Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

The History of NPS Science and Management

The Absaroka Volcanic Province

The Fastest Falcon

Volume 6 Number 2

Scenes from the "visitors pleasuring ground." NPS photo archives.

Rhetoric or Reality?

It's always interesting for an insider to hear someone else, someone like historian Dick Sellars, comment about how Yellowstone appears from a distance of time, space, or in this case both. As he talked with *Yellowstone Science* about his documentary history of National Park Service science and resource management, I had a sense that some things had changed very little, in public and bureaucratic attitudes. Our fundamental values as an agency and nation still strongly lean toward just what the title of Sellars' book implies: *preserving nature in the national parks*...a fairly static condition in which if all *looks* well, perhaps it is enough to satisfy our constituents, the American landowners, and park visitors from other lands.

Those of us prone to such contemplations wonder about the popular image of our parks and the friendly park rangers, which usually rank high if not atop the list of public agencies and their servants. It's the decripit roads and facilities that serve the public which have garnered the most public and political attention in the past two decades, not any apparent lack of research and scientific decision making. If parks are clean and rangers are smiling, can the resources really be in danger of irreparable decay or extinction?

Interesting, as well, is park ranger Brian Suderman's read of Sellars' history. His only criticism focuses on Sellars' failure to credit rangers with a stronger role in preserving resources through their primary assigned duties of law enforcement, visitor contact, and interpretation. Webster says to preserve is "to guard, to keep safe from injury, harm, or destruction; to keep up and reserve for personal or special use..." Certainly the park rangers of our history and present do so.

But it is common for the scientists and professional resource managers in the NPS to say that we are a long way from understanding and embracing science in our mission and our daily work. Is this rhetoric or reality? Voices in and outside the Service are sometimes accused of "crying wolf" about declining biodiversity or threats to cultural resources and the need for more money, staff, and time to manage such threats. Are scientists their own worst critics in decrying the state of their ranks and programs? Is it a matter of different perceptions—even between park rangers and researchers—of what it means to conserve park resources? Or have scientists failed to convincingly explain, to the public as well as to other NPS employees, the seriousness of resource threats and just what future improvement are needed to achieve "scientific" resource management?

Such questions come more easily than answers...so we continue to present features on research and preservation activities in Yellowstone, hoping to spread knowledge and provoke some thought among readers about what it means to preserve nature and culture in Yellowstone.

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Table of Contents

The Geologic History of the Absaroka Volcanic Province 2

Yellowstone's well-known features often obscure the older history of a vast volcanic field notable in its own right. A geologist sheds light on explosive events that rocked the landscape 50 million years ago.
by Margaret M. Hiza

The Evolution of NPS Science and Natural Resource Management: Rhetoric versus Reality 8

The National Park Service has a long record of stewardship, but has also tended toward tourism development while science programs languished. A historian argues that scientific resource management was —and is still—lacking in parks.
Interview with Richard W. Sellars

Greater Yellowstone Peregrines 16

Once one of the most endangered birds on the continent, this fast-flying predator has made a remarkable recovery inside and beyond Yellowstone's boundaries.
by Terry McEneaney, Bill Heinrich, and Bob Oakleaf

Review 22

Preserving Nature in the National Parks: A History by Richard West Sellars.
Reviewed by Brian Suderman

News and Notes 24

El Niño makes for Dry Snow Year • Lynx to be Listed Under Endangered Species Act • Experts Discuss New Zealand Mud Snails • Study on Cougar-Wolf Interactions • Satisfied Anglers

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On the cover: A photo of a peregrine falcon in flight. Photo courtesy Tom Maechtle. Above: a group of young peregrine falcons in a hacking box before release into Yellowstone National Park. Photo courtesy Bob Oakleaf. See related story on page 16.

Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190.

