriate observatory or visit its web site. Selected references on volcanic geology and hazards in these parks and monuments are listed in a later section of this volume.*

National Park/Monument	Volcano Observatory	Observatory Web Site	Monitored Volcano
Lake Clark NP, Alaska	AVO	http://www.avo.alaska.edu	Redoubt
"	"	"	Iliamna
Wrangell-St. Elias NP, Alaska	AVO	http://www.avo.alaska.edu	Mt. Wrangell
Katmai NP, Alaska	AVO	http://www.avo.alaska.edu	Mt. Katmai
"	"	"	Denison
"	"	"	Snowy
"	"	"	Mt. Martin
"	"	"	Mt. Mageik
"	"	"	Mt. Trident
"	"	"	Novarupta
"	"	"	Griggs
Aniakchak NM, Alaska	AVO	http://www.avo.alaska.edu	Aniakchak Caldera
Hawaii Volcanoes NP, Hawaii	HVO	http://hvo.wr.usgs.gov	Kilauea
	"	"	Mauna Loa
Halekala NP, Hawaii	HVO	http://hvo.wr.usgs.gov	East Maui
Yellowstone NP, Wyoming	CVO	http://volcanoes.usgs.gov/yvo/	Yellowstone Caldera
Mt. Rainier NP, Washington	CVO	http://vulcan.wr.usgs.gov	Mt. Rainier
Mt. St. Helens NM, Washington	CVO	http://vulcan.wr.usgs.gov	Mt. St. Helens
Crater Lake NP, Oregon	CVO	http://vulcan.wr.usgs.gov	Crater Lake
Lava Beds NM, California	CVO	http://vulcan.wr.usgs.gov	Medicine Lake*
Lassen Volcanic NP, California	CVO	http://vulcan.wr.usgs.gov	Lassen Volcanic Ctr.
Yosemite NP, California	LVO	http://lvo.wr.usgs.gov	Long Valley Caldera*

* Medicine Lake volcano & Long Valley caldera lie adjacent to Lava Beds NM &Yosemite NP, respectively.

AVO, Alaska Volcano Observatory, Anchorage AK, 907-786-7496; Fairbanks AK, 907-786-5365
CVO, Cascades Volcano Observatory, Vancouver WA, 360-993-8900
HVO, Hawaiian Volcano Observatory, Hawaii Volcanoes National Park, 808-967-7328
LVO, Long Valley Observatory, Menlo Park CA, 650-329-4795
YVO, Yellowstone Volcano Observatory, Salt Lake City UT, 801-581-7129

Volcano Warning Schemes

USGS volcano warnings involve a series of graded steps that generally correspond to increasing levels of volcanic unrest. As a volcano becomes increasingly active or as monitoring data suggest that a given level of unrest is likely to lead to a significant eruption, scientists declare a higher alert level (also referred to as status or condition levels). This alert-level ranking thus offers the public and civil authorities a framework they can use to gauge their responses to changing volcanic conditions. The highest alert level seldom involves a precise prediction of the specific time and size of an impending eruption, as that is a scientific capability not yet mastered for most volcanic situations.

Different warning schemes that differ in detail between regions and individual volcanoes are used in the United States. Volcanoes exhibit different patterns of unrest in the weeks to hours before they erupt, which means that uniform and strict criteria cannot be applied to all episodes of unrest. Moreover, different types of volcano hazards threaten communities, people, and economic activity so that a warning scheme must address specific hazards from a volcano. For explanations of the warning schemes used by the USGS, see http://volcanoes.usgs.gov/Products/Warn/warn.html

Volcano-Hazard Assessments

A volcano hazard assessment is an analysis of the nature and likelihood of future hazardous phenomena that could occur at a volcano. A volcano hazard assessment describes the likely type, size, and frequency of future eruptions from a volcano and usually includes a hazard-zonation map that estimates areas that could be affected by different volcano hazards (e.g., ash fall, lahars, lava flows). On hazard zonation maps, the boundaries between hazard zones typically are shown as solid lines but they should be interpreted as only approximately located and gradational.

