This toothed steppe, furrowed and gouged and spilled in pyramids, is not for persons whose homes are in tropical growth under cloudy skies. This is the last frontier, delivered to rock and desolation and set apart as a monument of its own.

— Vardis Fisher

_Idaho: A Guide in Word and Picture_, 1937

VOLCANIC CRESCENT

CRATERS OF THE MOON, sometime in the future. Steam and volcanic ash rise from the desert. A black flow of slow-moving lava blocks a muddy road. Thin sheets of fluid lava boil up from a 2-mile-long crack in the ground. In places along the crack, fountains of fiery cinders explode in the air. Molten rock, glowing orange, cools into black

BY BILL HACKETT AND BILL BONNICHSEN
The Snake River Plain and its relationship to the Columbia Plateau; previous page, East Fork of the Owyhee River; detail, geologist's rock hammer.

The next volcanic eruption — be it five years or 5,000 years from now — will be the latest episode in a story that has been written over the last 15 million years as the forces of nature have created the wide crescent of southern Idaho known as the Snake River Plain.

The plain, a 50- to 70-mile-wide belt of sage-covered lava and farmland, is the dominant geographic feature of southern Idaho. It is also one of the most widely known and most extensive volcanic regions on Earth. The birthplace of the volcanic belt is near the shared corners of Idaho, Oregon and Nevada, where the first eruptions occurred about 15 million years ago. Since that time, volcanic eruptions seem to have migrated eastward at 1 to 2 inches per year, with the most recent volcanic activity having taken place in eastern Idaho and Yellowstone. Viewed in terms of geologic time and the age of the Earth, the formation of the Snake River Plain—Yellowstone region is a relatively recent event, representing only a few tenths of one percent of the Earth's history.

Eruptions on the plain have come in cycles. For example, the Craters of the Moon lava field was formed by dozens of lava flows during eight eruptive periods over the past 15,000 years. Crusts. Lakes of molten lava form along the fissure. Sagebrush and grasses still burn at the edges of advancing flows, and clouds of billowing steam become afternoon thundershowers. At dusk, photographers capture the glowing lava beneath a smoky red sunset. The Snake River Plain, dormant for 2,000 years, comes back to life.
Shaded relief map of Snake River Plain produced on computer using digital topography. From U.S. Geological Survey map I-2206.

years. Each eruptive period lasted only a few years or decades and was followed by a long, quiet interval of a thousand years or more. These accumulated lava flows have buried the Snake River Plain to depths ranging from several hundred feet thick in southwestern Idaho to more than a mile thick on the eastern portion.

But what have the lava flows buried? Beneath the thousands of feet of blue-black basalt are the remnants of massive volcanoes — just like the caldera that occupies Yellowstone Park. The basalt lava flows we see on the surface are a relatively thin veneer covering these ancient volcanoes and the enormous deposits of tuff they created.

Most geologists believe the Snake River Plain volcanic belt was caused by the westward movement of the North American continent over a source of magma, or “hot spot.” These hot spots are fed by deep, upwelling currents of extremely hot, perhaps partially molten rock. Creeping upward at rates less than 1 inch per year, these volcanic plumbing systems, known as mantle plumes, can extend several hundred miles into the Earth’s interior and are the source of basaltic magma that erupts at hot-spot volcanoes.

Deeply rooted in the Earth’s mantle, the plumes essentially remain fixed in place for tens of millions of years while the continental plates shift above them. Like burn marks that form on a piece of paper as it is moved over a candle flame, hot-spot volcanoes erupt onto the Earth’s surface above these mantle plumes. Above any one hot spot, volcanism is active for a few million years and the volcanoes are slowly carried away from the heat source as the Earth’s crust shifts. Eventually they become extinct and are covered by subsequent lava flows and sediments.

Mantle plumes leave trails of hot-spot volcanoes that become progressively older as they move away from the plume. Thus, as the North American continent moved westward, the trail of volcanoes on the Snake River Plain that resulted from the mantle plumes moved eastward. The hot spot is believed to

BASALT, the most common type of lava, is high in iron and low in silicon and volatile gases. It typically comes to the Earth’s surface in mild eruptions, with the consistency of honey or peanut butter.

ASH AND TUFF FLOWS are created when rhyolite magma under tremendous pressure erupts in great explosions which send fountains of molten ash into the sky. As the ash falls back to Earth it spreads laterally and compacts under heat and pressure, welding together in layers of tuff.

The MANTLE is a zone of the Earth beneath the crust, starting 30-40 miles beneath the surface.

MAGMA is molten rock resulting from the melting of the upper mantle or deep crust.

Once molten rock erupts onto the Earth’s surface, it is called LAVA.
At the Idaho-Oregon border, where the Snake River Plain eruptions began 15 million years ago, superheated clouds of ash erupted in great explosions and cascaded across the terrain. When the flows stopped, the ash fused, creating deep layers of welded tuff.

have originated at what is now the junction of Idaho, Nevada and Oregon. The migration of the continent over the hot spot created a line of huge explosive volcanoes trending northeast. Geologists view southwestern Idaho as the oldest expression of the hot spot, and Yellowstone Park as the most recent.

The early volcanic activity was much more violently explosive than the relatively calm basalt lava flows that followed. The explosiveness of this early volcanic period is attributed to the type of rock being melted and put under pressure. The hot spot melted the Earth's lower crust, creating rhyolite, a type of magma containing dissolved water vapor and much silica. Rhyolite eruptions can be very explosive, with ash discharge 100 to 1,000 times more voluminous than the 1980 eruption of Mount St. Helens.

Frequently on the Snake River Plain, the volcanoes erupted in great explosive clouds of hot, gas-charged rhyolite ash that shot 5-10 miles into the sky. The superheated ash returned to Earth and flowed for miles, then bonded together, forming what is known as welded tuff. Once the explosive rhyolite magma had erupted, the hotter and heavier basalt magma rose to the surface, burying the rhyolite under successive flows that spanned several million years.

Layers of rhyolite pumice and ash flows can be seen in the walls of the Snake River canyon. Overlying these layers, exposed in cross section by the river, are layers of black basalt, which mark the second wave of volcanic activity on the plain.

In the wake of the hot spot, the Earth's crust has deflated into a long trough that is filling with sediments eroded from the surrounding mountains. Thus, the Snake River Plain can be thought of as a burial ground of ancient Yellowstone "national parks," each taking its place in line, awaiting coverage by younger lava and sediments.

Rhyolite flows on the Owyhee River canyon exhibit cooling fractures which, when eroded, yield talus slopes of large red rhyolite plates.