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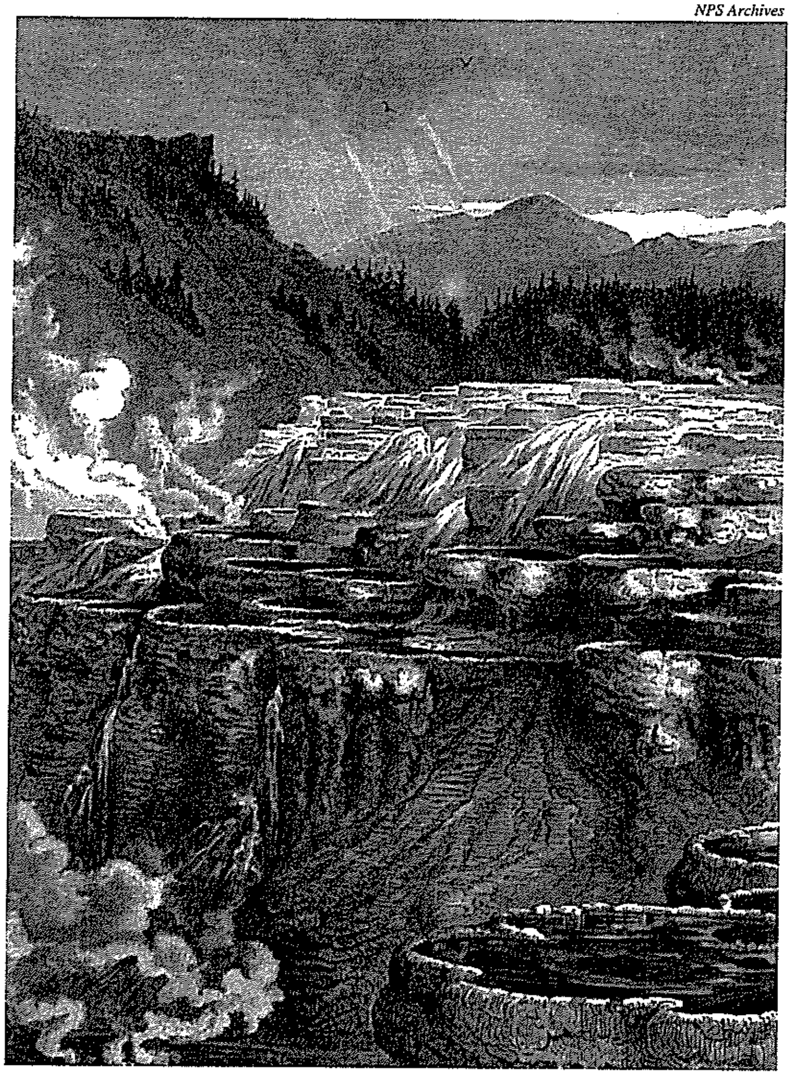


The Geologic History of the Absaroka Volcanic Province

By Margaret M. Hiza

Yellowstone National Park was established 125 years ago, primarily because unique geologic features of the Yellowstone region are among the world's greatest treasures. The high plateau rimmed by mountains, the world's largest geyser field, and the altered yellow rocks of the Grand Canyon of the Yellowstone are but a few features in the park which are the direct result of volcanic activity. Many readers are aware that part of the park is actually a large caldera that erupted violently only 600,000 years ago, in one of the largest eruptions known in recent geologic history; it may still erupt again. This young caldera also provides the heat source responsible for the largest geyser field in the world, and the numerous hot springs of the Yellowstone region. This heat comes from magma—molten rock below the surface.

However, volcanic activity is not new to the region; many of the rocks in the park formed from volcanism that occurred 50 million years earlier. This earlier eruptive activity produced another voluminous deposit of volcanic rocks, the Absaroka Volcanic Province. The province is the largest volcanic field of its age in the western United States, encompassing 9,000 mi^2 (23,000 km^2) of the greater Yellowstone region and roughly one-third of Yellowstone National Park (Fig. 1). Volcanological and geochemical features within these older volcanic deposits are not only unique to the region, but to the world.

The Absaroka Volcanic Province was a region of interest for early prospectors who mined gold and silver associated with old volcanic centers. It is a region famous to geologists for the first recognition and naming of the absarokite-shosonite-banakite series. This is a group of highly potassic volcanic rocks, first found and described in Yellowstone by Joseph Paxton Iddings in 1895. Also uniquely preserved within the Absaroka province are nearly the entire volcanic edifices of large stratovolcanoes together with proximal and distal volcanic deposits, well exposed in a terrain dissected by glaciers. These ancient volcanoes are similar in form to Mt. Rainier, Mt. Fuji, Mt. Kilimanjaro, and other modern stratovolcanoes, but because they are old and inactive, yet well-preserved with canyons cut through them by glacial activity, they afford geologists a unique opportunity to study the inner plumbing system of volcanoes (Figs. 2 and 3). Many of the exposed features of these stratovolcanoes were described during the Hayden Survey of the early 1870s. They were studied in detail by Thomas Jaggar and J.P. Iddings during a subsequent expedi-