The foundation of a hazard assessment is reconstruction of a volcano's history by detailed geologic mapping and dating of eruptive deposits from past activity. In identifying potential hazard zones by reconstructing a volcano's history, scientists assume that the future behavior of a volcano will be similar to its past behavior in terms of the type, frequency, and magnitude of events. A shortcoming of this assumption is that an unprecedented event can occur. To alleviate this problem, scientists sometimes consider the types and scales of eruptions that have occurred at other similar volcanoes as a guide to outlining hazard zones.

Hazard assessments provide the basis for land-use planning, design of monitoring networks, eruption forecasts, and emergency preparedness. An assessment can be developed either for near-term hazards during a period of volcanic unrest or for long-term hazards at currently quiescent volcanoes. By their nature, assessments are works in progress, subject to revision when new data or interpretations become available. Published hazard assessments for volcanoes in national parks and monuments are cited in the following bibliography with a notation if available in digital form.

Geologic Research

Research into volcanic processes is an integral part of USGS monitoring and hazard-assessment activities, and national parks are important sites for USGS volcanic studies. Data from geophysical monitoring networks in parks are analyzed to characterize the process of magma movement (intrusion) in relation to seismicity and ground deformation. Emissions of volcanic gas are analyzed to determine and the role of magmatic gases and fluids in driving eruptions. Geologic mapping of volcanoes in parks is undertaken to determine the type, extent, and age of surface deposits from previous episodes of eruptive and related activities, as the basis for estimating likely future hazards. Field, laboratory, and modeling studies are undertaken to understand how surface deposits were emplaced and how volcanic systems can change over time. Various aspects of hydrothermal systems also are studied and characterized.

Detailed geologic mapping of volcanic centers in several parks and monuments has been undertaken by USGS scientists over the past two decades, specifically at Mount Rainier N.P., Mount St. Helens N.M., Crater Lake N.P., Lava Beds N.M., Lassen Volcanic N.P., Yellowstone N.P., Aniakchak N.M., Katmai N.P., Lake Clark N.P., and Hawaii Volcanoes N.P. Geologic maps for Yellowstone and Hawaii have been published; the other maps are nearing publication in digital format (e. g., see the geologic resources inventory for Lassen Volcanic National Park at the end of this report.)

As an introduction to the available scientific literature, selected geoscience references to investigations of volcanoes in national parks and monuments are provided in this report. Additionally, a bibliography of recent publications from diverse volcanological research projects (not just those in parks) supported by the USGS Volcano Hazards Program is available at http://volcanoes.usgs.gov/Products/sproducts.html

Outreach

Diverse groups want information about volcano hazards and processes. USGS scientists share their volcanological expertise with public-safety officials, land managers, scientists in other institutions, business leaders, the media, land developers and planners, educational institutions, and citizens groups. A variety of methods to disseminate volcanic information are used, including maps, scientific publications, pamphlets, briefings, workshops, videos, digital databases, Web sites, newspaper articles and interviews with media. This familiarity with outreach within the USGS Volcano Hazards Program provides a strong foundation for working with NPS staff on much-needed outreach projects for volcanic parks.

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Available online at http://volcanoes.usgs.gov/Products/sproducts.html#fs

General Subjects
What are Volcano Hazards? (FS 002-97)
Cuales son las Amenazas o Peligros Volcanicos? (FS 144-00)
Volcanic Ash Fall - A "Hard Rain" of Abrasive Particles (FS 027-00)
Living With Volcanic Risk in the Cascades (FS 165-97)
Creating an Effective Fact Sheet (FS 008-97)

Alaska
Volcanic Ash - Danger to Aircraft in the North Pacific (FS 030-97)
Can Another Great Volcanic Eruption Happen in Alaska? (FS 075-98)
Historically Active Volcanoes in Alaska - A Quick Reference (FS 118-00)

California
Volcano Hazards of the Lassen Volcanic National Park Area, CA (FS 022-00)
Eruptions of Lassen Peak, California, 1914 to 1917 (FS 173-98)
How Old is Cinder Cone? Solving a Mystery in Lassen Volcanic National Park, CA (FS 023-00)

