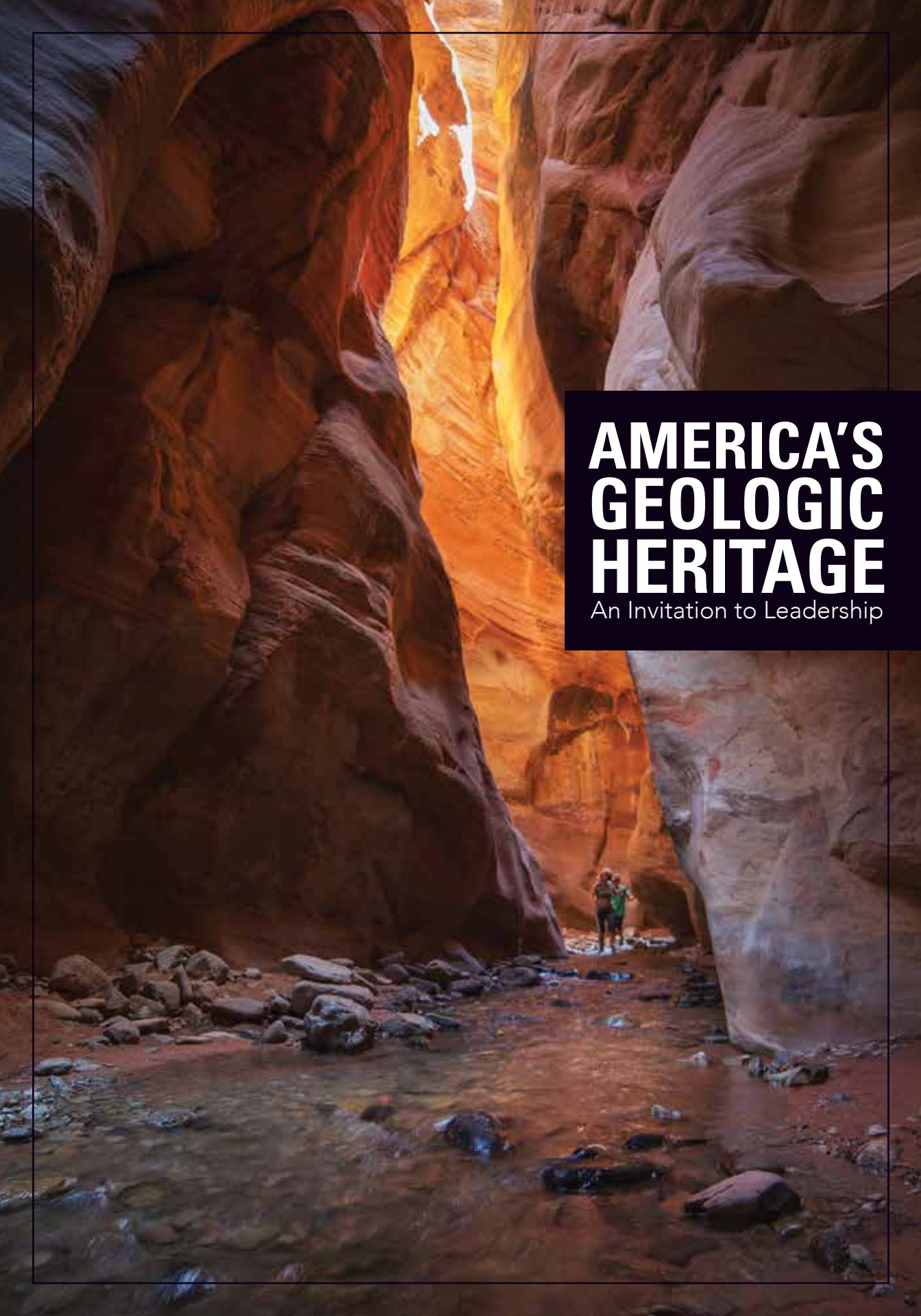

AMERICA'S GEOLOGIC HERITAGE

An Invitation to Leadership

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An Invitation to Leadership

AUGUST 2015

National Park Service, Geologic Resources Division
American Geosciences Institute

CONTENTS

"Here is your country.... Cherish these natural wonders, cherish the natural resources, cherish the history and romance as a sacred heritage, for your children and your children's children."

President Theodore Roosevelt
1903

CHAPTER ONE

Discovering Our Nation's Rich Geologic Heritage

America's geologic heritage arises from the features, landforms, and landscapes characteristic of the United States, which are conserved in consideration of the full range of values that society places on them, so that their lessons and beauty will remain as a legacy for future generations.

America's identity is rooted in our diverse geologic features, incredible landforms, and expansive landscapes. Natural features ranging from a single cave stalactite to an iconic landform like Delicate Arch to entire mountain ranges such as the Sierra Nevada are part of this identity. These striking features, compelling landforms, and quintessential landscapes are all part of what is called America's geologic heritage. For centuries we have explored, contemplated, and even sung about America's "purple mountain majesties" and a country spanning from "sea to shining sea."

Above: Hikers at the world's first national park, Yellowstone.

Experience is also a fundamental component of geologic heritage. We may walk on sandy beaches along the Gulf Coast or look out over sweeping vistas of the Colorado Plateau. We may touch rocks millions of years old in the Appalachians or listen to glaciers calving in Alaska. Every year, hundreds of millions of people travel across the country or even around the world to experience America's geologic heritage. Some trips are quick visits to a local park and others are once-in-a-lifetime journeys.

GEOLOGIC HERITAGE BUZZWORD

Geoheritage is simply an abbreviated form of the term geologic heritage. Many international organizations use it commonly, and its use in the United States is increasing. (Note: Because the prefix "geo" is also used to denote geographical or sustainability-related topics in the United States, this booklet uses geologic heritage throughout.)

Geologic features, landforms, and landscapes command such attention because of how we connect to them. They inspire a sense of awe and wonder, create experiences that we share with our friends and family, and are the subjects of stories, poems, dances, paintings, and sculptures. They are also the sites of bold scientific explorations and discoveries that resulted in historic advances in the earth sciences and continue to kindle the imagination. These connections are the heart of geologic heritage and the reason people have revered and protected special places for future generations to see and experience.

Active participation, personal investment, and knowledge are needed to ensure that significant features, landforms, and landscapes, as well as the stories of their human significance and geologic history are passed on to future generations. Most of the features that comprise our geologic heritage have developed through natural processes over millions of years and are nonrenewable. If damaged or lost, they can never be replaced.

We apply aesthetic, artistic, cultural, ecological, recreational, scientific, economic, and educational values to our geologic heritage. These values allow us to evaluate the significance of different sites, as well as provide a framework for understanding our connections.

Geologic heritage is a relatively new term to some people in the United States. However, here and across the globe, communities have worked to protect geologic heritage resources for many decades. You are invited to take a leadership role in celebrating and conserving the shared geologic heritage that has passed into our care and stewardship. Through formal designations such as parks, preserves, and monuments—as well as by education and other important means—Americans have established a tradition of protecting these special places. Now we all share the responsibility to carry that tradition forward.

Top to bottom: Examining fossils at Great Basin National Park; Tufa spires at Trona Pinnacles National Natural Landmark (BLM); Presenting a program in Bryce Canyon National Park.

AMERICA'S GEOLOGIC HERITAGE

Five Big Ideas of America's geologic heritage are explored in this publication:

- America's geologic landscape is an integral part of our history and cultural identity, and we have a proud tradition of exploring and preserving our geologic heritage;
- America's geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive;
- America's geologic heritage holds abundant values—aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific—for all Americans;
- America's geologic heritage benefits from established conservation methods developed around the world and within the United States; and
- America's geologic heritage engages many communities, and your involvement will ensure its conservation for future generations.

"The entire history of the United States has been shaped by the geological resources and features of the land. The influence of geology is pervasive throughout American history."

Dr. Harry A. Butowsky
NPS Historian
1990

CHAPTER TWO

Building an American Geologic Conservation Legacy

Human history is connected to local geologic landscapes and resources, and geologic heritage is an integral part of cultural identities around the world. This chapter introduces those connections in America and provides a brief history of how Americans explored their country's geologic landscape and began to preserve portions of America's geologic heritage for future generations.

CREATION STORIES AND CONNECTIONS TO THE LANDSCAPE

For thousands of years, American Indian cultures across the continent established religious and spiritual practices connected to particular landscapes and geologic features. Many of these practices celebrated human connections to the rest of the natural world and incorporated oral traditions of creation for both people and places. For example, the Klamath Indians of southern Oregon tell stories about the 7,700-year-old caldera-forming eruption of Mount Mazama in Oregon—in what is now Crater Lake National Park. Those stories include fiery conflict between the spirit of the mountain and the spirit of the sky leading to the banishment of the spirit of the mountain to the core of Mount Mazama. Numerous sacred places were worshipped and honored through traditions passed down over generations. These are some of the earliest examples of American geologic heritage values. Chapter 4 discusses these and other values associated with geologic heritage.

Above: Petroglyphs at McKee Springs in Lava Beds National Monument.

THE UNITED STATES REACHES WESTWARD

When Europeans arrived in the "New World," they established colonies along the east coast of the continent. Colonists began to utilize the same natural resources that had been central to American Indian cultures for millennia. The American identity of rugged individualism was born out of the challenges and opportunities posed by the vast American landscape. Much of the lure of the Americas resided in the economic and social opportunities that the diverse geologic landscape provided. Chapter 3 provides more information about the geologic history

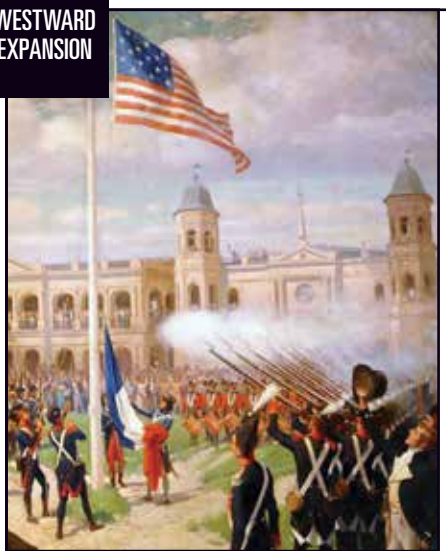
and processes that created these uniquely American landscapes.

Soon after the founding of the United States of America, the country was already looking beyond its borders and charting a course to span the breadth of the continent from the Atlantic Ocean to the Pacific Ocean. The country needed organized efforts to explore and incorporate the western "frontier." The Northwest Ordinance of 1787 facilitated the addition of new states into the young nation from the existing territories of the Ohio River Valley. About the same time, the Public Land Survey System was formed to efficiently administer private property claims. The nation effectively doubled in size with the Louisiana Purchase of 1803, which encompassed most of the Mississippi River Valley from the delta at New Orleans to the headwaters near the Great Lakes and west to the Rocky Mountains. Americans eventually came to view their expansion across the continent as Manifest Destiny.