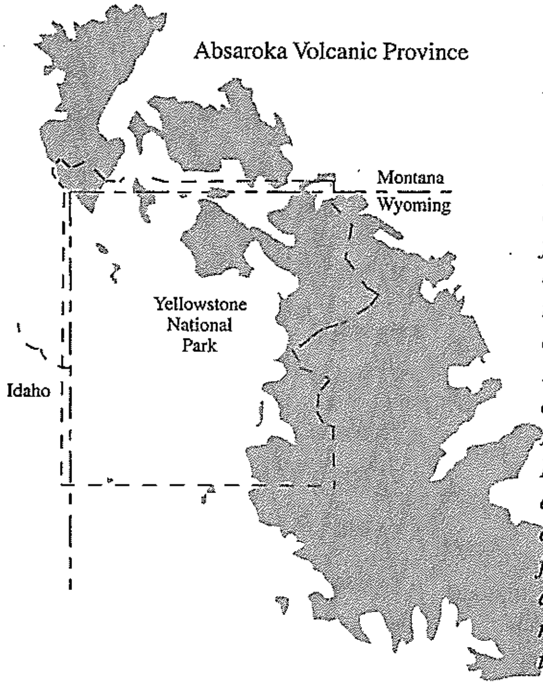
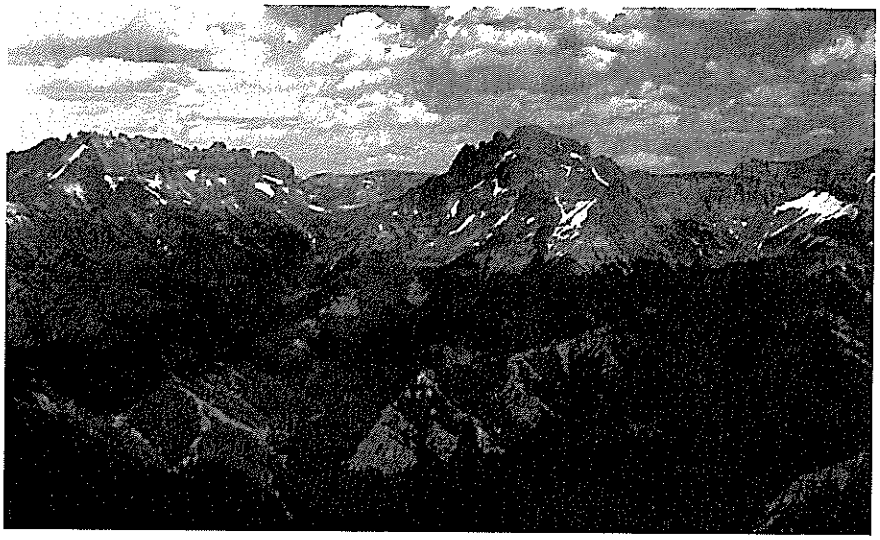
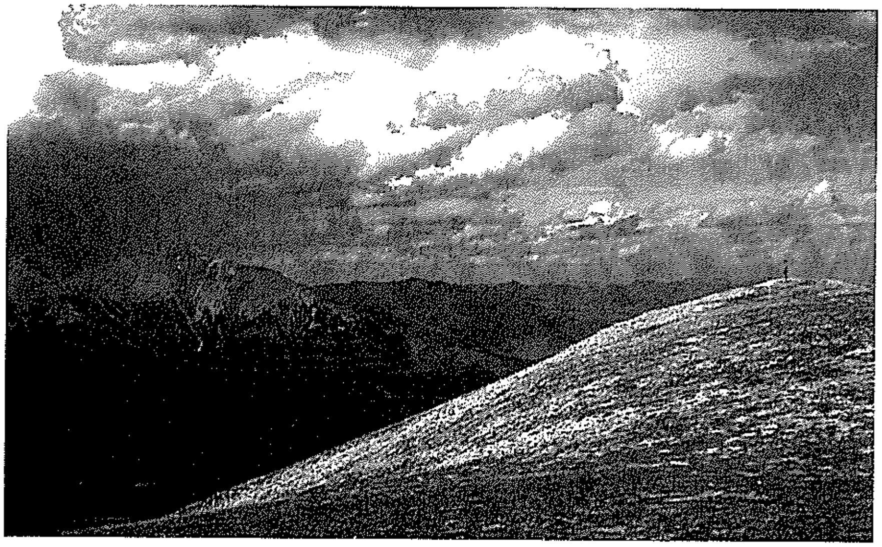


Figure 1. Map showing the distribution of volcanic rocks of the Absaroka Province in the greater Yellowstone region.