Hawaii
Living on Active Volcanoes - the Island of Hawaii (FS 074-97)
Explosive Eruptions at Kilauea Volcano, Hawaii? (FS 132-98)
Volcanic Air Pollution - A Hazard in Hawaii (FS 169-97)
Viewing Hawai`i's Lava Safely - Common Sense is Not Enough (FS 152-00)

Washington
Mount Rainier - Living with Perilous Beauty (FS 065-97)
Mount St. Helens - From the 1980 Eruption to 2000 (FS 036-00)

Non-Park Volcanoes
San Francisco Volcanic Field, Arizona (FS 017-01)
Future Eruptions in California's Long Valley Area - What's Likely? (FS 073-97)
Living With a Restless Caldera - Long Valley, California (FS 108-96)
Invisible CO_2 Gas Killing Trees at Mammoth Mountain, California (FS 172-96)
Scientific Drilling in Long Valley, California - What Will We Learn? (FS 077-98)
Mt. Hood - History and Hazards of Oregon's Most Recently Active Volcano (FS 060-00)
Glacier Peak (WA) - History and Hazards of a Cascades Volcano (FS 058-00)
Mount Baker (WA) - Living with an Active Volcano (FS 059-00)

Volcanoes Abroad
The Cataclysmic 1991 Eruption of Mount Pinatubo, Philippines (FS 113-97)
Lahars of Mount Pinatubo, Philippines (FS 114-97)
Benefits of Volcano Monitoring Far Outweigh Costs - The Case of Mount Pinatubo (FS 115-97)

Appendix 1

VOLCANISM IN NATIONAL PARKS
An NPS-USGS Workshop

26-29 September 2000 in Redding, California, and Lassen Volcanic National Park

TUESDAY, 26 September 2000

Morning Session — Overview of Key Issues. Moderator: Marilyn Parris, NPS

8:30-8:45 Welcome
- Marilyn Parris, Superintendent, Lassen Volcanic NP
- Lindsay McClelland, NPS liaison to USGS, Washington DC
- Marianne Guffanti, Coordinator, USGS Volcano Hazards Program, Reston VA

8:45-9:15 Volcanic hazards & processes in parks — examples from recent eruptions of Kilauea, Mauna Loa, Redoubt, Katmai, Aniakchak, Lassen, St. Helens
- Don Swanson, Scientist-in-Charge, USGS Hawaiian Volcano Observatory
- Willie Scott, Scientist-in-Charge, USGS Cascades Volcano Observatory
- John Eichelberger, Prof. of Volcanology, University of Alaska Fairbanks & Alaska Volcano Observatory

9:15-9:45 Major issues facing the NPS in volcanic parks — resource management, operations, planning, and interpretation
- Jon Jarvis, Superintendent, Mt. Rainier NP & Jay Robinson, Park Ranger, Hawaii Volcanoes NP

9:45-10:15 Discussion

10:15-10:30 Break

10:30-12:00 Rainier Panel — research at a "Decade Volcano," outreach, use of science in general management plans, NEPA process, interpretation, hazard management, etc.
- Chair, Barbara Samora, Park Biologist, Mt. Rainer NP
- Jon Jarvis, Superintendent, Mt. Rainier NP
- Jon Riedel, Park Geologist, North Cascades NP
- Tom Sisson, Geologist, USGS Menlo Park CA
- Carolyn Driedger, Hydrologist, USGS Cascades Volcano Observatory

12:00-1:30 Lunch

Afternoon Session — Planning for & Managing Long-Term Hazards. Moderator: Marianne Guffanti, USGS

1:30-1:45 **Monitoring networks — within Park boundaries and beyond**
- Don Swanson, Scientist-in-Charge, USGS Hawaiian Volcano Observatory
- Tom Murray, Scientist-in-Charge, USGS,Alaska Volcano Observatory

1:45-2:00 **Overview of USGS warning/notification systems**
- Marianne Guffanti, Coordinator, USGS Volcano Hazards Program

2:00-2:30 **Discussion**

2:30-2:45 **Break**

2:45-3:00 **USGS hazard assessments — what they are, what they mean**
- Willie Scott, Scientist-in-Charge, USGS Cascades Volcano Observatory