In the months leading up to the Louisiana Purchase, President Thomas Jefferson laid the foundation for the Corps of Discovery—to be led by Meriwether Lewis and William Clark—and tasked them to explore and document the newly acquired lands. Jefferson's instructions were to "explore the Missouri River, and such principal stream of it, as, by [its] course and communication with the waters of the Pacific Ocean… [that] may offer the most direct and practicable water communication across this continent for the purposes of commerce." Although the primary goal was to find a water route to the Pacific Ocean and establish trade along the route, the Corps was also tasked with describing various components of the vast area's geologic resources including

Top to bottom: The Corps of Discovery reached the Oregon coast in November 1805; Lewis and Clark gave Jefferson Peace Medals as "gifts"; National Historic Trail logo.

WESTWARD EXPANSION



Raising of the U.S. flag in New Orleans upon completion of the Louisiana Purchase.

The Louisiana Purchase of 1803—the single most significant act of westward expansion in U.S. history—roughly doubled the size of the nation by authorizing the purchase of more than 800,000 square miles of French-held territory between the Mississippi River and the Rocky Mountains. This purchase added a vast expanse of land with untold resources, provided uninterrupted commerce on the Mississippi River, and ensured access to the major southern port city of New Orleans—all of which helped to advance the young nation as an emergent global power.

"the soil and face of the country," "mineral productions of every kind," and even "volcanic appearances." The Corps of Discovery embarked on their journey in May 1804 after the treaty formalizing the Louisiana Purchase was signed in late 1803.

A NEW ERA OF GEOLOGICAL EXPLORATION

These early explorers set a standard that would be followed by subsequent survey teams dispatched throughout the 19th century. Shortly after the American Civil War, the rapidly growing population of the United States and the expansion of industry were taxing the nation's known natural resources. By the late 1860s, the General Lands Office noted that "proper development of the geological characteristics and mineral wealth of the country was a matter of the highest concern to [the American] people." In 1867, Congress for the first time authorized explorations in which geologic study would be the principal objective. One exploration would study the geology and natural resources along the route of the Transcontinental Railroad, and another would conduct a geological survey of the natural resources of the new state of Nebraska. These multi-year surveys also included other scientists, cartographers, artists, and photographers to document and map their findings.

The surveys ushered in a new era of geologically focused, federally funded explorers. Clarence King—later named as the first director of the newly formed U.S. Geological Survey—led the survey along the Transcontinental Railroad. Ferdinand V. Hayden led the geographic and geologic surveys into the future states of Nebraska, Missouri, Colorado, and Wyoming. That survey included the first scientific descriptions and grand artistic depictions of what would become Yellowstone National Park. John Wesley Powell, perhaps the most famous of this generation of explorers, was a Civil War veteran and geology professor from Illinois. During 1867 and 1868, his expeditions ventured down the Green and Colorado rivers. Powell's expeditions scouted and searched for an efficient north-south route across the Great Basin and Colorado Plateau. In 1869, Congress funded a second

Above: Grand Canyon at the foot of the Toroweap, looking east, 1882.

expedition, again led by Powell down the Colorado River and through the Grand Canyon. The one-armed geologist made detailed, often captivating field notes and observations, apprising Congress of the beauty of the Colorado Plateau and in particular the Grand Canyon. Between 1869 and 1879, George M. Wheeler surveyed the area south of the Central Pacific Railroad in what is now west Texas, New Mexico, Colorado, Arizona, Utah, Nevada, and southern California.

The contributions of trailblazers such as King, Hayden, Powell, and Wheeler elevated geology as a science. This carefully planned succession of cartographic and geologic explorations fostered a deeper understanding of the western frontier and its natural resources. Survey expeditions of the continental interior established routes of travel for settlers and railroads and were even relevant for the national interstate highway system a century later. These surveys also identified unusual and unique landscapes and geological features that are now recognized as major components of America's geologic heritage.

In addition to the scientific surveys of the west, the late 1800s were a time of rapid westward migration from the eastern colonial core of the United States. Some people ventured west to stake claims over the mineral wealth—silver and gold

GEOLOGIC HERITAGE IN ART

Thomas Moran painting The Grand Canyon of the Yellowstone, *1872.*

Thomas Moran painted landscapes as part of the 1871 Hayden Survey. His famous painting of Yellowstone Falls, which hung at the U.S. Capitol, was instrumental in connecting Congress to the unique beauty of the area and likely facilitated the establishment of the "Headwaters of the Yellowstone River" as a national park. The visual representation of geologic heritage was, and remains, a powerful endorsement for Yellowstone National Park and a prime example of the aesthetic and artistic values of geologic heritage. Learn more about the many values associated with geologic heritage in Chapter 4 of this publication.

rushes—afforded by the geologic history of the Rocky Mountains and Sierra Nevada Mountains. Others traveled west in search of new beginnings as farmers and ranchers lured by the opportunities of cheap or free land on the Great Plains. Such endeavors were facilitated by various Homestead Acts that provided a means to purchase and "improve" federal lands. The completion of the first Transcontinental Railroad in 1869 further opened access to the geologic landscape and resources across the United States. The General Mining Act of 1872 supported mining geologic resources on federal lands.

CALLS FOR PRESERVATION OF AMERICA'S GEOLOGIC HERITAGE

Through the geologic surveys and studies of the west, Americans were learning that geologic features were extraordinary components of the American landscape that provided insights into Earth history. They also realized that those resources were highly sought after and being exploited to fuel the industry and economy of the nation. Conservationists began to call for preservation of some of the country's most beautiful places. Although they did not use the term geologic heritage, their efforts were some of the first steps in that direction. The renowned naturalist and author John Muir (1838-1914) wrote passionately about the splendor of the Yosemite Valley and why it needed to be shielded from development and privatization. His efforts were instrumental with regard to the federal government's first large-scale effort concerning natural landscape preservation, when the Yosemite Grant deeded portions of the Sierra Nevada Mountains, including the Yosemite Valley, to the State of California in 1864. The act stated the "premises shall be held for public use, resort, and recreation." This grant set a national and international precedent for preservation of public lands as parks. Yosemite would become a federally managed national park in 1890.

Yellowstone was established as the first true national park in 1872 when Congress decreed areas in the Wyoming and Montana territories would be "set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people." The Yellowstone Act also outlined the level of preservation and protection of the new national park, stating that "regulations shall provide for

Above: Joining tracks on the transcontinental railroad, Promontory Summit, Utah Territory, 1869.

the preservation, from injury or spoliation, of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition." The natural curiosities and wonders of the park include the world's largest collection of geysers, more than half of all the geysers on the planet. This act was a landmark moment in the history of geologic heritage conservation because it included language that the park was both for "the people" and for the preservation of the park's globally significant features. It was the first time that Americans, through their elected representatives, recognized the values of a scenic geologic wonder and legally protected it, in its natural state, as part of the federal government. This milestone would prove to be the birth of a proud tradition of securing federal protections for hundreds of geologic features on public lands.

GUARDING A VULNERABLE HERITAGE

With limited legal, financial, and personnel resources, the United States found it difficult to manage these parks and to protect the resources to the extent outlined by Congress. The U.S. Army became critical to the management of parks and enforcement of regulations during the late 1800s and early 1900s. Nevertheless, concern continued to grow about the condition of America's natural and cultural heritage. The United States government codified efforts to safeguard national treasures via the Antiquities Act of 1906, which was signed into law by President Theodore Roosevelt. The act outlined penalties for "appropriating, excavating, injuring, or destroying any historic or prehistoric ruin or monument, or any object of antiquity, situated on lands owned or controlled by the Government of the United States." It also gave the president authority to set aside "historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the Government of the United States to be national monuments." Geologic features and landscapes were recognized as

Above: Theodore Roosevelt and John Muir at Yosemite Valley in 1903. Below: Soldiers on parade grounds at Yellowstone National Park.

objects of antiquity and scientific interest. In fact, Roosevelt established Devils Tower National Monument in Wyoming as the first national monument under the Antiquities Act in 1906. Devils Tower is a geological marvel, a prime example of an igneous intrusion of magma (molten material) that crystallized into a mass of columns, now exposed through erosion and towering nearly 900 feet above its base. Its story also reflects generations of cultural significance. The tower is revered by multiple American Indian nations and is central to many stories. One tells of an enormous bear chasing people to the stump of a great tree. As the tree then rose into the air, the bear scored the sides with its claws while the tower pushed upwards to the stars. Devils Tower illustrates how a geologic feature holds different values for different Americans.

In the early 1900s, the creation of national monuments and additional national parks led to a need for a centralized agency to manage these protected areas. Congress created the National Park Service in 1916 with a mandate to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The National Park Service Organic Act thus included many aspects of geologic heritage, from the landscape ("scenery") to specific geologic features ("natural objects"), as well as ensured they would be passed on to future generations. The National Park Service thus became the principal steward of much of America's geologic heritage. At its very beginning, the National Park Service recognized the importance of geology and geologic heritage to its mission. In 1917, Robert Sterling Yard, then chief of the National Park Service Education Division, stated, "geology is the anatomy of scenery," and "we base all our studies of national parks upon geology as the foundation. I believe that this idea must become the basis of any educational system which aims to make the parks useful to the people of the United States." Many other federal agencies,

Above: Devils Tower was the first site to be proclaimed a national monument under the Antiquities Act.

including the Bureau of Land Management, Forest Service, and Fish and Wildlife Service, in addition to state and local governments, also manage exceptional examples of America's geologic heritage. Surely, there is a geologic heritage site near you!

ADDITIONAL PROTECTIONS FOR AMERICA'S NATURAL RESOURCES

Americans took an unprecedented interest in protecting the natural environment and the ideals of heritage conservation in the 1960s with a wave of cultural and legislative changes. The National Natural Landmarks (NNL) Program, established in 1962 by Secretary of the Interior Stewart Udall, recognized sites of outstanding geological and biological value at the national level and further expanded the number of recognized geologically significant sites. NNLs are different from parks and monuments in that they could be owned federally, by a state or local community, or even privately. The Secretary of the Interior designated 138 NNLs in the 1960s—a number that has grown to nearly 600 sites.

Decades of development of national parks afforded unparalleled access via roads, lodges, visitor centers, and other accommodations to the nation's premiere geologic heritage sites. In 1964, the Wilderness Act ensured that "expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition." The legislation established the National Wilderness Preservation System to guarantee that certain places would remain

Below: Death Valley rangers mapping in Golden Canyon during the 1930s.

wild, and untrammeled by man. Unlike other public lands that featured extensive internal developments or multiple uses, these places would be free of permanent human structures and vehicles. Today, more than 750 wilderness areas, which cover nearly 110 million acres or about 5% of land, have been designated in the United States.

The United States sponsored, and was the first nation to ratify, the World Heritage Convention of 1972. This landmark agreement is the most widely accepted international conservation treaty in history. Of the 22 World Heritage sites in the United States, 16 exhibit outstanding geologic resources, and most are also units of the National Park System. Examples of these include the greatest volcanic mass on Earth (Mauna Loa) in Hawai'i Volcanoes National Park and the world's longest cave (at over 400 miles in length) at Mammoth Cave National Park.

Above: Cave features such as these at Carlsbad Caverns National Park are protected by federal law.