Figure 2. Photo of Rampart volcano east of Trident plateau showing remnant dipping lava flows on either side of volcanic edifice. Canyons which dissect the volcano are the result of glaciation.

Figure 3. Photo of Electric Peak as seen from the summit of Greys Peak in northern Yellowstone Park. Electric Peak is a portion of a volcanic edifice-related flow on Sepulcher Mountain. These formed during early volcanic activity in the Absaroka Volcanic Province. All photos courtesy Margaret Hiza.





tion by Alexander Hague and are the origin for volcanological terms now used the world over.

One example is the "laccolith" of Mount Holmes, which is the first of its kind ever described (Fig. 4). Preserved within these volcanic deposits is a world-class continental faunal assemblage, including early primate species found nowhere else on the planet. Entire ancient forests from a period of earth's history which was one of the warmest known are also fossilized within the large volumes of ash and coarse sediment. These deposits record a period of dramatic climate change to the cooler temperatures we experience today. How long this warm period lasted, and how quickly it changed, is not known precisely but may become clearer as the age of the volcanic deposits become better known.

Mapping and Dating Old Rocks

Since the late 1800s, the rugged and remote nature of the region has restricted geologic research to a limited number of studies that are still done by scientists traversing the park on horseback and on foot, as in the days of the Hayden Survey (Fig. 5). I began studying volcanic rocks of the Absaroka Volcanic Province in the greater Yellowstone region in 1990, as a graduate student at Montana State University. My early studies focussed on the sedimentary sequences, which were formed by similar processes as those witnessed by many geologists during the well-known eruption of Mt. St. Helens in 1980. After this event, volcanologists began to study the sedimentary record more carefully because of a new awareness of the dangers imposed by large volumes of sediment that are produced during volcanic activity. As my thesis study continued, I became increasingly aware of how little was known about the Absaroka Volcanic Province as a whole, even though it is located in an area famous for its geologic features.

Because so few studies had been done, it was impossible for me to assign an absolute age to the deposits I had been working on, or to compare them to rocks of the same age in other parts of the province. General age relationships between groups of rocks in the Absaroka

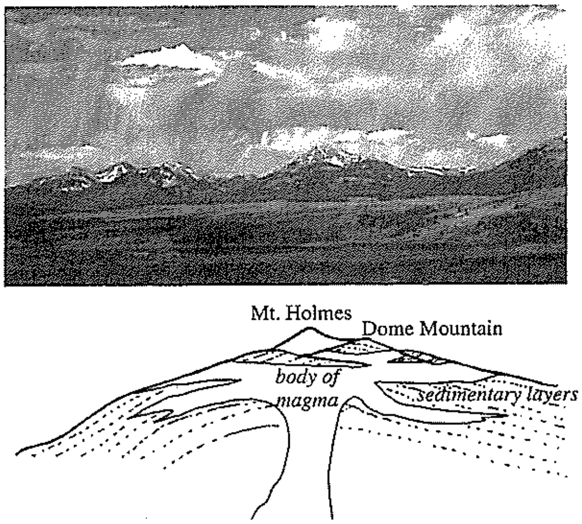


Figure 4. Sketch and photo of Mount Holmes, illustrating the features of a laccolith, which consists of sedimentary layers pushed upward by an invading body of magma.

Volcanic Province had been published in 1972 by Smedes and Protska. Although this work was an excellent preliminary study, it was based on only 14 isotopic dates, 10 of which were derived from rock samples along the southern margin of the province from only two sample localities. Only two samples within Yellowstone Park had been dated, and none of the rocks on which my study focussed had any age assigned to them. Even more astounding is the fact that the Absaroka Volcanic Province has never been completely mapped in detail. Only general maps based primarily on aerial photographs exist for much of the province today.

Much of this region has remained unstudied because of the rugged, mountainous nature of the Absaroka Volcanic Province, which encompasses the largest portion of roadless area in the conterminous United States, including portions of four wilderness areas, four national forests, and the eastern third of Yellowstone National Park. With the exception of the study by Smedes and Protska, the only other study of the entire province was conducted under the supervision of Hague in the late 1800s. Unfortunately, most of this early work was never published.