RHYOLITE magma is created by the melting of the continental crust at great depths. Rhyolite is thick magma high in silicon and volatile gases, which cause it to erupt violently as it reaches the Earth's surface.
Yellowstone National Park is the latest expression of the "hot spot" that is believed to have created the Snake River Plain. The hot spot is a stationary plume of partly molten rock from deep within the Earth. As the westward-moving continental plate passes over the plume, the continental crust is melted and magma erupts to the surface in tremendous explosions. The resulting calderas — huge craters — are later buried by sediments and flows of basalt magma.
Few natural events are more awesome than volcanic eruptions, which give us brief glimpses into the internal workings of the planet. The most ancient rocks on Earth are of volcanic origin; the crust of the Earth also is largely volcanic rock. Together with life-giving oxygen from photosynthetic plants, volcanic gases have produced the Earth's atmosphere and continue to add to it. Although most people think of volcanoes as symmetrical, snow-capped cones with ash billowing from their summits, these are only one variation.

Some volcanoes hardly look like mountains, but all have an essential ingredient — molten rock called magma. Most magma originates from the melting of the Earth's deep crust and upper mantle. Upon reaching the surface, the magma, generally known as lava, takes many forms depending on its composition and properties.

Basalt lava, the most common type on Earth, is dark due to its high iron content. The countless basalt volcanoes that erupt unseen beneath the ocean add about 1 cubic mile of new lava each year to the Earth's crust. Blocked by the thick continental crust, basalt eruptions are less common on land, but they do occur where continents are being torn apart during the creation of new ocean basins. Basalt also erupts in places like the Snake River Plain, where hot plumes of magma melt through the crust. Basalt typically reaches the surface as mild effusions of thin, fluid lava flows.

The Hawaiian word “pahoehoe” is used for the smooth, ropy-surfaced lava. Pillow lava is another basalt variety that forms underwater, where it develops a glassy skin. From 6 inches to 6 feet across, each pillow of lava resembles piles of extruded toothpaste or deflated beachballs. The spaces between the pillows are usually filled with pieces of a pea-sized glassy material.

Rhyolite, another volcanic rock, is a lava that is formed during the melting of the deep continental crust. It is typically pale and sugary; less commonly, it is glassy, in which case it forms black obsidian.

As opposed to basalt, rhyolite moves sluggishly and usually solidifies underground, forming huge bodies of crystalline granite that break the Earth's crust and slowly cool to form so-called plutons and batholiths. When rhyolite does erupt, however, expanding gases can literally blow the roof off the magma chamber, and entire continents can be blanketed with ash from the ensuing explosions.
As the underground rhyolite magma chambers are evacuated during eruptions, the overlying roof rocks often collapse inward like a fallen soufflé, forming a broad, shallow depression up to tens of miles across and up to thousands of feet deep. Known as calderas, these giant, circular depressions may have spectacular, steep walls such as Crater Lake in Oregon. Others are so broad and shallow that they are hardly recognizable as volcanoes. Filled by ash and pumice, they are nonetheless the sites of volcanism on its grandest scale.

In the long intervals between explosive eruptions, relatively quiet rhyolite eruptions commonly occur. Viscous lava flows ooze from fractures in the Earth’s crust. The pasty lava crystallizes very sluggishly and is often chilled to form obsidian, a dense variety of volcanic glass.

Huge, explosive eruptions of rhyolite are relatively infrequent in the geological record. On the Snake River Plain, they have occurred about once every million years or so. None has occurred during historic times.

Andesite lava, a third variety, is a fine-grained derivative of basaltic magma that forms small cinder cones and thick block-lava flows in places like Cedar Butte and Craters of the Moon. The beautiful volcanoes along the Pacific, the “Ring of Fire,” are andesite cones, but andesite is rare on the plain.

**LAVA TYPES**

A’A is the rough lava created as flowing lava cools and becomes viscous.

Pahoehoe is a smooth, ropy lava created when the surface of a basalt flow cools and the fluid material beneath keeps moving.

Blue dragon is pahoehoe lava containing titanium oxide, which creates an iridescent blue sheen.

Pillow lavas are formed when basalt flows into water. The outer surface cools into a glassy skin.

Andesite is intermediate in composition between basalt and rhyolite. Its pasty consistency forms rubbly surfaces and spines.

Obsidian is volcanic glass created by rapidly cooling, gas-free rhyolite lava.
The violence of volcanic eruptions depends on two components in magma: silicon and dissolved gases. The silicon content controls the viscosity of magma — its pastiness or resistance to flow. As with adding flour to pancake batter, increased amounts of silicon in the magma serve to increase viscosity. Water vapor is the major gas dissolved in most magma. Rising magma can also boil groundwater and touch off explosions that rip through the crust.

In principle, these eruptions resemble the opening of a bottle of soda pop, where high-temperature steam takes the place of the carbonation bubbles and viscous rhyolite magma the place of the soda pop. In the sealed soda pop bottle, gases are held invisibly in solution, which is analogous to water vapor dissolved in magma deep underground (such magma never contains gas cavities). When the bottle is opened, the expanding gas bubbles usually float gently to the surface, as they do in quiet volcanic eruptions of fluid, gas-poor magmas. But if the liquid is under great pressure and contains an excess of gas, as when the sealed contents are shaken, a liquid-gas froth may gush from the bottle. In a volcanic explosion, the internal pressure within the viscous, gas-charged magma is so great that the gas expands explosively, tearing the magma into bits of glassy froth called pumice, or bursting the bubbles themselves, resulting in tiny shards called volcanic ash.

That ash may spread for miles, settling and welding together to create deposits of tuff hundreds of feet deep. Usually these tuff deposits are buried by subsequent, less violent flows of rhyolite or basalt.

But where rivers have carved deep canyons, these layers of different lava flows can be seen in sequence, descending back into time as one views the walls from top to bottom. Viewed this way, our farms and towns perched atop the latest flows of basalt can be seen for what they are: a tiny episode of occupation on a land that has continually re-created itself by burying its former surfaces.

**Caldera formation.** Rhyolite magma rising from the depths bulges through the Earth's surface, then breaks through in a cataclysmic eruption which sends molten ash thousands of feet into the sky. Following the eruption, the now-fractured dome collapses into the evacuated magma chamber, forming a huge crater or caldera that may be tens of miles across and several thousand feet deep.
VOLCANIC ORIGINS

The Owyhee-Humboldt eruptive center, the area in which the first major eruptions of rhyolite occurred on the Snake River Plain, does not look like a typical volcano. Rather, it is a broad, dishlike area of about 40 by 60 miles that apparently collapsed during rhyolite eruptions. An obvious caldera did not form, perhaps because the magma chamber was too deep to allow the overlying rocks to cave in. At the central part of the Owyhee-Humboldt eruptive center is a field of basalt shield volcanoes and accompanying lava flows that are about 10 million years old. These are surrounded on all sides by older layers of rhyolite — mainly ash-flow tuffs — that are tilted inward toward the center of the basin, beneath the basalt.

