Geology of the Lower Owyhee River
Oregon's "Grand Canyon"

By Kenneth Giles and Kyle House

2026 Edition

Geology of the Lower Owyhee River

Oregon's "Grand Canyon"

By Kenneth Giles and Kyle House

Download free eBook at
OwyheeGeology.com

First published March 2025
This edition 2026 v1.0

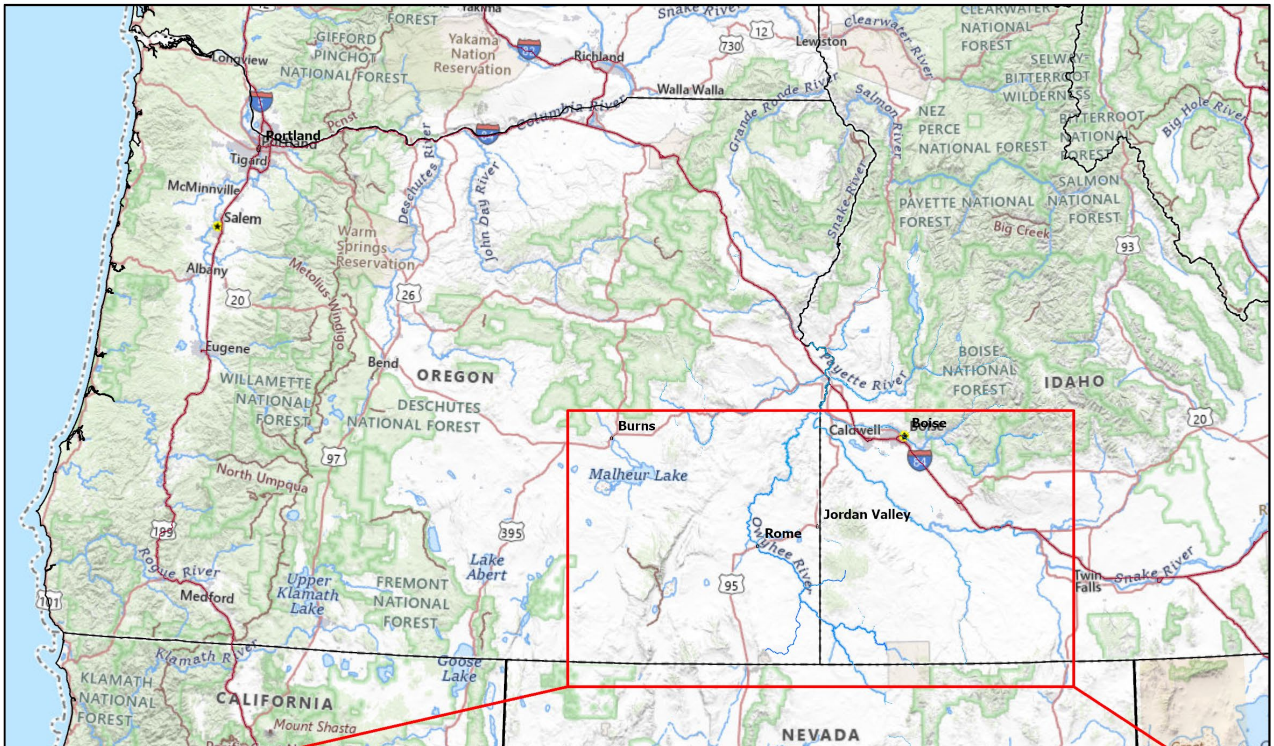
All photos and maps are by the authors, unless otherwise noted.

Kenneth Giles
giles1947@gmail.com
Woodland, WA

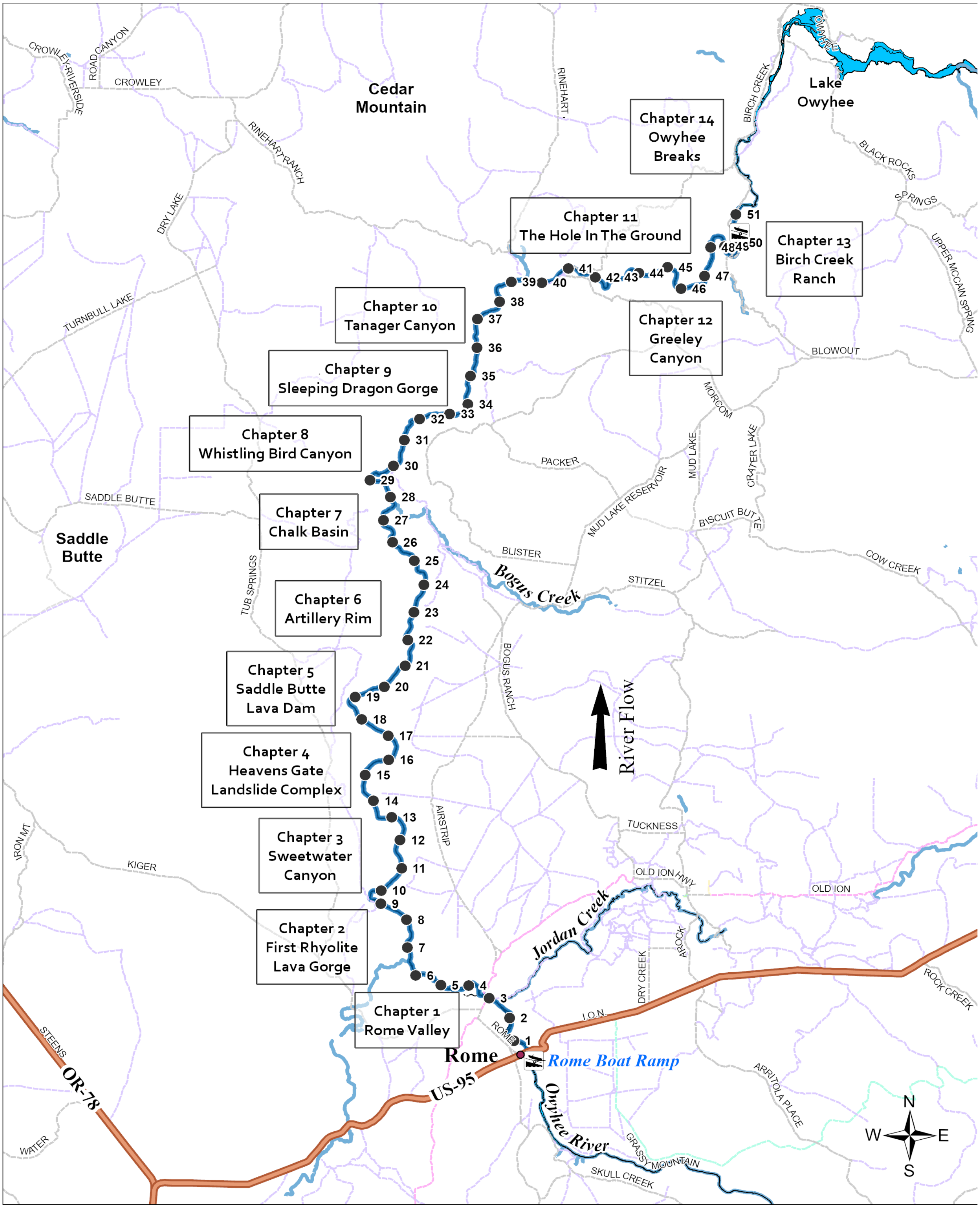
P. Kyle House
geokyle@arizona.edu
Flagstaff, AZ

Cover photo: "Sleeping Dragon Gorge and Tanager Canyon"
by Kyle House

Location of the Lower Owyhee River



Location of River Segments (Chapters)



Book chapters are arranged in the order that rafts travel, starting at the Rome boat ramp (mile 0) and ending at the Birch Creek Ranch boat ramp (mile 50), from south to north. Eight full-page boating guide maps are located at the end of this book.

Table of Contents

Introduction

Welcome to the Owyhee River, a unique geological playground where visitors will thrill to deep canyons, mysterious hoodoos, and rugged badlands. Often called “Oregon’s Grand Canyon,” the Owyhee is among the most remote places in the continental United States, almost inaccessible other than by boat during a brief spring rafting season.

Wild and untouched, 120 miles of the Owyhee was designated a National Wild and Scenic River by the U.S. Congress. This geological guide interprets the river’s most popular and spectacular 50-mile-stretch from the rafting put-in at Rome, Ore. to the Birch Creek takeout.

A lot is going on in this dry and windy landscape. Towering lava cliffs, narrow gorges, riverside hot springs, and colorful candy-striped mountains will catch your eye. Part of this exciting geography was created as recently as a few thousand years ago while sections are almost 16-million-years old. There’s evidence of ancient landslides and lava dams that trapped the Owyhee for thousands of years before its waters would break free, carving new channels and scouring out dogleg bends. Canyon walls display volcanic rock in almost every form: Vertical, pinkish rhyolite cliffs in Sleeping Dragon Gorge to multi-colored lakebed sediment and ancient lava flows in the badlands of Chalk Basin.

The goal with our Geology of the Lower Owyhee River is to explain what you see as you travel downriver, knowing there is a “WOW moment” around every bend. Try out a few hikes away from camp. Enjoy a hot springs riverside soak as did the first people who came into this region. Marvel at their ancient petroglyph-covered boulders. Try to imagine life on the Owyhee near Birch Creek where a group of hunter-gathers lived in pit houses almost eight thousand years ago. Wonder at the geology, enjoy the wildlife, and let the serenity of the Owyhee seep into your bones. This is a magical place with much to tell us.

As you explore the Owyhee River country, you may notice traces of the people who lived here long before us—stone tools, flakes of obsidian, historic relics, or even rock art along the river. These artifacts are part of a shared cultural heritage and are protected by law on public lands. Please enjoy discovering them with your eyes and camera but leave everything exactly where you find it. Removing or disturbing artifacts is illegal and erases important pieces of history. By treating these places with care and respect, we help preserve the Owyhee’s story for future generations and honor the Native peoples whose history is written across this landscape.

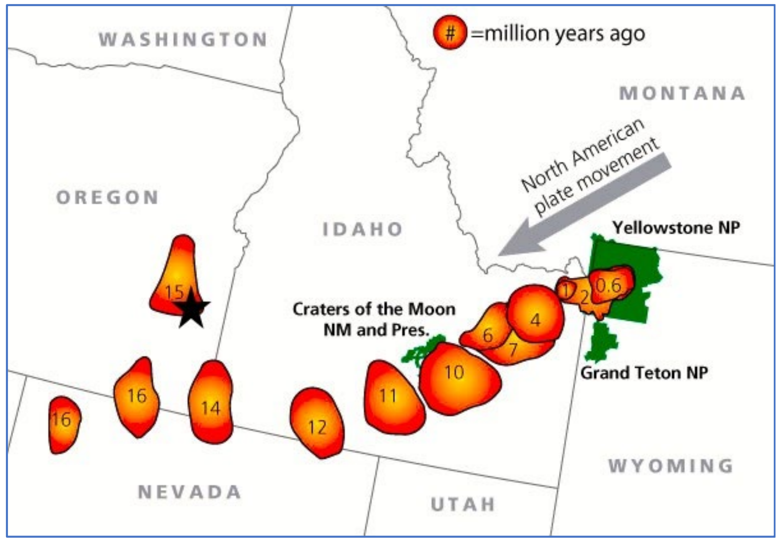
Kenneth Giles
Kyle House
2026

Four Key Events

The Yellowstone Hotspot

The wonderful Owyhee geology was made possible by the Yellowstone hotspot that created a huge pool of magma just below the surface here about 15 to 16 million years ago and left a trail of now buried explosive volcanic calderas in its wake. Today, the hotspot plume has rotated eastward under the North American plate and is now under Yellowstone National Park. Millions of years ago, hot springs, geysers, oozing lava flows, and caldera lakes like we see today at Yellowstone likely existed in this corner of southeast Oregon. So much time has passed that hotspot evidence has long since been eroded and buried by later geologic events.

Although the hot spot moved on, volcanic activity continued. Later eruptions created the Jordan Valley Volcanic Field and the rolling high lava plains that now cover the Owyhee landscape. More than once, lava flows dammed up the Owyhee River channel, altering its course. Almost everything we now see in the Owyhee Canyon is volcanic in origin and a consequence of the hot spot.



Trail of Yellowstone Hotspot volcanic calderas across North America began near here about 15 to 16 million years ago. Lower Owyhee River location marked with star. (Source: NPS.)

Birth of Owyhee Canyon

The bulk of the modern narrow and deep Owyhee Canyon was carved in only the past few million years. Before that, sometime between 2 and 5 million years ago, the ancestral Owyhee River occupied a much wider and shallower canyon.

Geologists think the birth of the ancestral river was probably caused by fluctuations in the level of ancient Lake Idaho. For more than 6 million years, Lake Idaho filled the Snake River valley with a huge lake about the size of Lake Erie. Water levels fluctuated but generally stood 1,000 to 1,600 feet above today's valley floor. The water was so high that there was little elevation difference between the lake surface and the surrounding Owyhee landscape, so streams emptying into the lake did not incise deep canyons.

Then sometime between 2 and 3.4 million years ago, the lake gradually overflowed to the west down what is now the Snake River, in the process carving Hells Canyon and leaving behind an empty lake basin—today's fertile Snake River Valley. The lake emptying took several million years, causing the ancestral Owyhee River's base level elevation to drop by over 1,000 feet. The drop in base level triggered accelerated erosion and downward cutting of the river channel, producing today's deep and narrow canyon.

Ancient Lake Idaho about 3 to 4 million years ago. (From Geology Underfoot in Southern Idaho by Shawn Willsey 2017)

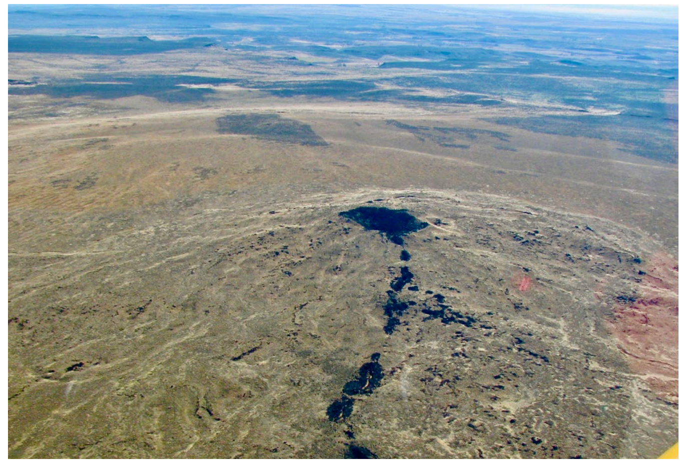
Four Key Events

Plateau forming lava flows

After the hotspot moved east into Idaho, volcanic activity persisted in southeast Oregon. The magma composition shifted from gummy rhyolite and andesite to highly liquid basalt. About 10 million years ago, volcanic fields consisting of shield volcanoes and fissures began erupting runny basalt lava flows that traveled miles from the vent.

Hundreds of lava flows probably occurred, each usually covering a small area. On high plateaus, newer lava covered older flows, forming an erosion-resistant “roof” over the ancient basin sediment. Thick canyon rimrocks developed when rivers eventually cut through the lava plateau. In basins, successive lava flows were interbedded with sediment layers, creating banded canyon walls.

The volcanic fields in southeast Oregon and Idaho represent some of the youngest and most extensive basalt volcanism in the western U.S. The Jordan Valley Volcanic Field alone, on the east bank of the river, has thirteen dated volcanic vents ranging in age from under two thousand years old to over five million years old. Coffeepot Crater, near the Birch Creek Historic Ranch, is 1,300 to 1,700 years old, one of the most recent dated eruptions in Oregon.



West Crater volcanic vent on the lava plateau near the Owyhee River erupted 70,000 years ago and filled the canyon with lava.

River changing lava dams

The Owyhee River is well known for its many lava dams. Lava flows repeatedly entered and dammed the river canyon, forming lakes that stretched up to 45 miles upstream, often redirecting the river. During the last two million years, at least six different lava dams are known to have formed across the river, some hundreds of feet high. Earlier dams likely existed, but evidence has been erased by erosion.

Although the lava dams no longer exist, abundant evidence of their existence can be seen in today’s canyon walls. When a dam-building lava flow enters a large body of water, the lava rapidly cools and usually fragments into pieces that accumulate in slanting layers in front of the flow. The formation is called a “lava delta,” like a river delta, but formed by flowing lava instead of water. The distinctive, orange-colored dipping layers in the lava delta are called “foreset beds”. The horizontal contact line between the dipping foreset beds and overlying lava flow marks the elevation of the water’s surface. “Lava pillows” are often found intermingled with the fragmented rocks in the foreset beds. These are lavas with bulbous, spherical, or tubular-shaped structures formed when lava is extruded underwater at slow effusion rates. Geologists look for lava deltas to figure out the geological history of the Owyhee Canyon.

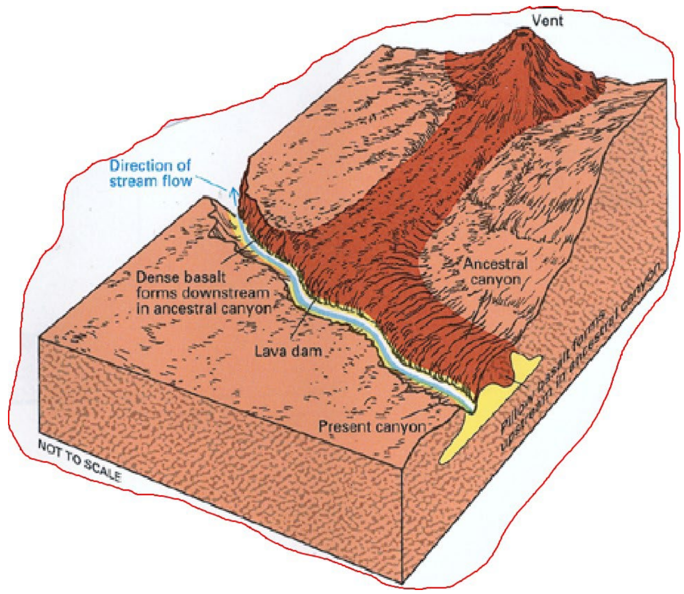


Illustration of a lava flow damming a river. (Source: USGS)

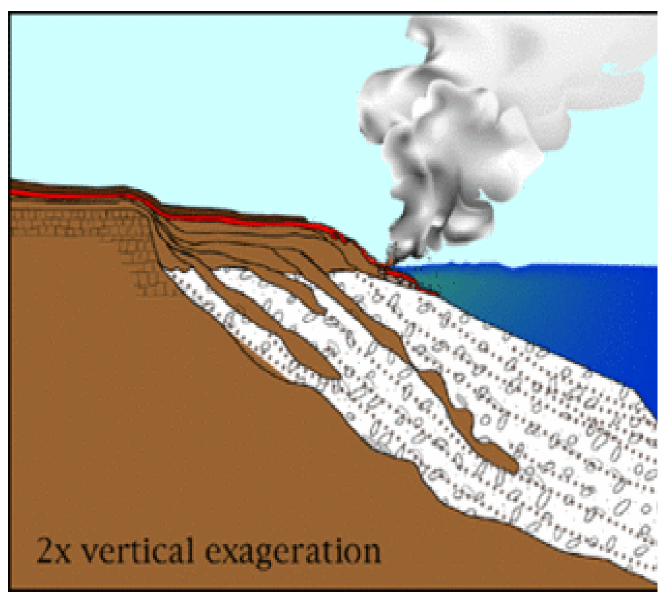


Illustration of lava delta showing lava flow entering water and creating slanted foreset beds and lava pillows. Source: USGS.

Sources: (Wood & Clemens, 2002), (Camp & Wells, 2021), (Willsey, 2017), (Staisch, et al., 2022), (Mehringer, 2004)

Chapter 1—Rome Valley (mile 0–6)

Mile 1: US-95 bridge crosses the Owyhee River. In the distance, 340-foot-tall Rome cliffs line the east bank of the Owyhee River. Green fields outline rich floodplain soils deposited by the modern river. (View north from rimrock.)