The 1960s and 1970s also saw passage of the Clean Water Act and Clean Air Act and the establishment of the Environmental Protection Agency to provide for healthier ecosystems and safeguard human health. In recent years, Americans have demonstrated a greater recognition of the interconnectedness of natural systems, embraced broader ecological concerns, and taken action to conserve our shared geologic heritage. The Federal Cave Resources Protection Act of 1988, for

GEOLOGIC HERITAGE BUZZWORD

Geoconservation is the application of management techniques to protect and conserve geologic heritage sites and collections.

example, provided for protection of caves and cave resources on most federal lands. Likewise, the Paleontological Resources Preservation Act of 2009 established a number of significant fossil resource protections. Under these laws, the Departments of Interior and Agriculture employ scientific expertise and principles in managing caves and fossils on the federal lands they administer. Also in 2009, Congress established America's first national geologic trail, officially designated as the Ice Age Floods National Geologic Trail. This geologic trail showcases the outstanding post-glacial landforms and geologic features from glacial lake outburst floods preserved in the Columbia River drainage basin of Montana, Idaho, Washington, and Oregon. The establishment of this trail provided one model for future geologic heritage preservation and multi-agency partnerships. At the same time, the National Landscape Conservation System Act formalized a preservation mandate for the Bureau of Land Management to unify management of its designated National Conservation Lands. As a result, areas described as some of the West's most spectacular landscapes—landscapes of the American spirit—are being managed and protected for future generations.

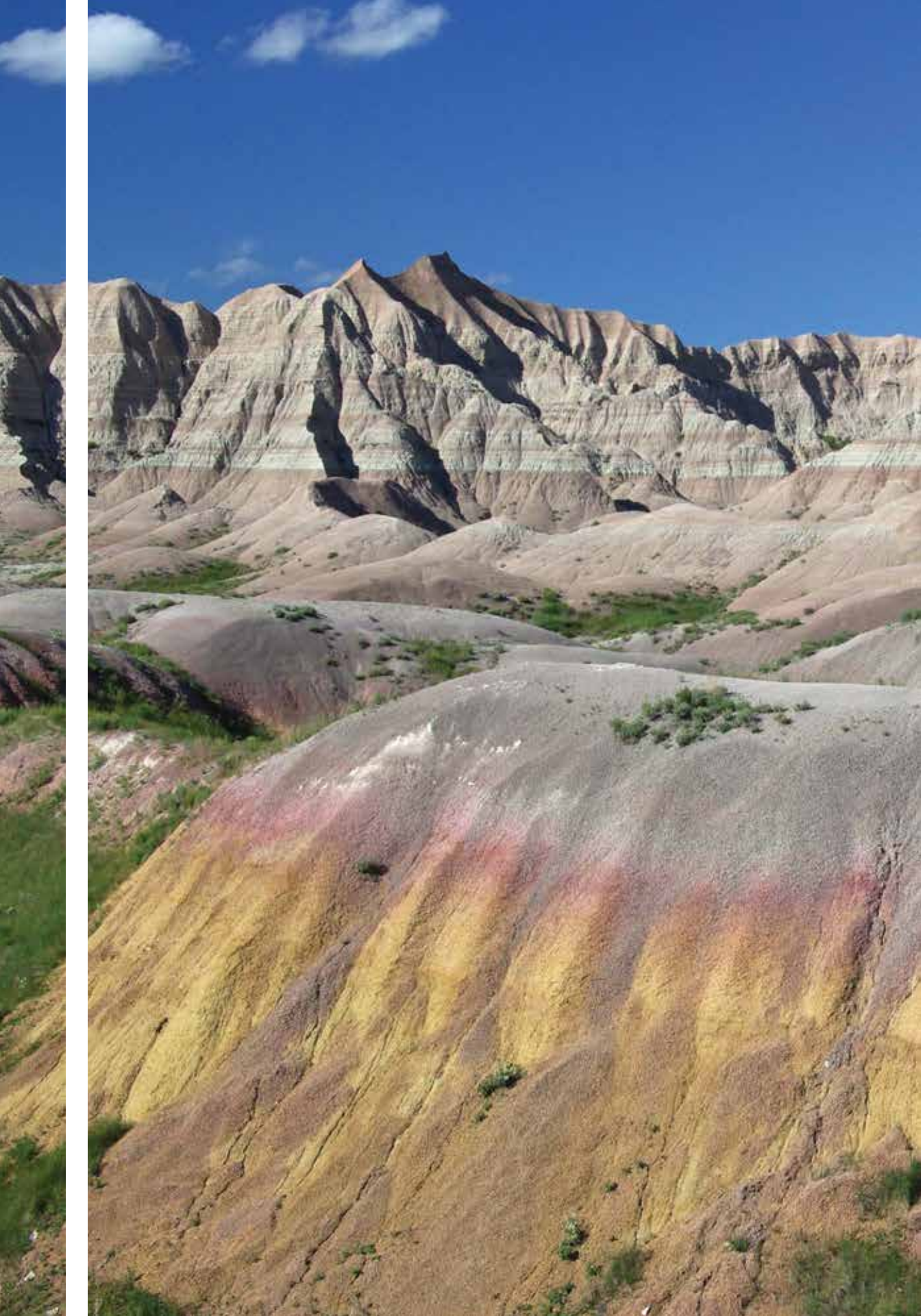
These are just a few of the more critical turning points when America has benefited from public recognition of the importance of geologic heritage. Today, we continue this long tradition of exploration, documentation, recognition, and conservation of our shared geologic heritage because many iconic geologic landscapes are still at risk. As development pressures continue to push into special places, individuals and groups work diligently to preserve the geologic heritage they value for future generations.

CASE STUDY

Fossilized wasp, Florissant Fossil Beds National Monument

Defenders of Florissant

Preserving geologic heritage does not always start with governmental protection. Grassroots efforts from concerned citizens can play critical roles. The fight to save Colorado's Florissant Fossil Beds from real estate development is one such example that culminated in a landmark legal case for the geologic heritage movement in the United States. In response to a plan to build houses atop one of the world's most important fossil sites, a grassroots coalition—the Defenders of Florissant—secured a restraining order to prevent the housing development. Argued in the Federal District Court in Denver, the case ultimately was won by the Defenders of Florissant. Florissant Fossil Beds National Monument was subsequently established in 1969 and remains among the richest and most diverse fossil sites on the planet. For more on this story, read *Saved in Time: The Fight to Establish Florissant Fossil Beds National Monument, Colorado* by Estella Leopold and Herbert Meyer, University of New Mexico Press, 2012.



"Earth processes that seem trivially slow in human time can accomplish stunning work in geologic time."

Keith Meldahl
Author and Professor
2011

CHAPTER THREE

Understanding Our Country's Geologic Heritage

The rich diversity of geologic heritage features in the United States results from a wide variety of geologic processes occurring over billions of years. This chapter discusses the role that the science of geology plays in understanding and describing the features and processes that comprise our nation's geologic heritage. It is an introduction to some of the regional-scale features and processes that may be found near you.

SCIENCE INFORMS GEOLOGIC HERITAGE

Science is a method of explaining features and processes through observation of the natural world. It is a way of thinking, organizing knowledge, gaining new insights, and understanding our world. Science progresses through observation and analysis, trial and error, and identifying patterns.

Geology is the scientific discipline dedicated to understanding the physical features and processes of Earth, as well as the history of the planet and its inhabitants since its origin. Therefore, geologic knowledge is key to understanding the processes that formed our geologic heritage features. It provides lessons from the past that are applicable today on our changing planet.

Above: First light on Turret Arch at Arches National Park.

One of the core concepts of geology is that "the present is the key to the past." This means that the processes that shape Earth today can be inferred to be the same processes responsible for the features preserved in the rock record. The sequence of beaches, coral reefs, and deep-water marine muds off the modern East Coast of the United States are similar to those preserved in the Paleozoic-aged (about 541 million to 252 million years ago) sandstones, limestones, and shales of the Grand Canyon. Geologists can thus infer that the Paleozoic rocks of the Grand Canyon were deposited hundreds of millions of years ago in a setting comparable to the East Coast of the United States.

The rock record provides information about Earth's history, formation, and processes. Geologists use this information to make predictions of the frequency and magnitude

GEOLOGIC HERITAGE BUZZWORD

Geodiversity refers to the existence of a wide variety of different geologic forms and processes within a specific geographic region. Geodiversity is similar to biodiversity (the variety of life-forms in a region). Maintaining a wide diversity of geologic habitats and systems is vital to life on Earth.

of geologic hazards. For example, ash layers, landslide deposits, and faults are evidence of volcanic activity, slope movements, and earthquakes. The rock and fossil record also has provided almost everything we know about the evolution of life on Earth. Fossils provide our only record of animal and plant evolution, migration, or extinction, including those related to previous climate changes. This record is particularly important as our climate continues to change.

AMERICA'S GEOLOGIC DIVERSITY YIELDS A RICH HERITAGE

The American landscape of mountains, plateaus, plains, volcanoes, glaciers, canyons, and beaches is one of the most diverse on Earth. The term geodiversity encompasses the full range of these landforms; the rocks, minerals, fossils, and soils that comprise them; the processes that created them; and their relationships to other Earth systems. In the natural world, geodiversity directly influences the distribution of plants and animals. A large part of our national identity and even our economy depends on the diversity of landscapes and geologic resources in the United States. Because of the richness of our geodiversity, we have the opportunity to conserve a wide variety of sites and collections as our geologic heritage for future generations.

PLATE TECTONICS BUILT THE FOUNDATION OF AMERICA

Plate tectonic and erosional processes that have been occurring for billions of years are largely responsible for the wealth of geodiversity in America. The theory of plate tectonics revolutionized the science of geology in the 1960s because it described global-scale mechanisms for creating continental landmasses and oceans—Earth's most massive features. Earth's crust is broken up into rigid plates that move above warmer and deformable material underlying the crust. No matter where you are on Earth, sea or land, you are on one of the tectonic plates. The plates are comprised of continental crust, oceanic crust, or a combination of the two. The North American Plate contains both types. Its continental

GEOLOGY BASICS

A Basic Understanding of the fundamentals of geology enhances your appreciation of geologic heritage sites and scenic vistas of the American landscape. Great information is available via websites such as:

- U.S. Geological Survey | www.usgs.gov/start_with_science
- NPS Geologic Education | http://go.nps.gov/geoeducation
- Earth Science Literacy Initiative | www.earthscienceliteracy.org

crust underlies nearly all of the lower 48 United States and Alaska and most of its oceanic crust is beneath the western half of the North Atlantic Ocean. All of the United States is on the North American Plate except for Hawaii and a sliver of western California—west of the San Andreas Fault—which are on the Pacific Plate.

According to plate tectonics, enormous Earth features such as continents, ocean basins, and mountain ranges result from interactions at the boundaries of plates. Plates collide with each other at convergent boundaries, are pulled apart at divergent boundaries, and slide past each other at transform boundaries. Rugged topography, deformed rocks, and earthquakes result from all three. Volcanoes are typical of convergent and divergent boundaries. All three plate boundary processes are present in the United States today. In addition, tectonic features called hot spots—stationary plumes of hot mantle material not associated with a plate boundary—exist in both Wyoming and Hawaii. The area far from the North American plate's boundaries is the stable interior or craton. All of these have contributed to assembling and shaping North America over the last 4.5 billion years. This diversity of processes created the geodiversity of America and is a significant aspect of our geologic heritage.