Geologists have long been puzzled as to what caused volcanism to occur 50 million years ago in the greater Yellowstone region, producing the Absaroka Volcanic Province 1,500-km inland from the margin of the North American plate. Through my study of this enigmatic volcanic field, I address fundamental questions about why magma erupts and where and why melting occurs during volcanic activity. To answer these questions, detailed mapping and sampling of major volcanic centers for detailed geochemical analyses is necessary. These analyses can be used to constrain models of melting based on our current knowledge of the chemical constituents of the earth's crust and mantle. These models are then used to located magma sources.

Another important aspect of my study is a basic understanding of the volcanic province—the sequence of eruptive activity, which I present here. This new work includes significant revisions to age relationships proposed by the earlier work of Smedes and Protska, produced by utilizing more precise modern dating techniques. K/Ar isotopic dating in previous work is based on measurement of ^{40}K (potassium), which decays to ^{40}Ar (argon) with time. This dating method requires very precise measurement of the absolute abundances of K and Ar found within K-bearing minerals in volcanic rock. An alternative technique is to irradiate the sample and thereby convert ^{39}K to another isotope, ^{39}Ar. This is the innovation of the ^{40}Ar/^{39}Ar method, which is more precise and accurate because it relies on proportions rather than absolute abundances. Isotopic dates produced by ^{40}Ar/^{39}Ar, used in this study, are combined with geologic mapping and published paleomagnetic data to piece together the sequence of volcanic eruptions that took place in Yellowstone Park.

The sequence of eruptive activity includes the eruption of ash-flow and fall deposits. These deposits result from large, explosive events that produce an eruption column and plume (Fig. 6). Pyroclastic flows also result from explosive eruptions, but move downhill across low-lying areas. These flows, as well as the eruption column, contain hot volcanic ash, pumice, and other rock fragments. However, deposits from an eruption column are different, because as the eruption column collapses it forms a blanket of ash and pumice across a broad region, instantaneously. New data on the age of these deposits permit their use as regional stratigraphic markers, which constrain the stratigraphy and history of geologic events within Yellowstone. Improved dating permits correlation of three widespread ash-flow tuffs, and has led to a new appreciation of the catastrophic nature of volcanism in the Absaroka Province. Because the three ash-flow tuff eruptions took place within a short period of time (geologically speaking) with many volcanic deposits between them, the age data has also illuminated how voluminous eruptive activity took place during a brief period.

Figure 5. Photo of author conducting fieldwork in the same historical fashion as earlier studies within the northern Absaroka Volcanic Province.

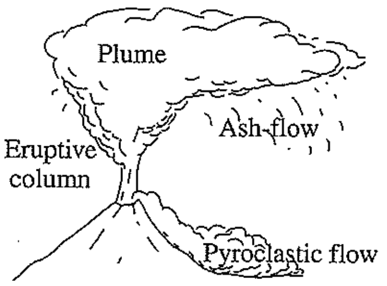


Figure 6. Sketch showing eruption column, plume, and pyroclastic flow.

"New Age" Volcanics

Eruptive activity of the Absaroka Volcanic Province began 53 million years ago (Ma) during a period of crustal extension, first recorded by movement along the South Fork detachment fault, which cuts the Eocene Willwood Formation. The Willwood Formation is a deposit that lies below the Absaroka volcanics, which are of similar age. At about the same time, smaller, scattered volcanic fields began to erupt in a broad belt extending from Oregon and Washington to the Black Hills of South Dakota. From the onset, eruption in the Absaroka Volcanic Province was highly explosive. Dacitic pyroclastic flows of hot, flowing volcanic debris erupted from small, localized volcanic domes in northwest Yellowstone and produced ash-flow tuff and pumice-fall deposits. These oldest known deposits are at the base of Sepulcher Mountain. Previously mapped as Lost Creek Tuff, an $^{40}Ar/^{39}Ar$ eruption age of 53.0 Ma indicates that these tuff deposits are four million years older than earlier estimates. This early event was followed by eruption of rhyolite ash-fall from the South Fork volcanic center, which can be seen on the South Fork of the Shoshone River. This eruption blanketed the Wind River Range south of Yellowstone with ash.