Geological history

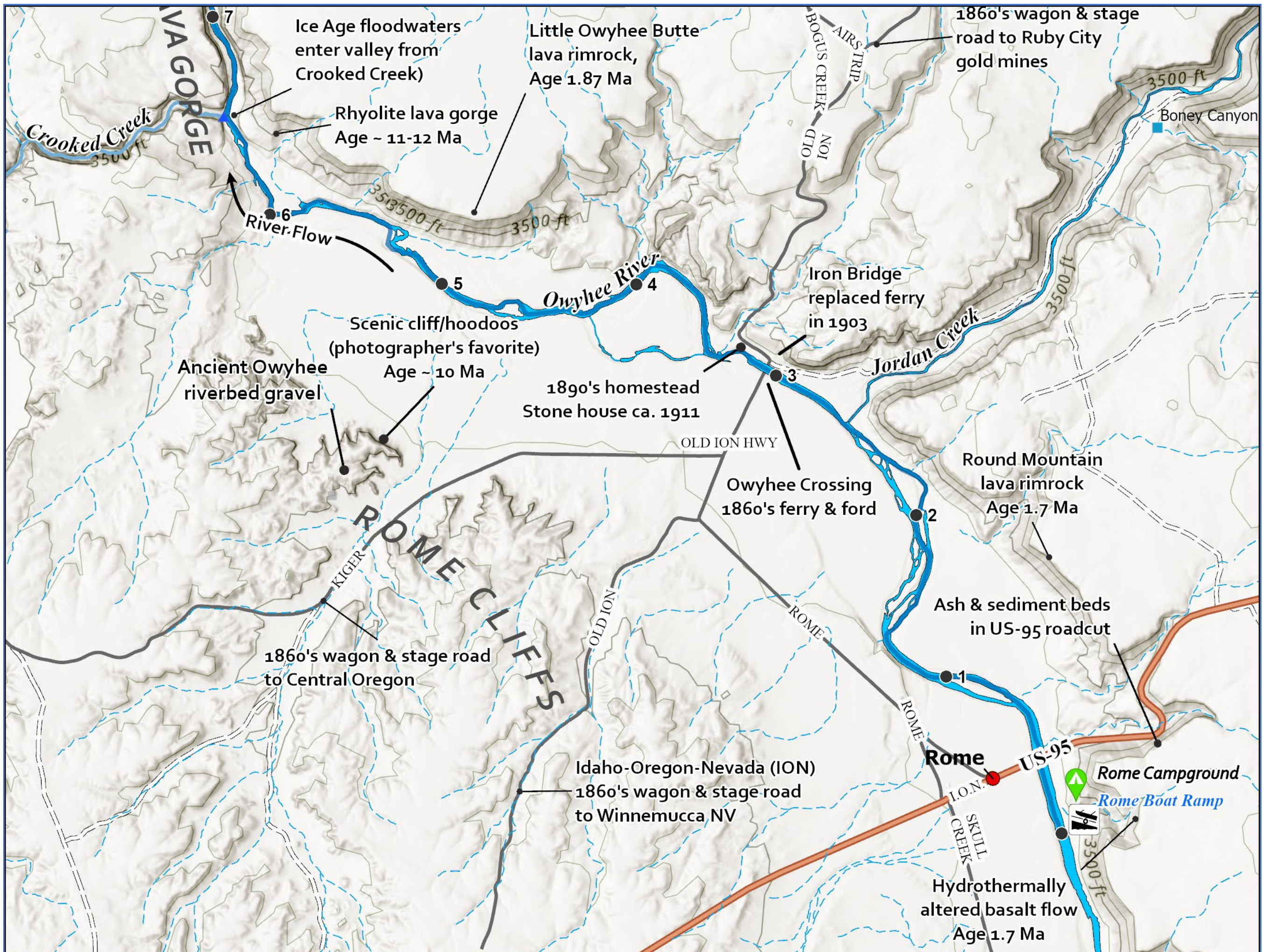
More than 10.8 million years ago, sediment began to accumulate in the area, as shown by the age of overlying volcanic ash deposits found near Arock, located a few miles east of Rome. The sediment was deposited in a large basin that formed here after the Yellowstone Hotspot passed nearby and basin and range faulting began; it's just one of the several basins that define the river corridor.

About 2 to 5 million years ago, after the sediments were deposited, the ancestral Owyhee River, together with its tributary Crooked Creek, started to carve out the Rome valley. Weathering and the erosional activity of these watercourses shaped the landscape, gradually forming the valley as it appears today, including the scenic badland formations that pioneers called the "Pillars of Rome."

The best way to experience the badlands and striking rock cliffs is to take a drive along Kiger Road, north of Rome Station on US-95. (See map.) If time allows, take a short hike through the sagebrush to any cliff and try to guess which, if any, layers of sediment were deposited in lake water (lacustrine), and which were deposited by a stream or flood (fluvial).

Before the Owyhee River existed, a series of poorly connected shallow lake basins (including this one) probably occupied today's river corridor from Rome to the Oregon-Idaho border. Downstream (north), the river corridor is lined with sedimentary strata like we see here in the Rome valley. The sediment changes somewhat when the river crosses into a new basin, each of which has its own history of local volcanic eruptions and sources of sediment, and possibly a different history of faulting and uplift. But in general, the Rome valley story applies to the sediment found throughout the Owyhee River corridor all the way to Lake Owyhee.

Mile 3: Aerial view of Owyhee River and Rome cliffs looking north. The lava plateau stretches to the horizon and consists of multiple lava flows, ages ~1.5 to 10 Ma. Jordan Creek joins the Owyhee in lower right corner.



The Rome valley sediment beds

At least three research papers have been published on the Rome sediment beds. The research shows that sometime between roughly 12 and 15 million years ago—before the first sediment—two thick lava flows flooded the basin floor. First came a basaltic lava flow, then a rhyolitic lava flow. Both lava formations are now visible at the northern end of the valley, where the strata have experienced modest uplift relative to the central valley. Researchers think these lavas underlie the entire Rome valley—its bedrock.

Streams and intermittent floods then carried material from surrounding volcanic highlands and deposited it onto gently sloping mudflats and floodplains in the basin, creating layer upon layer of coarse-grained sediment. At times a shallow lake formed that saw many changes in water level (including drying up) which caused the shoreline to frequently advance and retreat. Intermittent eruptions from nearby volcanic fields sometimes covered the basin floor with lava flows and volcanic tuff (ash and rock fragments), some of which were deposited in standing water. Over time, it all cemented into the multicolored rock layers that we now see in the valley walls. Eventually sediment filled up the basin, and it was probably roofed over by one or more lava flows—like the gently sloping lava plateaus we drive

Pillars of Rome rock formation near Kiger Road in the Rome valley. (Photo: Marli Miller.)

Rome cliffs: ancient floodplain, shoreline and lakebed sediment over 10.8-million-years old. Looking west from near Kiger Road (Photo: Marli Miller.)

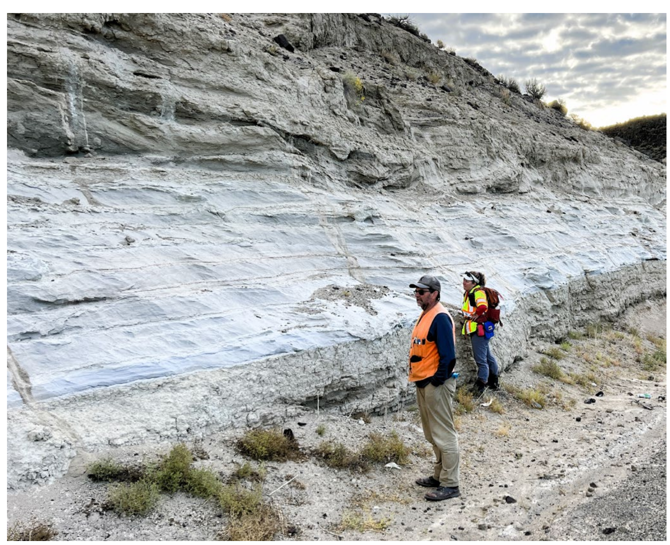
through on the way to the valley today. All this happened long before the Owyhee River existed.

In the final basin-filling phase, a long-lasting perennial (year-round) freshwater lake formed near today's Crooked Creek State Park. It's unclear whether it covered the entire basin or just a small area. The lake left behind an approximately 100-foot-thick layer of very fine-grained lakebed sediment containing abundant fish skeletons and vertebrate bones, including beaver. This fine-grained sediment is exposed below the Crooked Creek canyon rimrock, near US-95. The fish skeletons and vertebrate bones are from animals that we know lived between 4.8 and 9.0 million years ago, giving us a date range for the age of the lake.

Sediments exposed by US-95 roadcut

A good place to see freshly exposed layers of the Rome valley sediments is in the roadcut along US-95 where the highway descends into the valley. Here the sediment has been preserved beneath a protective lava rimrock. Elsewhere in the valley, the topmost sediments are often buried under lava flows or eroded away. The thick, light-colored layer in the roadcut is a bed of volcanic ash likely older than 1.5 million years based on overlying dated lava flows.

US-95 roadcut in valley rimrock showing upper layers of sediments. Light-colored layer near the base is volcanic ash.



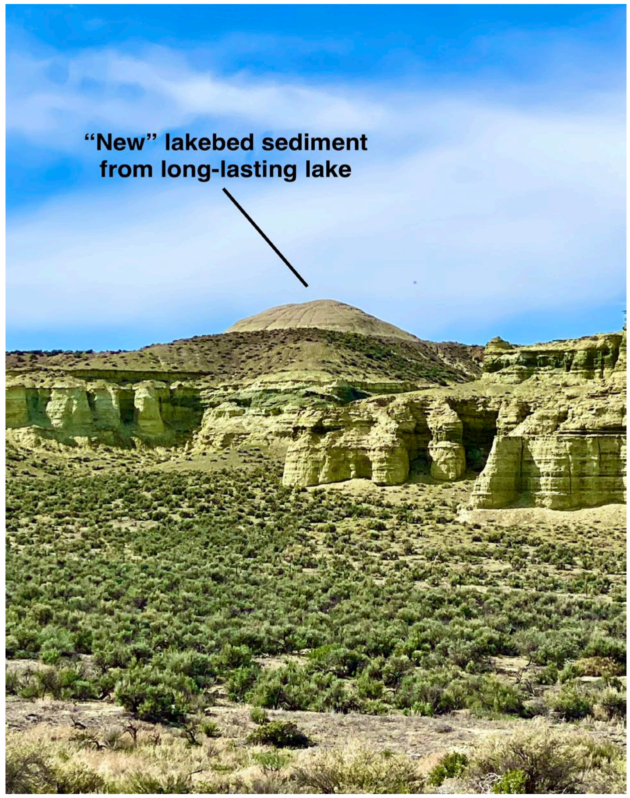
Closeup of volcanic ash layer likely more than 1.5-million-years-old in US-95 roadcut.

New lakebed sediment deposited

Geologists discovered a layer of fine lakebed sediment at about 3,600 feet in the Rome badlands, indicating that as the Owyhee River carved out the valley, lakes formed and deposited fresh sediment over older layers.

The lakes developed when lava flows from periodic volcanic eruptions on the surrounding plateau created temporary dams that blocked the Owyhee River. The lakes behind the lava dams sometimes extended many miles upstream and submerged the Rome badlands. Fine, light-colored sediment in the lakes settled and formed new layers over the older, coarse-grained Rome badlands. (See photo on following page.)

Published and ongoing research suggests that because of multiple large lava blockages that occurred downstream from about 1.9 million years ago to 600 thousand years ago, the Rome valley has cycled between a lake and a through-flowing river multiple times.



The distinctive tan dome is a "new" bed of fine-grained lakebed sediment deposited when a lava dam blocked the river downstream and created a long-lasting lake in the Rome valley. View north from near Kiger Road.

Zone of hydrothermal alteration above Rome boat launch

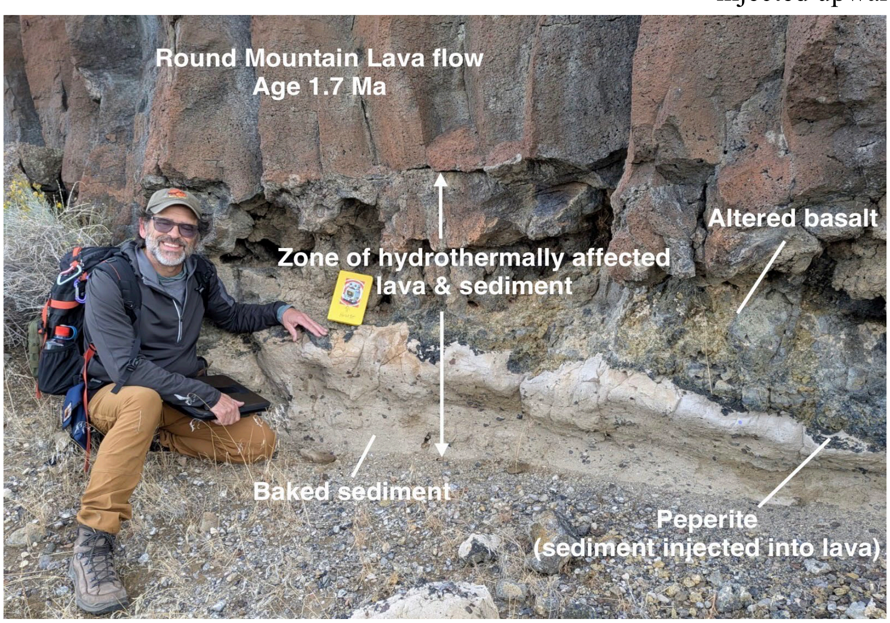
A fantastic exposure of hydrothermally altered basalt and sediment lies just a short hike uphill from the gravel access road to the Rome boat launch. An excellent place to see what happens when a lava flow encounters water. The Owyhee canyon is well known for its many examples of lava-water interaction, several of which are pictured and described in later chapters.

The lava flow erupted from a vent on Round Mountain about 1.7 million years ago and spilled into the Rome valley, which was possibly then filled by one of the short-lived lakes described earlier.

The heat of the incoming lava was so intense that it baked (fired) the underlying water-saturated sediment into a hard, clay-like rock. A short-lived but intense hydrothermal condition existed. Temperatures reached hundreds of degrees centigrade, water flashed into steam, the steam and super-heated water migrated through the wet sediment and into the overlying lava. Sediment was injected upward into the lava and soft lava sagged downward into the sediment, forming the "peperite" structures visible in the sediment-lava contact zone.

As the steam and super-heated water migrated upward into the overlying lava, it fractured the base of the lava into blocks that allowed hot water to circulate through it for a short time. Once fractured and permeable, the hot water and steam chemically altered the lava at the base of the flow into a zone of clay minerals and palagonite material.

At this site, peperite and altered lava help confirm that the flow entered a wet valley floor, supporting the interpretation of a lava-dammed river environment.



Zone of hydrothermally altered lava and sediment in the base of the rimrock near the Rome boat launch.

Mile 6.5: Brush-filled mouth of Crooked Creek. The entry point of ice age floodwaters from Alvord Lake into the Rome basin. Looking West.

Now dry lakebed of Alvord Lake, covered with clumps of brush. The notch in the distant rimrock was carved by ice age floodwaters exiting the lake to the Owyhee River.

Evidence of ancient riverbed

Researchers have discovered signs of an ancient riverbed about 1 to 2 miles west of the current Owyhee River, possibly dating to over 1.9 million years ago. If confirmed, this means that by about 1.9 million years ago, about 140 feet of today's 340-foot-deep valley was already exposed. That's over one-third of the valley's present depth. The river later shifted eastward, further widening the valley.

Evidence for the ancient riverbed consists of an unusual layer of river-rounded rocks and gravel about 200 to 230 feet above today's river level. These rocks lie beneath the layer of distinctive white lakebed sediment thought to have been deposited 0.6 to 1.9 million years ago when several lava dams blocked the river downstream. (Described earlier.)

Ice age outburst flood enters Rome valley

It's hard to imagine that the largest floodwaters yet documented in the Owyhee River canyon came down Crooked Creek. Today it's a small brush-filled tributary stream—not given a second glance. (See photo.)

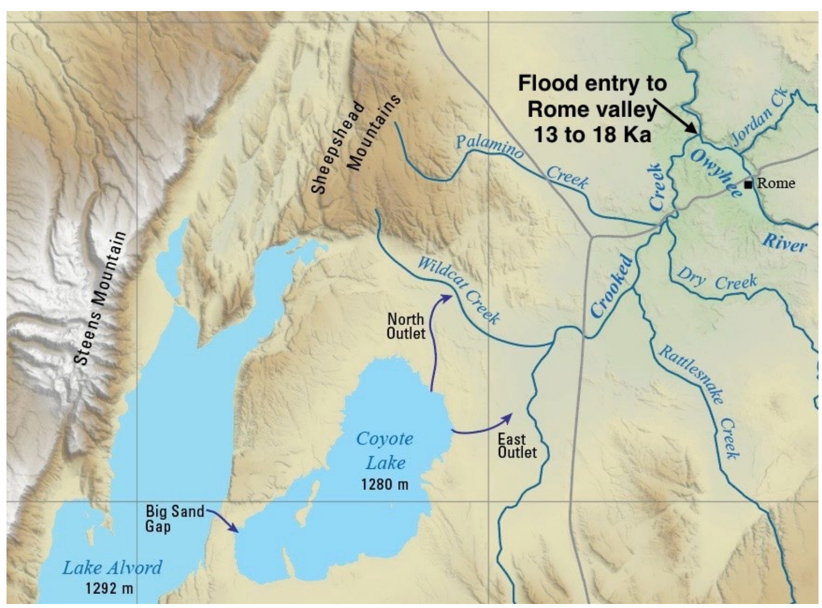
The flood(s) occurred 13,000 to 18,000 years ago, at the end of the last glacial advance. The floodwaters came from Alvord Lake, one of the many large lakes that existed at the end of the ice age in the high-desert region of the west. At its peak size, it was about 70 miles long and about 270 feet deep. Today it has little water and parts of it are known as the Alvord Desert. (See photo.)

At its largest, the lake overflowed into the Owyhee River via the Crooked Creek drainage. Abundant flood evidence exists. Along Crooked Creek geologists have found eroded canyons, scoured bedrock surfaces, scabland topography, numerous boulder bars and 15-foot boulders left stranded more than 100 feet above the present channel.

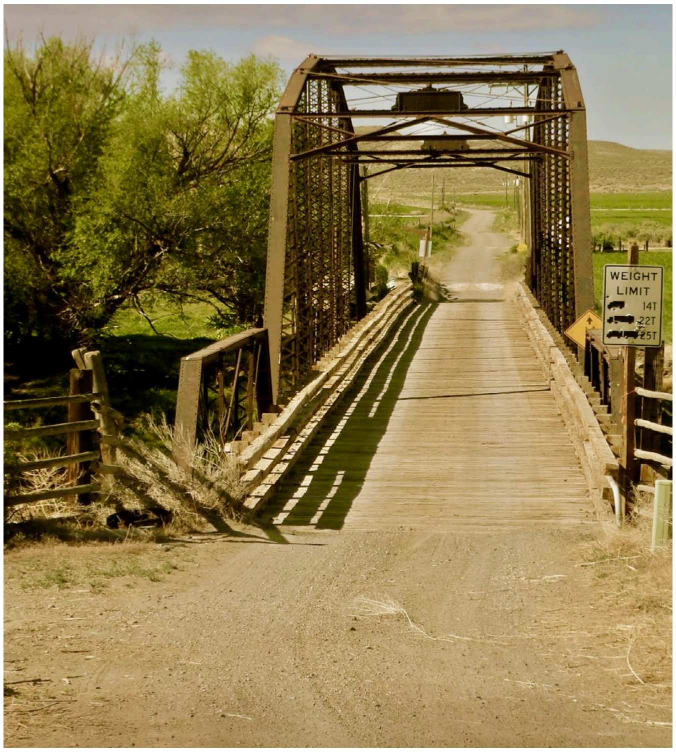
Based on the size of the lake and the topography and constrictions of Crooked Creek, geologists determined the peak downstream flood was about 350,000 cfs (cubic feet per second); 6x larger than the highest water flow (55,000 cfs on March 18, 1993) recorded on the Owyhee River since records began in 1950. The flood lasted at least 13 days, probably much longer.

As the floodwaters entered the Rome basin, they fanned out and flooded the valley upstream to the US-95 highway bridge. The shallow lake in the Rome valley lasted several weeks.