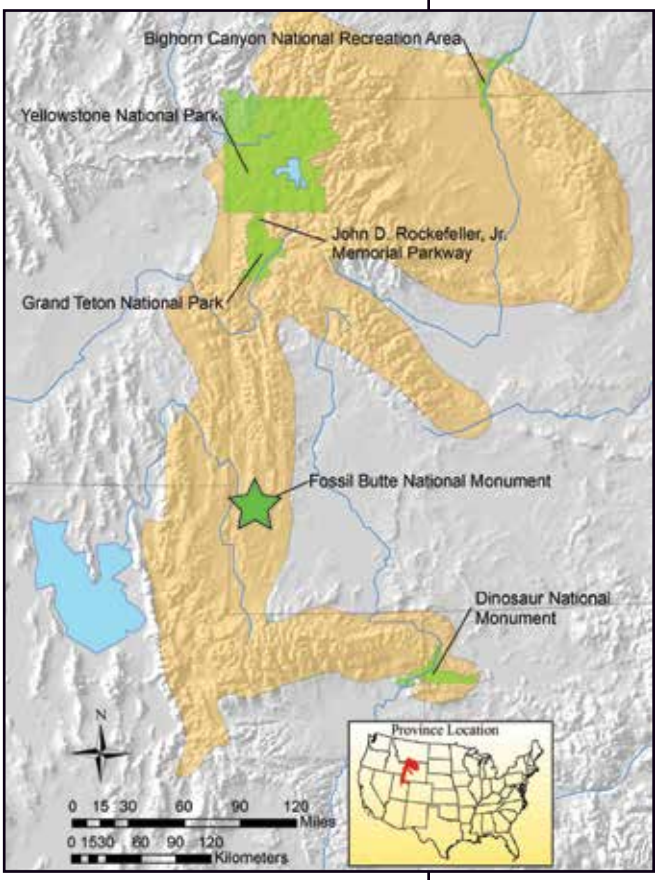
Above: At Point Reyes National Seashore, an active plate boundary and wave action create a craggy coastline.

Plate tectonics built the foundation of America. However, our modern landscape is not just the result of plate tectonics; it has also been modified by other active Earth processes. The sculpted landscapes we experience today were shaped by water, wind, gravity, ice, and time—the common agents of erosion. The combination of all these processes gives different parts of our country distinct and recognizable geologic characteristics.

GEOLOGIC FEATURES

The United States of America contains a spectacular array of geologic features that characterize the landscapes of our physiographic divisions and comprise our geologic heritage. While some, like mountains and volcanoes, were created

Geologic Heritage Resources Come in All Sizes

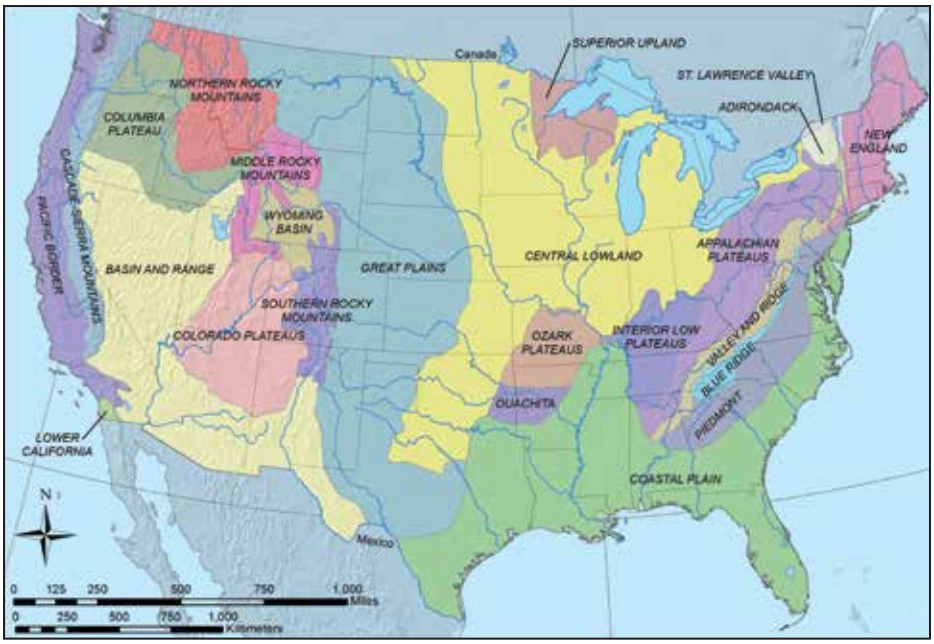


The amazing diversity of America's geologic features occurs at many scales. Mineral specimens, sand dunes, beaches, lava flows, karst landscapes, fossils, faults, and many more features contribute to our geodiversity. Protecting examples, from regional-scale to the microscopic, is important to the future of America's geologic heritage. An example of this can be seen at Fossil Butte National Monument in Wyoming, where individual fossils such as the 52 million-year-old *Knightia eocaena* fish include microscopic details that aid in their identification and contribute to their scientific significance and beauty. Different fossil specimens found together at an outcrop of rocks provide information about the ancient community of plants and other animals preserved there. The outcrops of Fossil Butte National Monument are found on the prominent landforms Cundick Ridge and Fossil Butte within the park. These landforms are part of the larger landscape—a high desert basin—amid the fold and thrust belts of the middle Rocky Mountain physiographic province.

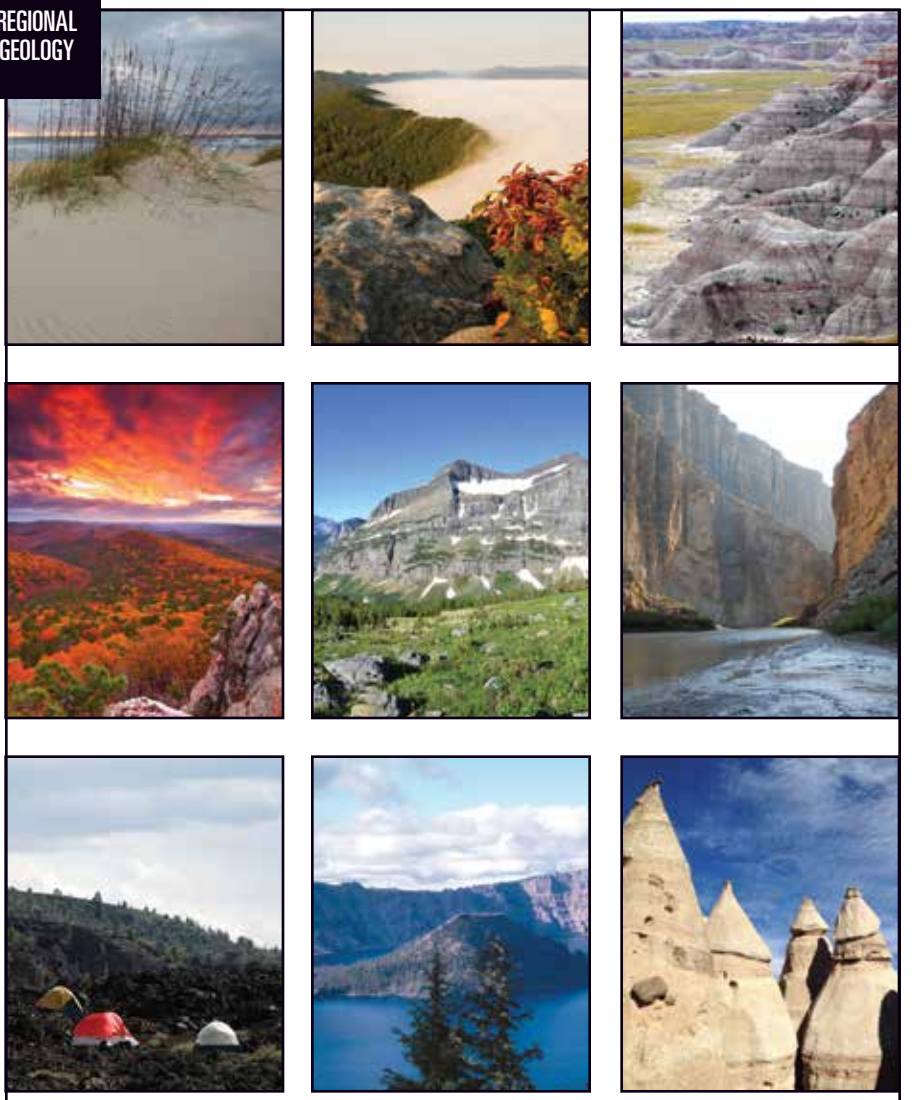
directly by plate tectonics, others are smaller-scale features connected to more localized events. All have stories to tell. The online resources offered by state geological surveys and public land agencies (see list of resources at the end of this publication) are great places to start learning about the natural features near you, such as:

- Beaches
- Caves
- Elements, minerals, and rocks
- Energy and economic resources
- Fossils
- Geysers, hot springs
- Glaciers
- Historic mines
- Karst landscapes
- Mountains and plains
- Rivers systems
- Soils
- Volcanoes
- Wind-blown landforms such as dunes

Above: Jointed granite at Joshua Tree National Park. Below: Map of physiographic provinces of lower 48 United States.



REGIONAL GEOLOGY



Geology in Your "Back Yard"

Every place in America is part of a physiographic province and has its own geologic characteristics that are a part of your local geologic heritage. Taking into account the landscape, rock type, geologic structure, and history (including plate tectonics), geologists divided the North American continent into eight major physiographic divisions. In the lower 48 states, these eight major divisions have been further differentiated into 25 provinces and then into dozens of sections.

You can learn more about the geologic and physiographic characteristics of where you live by visiting: http://go.nps.gov/regionalgeology.

"Everybody needs beauty as well as bread,
places to play in and pray in,
where nature may heal and give
strength to body and soul."

John Muir
Author, Naturalist, and Conservationist
1912

CHAPTER FOUR

Valuing America's Geologic Heritage in Many Ways

In previous chapters, we have explored the scientific foundation for America's geodiversity and its geologic heritage, and summarized some of the early attempts to recognize, understand, and conserve our geologic heritage. Next, we explore the values that our geologic heritage holds, regardless of social, ethnic, religious, economic, or educational background. Americans have recognized a portion of our shared geologic heritage by formally designating national park units at significant sites such as Badlands National Park, Acadia National Park, Big Bend National Park, and Santa Monica Mountains National Recreation Area. We celebrate and safeguard thousands of other undesignated geologic features and locations in many ways. We choose to conserve and protect examples of our geologic heritage for ourselves and future generations, because they are meaningful to us in specific ways.

In this chapter, we discuss eight of the many values, both tangible and intangible, that can be described and used to define the societal significance of geologic heritage sites. Our geologic heritage holds tremendous aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific value. These values allow us to evaluate the significance of different sites, as well as provide a framework for understanding our connections.

Above: A hiker pauses to take in the view from McAfee's Knob on the Appalachian Trail.