Then, during a period of only two million years, eruption took place over a broad region, encompassing the entire province and producing most of the Absaroka Volcanic Province deposits found in Yellowstone Park today. It began 49.5 million years ago with the eruption of Slough Creek Tuff. Erosional remnants of this ash-flow tuff are thick and extensive, and cover a large part of the area which is now the southern Beartooth Mountains and northern Yellowstone. It resulted from a large-scale explosive eruption that produced volumes of ash which covered an even larger area in the past. Preserved outcrops in the southern Beartooth Mountains are several hundred feet thick. In Yellowstone, the tuff is most visible west of Slough Creek, where it appears as a deposit with distinctive light and dark bands which can be seen when hiking along the Slough Creek trail. When the ash was deposited, some of it was hot enough to melt back together, becoming welded. The welded portion of the Slough Creek Tuff is black volcanic glass overlain by very light-colored nonwelded ash, which gives this deposit its striped appearance.

Lava flows on Sepulcher Mountain, Crescent Hill, Buffalo Plateau, and Elk Creek erupted from fissures following the eruption of Slough Creek Tuff. Pryoclastic flows are also characteristic of this eruptive period. Much of this debris was remobilized by water into volcanic debris flows, commonly called lahars. This kind of mobilization typically results from deposition of large volumes of fragmented material (mostly volcanic ash) on steep slopes, which kills plant life and chokes stream channels. Volcanically induced rainfall, in addition to ash-filled river water, act to remobilize volcanic debris into sediment-water mixtures which resemble rapidly flowing concrete.

Deposits similar to those in the Absaroka Volcanic Province have been produced during recent volcanic eruptions such as the 1991 eruption of Mt. Pinatubo in the Phillipines, where millions of cubic tons of debris were redistributed by lahars in only a few years following the eruption. In Yellowstone, deposition of lahar and streamflow deposits produced the Sepulcher and Lamar River formations, which are thick, coarse-grained deposits containing numerous upright fossilized trees. These deposits can be seen in the Lamar Valley surrounding the Lamar Ranger Station, along Icebox Canyon, on Sepulcher Mountain, and on Bighorn Peak. Eruptions from vents located in the Two Ocean Plateau area of southern Yellowstone also began about 50 million years ago, but most of the early deposits in this area were eroded away.

Marking Time

A second large ash-flow eruption occurred 48.8 million years ago, depositing the Lost Creek Tuff and Pacific Creek Tuff. Although mapped separately in the past, they are now correlated based on $^{40}Ar/^{39}Ar$ ages and shared geochemical composition. Products of this second large ash-forming eruption can be found across a broad region, from the Hellroaring trailhead and Floating Island Lake in the north to Two Ocean Pass at the southernmost margin of Yellowstone National Park—and beyond park boundaries. Deposits from large ash flows such as this one are important in determining stratigraphic relations and geologic history, because they are widespread and produced from an instantaneous event. They represent a time line or marker bed which allows correlation of volcanic deposits above and below them. Geologists can use the age of two or more of these deposits to estimate the volume of material erupted during a given period of time. Immediately above and below this ash-flow deposit, and correlated by its presence, are large volumes of fissure-fed lava flows that erupted near Sylvan Pass and the Mirror Plateau in eastern Yellowstone. Also correlated with this ash-flow deposit, where it is found in southern Yellowstone, are lava flows, pyroclastic flows, and lahar deposits of the Langford Formation. A period of broad uplift followed, producing widespread tilting and erosion, exemplified by the erosional unconformity at the top of the Langford Formation in southern Yellowstone. Deposits of the Langford Formation, ash-flow tuff deposits, and this well-developed unconformity can be seen along Pacific Creek, Two Ocean Creek, and from the Two Ocean Plateau trail.

Tracing the Tectonic Story

An ash-fall deposit in the Two Ocean Formation, now correlated with the Blue Point ash-fall in the greater Yellowstone region, erupted 47.5 million years ago

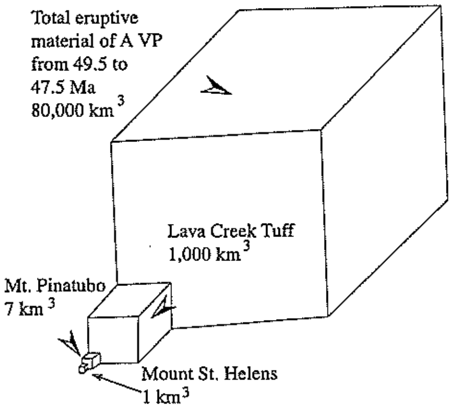


Figure 7. Volumetric comparison of ash-flow tuff produced by recent eruptions and total eruptive products from the Absaroka Volcanic Province, including the Yellowstone caldera eruption of Lava Creek Tuff which took place 600,000 years ago (modified after McBirney, 1979).