Though the evidence is much less complete, it's plausible that another older and much larger outburst flood occurred. Geologists identified an older (and higher) Alvord Lake shoreline that indicates older



Map showing path of floodwaters from Alvord Lake to the Owyhee River and Rome valley 13 to 18 thousand years ago.



Historic Owyhee Crossing bridge is the fourth oldest highway bridge in the state, built 1906. Dirt road is a wagon road that connected Idaho, Oregon, and Nevada (the old I.O.N. highway), built in 1860s.
Photo from Church of the Open Road Press blog post May 28, 2013.

periods of overflow into Crooked Creek and the Owyhee River. They also found flood deposits and drainage topography along Crooked Creek that could only have been created by a large flood with a peak discharge of 1.4 million cfs. The postulated older flood is 4x larger than the flood that occurred 13 to18 thousand years ago, and 25x larger than the highest modern water flow recorded on the Owyhee River since records have been kept.

History note: Owyhee Crossing

Rome Valley lies along a key route linking Idaho with Oregon and Nevada. It's one of the rare spots in SE Oregon where travelers can cross the steep, narrow Owyhee canyon without difficulty. Archaeologists believe that people have used the river crossings here for thousands of years.

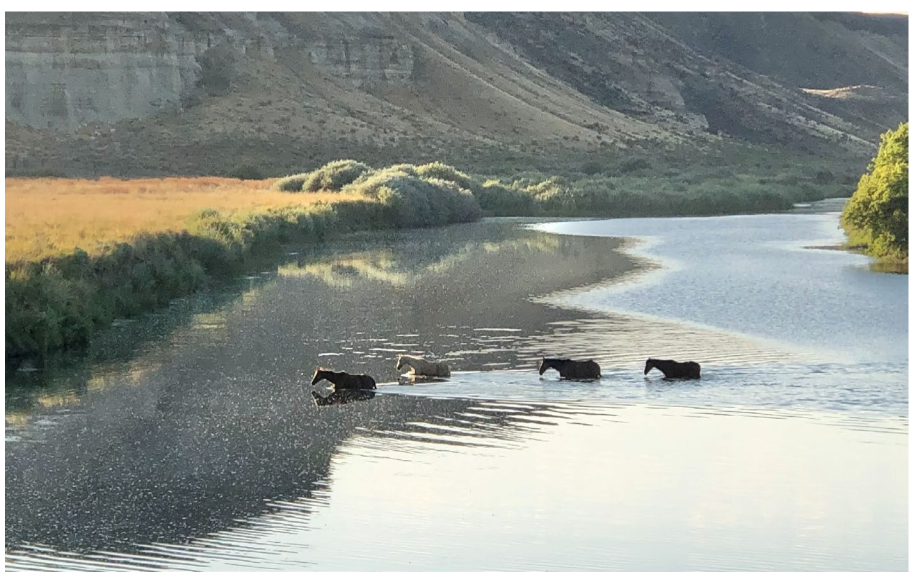
Owyhee Crossing: Gold miners and pioneers gave the name "Owyhee Crossing" to the well-used river ford at the mouth of Jordan Creek. Before the steel bridge was built in 1906, travelers either waded across the river during low water or paid a toll to ride a seasonal ferry during high water.

1860s wagon road: For about 20 years starting in 1863, this was an important and heavily used road that carried freight from California to the newly discovered gold mines in the Owyhee Mountains southeast of Jordan Valley. Initially it was a system of trails traveled on horseback with packtrains. By 1866 a toll road (the "Skinner Road") had been built from the Owyhee Crossing through the Jordan Valley and up to the mines, finally allowing wagons and stagecoaches to travel the route. Stagecoaches took days, freight wagons took weeks to reach Ruby City and Silver City (now ghost towns) from the nearest railroad at Winnemucca, Nevada. The road remained a heavily used wagon supply route until railroads finally reached Idaho in 1883. The old wagon road still exists and can be traced on Google Earth through the sagebrush from Owyhee Crossing to the Oregon-Nevada border.

Settlement in this rugged, arid corner of Oregon was minimal until gold was discovered in the Owyhee Mountains in 1863, leading to a rush of miners and the creation of several ranches along Jordan Creek for food supply. A part-time ferry was soon set up at the Owyhee Crossing in 1864 to help cross the river during high water. Rome valley's first permanent structure was likely a simple two-person stone house occupied seasonally by the ferry operator and assistant.

Native Americans: The Owyhee region was home to the Northern Paiute people. As miners moved into the area, a series of armed conflicts—often referred to as the "Indian Wars"—made the Owyhee Canyon and Rome Valley unsafe for non-Native settlement until sometime after about 1878.

Homesteads: Clint Duncan received the first homestead patent in Rome Valley in 1900, having



The Owyhee Crossing: Travelers have been wading (fording) the river here for thousands of years. A ferry was here before the bridge. (Photo taken from historic

Chapter 1—Rome Valley (mile 0–6)

First homestead in the Rome valley about 1892. The stone house was built about 1911 after the ferry ceased operation.
(Source: In Times Past, 1990, by Hazel Fretwell-Johnson.)

purchased the ferry operation at Owyhee Crossing and settled there in 1892 according to oral accounts. He continued running the ferry until the steel bridge was built, using a hand-crank/winch mounted on the ferry deck to pull the ferry across the river. In 1909, Duncan received approval to establish a post office named "Rome" inside his home. He continued running the ferry until the steel bridge was built. In 1911, his son constructed a stone house just downstream from the bridge, five years after the ferry stopped running.

By 1915, more settlers had moved into Rome Valley, leading to at least five officially patented homesteads along the river. At one time there were six water wheels in operation along the river to lift irrigation water into ditches supplying fields. (See Chapter 13, Birch Creek Ranch, for discussion of water wheels.)

Community of Rome: The small, unincorporated community of Rome is named after the post office set up by Duncan in his home in 1909. The post office moved between several ranches until it was closed in December 1933, after which the nearby community of Arock handled mail services.

Rome Station: The US 95 highway bridge over the Owyhee River was built in 1936 to support growing automobile traffic and the new U.S. highway system, replacing the smaller single-lane steel bridge and dirt road located three miles downstream. By the mid-1940s, Rome Station, comprising both a café and an automobile service station, was in operation near the new bridge.

Rome Station in 1963.
Source: Salem Public Library Historical Photo Collection

Source : (Sheppard & Gude, 1987), (Campion, 1979), (Ellison, 1968), (Wolf & Ellison, 1971), (Walker, et al., 1974), (Fretwell-Johnson, 1990), (Skinner, 2025), (Carter, et al., 2005), (Personius, et al., 2007)

Chapter 2—First Rhyolite Lava Gorge (mile 6–10)

Mile 7: First rhyolite lava gorge. About 11 to 12-million-years old. Looking downstream.

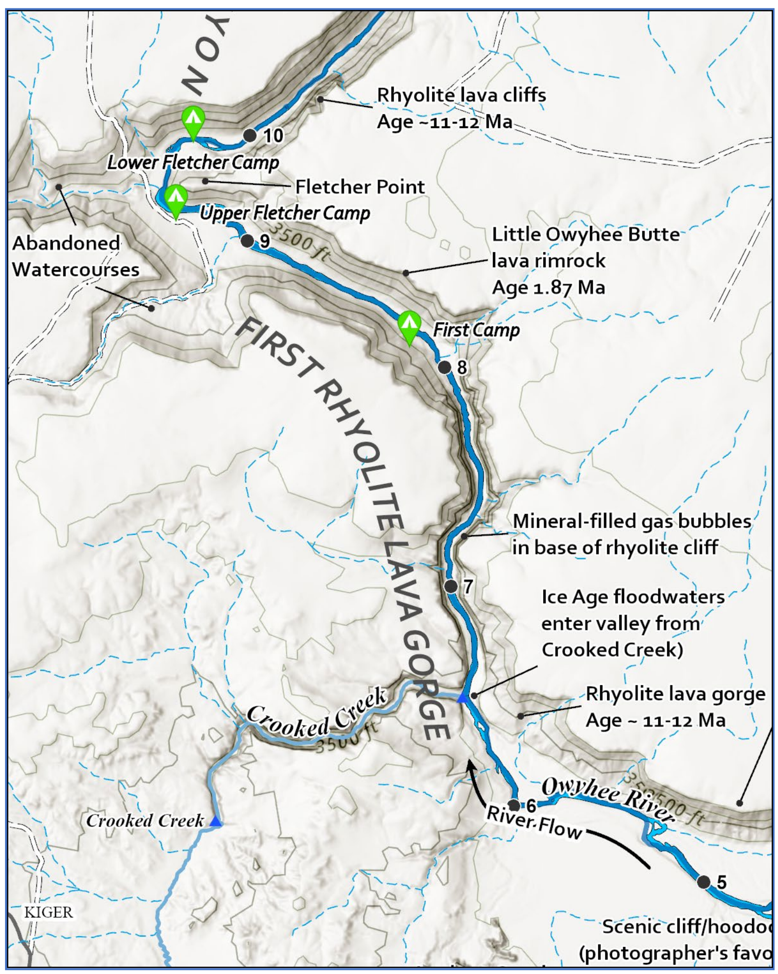
First Rhyolite Gorge (mile 6.5)

The narrow, orange-colored canyon just downstream of the mouth of Crooked Creek is informally named First Rhyolite Gorge. It is a very short gorge, a little over one mile long, which allows only 20-30 minutes to see it by boat at typical river speed.

The vertical walls, which rise 150 feet high, consist of a single layer of rhyolite lava—a type of volcanic rock commonly formed by eruptions along the Yellowstone Hotspot. The volcanic vent's location is unknown but likely nearby. Rhyolite lava is so viscous and slow moving that it usually only flows a few miles before it solidifies into rock.

Age: The gorge walls may be about 11 to 12 million years old, the same age as several rhyolite lava flows to the north (downstream) that have been laboratory dated. At least 24 different rhyolite volcanic centers were active in this corner of Oregon around this time.

Flow patterns: Rhyolite lava flows like toothpaste squeezed from a tube, piling up on itself, forming flow patterns visible as curls or swirls or bands. All those flow patterns are visible in the cliff face as you pass through the gorge. Also notice the vertical rock fractures



Mile 6.8 on river-left: Prominent swirl patterns and vertical cooling joints in the rhyolite lava cliff face.

called "jointing" caused by contraction as the hot volcanic rock cooled.

Vesicles: If you stop and walk along the base of the cliff on river-right at mile 7, you can find several places where the cliff face looks like Swiss cheese, loaded with gas cavities of assorted sizes and shapes (vesicles). The vesicles are often filled with secondary minerals that formed long after the lava cooled and was buried by sediment.

Uplift: Several geologists who studied Rome valley stratigraphy think the rhyolite lava flow may underlie the Rome sediment at depth, out of sight. We can see it here today because this portion of the lava flow was uplifted by ancient east-west faults as sediment was filling up the basin. The rhyolite lava flow was buried for millions of years until the Owyhee River encountered the erosion-resistant rock and cut a gorge through it. The base is not exposed so we are not able to determine its total thickness.

Mile 7 on river-right: Flow banded rhyolite lava cliff with abundant mineral-filled gas cavities.

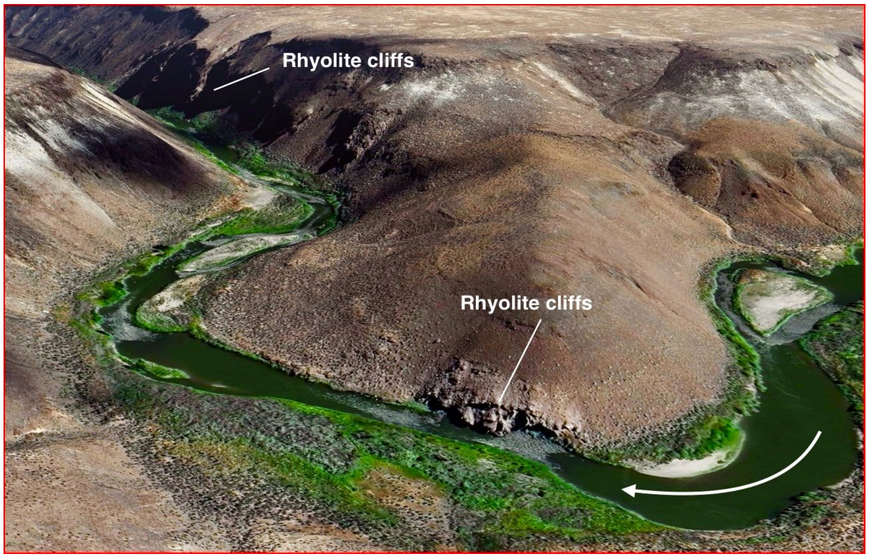
Mile 8.0: Little Owyhee Butte lava rimrock across from First Camp. (From Google Earth. Photo contributed by Sonny Thornborrow 5/2010.)

Little Owyhee Butte rimrock (mile 8)

At First Camp the river corridor changes from the narrow rhyolite walled gorge to a V-shaped, basalt lava rimrock lined canyon. From First Camp we can look across the river and see where the cliffs of First Rhyolite Lava Gorge end and interbedded basalt lava flows and sediment begin.

The canyon rimrock is a basalt lava flow from a nearby volcanic vent named Little Owyhee Butte located about 2 miles to the northeast. Its most recent eruption is dated 1.9 million years ago. Upriver, the rimrock contains features called "lava deltas"—evidence the hot lava flow encountered water. The water was probably the lake that temporarily filled the Rome valley after the river was blocked downstream by a lava dam. (See Chapter 4, section "Lava Delta in Ancient Lake" for details.)

Mile 10: Rhyolite lava cliffs continue for a short distance downstream of Fletcher Point and then transition to a V-shaped basalt lava rimrock canyon.



Mile 9.5: Fletcher Point. The Owyhee River curves around an obstruction of erosion-resistant rhyolite lava before resuming its northward course. (Google Earth image.).

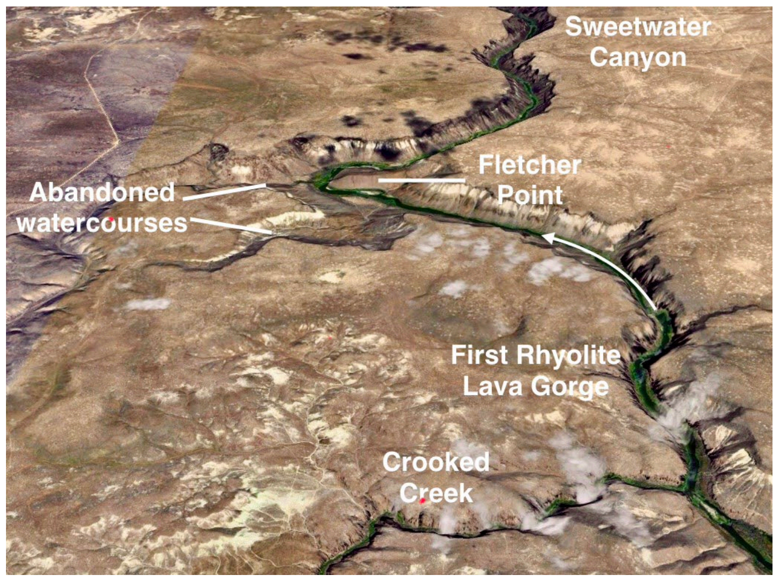
Fletcher Point (dogleg bend at mile 9.5)

At Fletcher Point, the river makes an abrupt dogleg bend before resuming its north-flowing course. The dogleg bend likely avoids an erosion-resistant mass of rhyolite lava concealed beneath the sagebrush and loose soil of Fletcher Point. The cliff at the dogleg bend, along with the 100-foot cliffs downstream and the 150-foot cliffs upstream, are all composed of rhyolite lava. The lava flow shapes the river's course here.

Abandoned watercourse (mile 9.5)

The side canyons located across the river from Fletcher Point are abandoned watercourses. They loop back to a lava divide above the Rome valley near Crooked Creek. These channels could be former courses of the Owyhee River or Crooked Creek, or they may represent a lake overflow from the Rome valley caused by a lava dam that blocked the Owyhee River downstream. The head of the watercourses near Crooked Creek is situated at an elevation of 3,700 feet, approximately 350 feet above the current river channel, suggesting its formation occurred in ancient times. Further research is required to ascertain the specifics regarding the origin and timeline of these canyons.

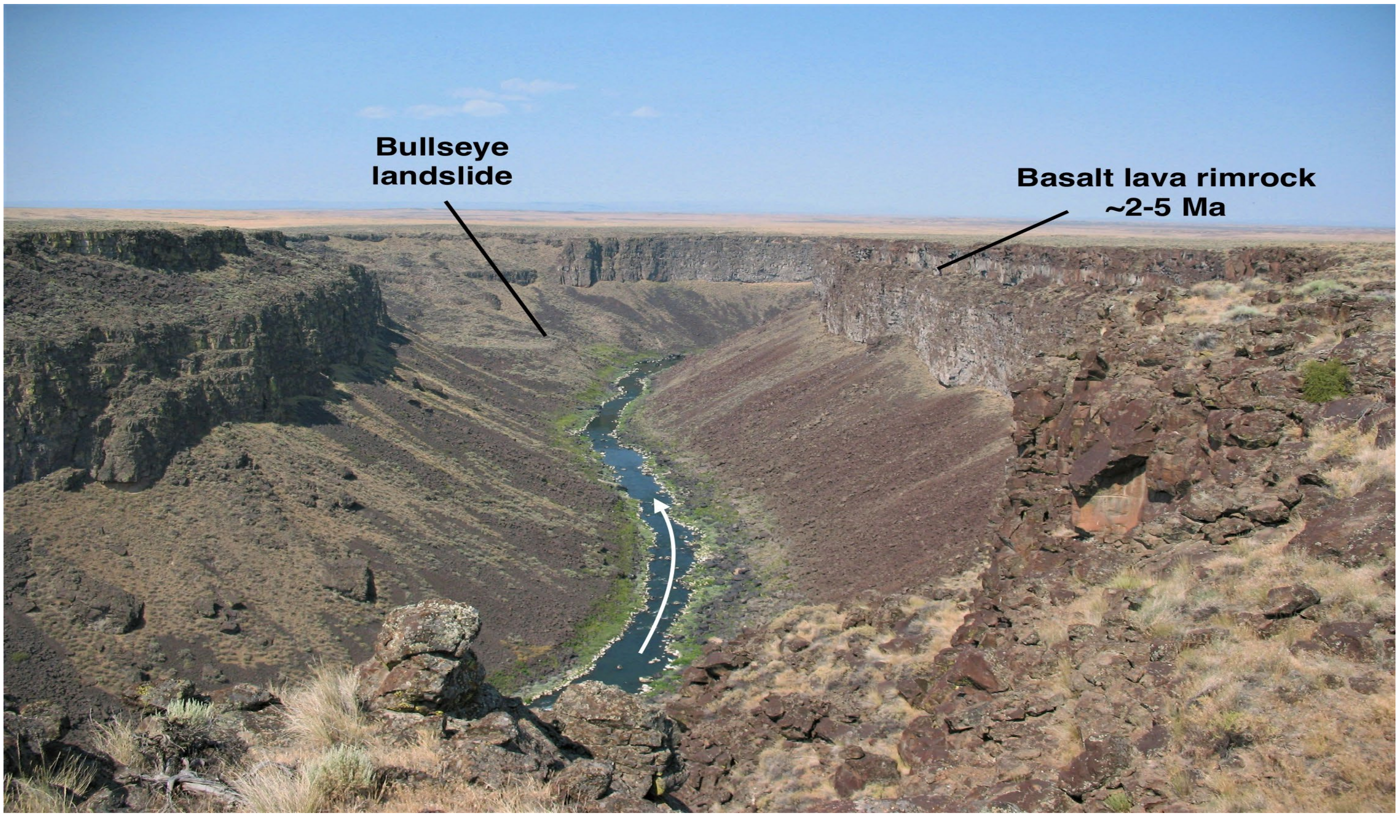
Sources : (Orr, 1985), (Evans, et al., 1990), (Evans, 1991), (Ellison, 1968), (ODGMI Map, 2021), (Wolf & Ellison, 1971), (Shoemaker, 2004), (Swenton, et al., 2022)



Mile 9.5: Abandoned watercourse(s) from Rome Valley join the Owyhee River at Fletcher Point. (Google Earth image.)