GEOLOGIC HERITAGE BUZZWORD

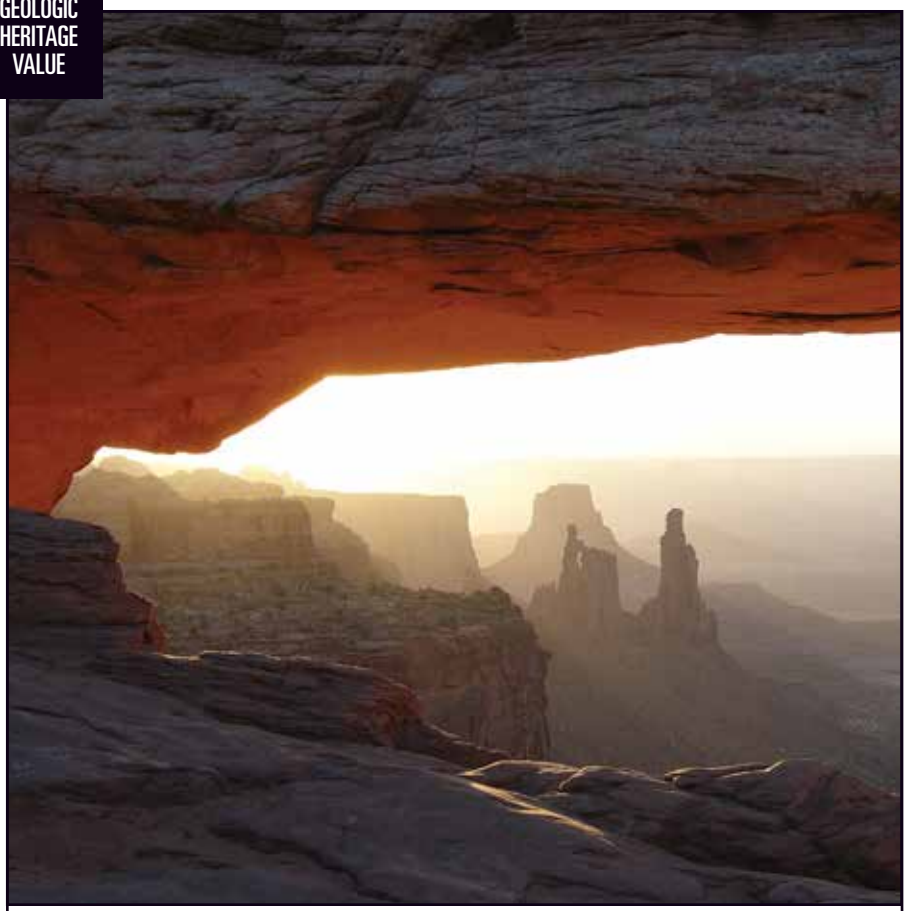
Geologic Heritage Values

You can learn more about the full value of geologic heritage sites and other protected areas by visiting: http://go.nps.gov/geoheritagevalues.

AESTHETIC VALUE

One of the best ways to appreciate the beauty of our geologic heritage is by viewing and experiencing it firsthand. Generations of Americans have ventured to our parks, monuments, and other geologic heritage areas to be inspired by the natural beauty, often simply termed its "scenery." The National Park Service Organic Act of 1916 specifically calls for the National Park Service to "conserve the scenery" for the "enjoyment of future generations." The geologic history of America has created a spectacular geodiversity—landscapes the likes of which, in many cases, are found nowhere else on the planet. From hikers, hunters, and vacationers, to artists, poets, and musicians, many people find meaning and inspiration in the strikingly beautiful features of our geologic heritage.

GEOLOGIC HERITAGE VALUE



View from Mesa Arch at sunrise in Canyonlands National Park.

Aesthetic Value at a Glance

Geologic heritage sites offer aesthetic value by:

- Provoking feelings of inspiration, awe, and humility;
- Serving as settings for memorable life events and community gatherings; and
- Providing opportunities for tourism and enjoyment of natural beauty.

ARTISTIC VALUE

A grand vista, such as the view from Skyline Drive in Shenandoah National Park, can kindle a sense of wonder and stimulate the imagination. As described in Chapter 2, Thomas Moran's painting of the Grand Canyon of the Yellowstone harnessed that intangible connection to the aesthetic value of the Yellowstone region to help establish the world's first national park. People find inspiration in nature, and geologic sites provide a source of the intellectual impulse for art, invention, and creative problem-solving. Some national parks and other geologic heritage areas have Artist-in-Residence programs to provide artists with unique opportunities to create works of art inspired by the scenery and to share their work with the public.

CULTURAL VALUE

Human culture is connected to local geologic landscapes. These connections are clearly evident in patterns of development that take advantage of the geologic landscape and resources. Deep connections are also clear from our cultural stories, art, songs, poems, traditions, and ceremonies that feature or celebrate American landscapes. Significant geologic heritage sites add cultural value when they provide a scenic setting for celebrations, weddings, family reunions, vacations, spiritual reflection, and other shared experiences.

GEOLOGIC HERITAGE VALUE

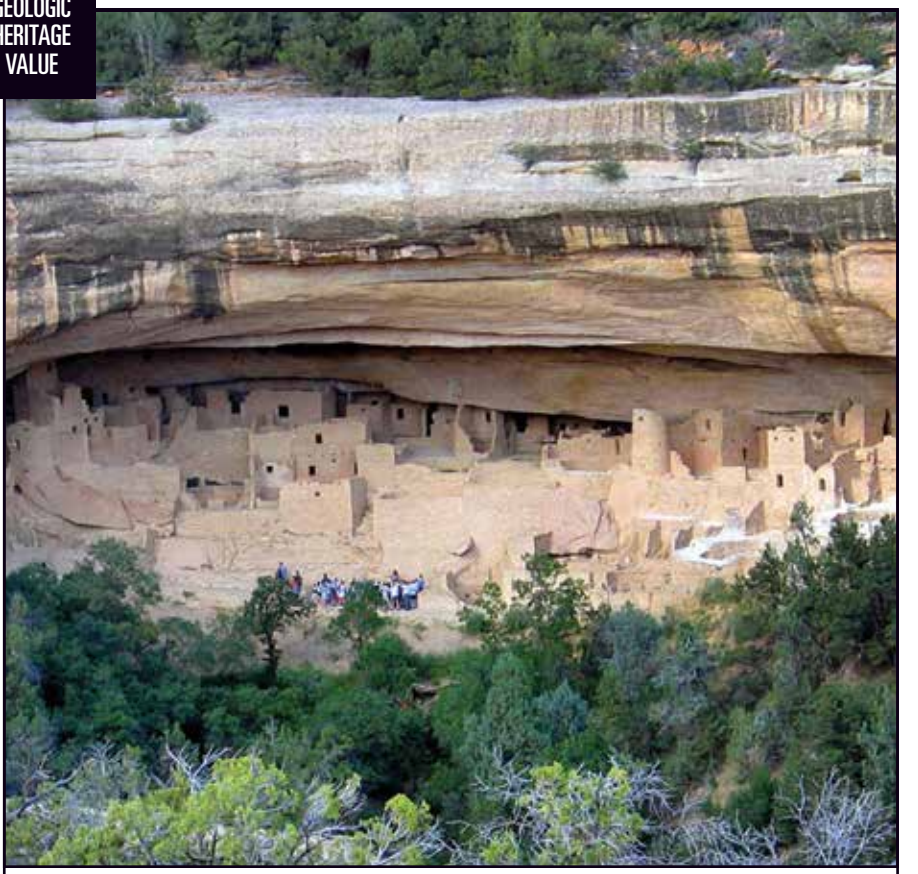
Artist-in-Residence paints in Arches National Park. For more information, see www.nps.gov/subjects/arts/air.htm

Artistic Value at a Glance

Geologic heritage sites offer artistic value by:

- Inspiring awe and fueling creative expression through the arts; and
- Promoting conservation through artistic appreciation of natural landscapes.

GEOLOGIC HERITAGE VALUE



View of Cliff Palace, Mesa Verde National Park.

Cultural Value at a Glance

Geologic heritage sites conserve cultural value by:

- Helping people identify with their communities' unique geologic places, as well as their connections to regional or even global landscapes and stories;
- Highlighting the human stories connected with geologic landscapes;
- Providing a communal reference for stories, music, and other arts and social practices; and
- Protecting natural places deemed sacred and inspirational, perhaps as destinations for personal exploration or pilgrimage or as monuments to previous cultures.

GEOLOGIC HERITAGE BUZZWORD

Geotourism is the term used internationally for the practice of hosting visitors at natural areas specifically to enjoy geologic features and processes. Many communities around the world are sustained by geotourism.

ECOLOGICAL VALUE

Four major systems—the geosphere (solid Earth), hydrosphere (water), atmosphere (air), and biosphere (living organisms)—interact to create Earth's ecosystems. Surficial geology is the interface with soil, water, and air that creates the diverse platform on which living things exist. Natural geologic heritage areas conserve not just the geologic foundation, but also places for ecosystem processes and change to occur. Conserving a variety of geologic heritage sites across an assortment of ecosystems maximizes natural area diversity. These intact ecosystems are more resilient and able to adapt to changes.

ECONOMIC VALUE

Geologic heritage sites are valuable components of local and national economies. Tourism to sites creates needs for travel, lodging, food service, and other hospitality and recreation-based businesses in local communities. In 2013, more than 273 million visitors to all National Park Service areas spent more than $14.6 billion in communities near these sites, supporting nearly 200,000 local jobs and contributing $26.5 billion

GEOLOGIC HERITAGE VALUE

Scientist points out larvae living among river cobbles in Rocky Mountain National Park.

Ecological Value at a Glance

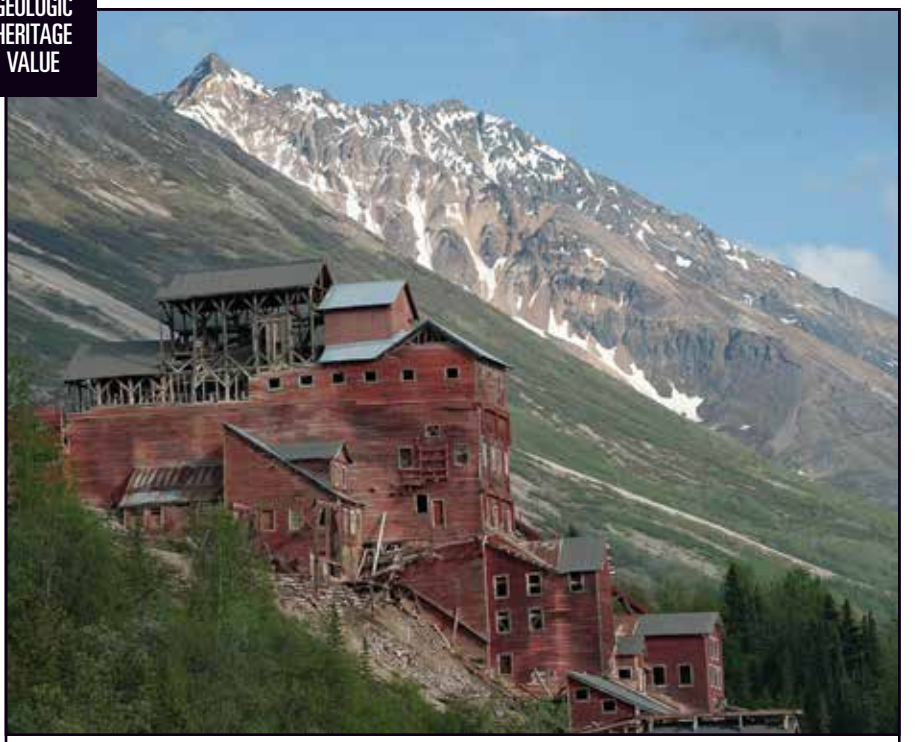
Conserving geologic heritage enhances ecological value by:

- Supporting a diversity of ecosystem services such as groundwater retention, nutrient reservoir, and carbon supply and sequestration; and
- Conserving portions of the geosphere and the linked portions of the other spheres in a natural state to maximize their resilience on a changing planet.

to the economy of the United States (see Cullinane Thomas et al. 2014). The federal budget for the National Park Service is about $2.7 billion, meaning that every dollar invested in the national parks by taxpayers creates nearly $10 in economic activity.