About 11 million years ago, volcanism shifted to the east, forming the Bruneau-Jarbidge eruptive center. Like the older Owyhee-Humboldt area, the Bruneau-Jarbidge center is a broad, downwarped region some 60 by 35 miles across. Between about 10 to 11 million years ago, a sequence of 11 or more welded, ash-flow tuff layers (the Cougar Point Tuff), at least 12 large rhyolite lava flows, and many thin basalt lava flows erupted within the basin. The eastern and northern margins of the eruptive center are now buried beneath the younger basalt lava flows of the central Snake River Plain. Farther south, the Cougar Point Tuff is magnificently exposed in the deep canyons of the Bruneau and Jarbidge rivers.

Each ash-flow deposit of the Cougar Point Tuff was typically formed by several glowing clouds of ash and pumice, spaced so closely in time that they welded and cooled as a single layer of tuff. Near the base, particles of volcanic ash were densely welded into obsidian or vitrophyre (obsidian with crystals). The emplacement of each layer was a distinct volcanic event, and buried soils and sediments between layers of welded tuff indicate the passage of considerable time between these cataclysmic eruptions.

About a dozen large rhyolite lava flows are located within the Bruneau-Jarbidge eruptive center, and several of them are exposed in deep canyons there. One of the most-studied flows is the...
The Owyhee River, like the Jarbidge and Bruneau rivers, was carved when Lake Idaho was suddenly drained by Hells Canyon of the Snake River. The canyon had eroded headward, creating an outlet for the huge body of water. The Owyhee River, which drained into Lake Idaho, then began eroding headward as its gradient was suddenly steepened by the dropping water level of the lake.
Dorsey Creek Rhyolite, a single lava flow that is exposed in the walls of the Jarbidge River canyon for a distance of about 25 miles. This flow has a minimum volume of about 20 cubic miles and is at least 700 feet thick.

Large-volume rhyolite lava flows similar to those of southwestern Idaho and Yellowstone are known in few other regions of the world. Because of the extensive exposures in the deep canyons of the Bruneau and Jarbidge rivers, the shapes and internal features of these unusually large lava flows have been well documented.

Rhyolite lava-flow interiors generally have three zones: a quickly cooled basal zone of glassy or chaotically broken rhyolite; a thick central zone of gray to reddish brown, finely crystalline rhyolite that formed during relatively slow cooling; and an upper cap and margins of sheeted, contorted and broken rhyolite. The large quantities of broken rubble on the tops and margins of rhyolite lava flows are formed as a chilled, brittle skin develops on the moving lava. The massive interiors of flows are typically more than 150 feet thick.

More than half of the Bruneau-Jarbidge eruptive center is covered by basalt lava flows, each ranging from 5 to 30 feet in thickness. The basalt lavas erupted from shield volcanoes scattered around the area. About 40 shields are known, each made of thin basalt lava flows and with a typically low profile. Most are circular or oval, with heights from 50 to 300 feet and diameters typically between one and four miles. Many have craters preserved at their tops. Since buried soils and sediments do not occur between the lava flows that erupted from a single volcano, it appears that the succession of basalt lava flows from each volcano erupted in only a few years. Much of the basalt evidently spread as thin sheets as a consequence of rapid discharge of fluid lava over relatively flat terrain.

**CLARENCE R. KING**  
(1842–1901)

He was "the best and brightest man of his generation," said historian Henry Adams; "the richest and most many-sided genius of his day." Clarence King of Yale — poet, mining engineer, a founder and the first director of the U.S. Geological Survey — was a hero from a golden age when the Intermountain West was the frontier of American science. An urbane man with a derby and bright yellow gloves, King, at age 25, organized the famous 40th Parallel Survey, a study of the high desert between the Rockies and the Sierra Nevada. The expedition reached Idaho in 1868. "The monotony of the sage desert was overpowering," King reported, yet the beryl-green Snake with its ragged cliffs was "dazzling" and "fantastic," a scene of "extreme beauty." King's investigation of volcanism in Idaho confirmed his belief that the Earth, younger than previously thought, was no older than 24 million years. His Idaho studies also contributed to a classic work on the western mountains, *Systematic Geology* (1878), a sweeping overview that showed how quakes, floods and eruptions altered the biological process of natural selection and accelerated the pace of ecological change.
The western Snake River Plain, a broad valley with Boise at its northeastern margin, is perhaps best considered as a troughlike structure that developed at the same time as other geologically young mountains of southern Idaho and northern Nevada. It began forming about 12 million years ago with major eruptions of rhyolite, followed by voluminous outpourings of basalt lava.

Large amounts of basalt lava, together with lake and stream sediments, were deposited onto the western plain as it slowly subsided during stretching of the Earth's crust. In the lower reaches of Bruneau Canyon, some 800 feet of basalt lava flows are exposed. Farther to the northwest, lake and stream sediments dominate the surface geology, but deep drilling has revealed that much basalt lava is buried far below the Earth's surface, indicating that several thousand feet of subsidence, or sinking, has occurred on the western Snake River Plain during the last few million years.

Considerable geologic evidence, including lake-deposited sediments, fossils and pillowed basalt flows, indicates that large lakes blanketed southern Idaho and filled the troughlike basin of the western Snake River Plain between 1 and 10 million years ago. Lake Idaho is a geological term for this series of lakes that waxed and waned with the changing climate.

In the lower Bruneau Canyon, as well as in other areas throughout the western and central Snake River Plain, features of the basalt lava flows and pyroclastic deposits suggest that the highest stand of Lake Idaho was about 3,800 feet above sea level. Lake Idaho was permanently drained 1 million years ago when a then-small tributary of the

Lake Idaho built a reef of algal mounds and snail shells, which is exposed near Bruneau in a rock formation known as the Hot Spring Limestone.

Pyroclastics are fragments of magma caused by expanding gases trapped in the lava. Basalt pyroclasts frequently fall to the ground in piles, building cinder cones.
Salmon River eroded headward, eventually reaching the lake and causing its waters to drain northward, forming the Snake. This tributary, eroded by the massive flood of water from Lake Idaho, became the Hell's Canyon of the Snake River.

During and after the final lake recession, the Bruneau River and other streams that emptied into the lake were left with mouths perched high above the lake floor. As these streams eroded downward, adjusting to the new base level, they carved deep canyons through the basalt. Thus the many magnificent canyons in southwestern Idaho, including those of the Owyhee and Bruneau rivers, owe their origins to the demise of enormous Lake Idaho.

During the era of Lake Idaho, volcanic eruptions and lava flows continued, with the interactions of magma and water creating unique geological features that can be seen throughout southwestern Idaho.

Explosive interaction of basalt magma and underground water and lake water produced large cones of fine-grained tuffs. The distinctive orange-brown color of these basaltic tuffs is due to palagonite, a substance that forms when hot basaltic glass chemically interacts with steam or water. Deposits of palagonite tuff can reach hundreds of feet thick near large volcanoes such as Sinker Butte. Some of these tuff cones built up above the lake level, and their eruptions changed from explosive magma-water reactions to Hawaiian-style fire fountains. Often the explosions were powerful enough to throw yard-wide blocks and bombs of basalt hundreds of feet from their source. The “caps” of welded spatter on Sinker Butte and Castle Butte protected the softer tuffs from erosion, so they remain as prominent landforms today.