Mile 9.5: Spectacular boulder of glassy flow-banded rhyolite lava on Owyhee riverbank at Fletcher Point.

Chapter 3—Sweetwater Canyon (mile 10–14)



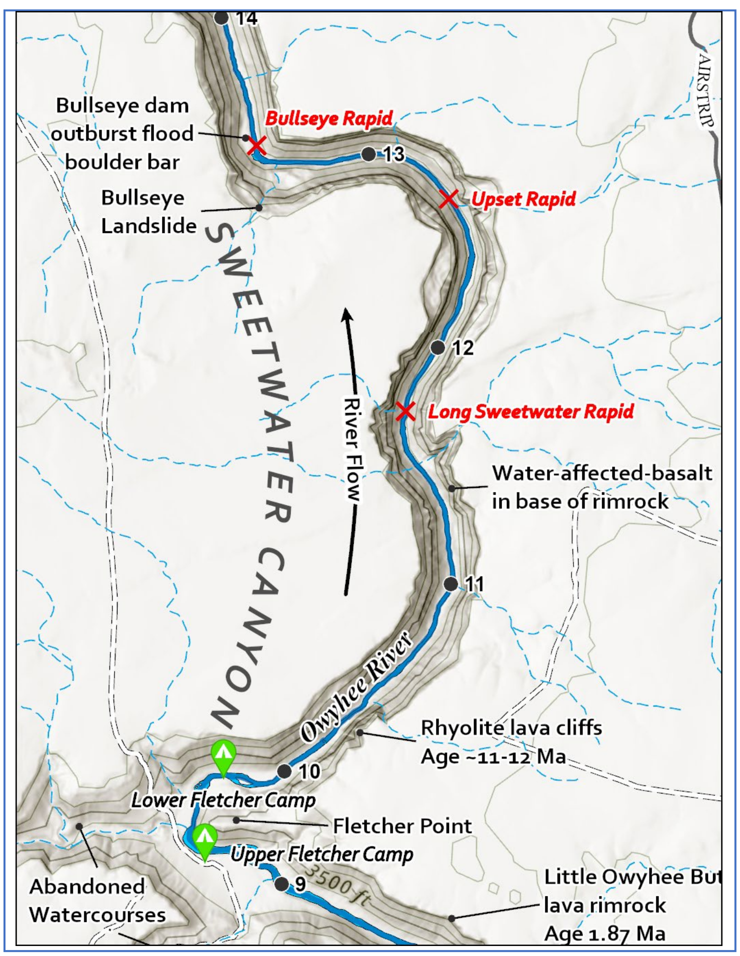
Mile 13: Sweetwater Canyon, looking downstream. Bullseye Rapid is just around the distant bend in the Owyhee River. Notice a section of the rimrock on river-left is missing—it collapsed and triggered Bullseye Landside that dammed the river.

Sweetwater Canyon (mile 10.5)

The Owyhee River incised through 150 feet of basalt lava and 300 feet of underlying soft sediment to create the narrow-walled, 450-foot-deep Sweetwater Canyon, an excellent example of a high lava plains canyon. It's nearly impossible to hike out of the rugged canyon until reaching Hike Out Camp at mile 14.5.

Multiple lava flows: The spectacular 150-foot-thick basalt lava caprock protects the underlying layers of soft sediment from erosion and preserves the canyon's scenic, narrow aspect. From a distance the canyon walls appear to be a massive single lava flow, but up close one can see the walls consist of dozens of relatively thin layers of basalt lava. The individual layers may be from different lava flows of different ages that may have pooled here at a low spot in the topography. Sometimes enough time went by between eruptions for sediment to accumulate between the layers. The geology hike from Hike Out Camp to the rimrock leads to an example of sediment sandwiched between two lava flows.

Age and source: The lava likely erupted from one of the volcanic vents at Owyhee Butte on the lava plateau about three miles west. Geologists think Owyhee Butte probably erupted multiple



times. The most recent eruption occurred 1.9 million years ago, the only laboratory-dated one.

Lava plateau: The high lava plateau on both sides of the river is covered with dozens of volcanic vents (now extinct) and overlapping basalt lava flows of various ages, only a handful of which have been laboratory-dated and mapped. The dated lava flows range in age from a few thousand years to over 10 million years old, and new flows bury older ones, making study difficult.

Ancient rivers: Deposits of fluvial (carried by water) conglomerate up to 100 feet thick are scattered on both sides of the rimrock—evidence that after the lava flow(s) occurred and before the modern Owyhee Canyon existed, the ancestral Owyhee River flowed on top of the plateau, in roughly this same location.

The base of the lava rimrock sits at approximately the same elevation as traces of an ancient riverbed in the Rome valley, so it's plausible that when the lava flow(s) arrived, the lava may have dammed a through-flowing river. Beneath the lava are hundreds of feet of light-colored lake and stream sediment like those found in the Rome valley upstream

Baked sediment & hydrothermally affected lava (mile 11.3)

Most of the underlying sediment in the canyon wall is covered by talus but in places it's visible and in contact with the overlying basalt lava. Notice the sediment is often an unusual pink color, not tan or white. This is a classic thermal alteration feature that geologists look for in the field. It means the underlying sediment in Sweetwater Canyon was saturated or covered with ground water when the lava flow arrived.

The heat of the incoming lava was so intense that it baked the underlying sediment into hard, pink-colored clay-like bricks, creating the distinctive, pink-colored band that underlies the canyon rimrock. The overlying lava flow was also affected by the intense hydrothermal condition. In this case, it altered the glassy basalt base into a zone of brown-colored palagonite—a mixture of iron-rich clay minerals, iron oxides and hydrated silica.

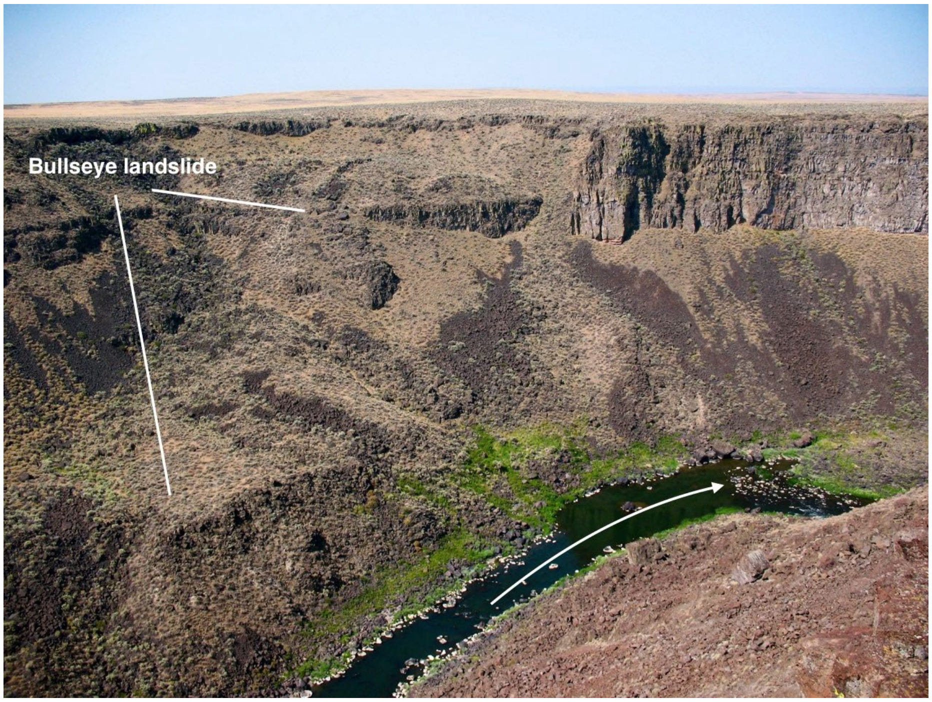
These features are best seen from river level with binoculars, climbing up the steep talus covered slopes in this reach of the canyon is hazardous. However, the geology hike trail from Hike Out Camp leads to a similar exposure above the camp and about a quarter mile downstream.

Mile 11.3: 100 to 200 feet above the Owyhee River, geologist examines baked sediment at base of lava flow in Sweetwater Canyon. An extensive zone of hydrothermally affected lava is visible overhead.

Mile 13.5: Bullseye Rapid from the rimrock. Rafts are being lined through the rapid at extremely low water in April 2021. The rapid was created by debris from an outburst flood when the Bullseye Landslide dam failed. Looking upstream.

Bullseye Landslide and Rapid (mile 13.4)

At the 90-degree bend in the river, Bullseye landslide descended from the rimrock and blocked the river with an earth and rock dam up to 150 feet high. After water infiltrated and overtopped the dam, the dam catastrophically failed. The resulting outburst flood carried boulders and debris downstream and deposited it on a boulder-bar that creates today's Bullseye rapid, just around the corner. There's a chance the landslide was caused by the Alvord Lake outburst flood (described earlier), but that would need to be confirmed by future studies. There are dozens of these landslides on the river.



Mile 13.4: Bullseye Landslide descended from the rim, leaving a notch in the canyon wall. It blocked the river with a landslide dam. Looking downstream.

Source : (Evans, 1991), (Ely, et al., 2012), (Skilling, et al., 2002), (Godchaux & Bonnichsen, 2002), (Bondre, 2006)

Chapter 4—Heavens Gate Landslide Complex (mile 14–18)

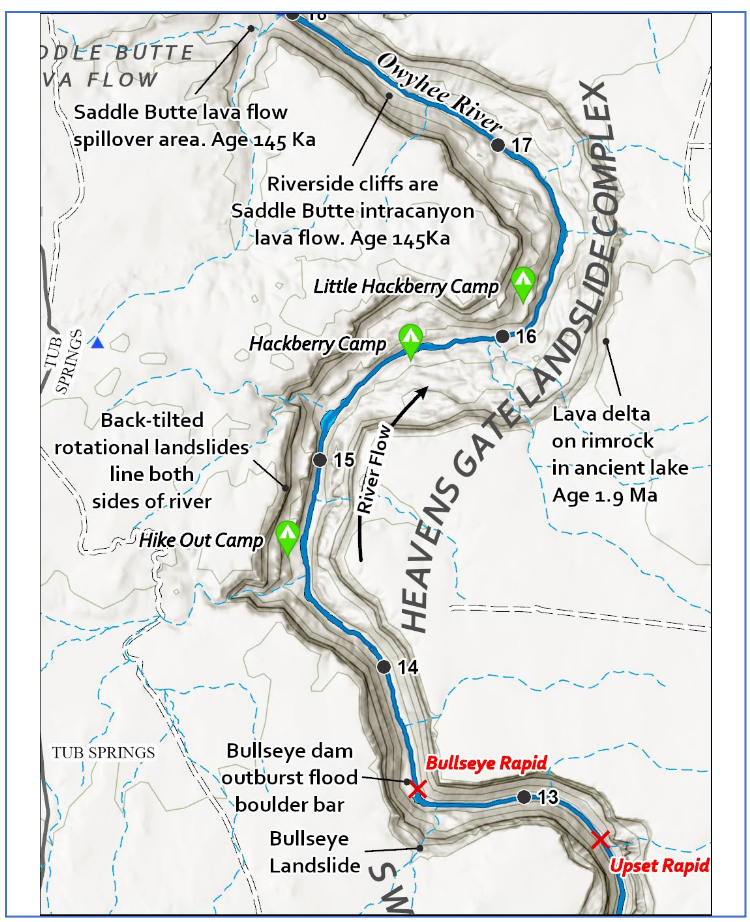
Mile 14: Heavens Gate Landslide Complex. Back-tilted rotational landslides line both sides of the Owyhee River. View downstream.

Heavens Gate landslide complex

The broken landscape where the scenic narrow canyon abruptly widens is informally called the Heavens Gate landslide complex. Here the river is lined on both sides with massive blocks of basalt lava that have broken off the canyon walls and slid down. Many of these landslides once blocked the river with dams over 100 feet high.

Rotational landslides: Though difficult to see from river level, notice the large broken blocks of rimrock are tilted at a back angle to the river. Geologists call these “rotational landslides”. They look like the underlying white sediment “rug” was pulled out from under them, causing them to collapse, spread, and rotate, creating a messy broken landscape in a widening canyon.

This type of landslide occurs when a stronger material such as basalt lava overlies a weaker material such as fine-grained sediment and the river undercuts the weaker lower layer, causing large blocks of rock to break off and slump down, tilted at a backward angle. Best seen by hiking a short distance up and away from the river, as the tilted blocks block the

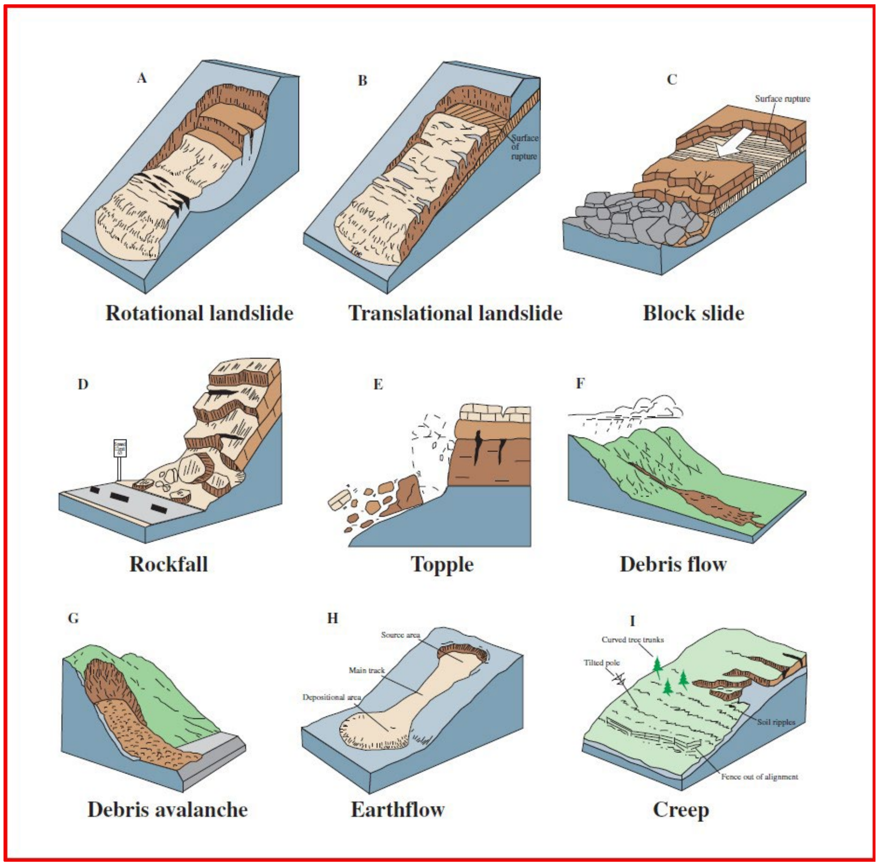


Mile 14.5: Aerial view of valley-widening "ping-pong" effect of landslides. Looking downstream to Hackberry Camp, located on right bank in center of photo.

Mile 15: Blocks of rotational landslides as seen from river. Looking downstream.

view from the river. The Heavens Gate landslides include some good examples of simple rotational failures with obvious intact stratigraphy, but also some weird forward-rotational/cantilever type, and various composites.

Age: These landslides are recent in the life of the 1.9-million-year-old canyon. Some are quite young; there are actively expanding cracks in the canyon walls overlooking Hike Out and Hackberry camps. Geologists have determined the landslides occurred roughly between 7,700 and about 140,000 years ago. The 7,700 years minimum age is based on a layer of Mount Mazama volcanic ash (the eruption that formed Oregon's Crater Lake) found in core samples taken from several landslides. The maximum age of 140,000 years is based on landslides of similar morphology found seven miles downstream at the Artillery Landslide Complex.



Types of landslides. (From USGS fact sheet.)

Ping-pong action: The largest landslides interact with each other in a "ping-pong" manner (over time) to redirect the river's course to other parts of the canyon and to widen the valley—creating lasting impacts on the canyon geomorphology. When a large landslide redirects the river to the opposite bank, the resulting incision and undercutting into soft sediment on that opposite canyon wall can induce additional landslides on that side. That new landslide in turn redirects the river back to the original bank, triggering landslides there—like a ping-pong game—constantly widening the valley. These back-and-forth events that began tens or hundreds of thousands of years ago continue to redirect the river and widen the valley even today.

Hike Out Camp hikes (mile 14.5)

Hike Out Camp has two excellent hikes. From camp if you bear slightly left (upstream) and follow the dry wash, it takes you up the canyon wall and ultimately out of the canyon onto the rimrock. There are great views looking down on the landslides, and you can see a lava delta across the river (described in the next section). Also visible across the river is a landslide with a closed (filled-in) depression that has been breached (eroded through) and has a great exposure of sediment including a layer of Mazama ash. One can also find ancient Owyhee River gravel that has been transported from the surrounding rim by the landslides.

If you hike all the way to the rimrock, along the way there are several places where you can find a layer of trapped sediment and gravel between the layers of lava, indicating that the canyon wall is made of multiple lava flows and sufficient time passed between flows for sediment to accumulate.

From camp, if you bear slight right (downstream) and follow the small draw between the two landslide slump blocks, an easy hike takes you about halfway up the canyon wall to the top of an extensive landslide slump block that has great views. You can see the lava delta across the river from here. A short walk upstream on the slump block brings you to another great example of hydrothermally-affected-rimrock lava. (See photo.)

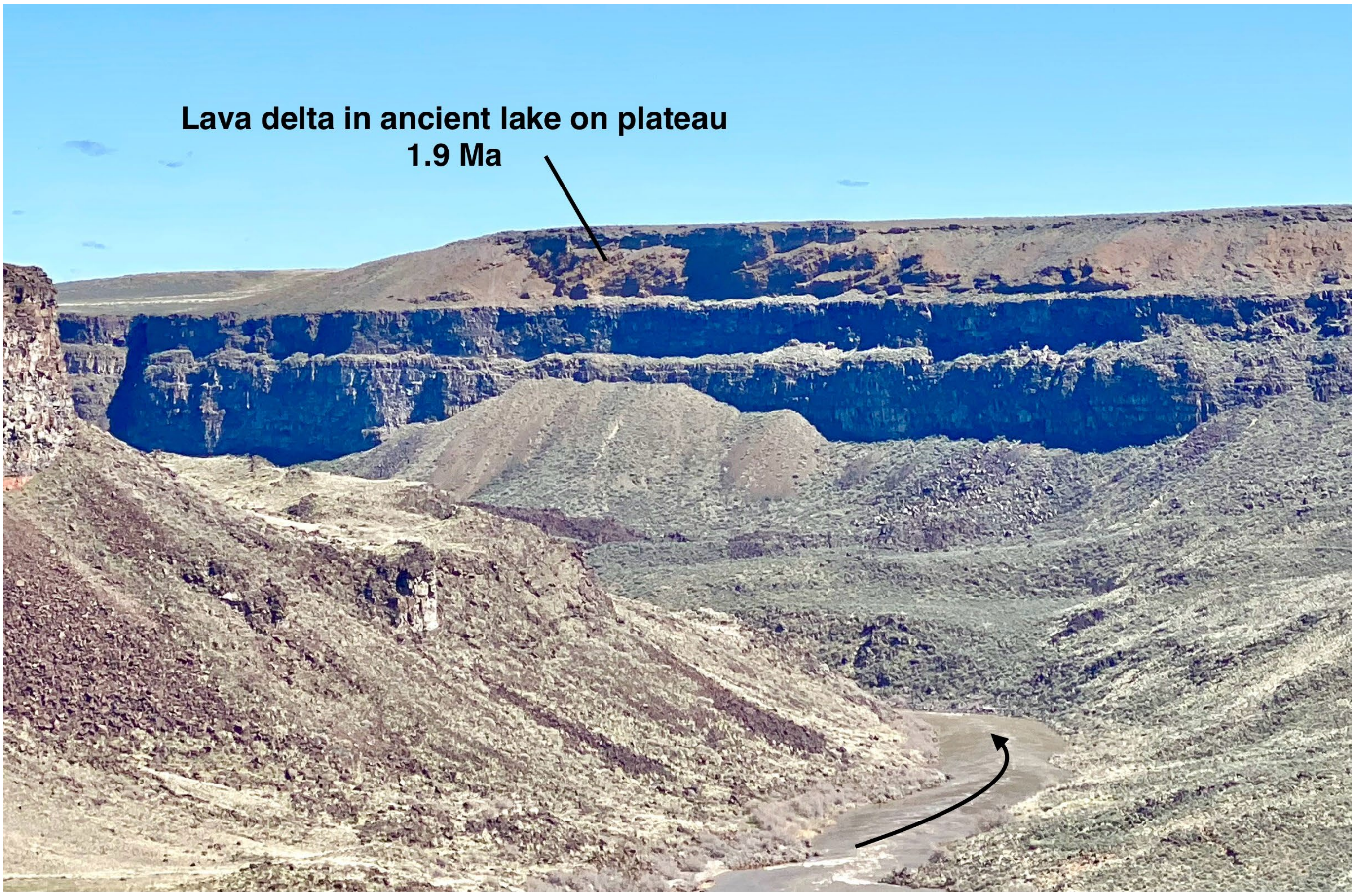
Mile 14.5: Hike Out Camp hike geology hike. The pillar consists of two different lava flows separated by a thin white layer of sediment.