and marks the end of widespread Absaroka volcanic activity in the park (Fig. 7). It is preserved on Two Ocean and Trident plateaus and can still be seen from the trail along Thorofare Creek. This same deposit can be seen outside Yellowstone, as light-colored layers of volcanic ash on Ramshorn Peak, on the north side of Highway 287 between Jackson and Dubois, Wyoming.

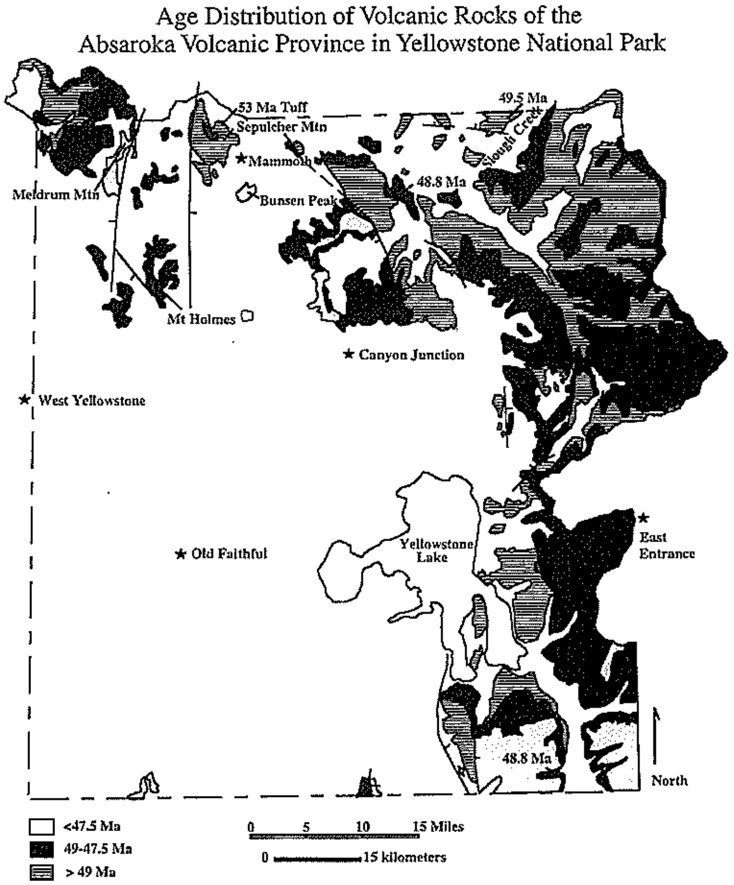


Figure 8. Map of Absaroka volcanic rocks in Yellowstone Park showing age relations based on recent stratigraphic correlations.

Estimating the volume of material erupted during the Absaroka period is not easy, because what remains today is an erosional remnant of what was originally produced. Any estimate must be based on where we see remaining deposits belonging to the Absaroka Province, and assuming that the area between these also contained material produced by this episode of eruptive activity. It is highly unlikely that the entire area now occupied by the younger Yellowstone caldera (c.a. 0.6 Ma to 0.06 Ma) once contained volcanic rocks of the Absaroka episode, because the earlier volcanic rocks surround the caldera today. During the two-million-year period between the eruption of Slough Creek Tuff, which occurred 49.5 million years ago, and the Blue Point ash-fall, nearly all of the Absaroka Province volcanism within Yellowstone was complete, and probably more than 80,000 km^3 of volcanic material had erupted (Fig. 7). In northern Yellowstone, the last eruptions produced volcanic domes of silicic lava (dacite to rhyolite composition), such as Bunsen Peak and Meldrum Mountain (Fig. 8). Silicic lavas such as these are very viscous and do not flow very far, producing these thick deposits.

Most of the younger Absaroka volcanic deposits in Yellowstone are limited to pumice, ash-fall, and light-colored rhyolite flows on Two Ocean and Trident plateaus, which are interbedded with deposits from lahars. These deposits are typical of the last period of volcanic activity, which ended with the eruption of Dunrud Peak rhyolite southeast of the park 43.7 million years ago. Although some of the youngest deposits in southern Yellowstone have not been dated, future work may allow them to be correlated with volcanic deposits in the surrounding region (Fig. 9).