Where the lava poured down underwater slopes, it formed bulbous masses of glassy-skinned rock — pillow lava. Thick accumulations of pillow lava made extensive deltas along some of the steeper shorelines. Other lava flows were altered into crumbly brown masses that look as if the rock had “stewed” in warm water.

**WELDED SPATTER** is an accumulation of lava bombs and ejected magma which melts together and cools, forming pillars and cones or capping previous volcanic eruptions.

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*This cross section of a volcanic crater was created when Sinker Creek eroded through the crater margin of the Montini volcano near Murphy. Basaltic tuffs were erupted from a large crater to the left and piled several hundred feet high. The cap of welded spatter on the top of the hill has protected the softer tuffs below from erosion.*
"The route was very rocky," said trapper Osborne Russell, crossing the plain in 1835:

On surveying the place I found I could go no further in a south or east direction, as there lay before me a range of broken, basaltic rock which appeared to extend for five or six miles on either hand and five or six miles wide, thrown together promiscuously in such a manner that it was impossible for a horse to cross them. I had plenty of provisions, but could not eat. Water! Water was the object of my wishes. Traveling for two days in the hot burning sun without water is by no means a pleasant way of passing time. I soon fell asleep and dreamed again of bathing in the cool rivulets issuing from the snow-topped mountains.

Russell and his contemporaries would have been surprised to learn that the barren land of the eastern plain would one day be irrigated by underground water pumped from buried basalt lava flows and sedimentary deposits.

The eastern Snake River Plain is underlain in places by more than a mile of basaltic lava flows, erupted mostly within the last 2 million years. Within the fractures and cavities of the basalt lava flow courses one of the eastern plain's most remarkable features — the Snake River Aquifer.

The aquifer is a huge network of underground water underlying about 10,000 square miles of south central and eastern Idaho, from the town of Hagerman northeast to Island Park. The aquifer is fed by rainfall and melting snow from a 35,000-square-mile area in the surrounding basin and range mountains. Several of Idaho's "lost rivers" meander for miles over permeable lava beds before they percolate into the ground. The eastern and central Snake River has only two northerly tributaries — Henry's Fork of the Snake and the Big Wood River. All other northerly streams disappear into the lava and feed the aquifer before reaching the Snake River. The underground water moves slowly through the volcanic rocks and sediments, at rates estimated to be 2 to 10 feet per day. Yet the yearly influx and discharge of underground water is substantial: about 8 million acre-feet — enough water to cover the entire state of Idaho in 1.5 inches of water. The total storage capacity may be equal to the present volume of Lake Erie, enough water to exceed four centuries of Snake River flow.

The aquifer feeds the Snake River in many places, notably at springs near American Falls and between Twin Falls and Hagerman. The Thousand Springs area near Hagerman contains 11 of the 65 largest cold springs in the United States. Between 1910 and 1950 the volume from the springs almost doubled due to upstream irrigation — ditch water drawn from the river that percolated into the aquifer.
SNAKE RIVER AQUIFER

Porous lavas along the Snake River provide an outlet for the Snake River Aquifer at Thousand Springs in the Hagerman Valley. The aquifer is fed by rain and snow from the mountains, whose rivers disappear into the porous basalt of the Snake River Plain. The water moves to the southwest through fractures in the basalt.
The discharge has since declined, due mainly to the increased use of groundwater for irrigation and to decreased diversions of surface water.

From April to October each year, nearly all of the Snake River water upstream from Twin Falls is diverted for irrigation, and aquifer-fed springs provide most of the river water that is used downstream for agriculture, aquaculture, power generation and residential consumption. A few impressive springs remain, although commercial development has diminished the former grandeur of the area.

The volcanic and hydrologic processes that created the Thousand Springs area have recurred many times on the eastern plain. North and east of what is now the town of Hagerman, basalt volcanoes were periodically active during the past half million years or so, filling several ancestral Snake River canyons with lava and forming temporary lakes. Later lavas that flowed into the lakes were highly fractured and created permeable pillow lavas, whereas those in the dry channel downstream of the dams were relatively dense and impermeable.

The Snake River has since eroded its present canyon farther to the south, cutting through the permeable pillow lavas and unleashing the groundwater contained in them. The emergence of springs is thus controlled mainly by the distribution of pillow lavas and other, less permeable lavas and sediments in the north canyon wall.

Geologic evidence of the river’s shift has been reported from many places on the plain. Pillow lavas and lake beds are exposed in the canyon of the Snake River near Bliss and Hagerman and along the Boise River canyon. On the eastern Snake River Plain, American Falls Lake was an ice-age lake that formed behind lava flows from vents near Massacre Rocks. Many well-preserved fossils of large ice-age animals have come from the ancient sediments of American Falls Lake.

Basaltic volcanism was generally very mild in character, with lava flows erupting from small shield volcanoes and fissures. Sedimentary deposits interlayered with the lava flows include sand dunes, wind-blown silt (known as loess), playa deposits, lake beds and river sediments. The eastern plain is dotted by dozens of shield volcanoes, each covering a few square miles and built by thousands of thin, fluid lava flows. Cinder cones...
are relatively uncommon on the eastern plain, and most are confined to volcanic rift zones where viscous, gas-rich magma erupted, such as at the Craters of the Moon lava field.

Many flows were fed by extensive systems of lava tubes — underground channels within the flows that developed when the lava crust congealed and insulated the still-fluid interior of the flow. When lava ceased to flow from the vent, many of the tubes drained and their roofs collapsed, leaving an underground network of tunnels.

Basalt lava flows on the eastern plain cover an even thicker and much larger accumulation of older rhyolite deposits, exposed around the edges of the plain, from the Cassia Mountains to the Teton Range on the southern margin, and from the Centennial Mountains to the Pioneer Mountains along its northern margin.

One place where the cover of basalt is sufficiently thin for the Snake River canyon to cut deeply enough to expose the underlying rhyolitic volcanic rocks is 212-foot-high Shoshone Falls, about 4 miles from the city of Twin Falls.

Shoshone Falls was probably created during the Bonneville Flood, about 15,000 years ago, when the natural dam holding back the waters of Lake Bonneville gave way, unleashing a monumental torrent which filled the river canyon. During the flood, the Snake River eroded Melon boulders of basalt were ripped from the walls of the Snake River canyon during the Bonneville Flood, rounded by bumping against one another and deposited in gigantic “gravel” bars several hundred feet above the Snake River.