Hackberry Camp hikes (mile 15.7)

Hackberry camp has a short easy hike to an actively spreading crack at the head of a small landslide located about 500 feet east and 60 feet elevation above the campsite. The crack is large enough to see in Google Earth satellite images and the protruding roots show it is recent.

Mile 14.5: Hydrothermally-affected-lava in base of rimrock above Hike Out Camp. (Explained in Chapter 3 – Sweetwater Canyon.)

Mile 15.8: Active recent landslide crack above Hackberry Camp—visible in satellite images.



Mile 16: A "lava delta" in the topmost lava flow. The slanted, orange-colored layers mark the location of an ancient lake.

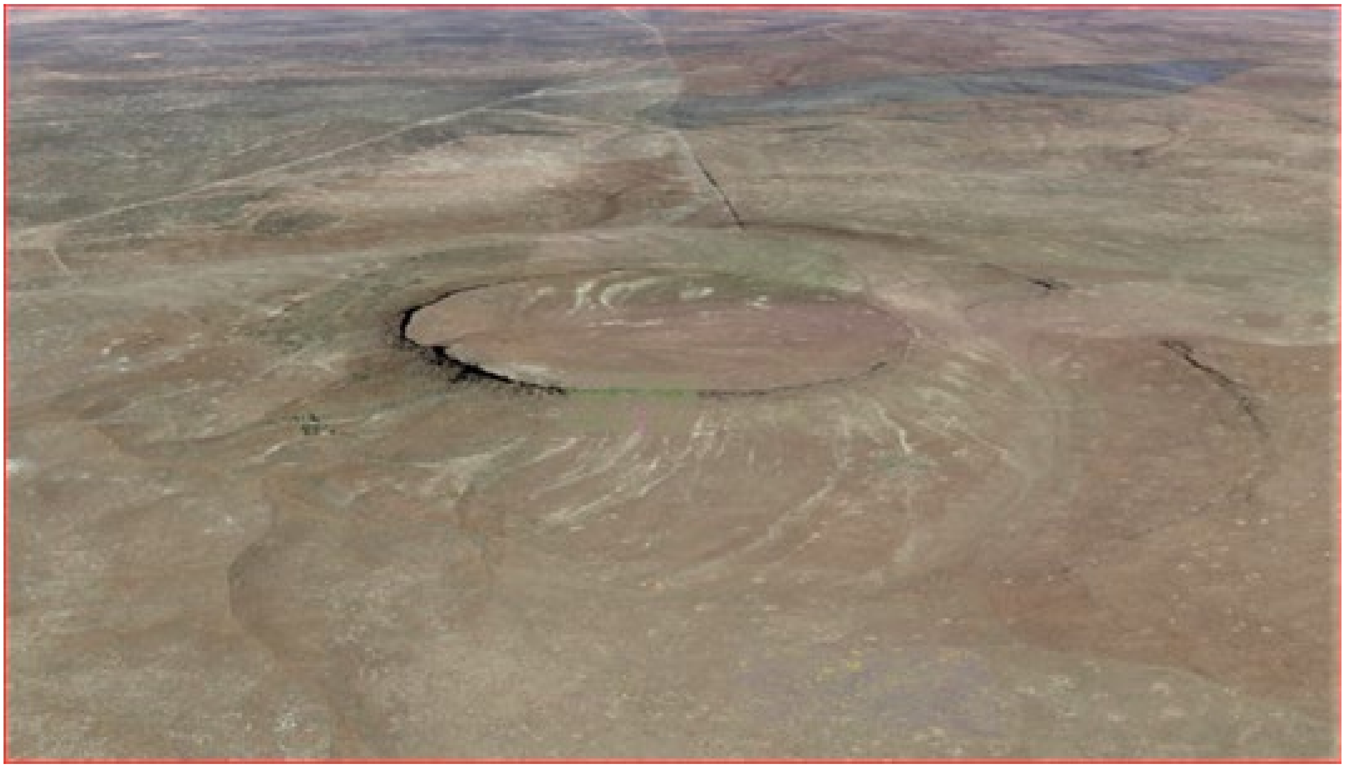
Lava delta in ancient lake (mile 16)

After Hackberry camp, look at the canyon rim—notice the topmost lava flow—the one with orange layers. These are "foreset beds," part of the "lava delta" that forms when lava enters a large water body. (See explanation of lava deltas in Key Events chapter.)

The orange dipping layers show there was an 80-foot-deep lake located on the plateau 1.9 million years ago, before the modern canyon existed. The Owyhee River is famous (among geologists) for the number of lava deltas it contains.

Where did the lake come from? Geologists think the ancient lake was created by a lava dam located 15 miles downstream near Sleeping Dragon Gorge (aka Iron Point). There, geologists found evidence that a lava flow blocked the river with a large dam that created a huge lake overlapping onto the plateau and extending many miles upstream to today's Burns Junction on Highway 95.

Mile 16: Close-up of dipping lava foreset beds in rimrock—evidence the lava flowed into an 80-foot-deep lake on the plateau 1.9 million years ago. (Yellow accent lines added for emphasis by authors.)



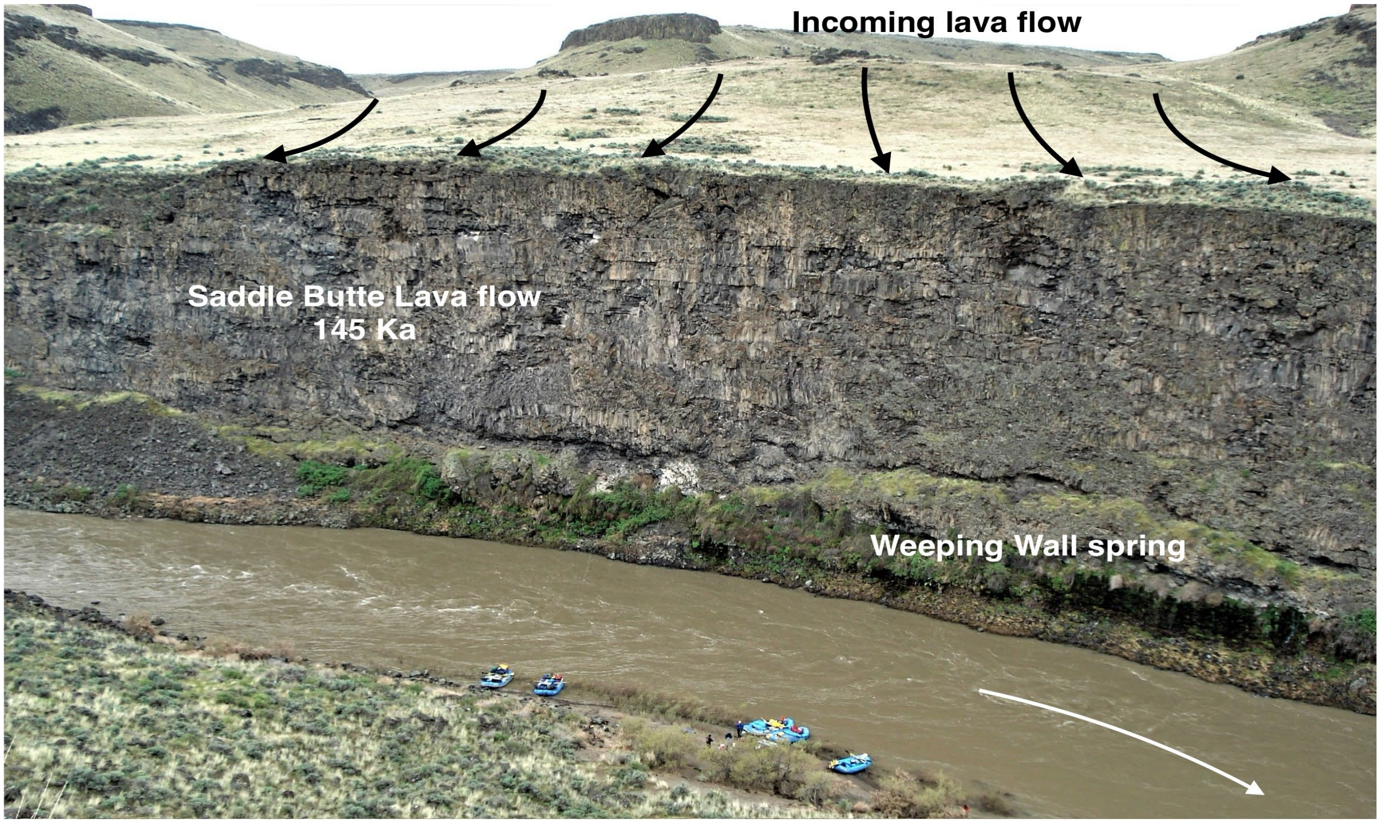
1.9-million-year-old Owyhee Butte shield volcano about 6.5 miles north of Rome, Oregon. (Google Earth image)

Shield volcano

The lava flow erupted 1.9 million years ago from Owyhee Butte, 5.2 miles away on the lava plateau. It was a 110-foot-high shield volcano (a broad domed volcano with gently sloping sides) with a 1,500-foot diameter bullseye crater filled with a lava plug or a solidified lava lake. The easily crumbled volcanic material surrounding the bullseye has since eroded away, leaving a moat-like circular depression around the crater. Nearly all the lava flows that cover the Owyhee plateau originated from small shield volcanoes like this one, or from simple fissures in the earth. (See Key Events for photo of volcanic fissure vent.)

Source : (Bondre, 2006), (Ely et al, 2012), (Egan, et al., 2015)

Chapter 5—Saddle Butte Lava Dam (mile 18–21)



Mile 18.1: A lobe of the Saddle Butte lava flow entered the Owyhee Canyon here 145,000 years ago. The lava blockage was about 150 feet thick.

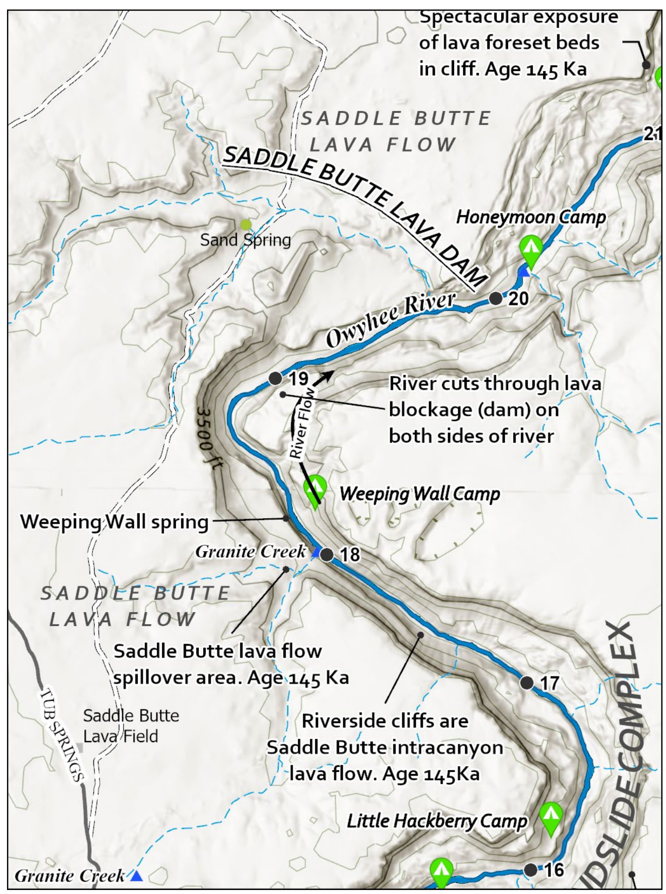
Saddle Butte Lava Flow (mile 18)

The basalt cliff at Weeping Wall spring is the Saddle Butte lava flow. It spilled into the canyon here from the lava plateau, extending one mile upstream and at least two miles downstream. The lava flow blocked the river with a well-studied lava dam.

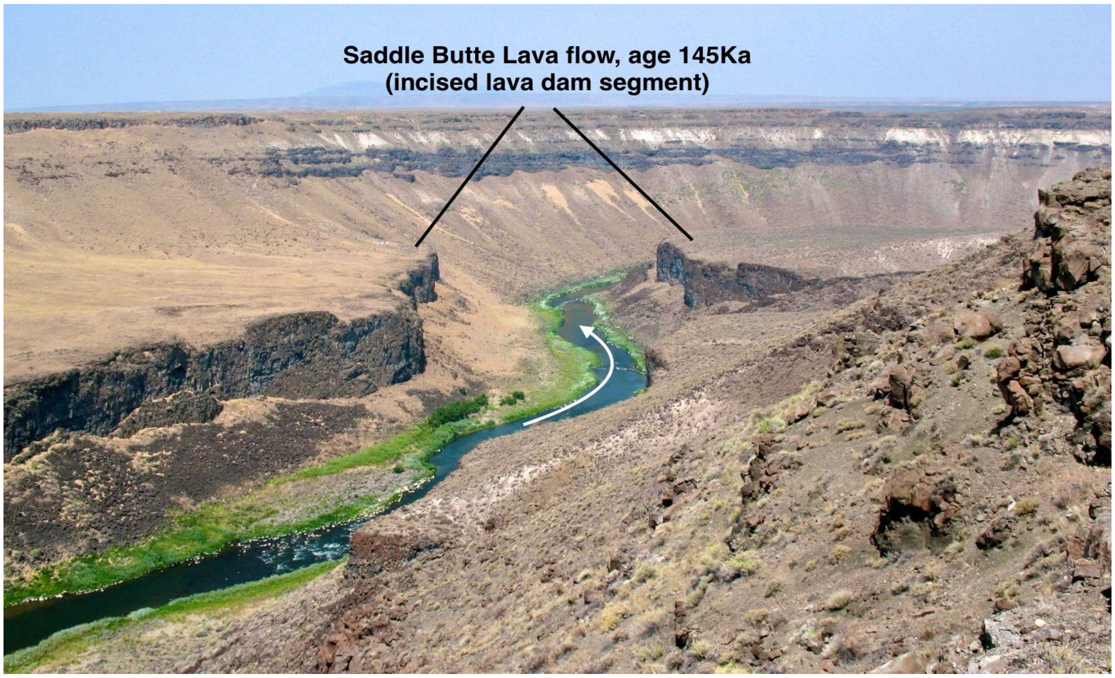
The lava erupted 145,000 years ago from a volcanic vent in the Sheepshead Mountains, flowing 20 miles eastward to the river. It divided into two lobes: one lobe entered the canyon here at Weeping Wall Spring, the other lobe entered about two miles downstream where the two flows overlapped. These lobes are considered one damming episode.

Tiered lava dam: The two entry points created a tiered lava dam. At Weeping Wall spring, the blockage reached approximately 150 feet in height. Further downstream, where the two lava flows overlapped, the height of the dam increased to about 260 feet.

The riverside lava cliffs upstream of Weeping Wall Spring display several exposures of lava foreset beds, which consist of fragmented rock and lava pillows resulting from lava-water interactions. These foreset beds indicate that the Saddle Butte lava flow was progressing in an upstream direction against the flow of the river water.



Chapter 5—Saddle Butte Lava Dam (mile 18–21)



Downstream of Weeping Wall spring, the river incised through the Saddle Butte lava flow that once blocked this reach of the river with a 150-foot lava dam. The distant rimrock contains two undated and unnamed basalt lava flows about 2–5 million years old. (Looking downstream/north).

Weeping Wall spring (mile 18.1)

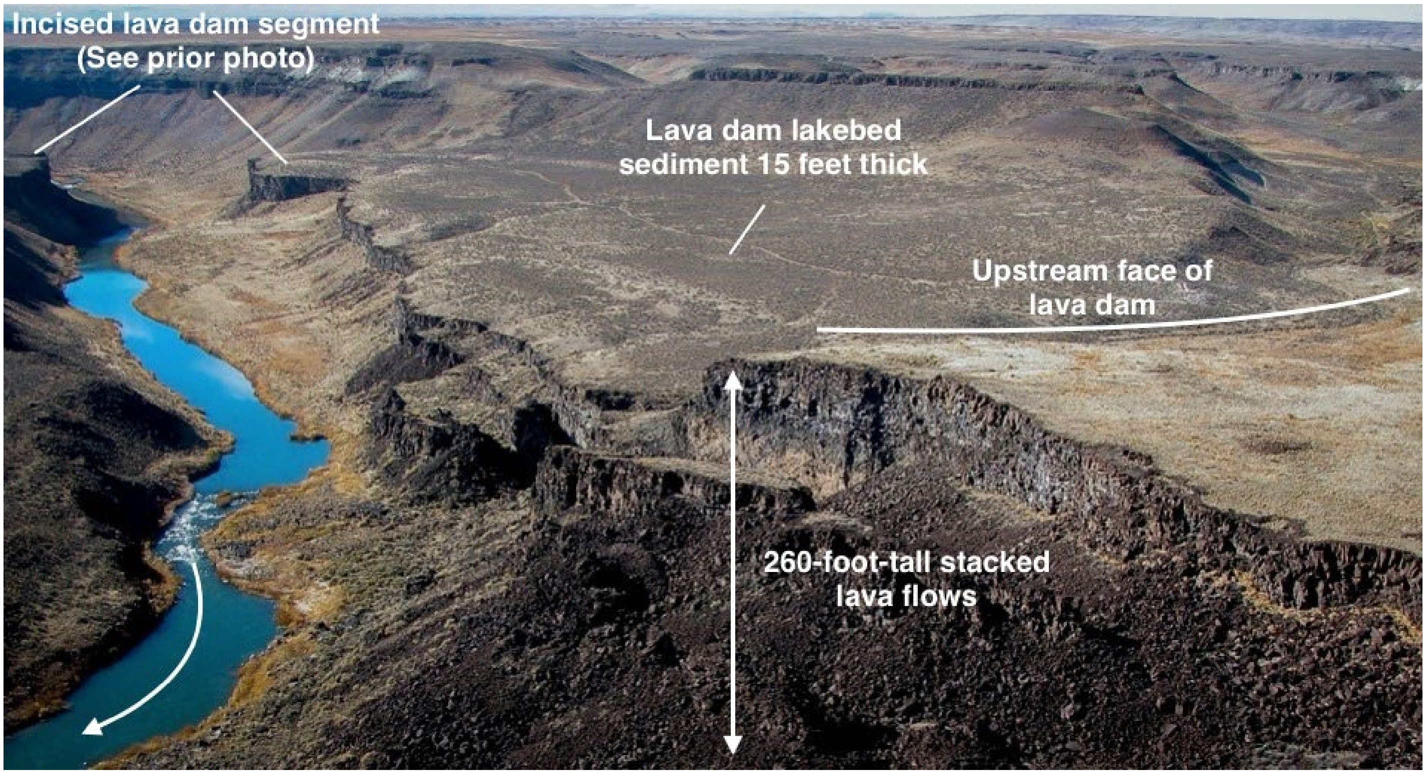
Cold, clear spring water emerges from the canyon wall at Weeping Wall spring, the only reliable water supply for miles around. The source of the spring water is probably rain and snowmelt from higher elevations many miles away. This region is underlain by a layer-cake stack of basalt flows and relatively impervious high-clay content sediment. When water flows along the boundary between the layers, it emerges as springs where a river canyon intersects the underground flow.