With continued research, lava flows and ash-falls will be traced to individual volcanoes within the Absaroka Volcanic Province. As the history of the volcanic field is pieced together, so is the tectonic history of North America. The age data from this study is combined with chemical analyses of major and trace elements and of isotopes of Nd (neodymium), Sr (strontium), and Pb (lead) from the volcanic rocks. This data is used to determine how and where the magma that erupted in the Absaroka Volcanic Province first formed, and why eruptions occurred within the North American Plate during this period. New stratigraphic information from my study can also be used in the study of important fossil assemblages, and to document a period of dramatic change in Earth's history. Understanding how the Earth's climate has changed, and its volcanic behavior in the past, enables us to better predict these types of behavior in the future.

Magnetic Polarity	Gallatin Range Beartooth Mtns	YELLOWSTONE PARK			S and E of Yellowstone
		Northwest	Northeast	Southeast	
Normal	HyaliteVolcanics & Mt Wallace Lava Flows & Lahars 47.7 Ma*			Pumice and Ash-fall Rhyolite Flows & Lahars	Dunrud Peak Rhyolite 43.7 Ma Mt Burwell Dacite 45.3 Ma Rampart Volcano 46.6 Ma Caldwell Canyon Rhyolite & Pinnacle Buttes Tuff 46.8 Ma
Reversed 47.5 Ma			**Blue Point Ash-Fall 47.5 Ma / Two Ocean Ash-Fall 47.5 Ma**		
		Bunsen Peak 48 Ma (FT)		Langford Fm Lava Flows & Lahars	Lava Flows at Kirwin Center Phelps Mtn Ptarmigan Mtn
48.8 Ma			**Lost Creek Tuff 48.8 Ma / Pacific Creek Tuff 48.8 Ma**		
	Independance Stock 48.5 Ma Big Creek Stock & Golmeyer	Mt Wallace & Sepulcher Lava Flows	Sylvan Pass & Mirror Plateau Lava Flows	Absarokite & Shoshonite Flows	
Normal	Rhyolite Domes Rhyolite & Absarokite Flows		Crescent Hill Elk Creek Lava Flows		Lower Trout Peak Ptarmigan Mtn Flows
49.5 Ma			**Slough Creek Tuff 49.5 Ma**		
	Independance Sill & Flow Breccia 49.9 Ma	Sepulcher Mtn Lava Flows Pumice Fall-Out Ash-Flow Tuff 53.0 Ma	Mt Wallace Lava Flows	Langford Fm Dike 50.2 Ma*	South Fork Center & Wind River Ash-Fall 50.5 Ma Rhyolite Tuff 51.5 Ma 52 Ma* Willwood Fm Ash-Fall

Figure 9. Stratigraphic relations of volcanic rocks within the Absaroka Province, with locations of rock types and formations subdivided within Yellowstone Park and surrounding areas.

Table 1. Types of volcanic rocks found in the Absaroka Province.

ROCK TYPE	OCCURRENCE	COLOR	MINERALS
Absarokite	Flows from prominent dark cliffs	Black/dark grey	Olivene/pyroxene
Shoshonite		Dark grey	Pyroxene
Banakite		Grey	Olivine/plagioclase/biotite
Dacite	Thick flows form knobs, or in explosive eruptions of ash-flow tuffs	Light grey/tan	Plagioclase/hornblende/biotite
Ryodacite		Tan/orange/pink	Sanidine/biotite/quartz
Rhyolite		Tan/orange/pink	Sanidine/biotite/quartz

Margaret Hiza is presently a graduate student in the department of Geosciences at Oregon State University. Her Ph.D. research on the Absaroka Volcanic Province has been funded by the U.S. Geologic Survey as an internship with the National Cooperative Mapping Division in Denver, Colorado. She began working in the province while working on her M.S. in Earth Science at Montana State University in 1990, under a National Science Foundation Fellowship. Her research has also been funded by grants from GSA, AAPG, Sigma Xi, The Colorado Scientific Society Pierce Memorial Fellowship, and the J.D. Love Fellowship. She plans to graduate this year and hopes to continue geologic research related to geochemistry and volcanism within the Yellowstone region.

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