The 212-foot-high Shoshone Falls — higher than Niagara — was created during the Bonneville Flood as the river eroded during the cataclysmic deluge.
The historic photograph above shows the awesome spectacle of Shoshone Falls. But in recent years the Snake River has been literally de-watered upstream for irrigation, leaving the falls with but a trickle of water, as seen in this aerial view below.
Lava river
on the Great Rift

headward, cutting the canyon deeper up-
stream. The flood was as short-lived as it was
immense. When the lake was drained and the
flood subsided, the erosion halted. Shoshone
and Twin Falls mark the headward erosion of
the canyon when the flood ended.

Deeply eroded volcanic rocks in the area
around the falls are evidence of a great deluge.
The floor of the canyon even today is still
strewn with boulders from the flood.

THE HEISE VOLCANIC FIELD

O
n the eastern plain, geologists have
identified three very large and extensive rhyol-
ite ash-flow sheets, ranging in age from 4.3 to
6.6 million years. Together with other volcanic
rocks and sediments, those three major ash
flows form the Heise volcanic field.

Rhyolitic deposits of the Heise volcanic
field cover more than 13,500 square miles in
southeastern Idaho. The three widespread
rhyolite ash flows include the
6.6 million-year-old Blacktail
Tuff, the 6 million-year-old
Walcott Tuff and the 4.3 mil-
lion-year-old Kilgore Tuff. Vol-
canic ash layers from these
eruptions are found across
much of the western United
States.

All three of these ash
flows erupted from major cal-
deras that are now largely bur-
ied beneath younger basalts
and sediments formed mostly
during the last 2 million years.

The 4.3 million-year-old
Kilgore Tuff seen in the
foreground is one of three
widespread ash flows from
the Heise volcanic field on
the eastern Snake River
Plain. The Lemhi Range can
be seen in the background.
THE GREAT RIFT

In places on the eastern Snake River Plain, basalt volcanoes form lines of fissure-fed lava flows, small shields, spatter and cinder cones, pit craters and open cracks called volcanic rift zones.

One of the best known is the Great Rift, a 60-mile-long zone that crosses the eastern plain from the Snake River near American Falls to Craters of the Moon National Monument. Most of the outpourings were of basaltic lava, but some of the pyroclastic cones at Craters of the Moon were produced by more violent eruptions of viscous andesite lava. Carbon-14 dating of burnt vegetation beneath the lava flows and paleomagnetic dating have shown that volcanism along the Great Rift occurred mainly within the past 15,000 years, and the youngest eruptions occurred only about 2,100 years ago. Three lava fields were formed, separated from each other by noneruptive or “dry” rift segments, where the ground was cracked open by underground magma, but no eruptions took place.

Along a 6-mile segment of the northern Great Rift, the Craters of the Moon lava field was formed by dozens of lava flows and pyroclastic cones from eight eruptive periods that occurred over the past 15,000 years. Each eruptive period probably lasted a few decades or centuries, and each was followed by a long, quiet interval of a thousand years or more. Lava and pyroclastics totaling about 8 cubic miles were erupted from within the Craters of the Moon area, one of the largest postglacial lava fields in the world.

South of Craters of the Moon, the Great Rift is marked by a 25-mile-long segment of open cracks from which no lava issued during the last 15,000 years. A small field of thin basalt lava flows developed at the south end of the open cracks about 2,200 years ago. Known as the Kings Bowl lava field, this was the site of a lava pond that was fed by a 4-mile-long eruptive fissure. When the eruptions ended, lava drained out of the fissure, allowing groundwater to flood into the crack. The resulting steam explosions formed a 30-yard-wide explosion crater, known as Kings Bowl. Drainage of lava has left a complex system of underground caverns deep in the Kings Bowl rift segment. Known as the Crystal Ice Caves, they are a natural refrigerator, trapping cold, dense winter air that maintains the caves at a temperature just below freezing. Impressive pools and columns of ice occur in multiple chambers along the rift, fed by 2 millennia of rain and snow that have dripped down into the frozen caverns.

The southernmost volcano along the Great Rift is Wapi Butte, a basaltic shield volcano that last erupted about 2,300 years ago, and produced nearly 1.5 cubic miles of thin, fluid lava flows.

HAROLD T. STEARNS
(1900–1986)

The Hawaiian Islands look nothing like the arid Snake River country, but USGS geologist Harold Stearns, an authority on Idaho and the South Pacific, explored the connection: both were volcanic regions where water flowed freely underground through strata of fractured basalt. Stearns' research on Hawaii began with the great eruption of Kilauea Volcano in 1924. His Snake River work ranged from oil and diamond exploration to the Hagerman fossil beds. Stearns also won high praise from President Calvin Coolidge for the first scientific investigation of the Craters of the Moon area. From 1947 to 1959 he mapped irrigation and hydroelectric projects downstream of Pocatello — 11 dam sites in all.
Great Rift: left, cinder cones mark the line of the volcanic rift zone in the Craters of the Moon National Monument; above, Highway 20 cuts across a tongue of lava near Craters of the Moon; lower left, an eruptive fissure along the Great Rift; below, a cinder cone at Craters of the Moon formed during the most recent eruptions on the plain 2,100 years ago.
EXPLOSIVE BASALT VOLCANISM

Although basalt volcanoes normally erupt mildly, explosive basalt volcanism has occurred on the eastern plain due to the interplay between rising basaltic magma and underground water. Pyroclastic cones and explosion craters occur in the Massacre Rocks area near American Falls, the Menan Buttes near Rexburg, the Kings Bowl crater along the Great Rift and several other scattered vents.

The Menan Buttes are basaltic tuff cones that erupted along a 3-mile-long fissure about 8 miles west of Rexburg. The cones were formed during subsurface injection of basaltic magma into water-saturated river gravels and basalt lava flows of the aquifer. The resulting explosions threw out sand-sized brown tuff, as well as rounded pebbles and cobbles from the underlying river deposits.

The depth and amount of underground water are major factors controlling the locations of explosive basalt volcanoes on the eastern Snake River Plain. Large explosive complexes such as the Massacre Volcanics and the Menan Buttes formed along the southern margin of the Snake River Plain, near the ancestral Snake River and in other places where the ground was saturated with water. By contrast, such features rarely occur and are small in volume on the northern part of the eastern plain, where the water table is deep underground, in many places greater than 500 feet.

Although basaltic volcanism has dominated the eastern plain for the past several million years, a few rhyolite volcanoes have erupted in the past half million years or so, forming conspicuous landmarks that were used by pioneers as they traveled westward on the Oregon Trail.

Big Southern Butte and East Butte are domes of viscous rhyolite lava that erupted through the basalt flows. Middle Butte is a cap of basalt lava flows, believed to have been uplifted by yet another rhyolite dome that never reached the surface.