The spring water emerges from a thick layer of Owyhee river-rounded boulders and gravel trapped under the laboratory-dated lava flow. The contact zone between the overlying lava flow and trapped river gravel marks the elevation and location of the Owyhee riverbed 145,000 years ago.

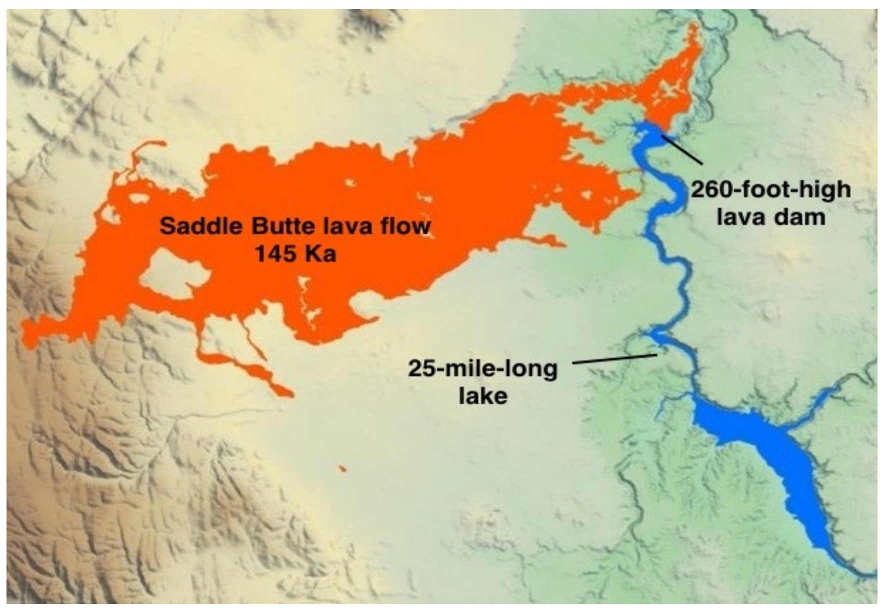
Geologists seek out locations like this where river-rounded gravel is trapped under lava flows. Trapped river gravel tells them the “where” of the ancient river channel. The date of the lava flow tells them the “when.” The combination of these allows for incision rates to be calculated. These are the metrics of the pace of canyon cutting and the evolution of landscapes connected to the river.

At this location, the riverbed elevation has changed little during the past 145,000 years and the river channel location not at all, despite the thick lava flow that once filled the river channel here. This is interesting because the river “rediscovered” this level after being blocked by two major canyon-filling lava flow events (Saddle Butte and West Crater), both of which affected the profile of the river channel here. The fact that the river quickly cut back down to close to the same base level, but no farther, reveals that the river’s long-term base level is probably controlled by the elevation at its confluence with the Snake River.

Mile 18.1: Weeping Wall spring emerges from Owyhee River gravel trapped under a 145,000-year-old lava flow.



Mile 19.8: Saddle Butte Lava Dam, age 145,000 years. Looking upstream/south.)



Mile 19.8: Saddle Butte lava flows 20 miles to river and blocks it, creating a lake stretching 25 miles upstream past Rome.

Saddle Butte Lava Dam (mile 19.8)

This reach of the Owyhee River has some of the world's best exposed lava dams! The 260-foot-high canyon rimrock lining the west (left) riverbank at mile 19.8 is one of the best examples. Named the Saddle Butte lava dam after the lava flow that created the dam, geologists have studied it well. The dam lasted for thousands of years and created a large upstream lake estimated to stretch 25 miles upstream past Rome. Evidence of the lake's existence includes approximately 15 feet of sediment and gravel that accumulated upstream of the dam and now covers the floor of the semi-circular basin behind the lava dam.

The dam was created 145,000 years ago when two separate lobes of Saddle Butte lava met and overlapped at this location, creating a layer-cake lava dam with a combined thickness of 260 feet. The bottommost flow entered the canyon upstream at Weeping Wall spring and then flowed down the river channel; the topmost flow entered the canyon downstream and then flowed upstream; the dam crest is where the two flows met.

How long did the dam last? It took less than 74,000 years to cut through and around the 240-foot-high blockage; an incision rate of at least 1 mm/year, the thickness of 10 sheets of paper each year. We know this because the river channel was eroded back down to near its former elevation (i.e., Weeping Wall spring) by the time another intracanyon lava flow entered the river downstream, dating to 70,000 years ago, from a volcano called West Crater.

Chapter 5—Saddle Butte Lava Dam (mile 18–21)

Mile 22: Profile of Saddle Butte lava flow at Virgin Bar Camp shows where the molten lava encountered river water. The contrasting inclinations of the lava foreset beds are caused by coalescing lobes of the flow. (Looking west.)

Foreset beds and lava pillows

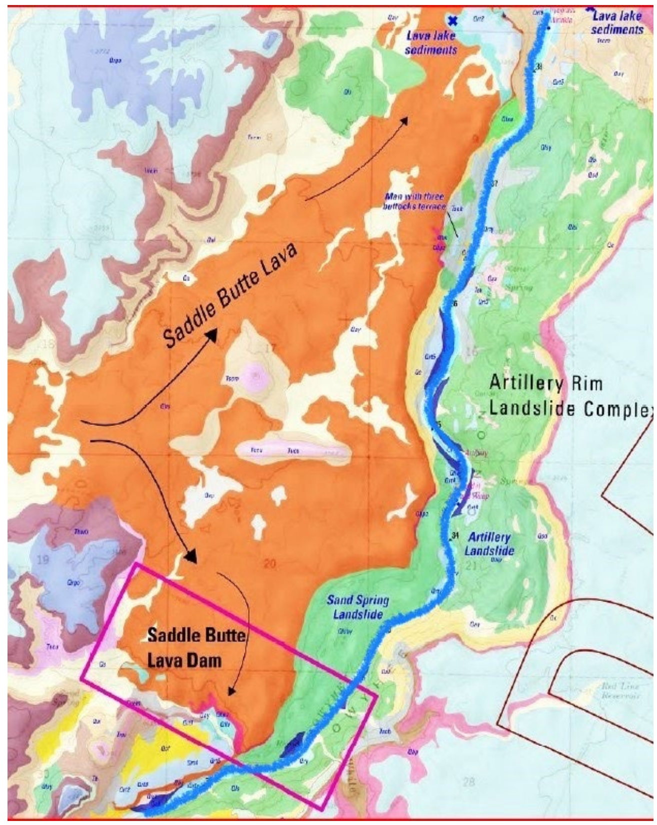
As the hot lava flowed into the growing upstream lake, the submerged portion of the Saddle Butte lava flow underwent rapid cooling into pillow basalt shapes; and steam explosions fragmented the lava into slanting orange-colored foreset beds. These are important features to geologists: the water's depth is marked by the contact line between the slanted orange-colored foreset beds and the overlying basalt cap-rock. The direction in which the lava flow is advancing is marked by the direction in which the foreset beds are slanting.

This reach of the river has several world-class exposures of foreset beds and lava pillows; evidence the lava flowed into water and displaced the river. Look for unusual orange-colored, slanting layers beneath a caprock of solid basalt along the rimrock on river-left. One exposure is in the face of the lava dam at mile 19.8, another is in the rimrock wall at Virgin Bar Camp, mile 21.5.

Relocated river channel

When the Saddle Butte lava flow arrived, it created a large flat lava plain that pushed the river out of its channel to the east, up against Artillery Rim. (See map.) The relocated river then incised a new channel along the seam between the hard lava plain and the soft sediment in the Artillery Rim canyon wall. In the process it undercut the basalt rimrocks on both sides of the river and triggered the landslides that continue to this day.

As you travel downstream (north), notice the extensive landslides on both sides of the river and that Saddle Butte lava covers the left bank but little, if any, lava is on the right bank. Neither the landslides nor the present river canyon existed 145,000 years ago. The Artillery Rim landslides are described more fully in the next chapter.

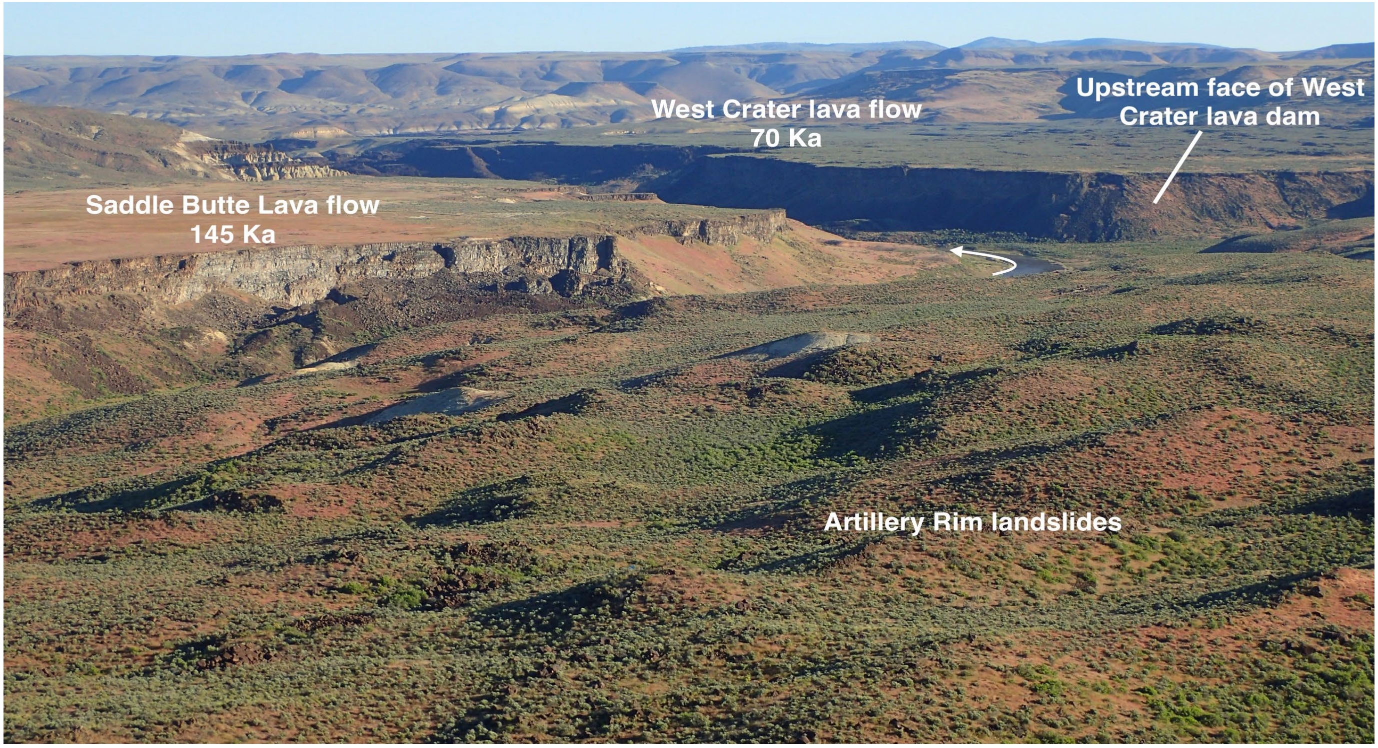


Mile 19 to 24: Geology map of Saddle Butte lava flow and dam. The lava flow pushed the river out of its channel and pinned it against Artillery Rim. (North is up.).

Lava flows have repeatedly entered and dammed the river canyon, blocked the river, and directed water over or around the dam crest, often redirecting the river. Saddle Butte is the first of the lava dams that geologists have studied between here and Birch Creek takeout: Saddle Butte, West Crater, Bogus Rim, and Deer Park. There are indications of at least six and as many as nine damming events based on other types of evidence.

Sources: (Ely, et al., 2012)

Chapter 6—Artillery Rim (mile 21–25)

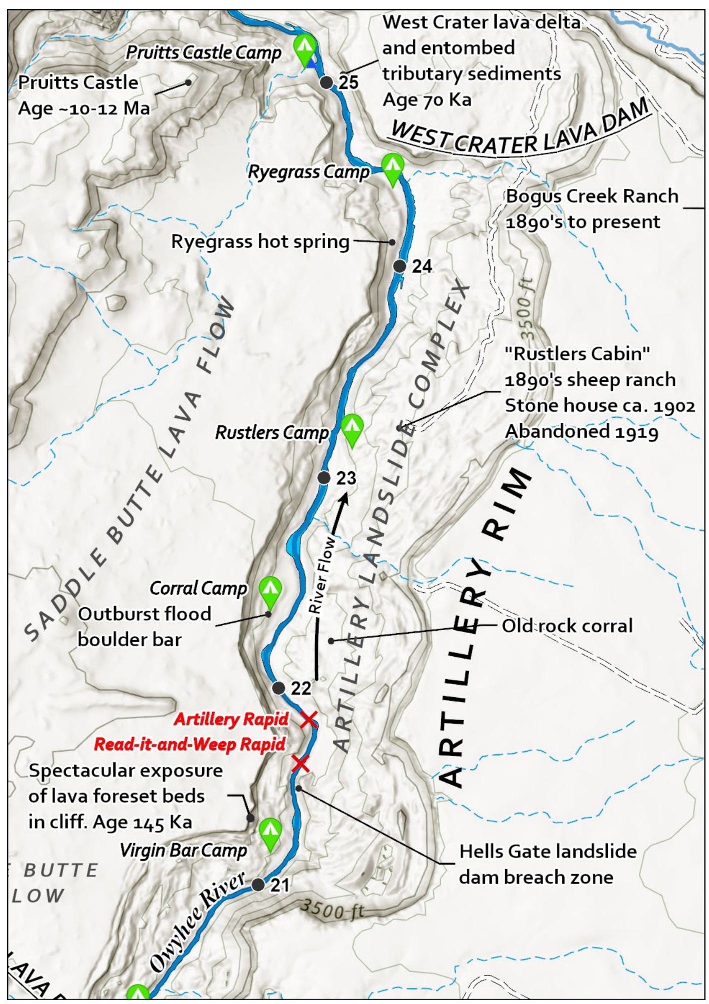


Mile 23: View downriver from above Rustlers Cabin of two different lava flows that dammed the river and altered its course during the last 145,000 years. In foreground is the hummocky surface of large landslide slump blocks from Artillery Rim.

Artillery Rim Landslide Complex

Downstream of the Saddle Butte Lava Dam, the river cuts through a fantastic series of landslides that blocked the river with short-lived dams and widened the canyon—known as the Artillery Rim Landslide Complex. The most impressive are on the right bank, massive rotational landslides consisting of a 50/50 mix of sediment and basalt, originating nearly 500 feet above the river on Artillery Rim and traveling up to 0.8 miles to the river. The landslides overlap and form a distinctive hummocky surface as they weather. (Best seen by hiking away from the river—the toes of the massive landslides block the view from the river. On the left bank are smaller basalt rockfalls from the Saddle Butte rimrock, much like the rockfalls seen upstream. One massive rock slab collapsed at Virgin Camp, creating an impressive rockfall there.

These are all recent landslides that get progressively older as you go downstream. The youngest (at Hells Gate) is estimated to be about 10,000 years old, the oldest (across from Ryegrass Hot Springs) is between 70,000 and 145,000 years old. If you walk up to Rustler's Cabin, you are walking on a landslide that occurred about 42,000 to 70,000 years ago.



Chapter 6—Artillery Rim (mile 21–25)

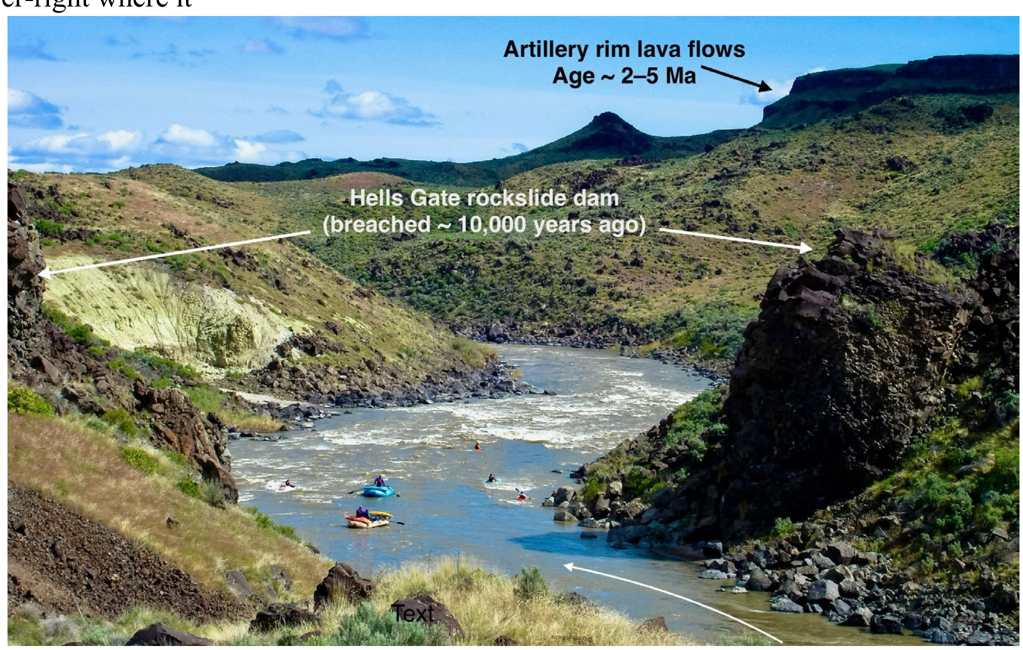
Mile 21.5: Hells Gate rockslide blocked the river with a short-lived dam about 10,000 years ago. The rockslide was triggered when the river undercut the weak sediment beneath the Saddle Butte Lava flow. When the dam failed, rock debris left in the river channel created today's Read-it-and-Weep rapid. View upstream.

Hells Gate rockslide dam (mile 21.5)

The dramatic pinch in the river at mile 21.5, "Hells Gate rockfall", was caused by a recent rockfall of Saddle Butte lava from the rimrock on river left. It created a rockslide dam that failed catastrophically and left a huge block of Saddle Butte basalt stranded on the river-right where it looms over the river, tilted to a nearly vertical position.

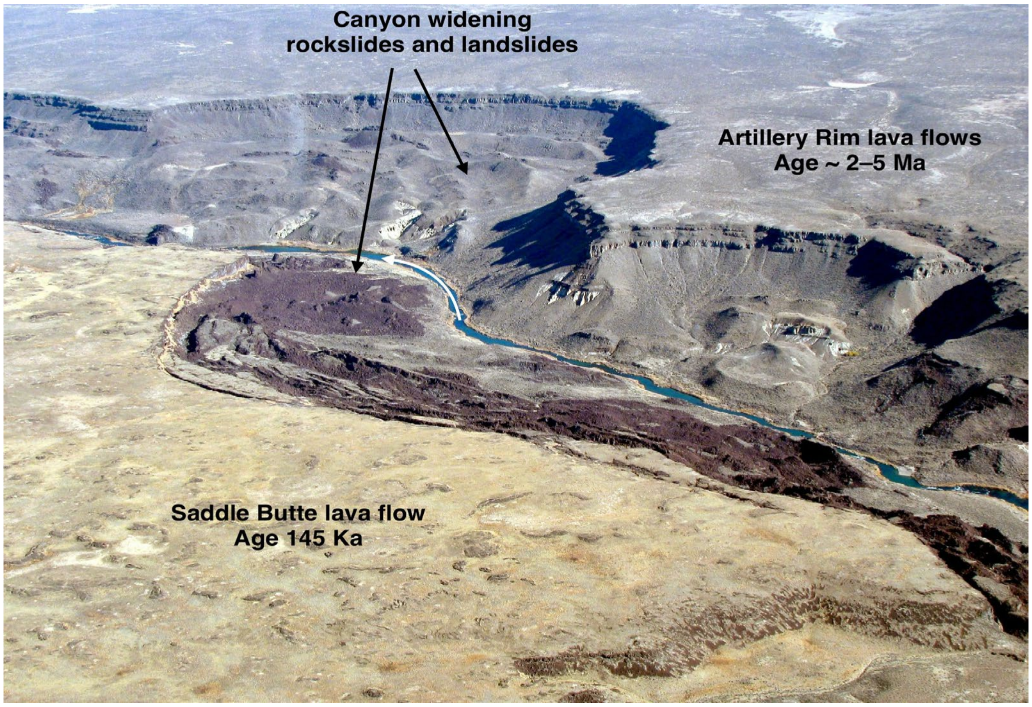
Just upstream was once another dam, slightly older and much larger, created when a massive landslide composed mostly of tan-colored sediment descended from the east canyon rim ("Artillery Rim") and blocked the river, leaving a large scallop-shaped "bite" in the rimrock above.