Geologic heritage sites may also have direct economic value associated with their past or present geologic resources (precious metals such as gold and silver) and energy resources (coal, oil, and natural gas). Abandoned mineral lands represent one type of geologic heritage feature originally valued primarily for economic opportunities. For example, between 1911 and 1938, the Kennecott Copper Mine, now a historic landmark within Wrangell-St. Elias National Park and Preserve in Alaska, produced more than $200 million worth of copper and supported a community of hundreds of people. Past mining sites tell us much about the economic forces that lured Europeans and others to North America, drove westward expansion, built the nation's cities, and continue to support our society.

GEOLOGIC HERITAGE VALUE



Kennecott Mines National Historic Landmark, Wrangell-St. Elias National Park and Preserve.

Economic Value at a Glance

Geologic heritage locations demonstrate economic value by:

- Supporting tourism, commerce, and employment in surrounding communities; and
- Showcasing natural resources that have supported economies and shaped American cultural history.

EDUCATIONAL VALUE

Earth scientists and students explore, observe, record, analyze, and draw reasoned conclusions about the features and processes they encounter in nature. Our nation's geologic heritage sites are exceptional settings for field work and education because they often are the best or only places to view a particular feature or process. The ability to examine geologic features in a functioning context with other natural processes is another tremendous benefit. Educational programs can use clearly observable examples from geologic heritage sites to help explain complex subjects such as ancient climate and environmental conditions, the history of life, or the formation of energy resources. Geologic heritage lessons are provided by educators in many formal (classrooms and lectures) and informal (park visitor centers and museums) settings.

RECREATIONAL VALUE

America's geologic heritage sites are exceptional settings for hiking, camping, biking, climbing, boating, and countless other outdoor recreational opportunities.

GEOLOGIC HERITAGE VALUE

Geoscientists-in-the-Parks intern presenting a geology program at Bryce Canyon National Park.

Educational Value at a Glance

Geologic heritage sites provide educational value by:

- Offering examples of geologic principles and processes for study;
- Providing formal and informal settings for instructing students or the public in science, history, culture, and other subjects; and
- Enhancing Earth science literacy—demonstrating natural processes and hazards and how human activities impact the environment.

In addition to allowing visitors to experience the geologic landscape of an area, outdoor recreation provides innumerable physical and mental benefits. The mission of the Let's Move! Outside program, led by the Department of the Interior, is to connect people with outdoor recreational opportunities near them and across the country to increase the physical and mental health of Americans. Working to maintain geologic heritage sites by removing litter, rehabilitating trails, or participating in other active science and educational programs provides rewarding ways to get moving outside—keeping you and your geologic heritage in great shape.

Outdoor recreation does not have to be just about adrenaline-pumping sports activities. There are also benefits to simply relaxing outside, breathing fresh air in open spaces, contemplating the natural solitude afforded by some geologic heritage areas, or even providing a brief change of scenery during a workweek. Outdoor recreation also does not have to involve a cross-country journey. A walk to a nearby park provides opportunities to explore geologic heritage in your local

GEOLOGIC HERITAGE VALUE

Children enjoy sand-sledding in Great Sand Dunes National Park and Preserve.

Recreational Value at a Glance

Geologic heritage locations provide recreational value by:

- Offering outdoor settings for improving physical health through activities and exploration;
- Providing natural areas for improving mental health through stress relief, appreciation of nature, and wilderness experiences; and
- Presenting opportunities for personal enrichment and discovery at local sites or those across the country.

landscape by observing simple things like the rocks of a streambed or local building stones.

SCIENTIFIC VALUE

Geologic heritage sites exhibit fundamental scientific value by providing opportunities for improved understanding of Earth's natural features and processes through observation, experimentation, and exploration. Geologic features such as canyons, caves, geysers, glaciers, mountains, and shorelines are natural "laboratories" for expanding our understanding of the geosciences. Many well-known geologic areas were sites of scientific discovery, places where specific

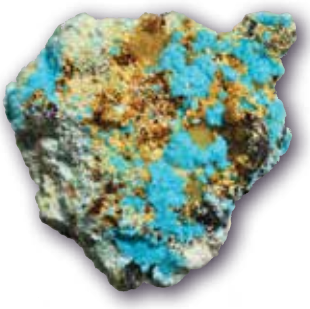
CASE STUDY

Red Rocks Amphitheatre in Morrison, Colorado.

Geology Rocks!

Red Rocks Park and Amphitheatre, managed by the City and County of Denver, provides an example of how scientific, ecological, aesthetic, artistic, cultural, recreational, and economic values are interconnected at geologic heritage sites. The park's scientific value is derived from the exceptional exposures of dramatically tilted 300 million-year-old sandstone—the eponymous red rocks—originally deposited in streams eroding the Ancestral Rocky Mountains. As a park, the site conserves open space in the ecosystems of the Front Range. Aesthetically, the beauty of the amphitheater and its surrounding landscape has inspired musicians and other artists for generations and contributed to the park's cultural value. Artistically, it has been a premier concert venue since the early 20th century, hosting world-class musicians, whose fans have been inspired by not only performances but also the echoes and reflections of the surrounding rocks. Recreationally, the site is popular with Denver-area hikers, bikers, and stair climbers, and it hosts fitness and yoga events. With more than 900,000 patrons of the venue's more than 100 events each year, and with an estimated 1 million other recreational visitors annually, the site has a profound impact on the local economy.

rock layers or fossils were first studied and described. In addition, museums, universities, and science centers preserve and interpret some of the most important examples of geologic heritage—fossil, mineral, and other geologic collections that include extraordinary or representative specimens. Insights from studies of the rock record expand our understanding of Earth's dynamic systems, which allows us to discover our past and apply that knowledge to current issues such as climate change.



Right: Sample of the mineral Grandviewite, a copper mineral, only known from the mines on Grandview Mesa in Grand Canyon National Park.

GEOLOGIC HERITAGE VALUE

Geologists document glacier change in Kenai Fjords National Park.

Scientific Value at a Glance

Geologic heritage features reinforce scientific value by:

- Preserving the records of planetary history and evolution at geologic heritage sites and in museum collections;
- Allowing for the study of natural sites to facilitate scientific examination, discovery, data collection, and experimentation; and
- Providing access to scientifically monitor, evaluate, and understand natural processes and human impacts as they change over time.

"Everything we have, we inherited from the past, and everything we use or lose deprives future generations of it. That, in a nutshell, is the case for valuing and conserving abiotic nature."

Murray Gray
Author and Professor
2004

CHAPTER FIVE

Doing the Important Work of Geologic Conservation

America's geologic heritage is conserved for the full range of values that society places on them, so that their lessons and beauty will remain as a legacy for future generations. This document has shown how billions of years of Earth history are responsible for the diverse geologic features and processes found in America. We have explored the tradition of geologic heritage conservation in the United States and outlined eight key values associated with geologic heritage areas. This chapter provides examples of geologic heritage conservation methods and describes some of the practices of international programs as well as ongoing conservation efforts in the United States.

GEOLOGIC HERITAGE CONSERVATION METHODS

Many nations have well-established procedures for the conservation of natural and cultural heritage resources. The practices of conservation of geologic heritage, sometimes referred to as geoconservation, are becoming global in practice and scope, but—like cultural heritage conservation—they require individual and local participation for success. Conservation efforts involve a variety of activities, including developing laws and policies, preparing geologic monographs, determining significance, conducting gap analyses, maintaining a site registry, managing resources, assessing vulnerability, protecting resources, documenting damaged or threatened sites, and offering education and outreach programs. Your contributions to these activities will help promote geologic heritage conservation.

Above: A scientist mapping cave passages at Buffalo National River.

Laws and Policies

Conservation of geologic heritage sites is carried out under the authority of federal, state, and local laws. Land-management agencies also work under established regulations and policies. Citizens and community groups can meet with elected

officials to ensure their values are being addressed in new or current legislation. We all are stakeholders in our shared geologic heritage, and we all should stay informed and engaged with how sites are managed and protected.

Geologic Monograph

Often the first step for a geologic heritage conservation program is visiting the site and preparing a detailed report about the area's geologic history, setting, and features. The geologic monograph serves as a scientific baseline for a site's condition and significance. The findings can help to identify important resources and lead to recognition through formal conservation programs.

Determination of Site Significance

Each land-management agency has its own legislated criteria for determining significance based on scientific, ecosystem, aesthetic, cultural, recreational, educational, and economic values, in addition to concerns voiced by individuals and communities. Site selection involves input from many interested parties, locally and regionally. One of the key features of the American tradition of geologic heritage is the willingness to hear and consider citizens' voices when determining the significance of sites.

Gap Analysis

Determining which parts of the landscape warrant special designation is challenging.

CONSERVATION PARTNERS

Model of Maiasaura *nest at the Natural History Museum, London.*

The Nature Conservancy on Egg Mountain

The Nature Conservancy, a major conservation organization in the United States, often collaborates with local, state, and federal land management agencies. An ambitious undertaking by the Nature Conservancy in partnership with the Museum of the Rockies in Montana is found in Montana's Pine Butte Swamp. The main feature of this site is an important wetland habitat, but conservation efforts have been expanded to protect both ecological and geologic heritage. Approximately 80 million years ago, this area was habitat for herds of plant-eating dinosaurs. A site within the preserve called Egg Mountain harbors a particularly significant paleontological find—the fossilized remains of nests, eggs, hatchlings, and juveniles of the duckbill dinosaur *Maiasaura,* or "good mother lizard." Protection of this site is strongly supported by the partnership. The Museum of the Rockies continues scientific research into the habitat that supported dinosaurs while the Nature Conservancy maintains the easement to protect the site into the future.

One way in which programs evaluate potential sites for additional protection is to conduct a gap analysis. A gap analysis begins by identifying geologic features or landscapes that fully represent our geologic heritage, so that the regions, themes, stories, and values that are not currently protected and interpreted can be delineated. Experts within geologic heritage communities can be invaluable in identifying and evaluating underrepresented features and sites.

CONSERVATION PARTNERS

Rare saber-tooth cat skull discovered by Kylie Ferguson in Badlands National Park.

Kylie's Conservation Story

While hiking at Badlands National Park in May 2010, seven-year-old park visitor Kylie Ferguson made a rare and important discovery. Kylie and her mother found a fossil near the park's visitor center. But instead of digging it up, Kylie recalled lessons from the park's Junior Ranger program and left the fossil undisturbed.

She noted the location and reported it to park paleontologists, who then monitored the fossil. Over the following summer, rain and wind slowly exposed this fossil, prompting park staff to excavate what turned out to be a museum-quality skull of a saber-toothed cat. Kylie's discovery and subsequent reporting is a model for geologic heritage. Today's young people are the next generation of geologic heritage stewards. Learn more about Kylie's story here: http://go.nps.gov/kyliesfossilfind.