The Menan Buttes were formed when rising basaltic magma encountered water-saturated river gravels. The resulting explosions threw out tuffs, gravels and exploded lava, creating the buttes; left, Big Southern Butte is a dome of rhyolite lava that erupted through the basalt lava 300,000 years ago.
Along the Great Rift a sea of stone extends in all directions. Waves and whirlpools of blue-black lava stand fixed in time. The Great Rift crosses the eastern Snake River Plain as a narrow zone of open cracks, fissure-fed lava flows and pyroclastic vents whose northern end is marked by the Craters of the Moon lava field.

Over the past 15,000 years, hundreds of lava flows, cinder cones and spatter cones were formed during eight major cycles of volcanism at Craters of the Moon. Radiocarbon dates of charred vegetation under the lavas and cinders suggest that each of the eight eruptive periods probably lasted only a few decades or centuries, but were separated by long, quiet intervals of a thousand years or more. About 8 cubic miles of lava and tephra were erupted at Craters of the Moon, making it one of the largest postglacial lava fields in North America.

Early twentieth-century geologists and adventurers such as Harold Stearns and Robert Limbert were among the first to write about this raw landscape and its diverse community of plants and animals. Their superlative descriptions and recommendations helped generate interest in the Craters of the Moon National Monument, established in 1924.

The Craters of the Moon lava flows have an unusually wide-ranging chemical makeup; they are much more diverse than is typical of basalts elsewhere on the plain. Craters of the Moon lavas range from highly fluid, gas-poor basalt, which created small shield volcanoes, small spatter cones and tube-fed lava flows, to pasty, gas-rich lavas that erupted violently to form large cinder cones, or poured sluggishly from open cracks to form rubbly, steep-sided lava flows. These landforms mimic those of better-known hot-spot volcanoes such as the Hawaiian Islands, where lava flows are quickly covered by tropical vegetation and are soon weathered by drenching rains. But in the arid climate of southern Idaho, soils form slowly and plants find it hard to gain a foothold. Thus, the several-thousand-year-old cones and flows seem as if they formed only yesterday.

The geologically young, voluminous lava outpourings at Craters of the Moon seem to betray the hot-spot theory for the origin of the plain. If the hot spot is now reckoned to underlie Yellowstone, then why have the most recent eruptions occurred at Craters of the Moon, 150 miles from the hot spot? Although the Craters site is the largest postglacial lava field on the Snake River Plain, some eight more lava fields have also formed in the region within the past 15,000 years. These young lava fields erupted from several volcanic rift zones, and together they cover more than 10 percent of the eastern Snake River Plain. Geologists view this as "residual volcanism," volumetrically unimportant in the grand scheme of things, but hinting at the huge amount of heat and magma that still remains under the Snake River Plain more than 6 million years after the hot spot passed beneath the area.

Are future eruptions likely here? Volcanism at Craters of the Moon spanned 15,000 years of time, and its eight eruptive periods were separated by quiet intervals averaging about 2,000 years. Craters of the Moon last erupted a little over 2,000 years ago. Could it happen again? Geologists predict it will.
MOUNTAIN NEIGHBORS

The mountain ranges of southern Idaho end abruptly against the eastern Snake River Plain. The highest point in the state — 12,662-foot Borah Peak — is only 50 miles from the flat, mile-high lava plains.

The surrounding peaks are part of the Basin and Range Province, a distinctive region of mountains and valleys that are found throughout much of the western United States and northern Mexico. The region includes most of the terrain between the Rocky Mountains and the Sierra Nevada of California, where geologically young, precipitous mountains rise from encircling aprons of sediment that have been shed into the intervening valleys. There are more than 150 mountain ranges in the Basin and Range Province, each trending north-south and rising 3,000 to 5,000 feet above the surrounding lowlands.

Most of the ranges in southeastern Idaho are composed of uplifted sedimentary rocks deposited in ancient seas that intermittently covered parts of western North America between about 200 and 700 million years ago. Many ranges are capped by lava or volcanic tuff that was erupted much later, as the mountains began to uplift. The mountain ranges are typically asymmetrical with a steep slope on one side and a gentler one opposite due to curved faults that have uplifted one side of the mountain more than the other. The mountains “grow” by the uplifting and tilting of ancient strata, much like rows of closely spaced dominoes that have been pushed over. Weathering and erosion of the uplifted rocks then produces large amounts of sediment.

Mountain uplift and the shedding of sediments into the adjacent valleys have gone on for about the past 17 million years in the Basin and Range Province. Geological reconstructions suggest that the Earth’s crust has been stretched in an east-west direction.
by at least 50 percent during that time. The cause of the stretching can be attributed to upwelling convection currents in the Earth's mantle beneath a huge area of western North America. In the stretching process, cool, brittle rocks within a few miles of the Earth's surface fracture and fault into rugged mountains, but hotter rocks of the deep crust stretch like taffy.

Mountain building is an active process in Idaho today, as evidenced by numerous historical earthquakes to the north and south of the eastern Snake River Plain. California's frequent tremors notwithstanding, two of the largest earthquakes recorded within the United States occurred at Hebgen Lake, Montana, in 1959 and near Borah Peak, Idaho, in 1983. Both tremors were greater than magnitude 7 on the Richter scale. Both were located within a zone of frequent earthquakes that extends from eastern-central Utah into eastern Idaho and Montana, marking the active eastern edge of the Basin and Range Province. During both earthquakes, the ground was broken along mountain fronts, indicating uplift of a mountain range and downthrow of its adjacent valley. Thus, the forces that have been pulling apart the crust of the western United States during the past 17 million years continue today, causing renewed uplift of jagged, youthful mountains that would otherwise be quickly worn away by erosion.

The Borah Peak earthquake of 1983 was part of the fault-block mountain-building process that has lifted the Lost River Range. While the focus — the origin of the earthquake — was located beneath the valley, a fault scarp showing the vertical displacement of the quake cut across the lower flank of the mountain range.
SOILS OF THE PLAIN

During the lengthy intervals between basaltic lava outpourings on the eastern plain, large tracts of barren lava were blanketed by thick accumulations of wind-blown silt known as loess. Deposits continue to accumulate today during wind storms. Microscopic examination of loess shows that it contains little volcanic material and is mostly made of components derived from older lake beds to the west. The well-drained, fertile soils of southern and eastern Idaho thus are not formed directly by the weathering of the underlying volcanic rocks, but have been blown onto the Snake River Plain by winds during the past several million years.