Geologists believe these are among the youngest landslides and dams on the river, estimated to be about 10,000 years old based on the youthful morphology of the landslide surfaces. Unlike lava dams, landslide dams are very short-lived (80% fail within a year), so neither of these blockages existed long enough to deposit any noticeable lakebed sediment upstream of the dams. However, evidence of high-energy outburst floods tells us the dams did survive long enough to create sizable temporary lakes.



Closeup view of Hells Gate rockslide dam (breached). One of the youngest landslide dams in the canyon.

Chapter 6—Artillery Rim (mile 21–25)

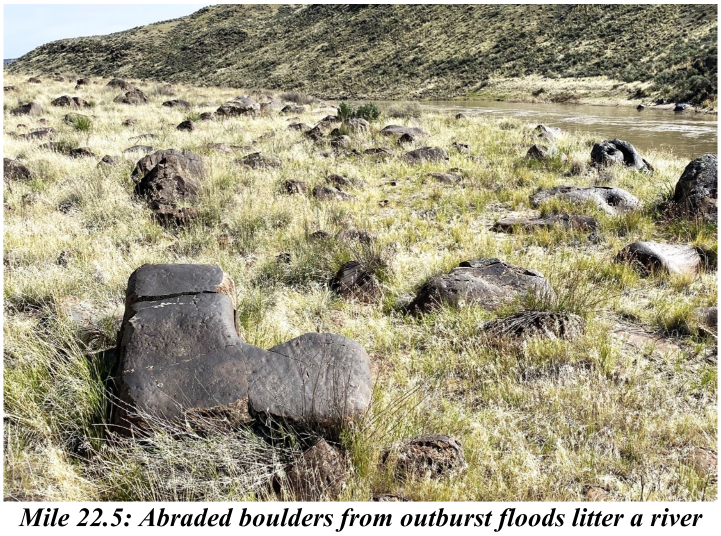


Saddle Butte lava flow pinned the river against Artillery Rim where it incised a new channel and triggered a series of landslides and rockslides. The valley-widening ping pong effect of the landslides is evident in the shape of the canyon.

Outburst flood boulder bars

Outburst floods from the failed dams left trails of boulders downstream in the river channel, creating today's Read-it-and-Weep and Artillery Rapids. The river has not been able to move the heavy clasts since the flood. Some boulders have been abraded into fantastic shapes; others are covered by percussion marks from collisions with other rocks in the powerful floodwaters. One distinctive shaped boulder was selected by ancient native Americans for a spectacular panel of petroglyphs. (See Chapter 11 for petroglyphs discussion.)

Most petroglyphs in the Owyhee canyon are found on the weathered surfaces of outburst flood deposit boulders. This panel of petroglyphs is undated but may be thousands of years old based on full regrowth of rock varnish and uniform color.



Mile 22.5: Abraded boulders from outburst floods litter a river terrace near Corral Camp downstream of Hells Gate landslide dam. Probably deposited about 10,000 years ago.

Rustlers Cabin, aka "The Navarro". Built ca 1902 and abandoned 1919. Once a thriving sheep-ranch. Source: Hazel Fretwell-Johnson, "In Times Past", 1990

History note: Rustlers Cabin (mi 24)

By the late 1890s, a pioneer homestead occupied about two miles of the east riverbank below Artillery Rim at river mile 23. The original 1901 Land Office survey shows a home and two fields located here. Access was by a wagon road (trail) that connected to another homestead at Bogus Creek ("Horn's House") about two miles away and then climbed out of the canyon to Jordan Valley.

The survey also shows a trail fording the river at Ryegrass hot spring and heading west across the lava plateau to a "Harney City". No evidence of the trail exists today. The river ford was probably the hardened mudstone ledge that creates today's "wrinkle rapid"; the ledge can be crossed on foot in the summer at low water. (See photo.)

On BLM maps, the site is named "Rustlers Cabin" but it was originally called "The Navarro", for the family that built the stone house and lived in it from 1902 to 1919. It was then a thriving sheep ranch with several well irrigated fields and rock corrals. Remains of an old horse-drawn mower are located near the house. Subsequent owners used the property for livestock grazing and the house was abandoned and fell into ruin.

On Google Earth you can clearly see the remains of two pioneer rock corrals, one near the remains of the stone house and another upstream on a high bench across from Corral Camp. The corrals were both located near springs providing year-round water.

Owyhee historian Bill Crowell says on his blog that after the homestead was abandoned, "during the pre-WWII period, its remoteness and remaining buildings and corrals made it an excellent hideout for rustlers…"

The land remains in private ownership today, perhaps the only privately owned riverfront acreage left in the Wild and Scenic River corridor.

Mile 23: Remains of "Rustlers Cabin" today.

Ryegrass hot spring (mile 24)

The main tub at Ryegrass hot spring is a popular stop along the river and conveniently located for those staying overnight at one of the nearby Ryegrass campsites. A smaller bath is located a short walk upstream of the main bath.

According to geologist L. Kittleman: "Hot springs are evidence of volcanic heat below the earth's surface. The water is not itself of volcanic origin. It is ordinary rainwater that seeps into fractures in the earth's surface, circulates as groundwater, and comes to the surface again at favorable places (such as faults). In recently active volcanic areas, hot rocks are unusually close to the surface. In the Owyhee region the rise in temperature with depth is in places as much as 13 degrees F per 100 feet, which means the boiling point of water could be reached at a depth of only 1,100 feet."

The hot spring waters feeding the main bath emerge from a rock formation consisting of thin layers of hard, brittle mudstone. Hot groundwater probably hydrothermally altered what were originally soft layers of mudstone into these hard erosion-resistant rocks.

At low-to-medium river levels, you can see a horizontal ledge of this hardened mudstone along the shoreline below the main bath. The hardened mudstone formation extends across the river and at low water forms a frothy obstruction, "Wrinkle Rapid", that's clearly visible in satellite images and lines up perfectly with the springs feeding the main bath.

Lakebed sediment: While soaking in the hot springs, look across the river at the rounded mounds of white/tan-colored sediment on the opposite bank. These mounds are remnants of lakebed sediment that was deposited 43,000 to 70,000 years ago when a large lake existed here. The lake formed behind the West Crater lava dam located just a half mile downstream, described in the next section.

Hydrothermally affected lava: The nondescript slope behind the hot spring is an ancient basalt lava flow on the mudstone, now heavily altered into a crumbly rock that disaggregates to small fragments upon exposure to weathering. This crumbly basalt rock is common throughout the entire river corridor. It's another example of hydrothermally affected lava—created when hot lava encounters water.

Mile 24: Main bath at Ryegrass hot spring. The frothy riffle ("wrinkle rapid") is created by a ledge of hydrothermally altered mudstone. On the opposite bank are mounds of tan-colored lakebed sediment deposited 43,000 to 70,000 years ago behind a lava dam.

Mile 24: Ledge of erosion-resistant hydrothermally altered mudstone at Ryegrass hot spring. The brush-covered slope is an overlying layer of hydrothermally affected lava, altered to a crumbly rock.

Mile 24.5: West Crater lava dam. Across river from Ryegrass Hot Spring, looking downstream/north.

West Crater Lava dam (mile 24.5)

Just downstream of Ryegrass Hot Spring, notice the 270-foot-tall dark basalt cliffs on river-right. These cliffs are the upstream face of another well-studied lava dam. At 70,000 years old, the West Crater lava dam is the youngest lava dam on the lower Owyhee River.

Source: The lava erupted from a volcanic vent named West Crater on the high lava plateau about 8 miles SE. It traveled down Bogus Creek into the Owyhee Canyon, creating the lava dam and a 6-mile-long lava plain, parts of which have eroded into the scenic basalt badland named "Lambert Rocks".

Blockage: The lava flow pushed the river out of its channel and redirected it to the west. The old river channel (before the incoming West Crater lava flow buried it) continues due north, somewhere under the basalt cliffs in front of you. This is the second time the river has been redirected by a lava flow. The first was 145,000 years ago when the Saddle Butte lava flow came downriver and blocked the river here.

Over a period of tens of thousands of years, the river incised a new channel in the lava. A unique geological feature downstream named Dogleg Bend has allowed researchers to study how long it took for the river to incise through the lava flow and establish its present course. For additional details, refer to Chapter 7—Chalk Basin.

Upstream lake: A large lake 270 feet deep formed behind the lava dam, extending upstream to the Rome valley where the water was 30 to 50 feet deep. The lake persisted for tens of thousands of years, during which time the river's new course was over the top of the new lava dam and downstream on the surface of the lava flow. The dam overflow waters left behind shallow water channels eroded in the rim top lava and river-rounded boulders on the rim top.

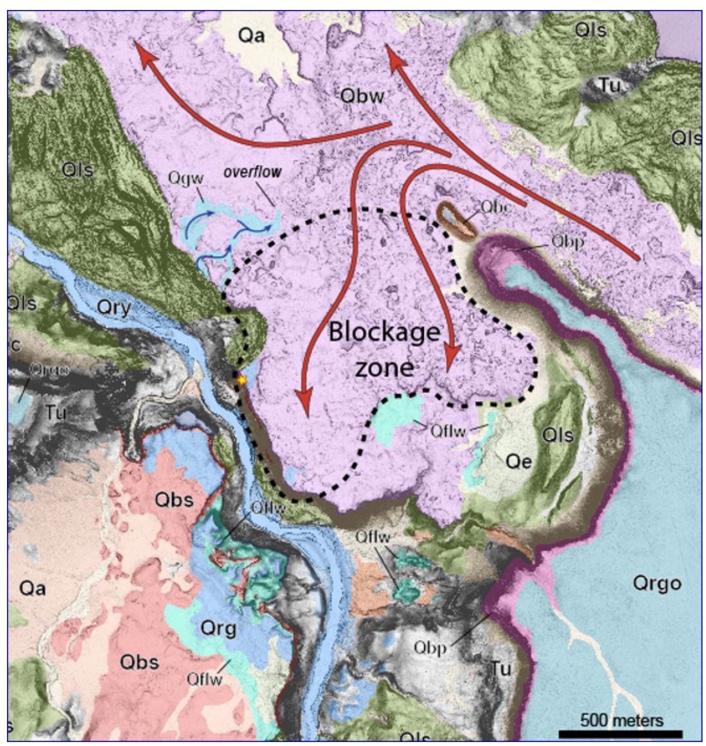
Some of the lakebed sediment still exists. Across from Ryegrass hot springs, you can see rounded mounds of white/tan colored lakebed sediment on the sagebrush flats near the basalt cliffs. In the lakebed sediment, geologists found two layers of Mount St. Helens ash that were deposited 55,000 and 47,000 years ago, evidence the lake existed for at least 23,000 years after the dam formed.

Buried tributary: The cliff-face across from lower Ryegrass camp at mile 25 contains a lot of geological history starting with a blob of white sediment high in the canyon wall. This is an entombed remnant of Ryegrass Creek that was buried 70,000 years ago by the West Crater lava flow. The creek bed sediment was exposed when the Owyhee River cut its present channel through the West Crater lava, truncating Ryegrass Creek on river left. (Best seen by a short hike upstream from Pruitts Castle camp or a slightly longer one from Ryegrass camp.)

Mile 25: Profile of West Crater lava dam. A spectacular exposure of stacked lava flows with lava pillows, slanted foreset beds, and a buried tributary streambed. About 1 mile downstream of Ryegrass Hot Spring.

Lava pillows and slanting foreset beds: In the same canyon wall as the entombed creek bed sediment, you can see a stop-action snapshot of the West Crater lava dam as it was being formed. A wall of West Crater lava was flowing upstream, pushing the lake water in front of it, leaving a trail of chilled rocks in slanted layers, until eventually halting near Ryegrass hot spring. Beneath the topmost layer of lava, notice the thick, orange-colored, dipping foreset beds and lava pillows created by contact with the lake water—a lava delta. The contact line between the dipping foreset beds and lava cap-rock marks the elevation of the water's surface.

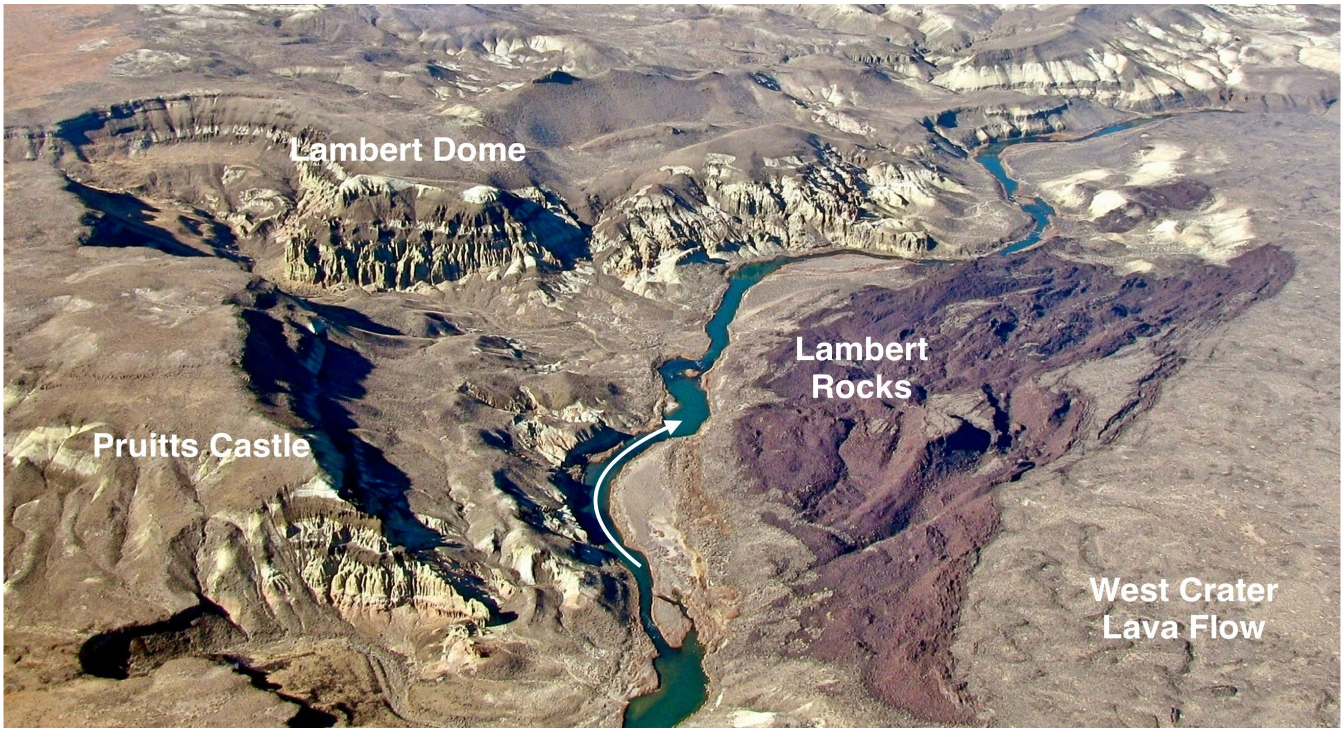
Chalk Basin sediment: Downstream, you are following the new river channel carved about 40,000 to 50,000 years ago when the lake behind the West Crater lava dam drained. Notice that different strata are exposed on each side of the river: soft sedimentary layers on the river-left and hard erosion resistant lava flows on river-right. The river avoided the hard lava and carved its new channel in the soft sediment of Chalk Basin.



Mile 24.5: West Crater lava flow is shown with red arrows and purple color. Lava dam blockage is outlined with dotted line. (North is up and river flow is from bottom to top.)

Sources: (Kittleman, 1973), (Ely, et al., 2012), (Markley, 2013), (Othus, 2008), (Brossy, 2006), (Orem, 2010), (BLM General Land Office Records Search, 2024), (Crowell, 2022), (Fretwell-Johnson, 1990)

Chapter 7—Chalk Basin (mile 25–30)



Mile 25: Aerial view of Chalk Basin. (Looking north.)

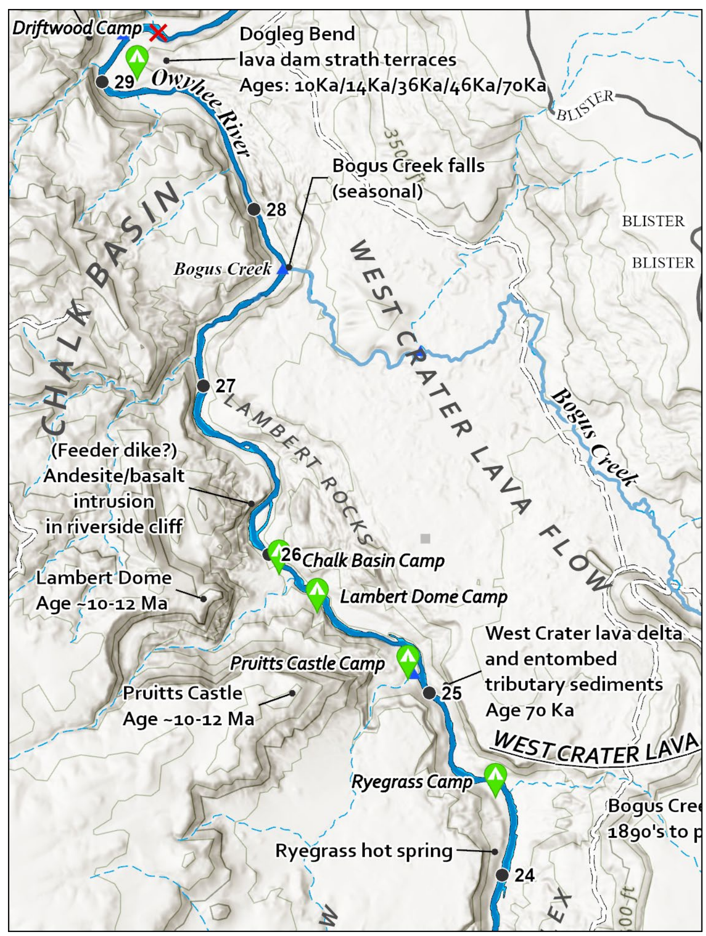
Geological history

Chalk Basin attracts hikers and photographers with its hoodoos, spires, and domes. The canyon walls show alternating layers of basalt lava and lakebed sediments, reflecting cycles of eruptions and periods when shallow lakes filled the basin.

Age: The lowest approximately 500 feet of strata, which includes 400-feet-tall Pruitts Castle and Lambert Dome, were deposited over a 2-million-year period, beginning about 12 million years ago and ending about 10 million years ago. (Based on an upper layer of interbedded Devine Canyon tuff dated 9.68 million years old, and underlying Iron Point rhyolite (aka Sleeping Dragon Gorge) dated 11.84 million years old.)

Lakebed sediment: Shallow lakes and swamps left layers of silt, clay and mud; some of which contain shell fragments and ripple marks. Shrinkage cracks suggest the lake periodically dried up. Fossils (horse, beaver, and shells) are dated from the same geologic period as fossils found in the Rome Beds. The sediment is clay-rich and super-susceptible to erosion (basically lubricated mud), easily eroding into the canyons, ravines, gullies, hoodoos, spires, and other formations that make up the Chalk Basin.

Lava flows: As the sediment built up, lava flows repeatedly flooded the shallow lakebed, creating distinctive bands of dark colored rocks in the canyon walls.