3:00-3:15 **Incorporating hazard assessments into the NPS planning process**
- Louise Johnson, Chief of Natural Resource Mgt., Lassen Volcanic NP

3:15-3:45 **Discussion**

3:45-4:45 **Panel on dealing with eruptions and unrest crises**
- Don Swanson, Scientist-in-Charge, USGS Hawaiian Volcano Observatory
- Willie Scott, Scientist-in-Charge, USGS Cascades Volcano Observatory
- Terry Keith, Chief Scientist, USGS Volcano Hazards Team, Menlo Park CA

4:45-5:30 **Poster Sessions**

6:00 **Reception**

WEDNESDAY, 27 September 2000 — Field trip through Lassen Volcanic NP

- Led by Mike Clynne and Bob Christiansen of the USGS
- Depart from Red Lion in 2 buses leaving at 7:30 AM and 8:00 AM. Lunches provided.
- Field trip will last approximately 10 hours

THURSDAY, 28 September 2000

Morning Session — Research in Parks. Moderator: Lindsay McClelland, NPS

8:15-8:30 **Role of USGS science in hydrothermal studies**
- Marianne Guffanti, Coordinator, USGS Volcano Hazards Program

8:30-8:45 **Microbial studies in hydrothermal systems**
- Ann Deutch, Research Permit Facilitator, Yellowstone NP

8:45-9:00 **Discussion**

9:00-9:45 **Panel — Focus on Yellowstone**
- Chair, Bob Christiansen, Geologist, USGS Menlo Park, CA
- Bob Smith, Prof. of Geophysics, University of Utah, Salt Lake City
- Paul Doss, Supervisory Geologist, Yellowstone NP
- Nancy Hinman, Geologist, Yellowstone NP
- Linda Young, Assistant Chief of Interpretation, Yellowstone NP

9:45-10:00 **Break**

10:00-10:15 **Vog studies at Kilauea — ecosystem & human health effects of volcanic gases**
- Tamar Elias, Geochemist, USGS Hawaiian Volcano Observatory

10:15-10:30 **Volcanic studies in Alaska**
- Chris Waythomas, Geohydrologist, USGS, Alaska Volcano Observatory

10:30-10:45 **Discussion**

10:45-11:30 **Panel on new research directions in the NPS & USGS and applications to Park issues**
- Chair, Terry Keith, Chief Scientist, USGS Volcano Hazards Team
- Paul Doss, Supervisory Geologist, Yellowstone NP
- Bob Christiansen, Geologist, USGS Menlo Park CA
- Danny Rosenkrans, Geologist, Wrangell-St.Elias NP

11:30-12:15 **Panel on NPS process issues — planning, permitting, wilderness access**
- Chair, Tim Goddard, Computer Specialist, NPS Natural Resource Information Division
- Louise Johnson, Chief of Natural Resource Mgt., Lassen Volcanic NP
- John Eichelberger, University of Alaska & Alaska Volcano Observatory
- Terry Keith, USGS Volcano Hazards Team Chief Scientist
- Rick Potts, NPS Wilderness Steering Committee

12:15-1:45 **Lunch**

Afternoon Session — Effective Interpretation of Volcanic History, Features, Ecosystems, and Unrest.

1:45-2:45 **Group discussion on effective interpretive products and programs for park visitors and managers**
Moderated by Ann Deutch, Yellowstone NP, and Steve Brantley, USGS Hawaiian Volcano Observatory

2:45-3:00 **Break**

3:00-4:00 **Group discussion on effective training of Park staff, including staff safety**
Moderated by Jim Gale, Chief of Interpretation, Hawaii Volcanoes NP, and Michael Clynne, USGS Menlo Park CA

4:00-4:30 **Sub-group composes summary of recommendations; free time for others**

4:30-5:00 **Presentation of recommendations**

FRIDAY, 29 September 2000

Morning Session — Resource Management Issues and Need. Moderators: Marsha Davis, NPS, and Bonnie Murchey, USGS

8:00-9:30 **Large group brainstorming** aimed at identifying and resolving resource management issues and needs related to the effect of human activities on geologic processes and features of volcanic terrain, includes short (3-4 minute) park presentations.