In places, the wind velocities and the supply of sandy material are great enough to produce large sand dunes. The most impressive sand dunes on the plain occur at the Bruneau Dunes State Park in southwestern Idaho and in eastern Idaho near the town of St. Anthony, where active and vegetated dunes partially cover rhyolite ash-flow tuffs and basalt lava flows of the Juniper Buttes.
THE YELLOWSTONE COUNTRY

Although the early period of explosive rhyolitic volcanism has ended on the plain and those volcanic centers are partly or entirely covered by younger basaltic lava flows, relatively recent rhyolitic volcanism is still quite evident in the broad region of thermal features on the Yellowstone Plateau. Island Park in eastern Idaho is geologically a transition between Yellowstone and the low-lying terrain of the eastern plain. The Island Park topographic basin was formed by several cycles of rhyolitic and basaltic volcanism during the last 2.1 million years. Each cycle apparently built over a period of several hundred thousand years, as rhyolite lava flows were erupted from ringlike fractures above a large and growing magma chamber. Each cycle culminated with the explosive eruption of ash-flow tuffs and widespread airfall ash. Each catastrophic eruption probably lasted only a few days but produced 70 to 600 cubic miles of ash-flow tuff. By comparison, the total volume of material emitted from Mount St. Helens in 1980 was less than 1 cubic mile.

The largest of the ash-flow sheets — the Huckleberry Ridge Tuff — was erupted about 2.1 million years ago from a caldera that encompassed most of the Yellowstone–Island Park region. A segment of that caldera still remains as Big Bend Ridge, a curved ridge that forms the southern and western boundaries of the Island Park basin. During the second cycle of rhyolitic volcanism, the Mesa Falls Tuff (70 cubic miles in volume) was erupted from the Henry’s Fork caldera, a smaller collapse depression nested within the first-cycle caldera. Within the Henry’s Fork caldera, the Upper and Lower Mesa Falls of the Henry’s Fork cascade over cliffs of the densely welded Mesa Falls Tuff.

The last climactic rhyolite volcanism in the Yellowstone–Island Park area produced the Lava Creek Tuff, which erupted about 600,000 years ago from the Yellowstone caldera in what is now the center of the national park. The tuff has an estimated volume of nearly 250 cubic miles, and covers most of Yellowstone National Park and the Island Park basin. After eruption of the Lava Creek Tuff, large rhyolite lava flows issued from ringlike fractures of the Yellowstone caldera, and several of them traveled westward, where they now form the eastern topographic rim of the Island Park basin. Thus, what has been called the “Island Park caldera” is not a single caldera, but a complex feature that formed during three cycles of rhyolitic volcanism spanning the past 2.1 million years.
“O
ne day,” said Ferdinand V. Hayden, “the intelligent American will look upon the
map and recognize with conscious pride that this place hath not its equal in all the world.”
Hayden, writing from the Yellowstone country in 1874, belatedly confirmed the natural
wonders that trappers like John Colter had known since Jeffersonian times. In an effort to
preserve its exotic features, Congress set aside much of what is now northwestern Wyoming
and adjacent portions of Idaho and Montana. It was America’s first national park. The
rugged and geologically youthful terrain of Yellowstone is mostly of volcanic and glacial
origin. The park covers the central part of the world’s largest thermal area — a 1,400-square-
mile, mountainous plateau with an average elevation of about 7,000 feet. The park itself,
about a third of the plateau, preserves outstanding hot springs, geysers and mud pots, all
surface expressions of a huge 2-million-year-old magma system overlying a hot spot in the
Earth’s upper mantle.

Over the past 2 million years the plateau has been the site of huge but infrequent
eruptions of rhyolite lava, ash and pumice. The last eruptions of rhyolite lava occurred about
70,000 years ago.

The Yellowstone caldera is a broad, oval-shaped depression about 25 by 45 miles in
size. It formed about 600,000 years ago when the last cycle of volcanism climaxed and the
Lava Creek Tuff was explosively erupted. Since that time, voluminous lava flows of
rhyolite obsidian have obscured the rim of the Yellowstone caldera.

At present, the Yellowstone Plateau is one of the most seismically active regions of
North America. During the 15 years between 1973 and 1988, scientists recorded about 15,000
earthquakes greater than 2 on the Richter scale. In 1959, the 7.5 Hebgen Lake earthquake
occurred along a fault centered about 10 miles west of Yellowstone. The
largest tremor ever recorded in the
Rockies, it changed the behavior of hundreds of geysers and hot springs.
Earthquakes help maintain the thermal activity of the region. If not for
tremors, mineral matter would quickly seal off the fault zones that
channel fluids to the surface.

A large body of partly molten rock lies beneath the northeastern
part of the Yellowstone caldera. The
mass of hot material starts at a
depth of about 6 miles, encompasses the whole caldera, and extends
downward into the Earth’s mantle.
Called the Yellowstone plume or hot
spot, it has been the source of the
1,000 cubic miles of rhyolitic ash and
lava that have erupted from the
 caldera during the last 2 million years.
Heat and pressure within the Earth cause water to rise to the surface, where it erupts in a variety of forms, such as the geysers, mud pots and hot springs found in Yellowstone Park.

GEOTHERMAL FEATURES

The Yellowstone hot spot is also the source of heat for nearly 10,000 hot springs and several hundred geysers. The hot springs and geysers occur when rain and snowmelt soak into the ground and percolate through fractured volcanic rocks to depths of a mile or more. There the fluids are heated. Hot water returns to the surface along permeable faults. Thus, the thermal features of Yellowstone are not randomly distributed throughout the park, but tend to occur where fluid pathways are available through fractured rocks.

Geyser#s, saline hot springs that erupt, are short-lived and fragile features. Many have become inactive during historic time, as a result both of natural events and of man’s activities. Of the 10 major geyser areas in the world, only three — in Yellowstone, Iceland, and Kamchatka — remain essentially undisturbed.

Geyser#s require very specific physical and thermal conditions. There must be a potent source of heat, usually magma or hot-but-solidified rocks; abundant underground water must form a deep convection system; and there must be a focused pathway (usually a major fault or fracture in the Earth’s crust) for the hot fluids to rise toward the surface at temperatures close to boiling. Near the surface, the underground water and steam need a shallow, cavernous storage system. These systems must have a constricted surface opening in order to squirt fluids into the air. Finally, the storage system must be capable of recharging and reheating between eruptions.

When these conditions are not met, features other than true geyser#s develop. If there is no focused pathway to the surface, fluids may remain underground. If the heat source is
not hot enough, or if there is too much cool ground water, then warm springs may result. An example is the travertine (limestone) terraces at Mammoth Hot Springs, Wyoming. If underground temperatures are very high but there is little groundwater present, then dry steam vents (fumaroles) will form. Acid vapors from fumaroles alter the volcanic rocks into clay, forming mud pots and mud volcanoes. If the surface opening is too large or if the shallow reservoir allows free circulation, then instabilities may not develop and the hot spring may simply boil but not erupt. Such vents are called "perpetual spouters."