The National Park Service Junior Paleontologist program provides opportunities to explore the ways paleontologists work, learn about changes throughout Earth's history, and protect fossils in our national parks. Learn more about the program online at http://go.nps.gov/jrpaleo.

National and International Registries

A central aspect of many heritage programs is documenting resources and site conditions as part of a formal registry. Registries, such as the National Register of Historic Places, established under the National Historic Preservation Act of 1966, provide an important accounting of heritage resources and values being conserved. Currently, there is no comprehensive national registry that includes all geologic heritage sites in the United States. Establishing a national registry, which requires community support, will help strengthen the connections between geologic heritage sites and ensure that best management practices are applied nationwide.

Site Management

Resource management activities within geologic heritage sites include planning, inventory, monitoring, research, education, restoration, and protection. Data and information management (including curated collections or research libraries) are also an important aspect of comprehensive site management. Increasingly, these activities rely on community support to successfully meet the mission of a particular site. In some cases, public-private partnerships have been developed to effectively carry out the work and mission of the sites.

Periodic Condition Assessments

Most sites should be evaluated on a regular schedule, when possible, to determine the condition of resources and whether that condition is improving, declining, or remaining stable. These types of monitoring activities may involve citizen scientists. Condition assessments help to ensure that sites are not lost to gradual degradation that otherwise might go unnoticed. The National Park Service and Geological Society of America publication, *Geological Monitoring,* presents scientific methodology for monitoring many different geologic resources.

Vulnerability Index

Geologic heritage resources are extremely diverse and spread across vast tracts of land. A vulnerability index is a tool to develop quantitative or qualitative rankings to focus attention on the resources most vulnerable to loss or damage. Particularly rare or fragile resources, such as cave, paleontological, and mineral specimens, require special consideration from site managers and law enforcement.

Resource Protection

Unfortunately, designation alone cannot ensure that geologic features are protected from theft, damage, or vandalism. Protecting nonrenewable geologic heritage resources so they can be enjoyed by future generations requires education and involvement of site visitors and special training for law enforcement officials. The observations and reports made by recreational visitors and citizen scientists are important to minimize vandalism and other damage at remote and sensitive sites. Always report observed or suspected activities that could damage geologic heritage resources to on-site staff or landowners.

Documenting Damaged and Threatened Sites

The inventories, records, and reports produced by formal heritage conservation programs enable us to identify sites where

Top to bottom: Paleontologists examining fossils at Denali National Park and Preserve; Ranger speaking with visitors on the Alaska Railroad; Educators participating at the University of Colorado's STEMapalooza.

resource values are being adversely impacted by natural processes or human activities. Although it is not desirable for a site to appear on a list of damaged or threatened areas, such lists can provide a powerful rallying point to increase community awareness and involvement for improving site conditions and conservation efforts.

Education and Outreach

Guided field trips, interpretive signage, lectures, presentations, publications, documentaries, and online formal and social media are used to facilitate public engagement and appreciation for geologic heritage sites. Educators, museum staff, and park interpreters all play important roles in promoting geologic heritage education.

AN INTERNATIONAL TRADITION

The formal recognition of geologic heritage sites and features is carried out by a number of international, national, state, and local government entities. At the international level, the United Nations World Heritage Program, part of United Nations Educational, Scientific and Cultural Organization (UNESCO), designates cultural and natural areas as significant according to criteria established at the 1972 World Heritage Convention.

Above: Scientist documents glacier change, Lake Clark National Park and Preserve.

World Heritage sites have been judged as bearing global significance, holding universal human value, and being worthy of cultural preservation and nature conservation. In recent decades, these locations have received the highest level of international designation but are managed according to local laws, regulations, and policies.

Geoparks are another UNESCO initiative to recognize and protect culturally and scientifically important locations specifically for their geologic significance. The Global Geopark Network, established in 1998, is a consortium of geoparks with internationally significant geological heritage. Geoparks implement strategies for holistic heritage management, promotion, and sustainable development that are globally integrated, yet respectful of local traditions and desires. Geoparks are found throughout much of the world. The European Geopark Network and the Asia Pacific Geopark Network presently lead international efforts for geologic heritage conservation in their regions.

Many sites within the United States are internationally recognized through UNESCO as World Heritage sites, the majority of which also have geologic significance. Most of these are also part of the National Park System. In 2014, North America's first Geopark was designated at Stonehammer

Hawai'i Volcanoes National Park contains two of the most active and accessible volcanoes in the world.

World Heritage Sites

UNESCO World Heritage sites are places that have been deemed to hold universal human value. There are 1,007 of these cultural and natural sites in 161 countries worldwide, and all are protected by international law. The United States hosts 22 World Heritage sites, 16 of which can be considered geologically significant:

- Carlsbad Caverns National Park, New Mexico (1995)
- Chaco Culture National Historical Park, New Mexico (1987)
- Everglades National Park, Florida (1979)
- Grand Canyon National Park, Arizona (1979)
- Great Smoky Mountains National Park, Tennessee and North Carolina (1983)
- Hawai'i Volcanoes National Park, Hawaii (1987)
- Kluane / Wrangell-St. Elias / Glacier Bay / Tatshenshini-Alsek, Yukon Territory and British Columbia (Canada) and Alaska (United States) (1979)
- Mammoth Cave National Park, Kentucky (1981)
- Mesa Verde National Park, Colorado (1978)
- Monumental Earthworks of Poverty Point, Louisiana (2014)
- Olympic National Park, Washington (1981)
- Papahānaumokuākea, Hawaii (2010)
- Redwood National and State Parks, California (1980)
- Waterton Glacier International Peace Park, Montana and Alberta, Canada (1995)
- Yellowstone National Park, Idaho, Montana, and Wyoming (1978)
- Yosemite National Park, California (1984)

To see the current official World Heritage list for all sites, visit http://whc.unesco.org/en/list.

in New Brunswick, Canada. There are no UNESCO Geoparks in the United States.

THE AMERICAN APPROACH

For more than a century, the American people have assigned significance to national geologic treasures with more than 30 types of designations. Many areas with iconic geologic heritage features have been designated as parks, monuments, preserves, reserves, seashores, lakeshores, sanctuaries, refuges, natural history areas, natural landmarks, and other types of formally protected sites. Others places, recognized informally, serve as points of interests, outdoor classrooms, and cultural landmarks.

Designated State or Federal Lands

Nationwide, a number of government agencies share responsibilities for protection of iconic geologic features within designated lands, including:

- National Forest System (Forest Service)
- National Landscape Conservation System (Bureau of Land Management)
- National Natural Landmarks (also on private lands)
- National Park System (National Park Service)
- National Wilderness Preservation System
- Scenic Byways
- State Parks
- World Heritage Sites

Designations such as national park and national monument are made by either Congress or the President, and usually protect areas of government-owned land with specific mandates for management of resources. The National Park Service is internationally recognized as a model for designation and protection of special places based on national significance, resource values, suitability, and feasibility associated with each particular location. Under conservation assistance programs such as the National Natural Landmarks program, privately owned sites can be recognized as geologic landmarks without changing the ownership status of the land.

Undesignated Geologic Heritage Sites

Importantly, designated sites are complemented by a wealth of undesignated sites scattered throughout the United States. These undesignated areas represent important pieces of our geologic heritage and add to overall geodiversity. For example:

- Building stones
- Community landmarks
- Geologic points of interest:
  - Outcrops of bedrock
  - Quarries and road cuts

Above: Sand Island lighthouse (c.1871) features sandstone quarried on-site, Apostle Islands National Lakeshore.

- Trackways
- Highpoints and peaks
- Scenic overlooks

These sites are important because they provide insights into local and regional Earth history and processes. Undesignated geologic heritage sites near where people work, live, and play provide countless opportunities to touch nature and enjoy the outdoors.

In addition to outdoor geologic sites, many communities host museums that feature extensive geology collections and exhibits. Museums not only curate important collections of fossils and minerals, but many conduct active scientific research and educational programs. At museums like the American Museum of Natural History in New York, only 8% of the geologic collection is on display to the public at any given time. The much larger portion of the collection is conserved behind the scenes but accessible for scientific studies. Lessons learned in your local museum can help you to better understand and appreciate your favorite geologic heritage sites.

GEOLOGIC HERITAGE

Visitors to the Ansel Adams Wilderness are rewarded with pristine views of glacially carved valleys and peaks.

Know Before You Go

Whatever place you choose to explore, you need to learn about the area and who owns the property, obtain permission or permits, and investigate site-specific regulations *before* you visit. It is important to respect public and private lands, as well as the people and other living things there. To learn more, see the additional resources at the end of this publication.

"When we see land as a community to which we belong, we may begin to use it with love and respect."

Aldo Leopold
Author, Forester, and Conservationist
1949

CHAPTER SIX

Coming Together to Protect Our Geologic Heritage

America has a long history of conservation and a rich diversity of geologic resources. The nation enjoys and values its geologic heritage, and has the tools and methods necessary for geoconservation. Next, we turn our attention to an essential element in any conservation effort—participation.

Each of us has a role to play in ensuring our nation's geologic resources, stories, and values are conserved for future generations. This chapter provides examples of who is conserving geologic heritage and how, as well as suggestions for getting involved at a local, national, or even global level. There is much you can do. Perhaps the most important way to help protect our shared geologic heritage is to be aware of and get involved in the ongoing effort to strengthen geologic heritage conservation.

Even if we do not always refer to the focus of our activities as geologic heritage conservation, many of us already are engaged in this effort. Important contributions are already being made by professional societies, government agencies, nonprofit organizations, and private corporations. Individuals are also working, independently and in partnerships, to uphold the tradition of respecting and conserving the nation's natural systems and geologic features. These communities provide the foundation for conservation and stewardship of the geologic treasures we have inherited.

Above: A family celebrates together at The Windows in Arches National Park.

GEOLOGIC HERITAGE COMMUNITIES

You do not have to be a geologist to appreciate and protect geologic heritage. Conservation efforts require many groups with different skill sets. Each community working within its sphere of influence and expertise can help make geologic heritage relevant to its constituents and develop links with other communities. When these communities join efforts, geologic heritage resources and people benefit from better conservation, science, and educational programs.

Government entities can carry out their mandates and, in some cases, provide financial or technical assistance through

conservation assistance programs, but communities are needed to bring geologic heritage to the state and local level and into classrooms. These communities depend upon individuals like you to apply their skills and interests to achieve common goals. Americans from various backgrounds and affiliations share a major stake in learning about, promoting, and conserving geologic heritage.

Artists

Artists celebrate the aesthetic values of geologic heritage in story, song, and visual representation. In doing so, they also promote awareness of the deep emotional connection and cultural relevance of our geologic heritage. Artists and photographers play a major role in bringing these issues to our attention, and inspiring active stewardship of geologic heritage.

Avocational Organizations

Environmental alliances, citizen scientists, recreational groups, and outdoor enthusiasts from many different types of clubs are ardent explorers and supporters of geologic heritage sites. They contribute to the body of geologic knowledge in significant ways and can be effective in advocacy related to conservation and public projects. Groups such as the Sierra Club have been instrumental in saving and preserving significant geologic areas including Yosemite Valley and Mount Rainier.

Business Groups and Associations

Businesses often recognize the exceptional economic value of geologic resources, as well as the development potential associated with tourism and recreation at geologic heritage sites. The tourism industry has become a major part of the effort to support recognition of geologic heritage.