9:30-9:45 **Form breakout groups on identified issues and needs.**

9:45-10:00 **Break**

10:00-12:00 **Breakout groups convene** to develop action plans describing the identified resource management issues and needs and recommending direction for future actions.

12:00-12:30 **Large group reconvenes,** action plans are turned in and breakout groups report on their progress.

12:30 **WORKSHOP ADJOURNS**

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Appendix 2

Geologic Resources Inventory for Lassen Volcanic National Park

A geologic resources inventory session was held on the last day of the workshop in order to (1) discuss and identify the geologic resources of Lassen Volcanic National Park (LAVO); (2) address the status of geologic mapping of the area for future compilation of paper and digital maps; and (3) assess resource management issues and needs, including geologic hazards. Staff from the National Park Service Geologic Resources Division (GRD), LAVO, and USGS attended. GRD has conducted similar sessions at other national parks as part of the NPS Inventory and Monitoring and Geologic Resources Inventory programs. The following summarizes some initial results of the inventory session, including recommendations for additional studies and publications.

USGS scientists Michael Clynne, Patrick Muffler, and Robert Christiansen have conducted geologic mapping of the Lassen Volcanic Center with the objective of publishing a geologic map of LAVO and vicinity at a scale of 1:50,000. The map area encompasses more than 30 USGS 1:24,000 quadrangles. About 98 percent of the field work is completed. Clynne is currently preparing map unit descriptions and correlations, and Patrick Muffler and David Ramsey are assembling a digital database. ArcInfo digital geologic coverages of the quadrangles are available from Ramsey (dramsey@usgs.gov); data in the coverages are for internal use only until they are formally published. At present, no geologic cross sections are included. A few of the quadrangles have been published as USGS Open-File Reports. The 1:50,000 map will be accompanied by a summary (about 10 pages) of the regional geologic setting and evolution.

A more comprehensive geologic summary of the Lassen region is needed by the National Park Service, ideally modeled after USGS Professional Paper 729-G on Yellowstone's volcanic geology (Christiansen, 2001) and USGS Professional Paper 1616 on Wrangell-St. Elias National Park and Preserve, Alaska (Winkler, 2000). Lassen's rich history of geologic exploration should be covered in the publication, and geochronology information should be included.

Good information is available to build the geology portion of the park website. The Workshop field trip guide to the Lassen area could be produced as a USGS Open-File Report and added to the website after internal USGS review. Clynne has produced several USGS fact sheets about Lassen, available from: http://volcanoes.usgs.gov/Products/sproducts.html#fs.

A discussion of volcanic hazards at LAVO and a hazard-zonation illustration are presented in Fact Sheet 022-00 (online at http://wrgis.wr.usgs.gov/fact-sheet/fs022-00/fs022-00.pdf). A new publication on the 1915 eruption and the Chaos Crags area (Christiansen and others, 2001) could be used by multiple land agency managers and stakeholders in the area. In addition to hazards associated with potential future eruptions, geologists noted that Brokeoff Mountain has high potential for landslides; several square miles are already covered by landslide material. Geothermally altered areas also pose an increased risk for rockfalls and landslides. Mudflow hazards were assessed in Marron and Laudon (1986). Debris flows in Lost Creek have contributed sediment that has affected downstream communities. A USGS Open-File report on Lassen's volcanic hazards will be prepared in 2002.

Clynne's database of rock analyses with latitude and longitude coordinates could be incorporated into the LAVO geologic database. Clynne provided a Lassen bibliography to supplement bibliographic data supplied by GRD. Aeromagnetic and gravity databases also exist. Surficial geology and glacial features should be part of a comprehensive geologic database. A glacial mapping initiative was suggested to refine the work of Kane, who mapped some glacial deposits in LAVO. Baseline inventory and monitoring should be a priority for the Bumpass Hell geothermal area and other geothermal areas outside of the park. USGS Known Geothermal Resource Area data would provide initial information. Park staff also expressed interest in a comprehensive soils map. The Natural Resources Conservation Service will conduct a soil survey for the park in 2002. Some soils are known to have high mercury contents.