Although causes of geyser eruptions are complex, the phenomenon can be described generally in terms of the boiling behavior of water. Geysers are unstable saline hot springs that contain boiling or near-boiling water. Their underground plumbing systems might be compared to cavernous, vertical pipes that may extend several hundred feet underground. On the surface, the water column is boiling at atmospheric pressure and its temperature is thus about 199 degrees F. But hundreds of feet underground, the water is under considerable hydrostatic pressure. Thus, water may reach a temperature of several hundred degrees. When the water in any part of the system is heated close to its boiling point, then a very small drop in pressure will cause the water to explosively "flash" into

Above, Beehive Geyser — the timing of eruptions depends on how long it takes the "plumbing system" to be recharged by hot water and how long it takes to reheat the water to boiling temperature; left, the vivid colors of pools such as Grand Prismatic Spring result from microorganisms living in the water.
### Ferdinan D V. Hayden (1829–1887)

Excitable, impulsive, a gifted fossil-hunter with a flair for self-promotion, Ferdinand Hayden was to western science what John J. Astor had been to the fur trade: its visionary thinker, its marketing genius and entrepreneur. As head of the wide-ranging United States Geological Survey of the Territories, 1867 to 1879, Hayden brought photographers, artists, scientists and surveyors to some of the West’s most exotic vistas. His Snake River work was mostly confined to the headwaters in the Grand Teton region, but Hayden, a theorist, was one of the first to advance the notion that Idaho and much of the West were the beds of ancient freshwater lakes. His masterpiece of promotional science was an 1871 report that sold Congress on the idea of a wilderness sanctuary in the Great Geyser Basin of the Yellowstone country, now a national park. Hayden immediately understood that Yellowstone was the vast crater of a giant eruption. It was a “land of enchantment,” Hayden reported. “All the brilliant feats of fairies and genies in the Arabian Nights’ Entertainments are forgotten in the actual presence of such marvelous beauty.”

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Travertine terraces at Mammoth Hot Springs.

Steam. This can happen as a consequence of boiling in the upper levels of the water column, since a pressure drop is caused by rising steam bubbles. At some point in the plumbing system, flashing eventually occurs, and a mixture of steam and water is propelled out of the orifice. The eruption of fluids lowers the pressures in successively deeper levels of the system and flashing occurs as a downward-propagating chain reaction. The steam explosion causes fluids to be erupted from the reservoir. The time between geyser eruptions depends on how long it takes the plumbing system to be recharged with hot water, the time required for this water to reheat to its boiling point, and the amount of fluid that was discharged during the previous event. Some irregularity is thus typical of most geysers, including “Old Faithful.”
OUR FUTURE, OUR PAST

The spectacular thermal features of Yellowstone and the Snake River country are ours to enjoy during this respite between major eruptions. What might tomorrow bring? Mark Twain spoke for geologists when he claimed that it was “extremely difficult to make predictions, especially when they concern the future.” And yet we make the attempt.

The precise nature and timing of future events is surely beyond our present knowledge, but the violent volcanic past is a guide to some general assumptions. On the eastern plain, the Great Rift, which has been active since the Ice Age, is the most likely region of future volcanism. It is conceivable that readers of this book might one day visit the Craters of the Moon area to witness basaltic eruptions along the Great Rift. It also is quite probable that explosive eruptions will rock Yellowstone sometime during the next few hundred thousand years.

In the more distant future, the Yellowstone area may one day become a sage-covered depression much like the eastern plain. In millions or tens of millions of years, a section of southwestern Montana may have its own large caldera northeast of Yellowstone, a future volcanic area of hot springs and geysers. Although this certainly reaches beyond the span of human existence, to the geologist it seems a moment away — less than 1 percent of the Earth’s history. The time span of scientific imagination knows no bounds.

In the meantime, we can refine our predictions by studying the catastrophic events that created the volcanic crescent, a harsh setting for life. Here on barren lava the plants fight for precarious footholds. Wildlife follows lost rivers, searching porous rock for marginal water sources. Humans, repelled by treacherous lava, are attracted to it as well. All inhabitants of the plain contend with the ancient forces that continue to mold our lives.
Bruneau and Jarbidge River Canyons
The Bruneau and Jarbidge rivers have carved several-hundred-foot-deep canyons into the high desert plateau of Owyhee County. The canyons, carved in lava following the sudden draining of Lake Idaho, provide a cross-section of the eruptions that occurred in southwestern Idaho. *Southeast of Bruneau.*

Bruneau Dunes
At the Bruneau Dunes, windborne sand has been deposited in a depression created by an old meander in the Snake River. One dune is 470 feet tall. *East of Bruneau.*

Malad Gorge
The Malad River cuts through a 250-foot gorge and plunges down stairstep falls before reaching the Snake River. *West of Bliss on Interstate 84.*

Thousand Springs
At Thousand Springs, groundwater from the Snake River Aquifer bursts from the canyon walls and flows into the Snake. Much of the flow has been diverted for power production and trout farming. *East of Hagerman on Highway 30.*

Shoshone Falls
When there is enough water in the Snake River, the 212-foot-high falls are a thundering cataract. Geologists believe the falls were created during the Bonneville Flood 15,000 years ago. Today, upstream irrigation diverts water, leaving only a trickle for most of the year. *Northeast of Twin Falls.*

Shoshone Ice Caves
In these lava tubes a constant temperature of 28–33 degrees creates natural refrigeration that allows ice to remain year-round. The cave is 1,000 feet long and 40 feet high. Mammoth Cave, a one-mile-long lava tube, is nearby. *North of Shoshone on Highway 75.*

Craters of the Moon
"Craters" is the northwestern section of the Great Rift volcanic rift zone. The Craters of the Moon lava field was formed by dozens of flows and pyroclastic cones that formed during eight eruptive periods over the last 15,000 years. *West of Arco on Highway 93.*

Big Southern Butte
Rising 2,500 feet from the plain, the butte is rhyolite that erupted through the basalt flows 300,000 years ago. *Southeast of Arco.*

City of Rocks
Some of the oldest formations in the United States are found among the towering granite rocks that have been carved into a variety of interesting shapes by centuries of weathering. *South of Albion.*

Massacre Rocks
Here, the Snake River has cut through the basalt veneer, exposing older rhyolite rock beneath. Remnants of the Bonneville Flood are seen in the boulder bars within the canyon and the channels carved adjacent to the canyon on the north side. *West of American Falls on Interstate 86.*

Heils Half Acre Lava Field
This 180-square-mile lava field is radiocarbon dated to be 5,200 years old. *Between Blackfoot and Idaho Falls.*

Menan Buttes
The largest of the two buttes rises 800 feet high. Both are formed of basalt tuff and have deep craters. *Near Rexburg.*

St. Anthony Sand Dunes
Sand blown across the Snake River Plain has collected in this area of 150 square miles. *North of St. Anthony.*

Mesa Falls
At Upper and Lower Mesa Falls the Henry’s Fork of the Snake River cascades over cliffs of densely welded tuff. The upper falls drops 114 feet. *Northeast of Ashton.*

Big Springs
Issuing from rhyolite lava flows, Big Springs is a major source of the Henry’s Fork of the Snake River. *Eastern margin of the Island Park basin.*