The economic value of mineral and energy extraction can compete with conservation, but such factors can also lead to creative collaboration in meeting both interests. The history of mining is an important part of the nation's geologic story which is often best told by working with industry support.

Educators

Educators convey geoscience concepts in both formal education environments, such as schools and universities, and informal settings, like parks and science museums. Educators have the important role of teaching Earth science concepts and creating meaningful and relevant learning opportunities related to geologic features and processes. Geologic heritage sites provide ideal classrooms and teachable moments for this body of knowledge.

Elected Officials

Our elected officials, from the local to the national level, craft legislation to establish new, or conserve existing, geologic heritage sites. Their legislation also provides funding critical to managing the sites. Politicians meet with local citizens to discuss the values associated with geologic heritage areas and how best to provide legislation to support them.

Historic Preservation Community

Historians study the people, places, stories, and events that together define our culture. Almost every American historical narrative is

Top to bottom: Geoscientists-in-the-Parks in Badlands National Park contribute to educational programs; Recreational visitors to Sequoia National Park discover geologic connections; Scouts enjoy National Fossil Day, which has a community of more than 320 partner organizations.

inextricably linked to the geologic landscape where events have taken place. Historians recognize the traditional uses and cultural significance of geologic heritage sites and are often important advocates for preservation of their cultural values.

Land Managers

Land managers play a central role in supporting geologic heritage. The responsibility of day-to-day management of special geologic sites, such as parks or recreation areas is often tasked to federal, state, and local government agencies. Land-use managers work within their mandates to conserve the values of these places for future generations while making them accessible to current visitors, as well as compatible mineral or energy resource development.

Museum Professionals

Museum professionals interact with other scientists, educators, and the general public to promote the exploration of our natural world, conserve important objects, and share curated collections. Museum professionals may display specimens and facilitate education programs about the history of Earth and life to build a wider understanding of our relationship to the planet. Museum specimens (minerals, fossils, rock samples) are important pieces of our geologic heritage.

Above: Paleontologist working in the fossil preparation lab at Badlands National Park.

Scientists

Scientists explore the nature of the planet and share knowledge of Earth materials and processes. They help to determine the scientific value of geologic heritage sites, as well as understand their ecological values. Geoscience agencies such as the U.S. Geological Survey, in addition to state geologic surveys, universities, professional societies, and museums maintain scientific data and promote understanding of Earth's systems, monitor changes in those systems, and enhance our ability to predict future changes that could impact society.

AN INVITATION TO YOU

The future of geologic heritage will be written by those who accept this invitation and take an active role. You may already be part of one of the above communities or groups, or perhaps you are looking for a new way to be involved in conserving geologic heritage. Getting involved begins with discovering what excites you about our shared geologic heritage and what values

are important to you. How do you value geologic heritage sites? What will be your legacy? What will you do?

Join in the shared work of conserving our geologic legacy! There is much to be done—and many rewards for your endeavors. Together we can sustain the traditions of geologic heritage conservation, so that future generations can enjoy the same treasures of geologic heritage that have been entrusted to us.

GEOLOGIC HERITAGE

Volunteering is a fun way to become involved in your geologic heritage. Geoscientists-in-the-Parks interns serve at Congaree National Park.

Getting Involved

Join with a group of like-minded individuals eager to explore and share in your enthusiasm for geologic heritage. Groups of dedicated individuals can have significant influence by promoting and sharing geoconservation. Consider the following for deeper involvement:

- Learn about and visit a geologic heritage site.
- Volunteer at a museum or geologic heritage site.
- Participate in conservation efforts through groups like the Nature Conservancy, the Student Conservation Association, Geoscientists-in-the-Parks, GeoCorps America, and Youth Conservation Corps.
- Join a local rock and mineral club.
- Blog about your local geologic heritage sites.
- Write to your elected representatives to support geologic heritage conservation.
- Become involved in local and regional land-use planning processes.
- Help to designate and conserve your local geologic heritage site.
- Publish articles on your area of expertise related to geologic heritage.
- Invite your friends to join you!

"Today, our open spaces are more precious than ever —and it's more important than ever that we come together to protect them for the next generation."

President Barack Obama
2011

RESOURCES

ADDITIONAL RESOURCES

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INTERNET RESOURCES

National Park Service (NPS)
www.nps.gov/index.htm
www.nature.nps.gov/geology/index.cfm

United States Geological Survey (USGS)
www.usgs.gov

Bureau of Land Management (BLM)
www.blm.gov

United States Forest Service (USFS)
www.fs.fed.us

National Natural Landmarks Program (NNL)
www.nature.nps.gov/nnl

America's Geologic Heritage
www.nature.nps.gov/geology/geoheritage/index.cfm

Let's Move! Outside
www.letsmove.gov/lets-move-outside

Explore Your America
www.recreation.gov

Association of American State Geologists (AASG)
www.stategeologists.org

Geological Society of America (GSA)
www.geosociety.org

American Geosciences Institute
www.americangeosciences.org

Earth Science Literacy Initiative
www.earthscienceliteracy.org

American Geophysical Union (AGU)
http://sites.agu.org

UNESCO World Heritage
http://whc.unesco.org

Global Geoparks
www.unesco.org/new/en/natural-sciences/environment/earth-sciences/global-geoparks

Geoheritage Journal
http://link.springer.com/journal/12371

Above: Eruption of Pink Cone geyser, Yellowstone National Park.

ADDITIONAL PHOTO CAPTIONS & CREDITS

All photos courtesy of the National Park Service, except as noted.

Cover image: Visitors exploring Zion Narrows in Zion National Park, Utah. Copyrighted photo used courtesy of Ian Parker, Evanescent Light Photography, 2013.

Inside cover and page 1: Backpackers visiting the remote geologic wonders of Denali National Park and Preserve.

Pages 2-3: Hikers enjoying the dramatic colors and craters in Haleakalā National Park. Photo by Jon Schmitz, Haleakalā National Park, 2014 Share the Experience photo contest.

Pages 4-5: Mountain ridges fading into the distance are an iconic scene in Great Smoky Mountains National Park. Photo by Bob Carr, Great Smoky Mountains National Park, 2014 Share the Experience photo contest.

Page 6: NPS photo by Jim Peaco.

Page 7 (middle): Photo by Ken Lee, California Desert National Conservation Area, BLM, 2014 Share the Experience photo contest.

Pages 8-9: Scott's Bluff, now a national monument, was an important waypoint for travelers on the Oregon and Mormon trails in the 1800s.

Page 11 (top): Photo by Kathy Christiansen, Oregon Coast National Wildlife Refuge, 2014 Share the Experience photo contest.

Page 11 (middle): Photo courtesy of the National Museum of American History—Smithsonian Institution.

Page 11: Painting by Thure de Thulstrup, 1904.

Page 12: Illustration by William Henry Holmes, 1882.

Page 13: Department of the Interior Museum.

Page 14: National Archives photo by Andrew J. Russell.

Page 15 (bottom): U.S. Library of Congress photo.

Page 16: Charles Peak, Devils Tower National Monument, 2014 Share the Experience photo contest.

Page 18: Photo courtesy of Ronal Kerbo.

Page 20-21: Colorful rock layers in Badlands National Park, South Dakota. NPS photo by Larry McAfee.

Page 22: NPS photo by Jacob W. Frank.

Page 24: Photo by Frances Freyberg Blackburn, Point Reyes National Seashore, 2014 Share the Experience photo contest.

Page 25 (top left): Fossil Butte is the namesake geologic feature of Fossil Butte National Monument. Photo by Tyra Olstad.

Page 25 (middle left): Fossils are exposed in rocks on the butte.

Page 25 (bottom left): These fossils contain exceptional, even microscopic, detail.

Page 25 (right): Shaded relief map showing the regional scale geologic features of the middle Rocky Mountain province (in yellow) and the location of national parks. NPS graphic by Jack Wood.

Page 26 (top): NPS photo by Robb Hannawacker.

Page 26 (bottom): NPS graphic by Jack Wood.

Page 27 (top left): Sea oats and dunes, Cape Hatteras National Seashore.

Page 27 (top middle): Fog flows through Cumberland Gap on the edge of the Appalachian Highlands, NPS photo by Scott Teodorski.

Page 27 (top right): Norbeck Pass, Badlands National Park.

Page 27 (middle left): Sunset over the Ouachita National Forest, NPS photo by Laura Vu.

Page 27 (middle): Pigeon Pass, Glacier National Park.

Page 27 (middle right): Santa Elena Canyon, Big Bend National Park. NPS photo by Ann Wildernuth.

Above: Denis Bay on St. John Island, Virgin Islands National Park.

Page 27 (bottom left): Camping in volcanic field, Craters of the Moon National.

Page 27 (bottom middle): Wizard Island, Crater Lake National Park.

Page 27 (bottom right): Unusual "Tent Rocks" in BLM's National Landscape Conservation System. Photo by Mary Kolf Russell, Kasha-Katuwe Tent Rocks National Monument, 2014 Share the Experience photo contest.

Pages 28-29: View of Half Dome in Yosemite National Park. Photo courtesy of Don Wood.

Page 30: Photo by Drew Myers, Appalachian National Scenic Trail, 2014 Share the Experience photo contest.

Page 31: Photo by Robert D. Wood.

Page 32: NPS photo by Kait Thomas.

Page 34: NPS photo by Brittni Medina.

Page 35: NPS photo by Neal Herbert.

Page 38: Photo by Scott Ingram (CC BY-NC 2.0).

Page 39 (top right): NPS photo by Michael Quinn.

Page 39 (center): NPS photo by Jim Pfeiffenberger.

Page 40-41: A remote river wends its way along the Arctic Divide in Gates of the Arctic National Park and Preserve. NPS photo by Sean Tevebaugh.

Page 42: Photo courtesy of Charley Young.

Page 43: Photo from Wikimedia Commons (CC BY-SA 4.0, 3.0, 2.5, 2.0, 1.0).

Page 45 (bottom): NPS photo by Jim F. Wood.

Page 47: Photo courtesy of Anne Poole.

Page 49: Photo by Mariusz Jeglinski, Ansel Adams Wilderness, 2014 Share the Experience photo contest.

Page 50-51: A ranger leads a hike in Santa Monica Mountains National Recreation Area.

Page 52: Photo by Beth Loehfelm, Arches National Park, 2014 Share the Experience photo contest.

Page 53 (middle): Photo by Paul Erickson, Sequoia National Park, 2014 Share the Experience photo contest.

Page 53 (bottom): Photo courtesy of Jim F. Wood.

Page 56-57: President Barack Obama visits the South Rim of the Grand Canyon National Park in Arizona on August 16, 2009. Photo via http://whitehouse.gov.

Page 59: Photo by Stephanie Powell, Virgin Island National Park, 2014 Share the Experience photo contest.

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National Park Service

The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

The Geologic Resources Division assists the National Park Service and partners in the servicewide coordination, support, and guidance necessary to understand and implement science-informed stewardship of geologic and associated park resources; reduce impacts from energy, mineral, and other development; and protect visitor values.

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AGI was founded in 1948, under a directive of the National Academy of Sciences, as a network of associations representing geoscientists with a diverse array of skills and knowledge of our planet. The Institute provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment. With a network of 50 member societies, AGI represents more than a quarter-million geoscientists.

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