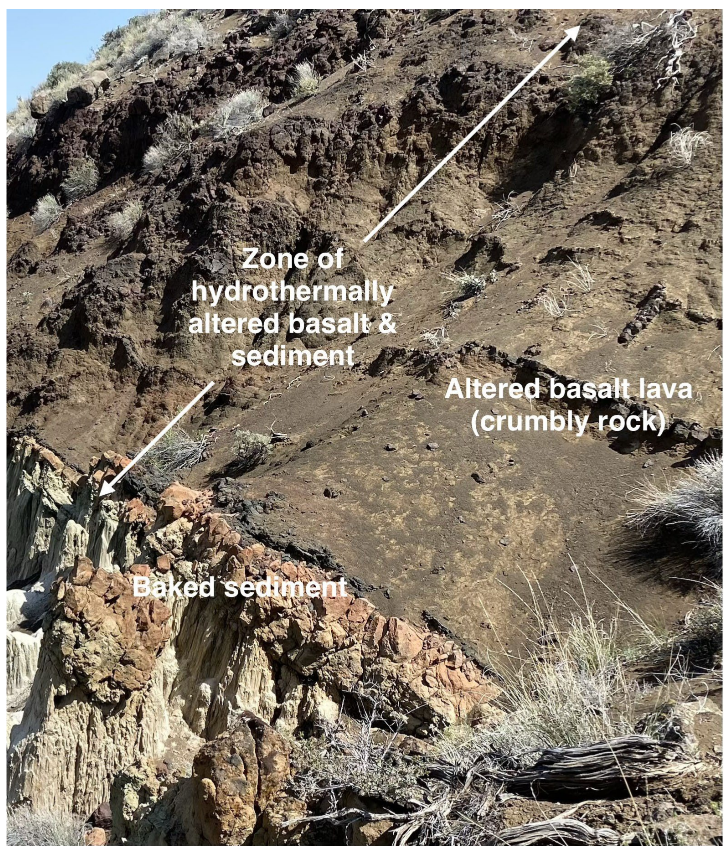
Mile 25: Pruitts Castle lakebed sediment and zone of red oxidized sandstone.

Reddish baked sediment and crumbly basalt

The heat of the incoming lava was so intense that it sometimes baked (fired) any underlying water-saturated sediment into a red, clay-like rock. The baking and staining dies away at a depth of a few inches to a few feet beneath the lava flow.

The short-lived but intense hydrothermal condition fractured the lava and allowed hot water to circulate through it for a brief time. Once fractured and permeable, the hot water and steam chemically altered the lava into a brown crumbly rock, probably a mixture of iron-rich clay minerals and palagonite material. This brown crumbly altered basalt is found at all elevations and locations in Chalk Basin, suggesting the basin floor was saturated or covered with water for most of its life.

Excellent exposures of altered rock caused by lava-water interaction are found throughout the river corridor. (See Chapters 1, 3 and 4 for more examples.)



Example of reddish baked sediment and overlying lava flow that did the baking in Chalk Basin.

Mile 26: Lambert Dome: A sequence of basalt lava flows and lakebed sediment/tuff deposited 10-12 million years ago. 70,000-year-old Lambert Rocks is visible in lower right corner foreground.

Bimodal volcanic system

Chalk Basin is cited by geologists as a classic example of a **bimodal volcanic system**, where both runny basalt lava and viscous rhyolite tuff/lava erupted in the same area during the same period.

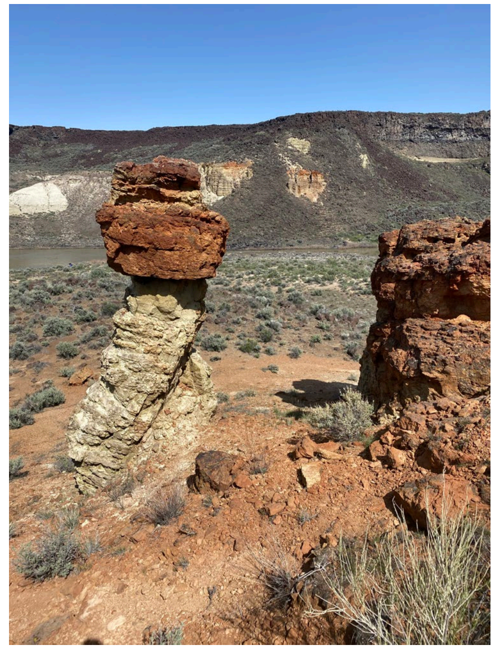
Bimodal volcanism is a hallmark of the Yellowstone Hotspot. Chalk Basin lies near the track of the hotspot, whose bimodal volcanic character has been extensively studied in southwestern Idaho and eastern Oregon.

The basalt mode of the eruptions produced the sequence of basalt lava flows exposed in the face of Lambert Dome. The rhyolite mode produced the 11.8-million-year-old rhyolite tuff and lava flows in the canyon walls just 3.5 miles downstream—in Whistling Bird Canyon, Sleeping Dragon Gorge and Tanager Canyon.

Together, these nearby basalt and rhyolite sequences illustrate the hallmark bimodal pairing that researchers began recognizing more than fifty years ago.

Mile 26: Lambert Dome's peak consists of two thick lava flows covered with a "hat" of lakebed sediment. A thin line of baked sediment separates the two lava flows.


Mile 26: Spires of red oxidized sediment at Lambert Dome.


Mile 25.5: Oxidized sandstone caprock near Pruitts Castle.

Oxidized sandstone and caprocks

Red sandstone: There are extensive reddened zones in the sediment that were not baked by lava (there is no lava/igneous material on top to do the baking). These zones are oxidized sandstone, a layer of permeable rock that has been altered (oxidized) by circulating hot mineral-rich water from igneous activity. These altered rocks are strong evidence that a long-lived near-surface magma system was active here as the basin was filled with sediment.

Caprocks: Most pinnacles and towers have black or red rock caps. This is because basalt flows, consolidated tephra, oxidized sandstone, and strongly baked rock are all more erosion-resistant than the soft lakebed sediment.

Geology hikes in Chalk Basin

Pruitts Castle and Lambert Dome are considered exceptional locations for photography. In addition, these areas provide excellent options for hiking and camping. Although the formations are less than a mile apart, an east-west fault separates them, causing their exposed strata to differ.

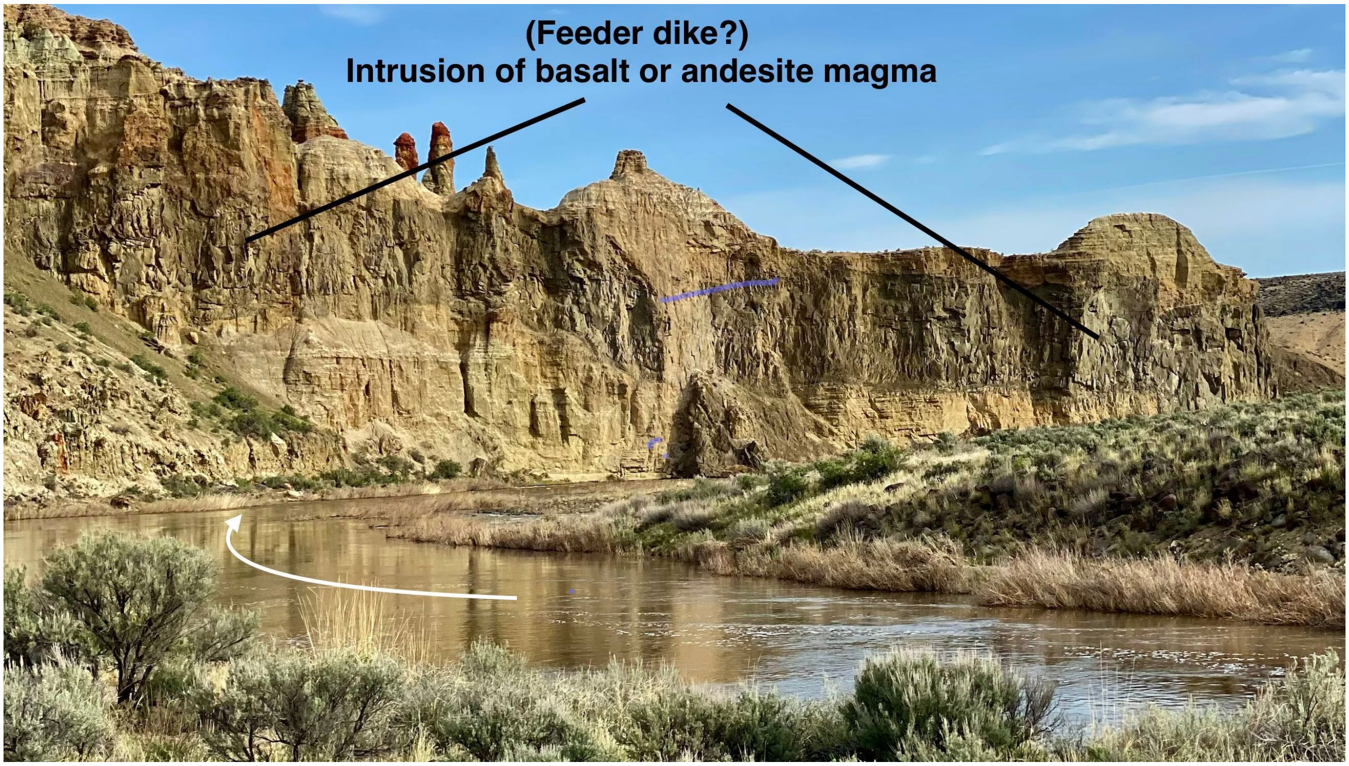
Ryegrass Camp: Starting from Ryegrass Camp, you can hike two and three miles across the lava plateau to access the summits of Pruitts Castle or Lambert Dome. This route does not require hazardous climbing. There is no easy direct route downstream from Ryegrass Camp to reach the formations along the river.

Pruitts Castle, Lambert Dome & Chalk Basin Camps: An easy walk through the sagebrush from any of the three lower camps leads to excellent views of the nearby formations. Reach the spires and hoodoos by walking up the dry washes.

Loop hike: It’s possible to do a loop hike to the foot of both Lambert Dome and Pruitts Castle in a few hours of moderate hiking from any of the lower camps. The route is up and over the 200-foot-high sagebrush-covered slump-block (foothill) on the NE flank of Pruitts Castle, not along the river. (See aerial photo.)

Summit hikes: It’s possible—but not recommended—to hike to the summit of either Pruitts Castle or Lambert Dome via steep, hazardous paths of loose rocks. Hiking poles are necessary, and a rope is recommended for descending. Reach Pruitts Castle's summit through the dry wash on its south side. Reach Lambert Dome’s summit through the dry wash on its north side.


Mile 26: Geology hike on north flank of Lambert Dome.



Mile 26: Possible feeder dike to lava flow(s) in Chalk Basin, stepping upwards through 10 to 12-million-year-old lakebed sediment/tuff. The intrusion is about 20 to 30-feet-thick at river level.

Magma intrusion (feeder dike?)

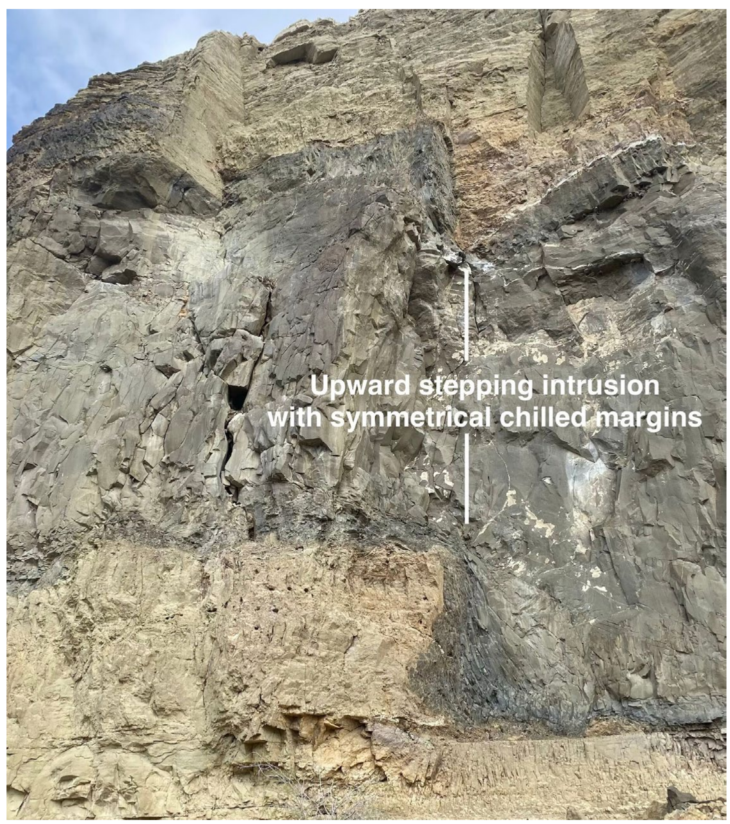
Magma does not always reach the surface. It sometimes travels underground, oozing through cracks and fractures in the earth, muscling its way into the lakebed sediment, and solidifying within the sedimentary layers into basalt and andesite rocks called **intrusions**. If the magma reaches the surface and erupts as a lava flow, the intrusion that fed it is called a **feeder dike**.

The easiest to see example is the cliff face with the reddish pinnacles immediately downstream (north) of Lambert Dome. The 20–30-foot-thick dark rock near the water is an upward-stepping andesite or basalt magma intrusion. It exhibits feeder dike characteristics but lacks evidence of surfacing. If it is a feeder dike, it could have fed lava to Lambert Dome.

Look closely and notice the symmetrical paired offsets in the sill's floor and ceiling where it forced the layers of sediment apart and stair stepped upwards, separating the sediment up to 150 feet as it moved farther upslope.

Notice the **chilled margins**, these form along the contact between the hot magma and surrounding cooler sediment where heat is lost very rapidly. The fast crystallization produces fine grain size and flow banding.

This rock exposure is only viewable by raft or binoculars, it's not reachable on foot.



Closeup of upward stepping intrusion showing symmetrical (paired) top and bottom contacts. About 20-30 feet thick. (View from raft.)

Mile 26: Lambert Rocks is a fresh-looking, still-spreading landslide of West Crater lava across from Chalk Basin.

Lambert Rocks

The colorful landslide across the river from Chalk Basin is Lambert Rocks. The broken rock surfaces are still very raw and fresh looking, suggesting the landslide is recent. The lava rimrock that collapsed is part of the West Crater lava flow that dammed the river and re-directed the river into its present channel 70,000 years ago. As it incised its present channel, the river undercut the soft sediment and caused it and its heavy load of overlying lava rimrock to collapse.

The original river channel (before it was redirected here) lies to the river-right (east), beneath the still-intact sections of West Crater lava.

Sources : (Plumley, 1986), (Evans, et al., 1990), (Walker, et al., 1966), (Ferns, et al., 1993), (Godchaux & Bonnichsen, 2002), (Bishop, 2025)

Mile 27.8: Bogus Falls cascades down from Lambert Rocks after a heavy rainfall. A rare sight—usually a dry streambed. View east, on river right.

History note: Prehistoric Chert Quarry

Prehistoric quarry: The Owyhee Canyon has been home to prehistoric people for almost 10,000 years based on dated archaeological sites located downstream at Birch Creek and upstream at Dirty Shame Rockshelter. In Chalk Basin, Washington State University anthropologists uncovered evidence of a chert quarry and accompanying camp area used by hunter-gatherers to make stone tools.

Chert processing: Anthropologists studied the site over two field seasons, 2004 and 2005. They found abundant flakes and fragments of chipped rocks from chert processing, but few accompanying cultural artifacts, and no cooking hearths, suggesting this was an occasionally used surface campsite.

By analyzing thousands of tiny chert flakes and fragments found at the camp area, researchers learned the raw chert was processed in two steps. Up at the quarry, the large (and heavy) raw chert nodules were roughly worked down into smaller "cores" before being transported down to the camp area. At the camp area, the chert cores were then carefully converted into cutting tools such as knives and projectile points.

No organic material was found for carbon dating, so the site's age was estimated from the styles of six chert fragments. The styles were in use from approximately 7,000 to 650 years ago, coinciding with when prehistoric hunter-gatherers are known to have lived 18 miles downstream at the Birch Creek archeological site.

Mile: 25.6: Chert nodules. Raw material gathered by prehistoric hunter-gatherers for stone tools.

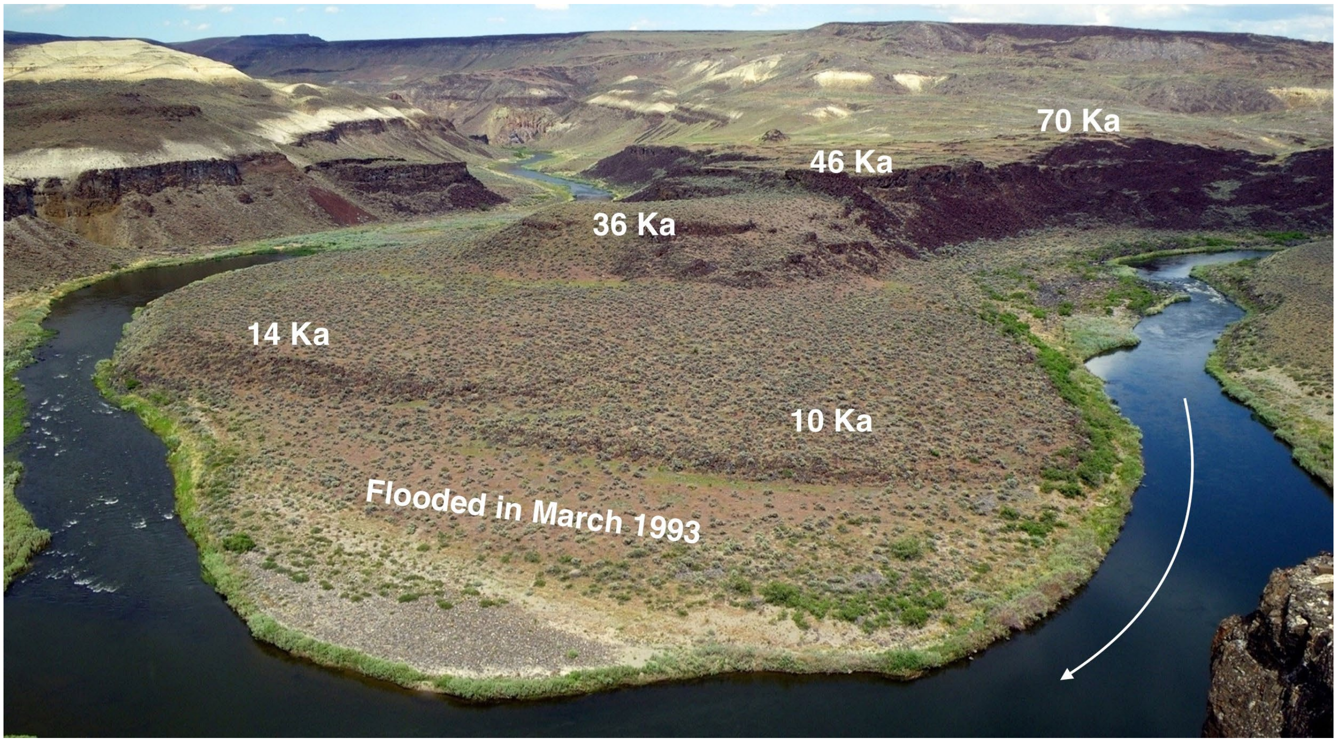
Mile: 25.6: Prehistoric people once camped in Chalk Basin. The dark layer in the distant cliff is an intrusion, possibly a feeder dike.

The chert: The chert found here is a tool-quality, milky-white rock nodule that looks somewhat like agate. It was created when hydrothermal fluids circulated through voids and cracks in the buried layers of volcanic sediment and tuffs, and silica precipitated out of the fluid, forming solid nodules and veins of silicate minerals (the chert).

Farther downstream (from Birch Creek to Red Butte) a different variety of tool-quality chert was used by the prehistoric hunter-gatherers living there. Known to archaeologists as "Owyhee silicified mudstone", it is readily available as river cobble in gravel bars lining the river. It was used as far back as 6,600 years ago to make stone tools found at the Birch Creek archeological site. It was also used as recently as 450 years ago in stone tools recovered at the Lost Dunes bison butchering camp archeological site near Malheur Lake, Oregon.

Archeologists broadly use the term "chert" to include any stone that fractures conchoidally (with smooth, curved surfaces) and is suitable for flaking into stone tools, composed of crystalline quartz (silicon dioxide). Examples are flint and agate.

Sources: (Wilson, 2007), (Lyons, et al., 2003)



Mile 29: Dogleg Bend: Ages of boulder deposits on terraces mark how long it took to remove the West Crater lava dam. View east. Source: Ely et al, 2012

Dogleg Bend Lava Dam Terraces (mile 29)

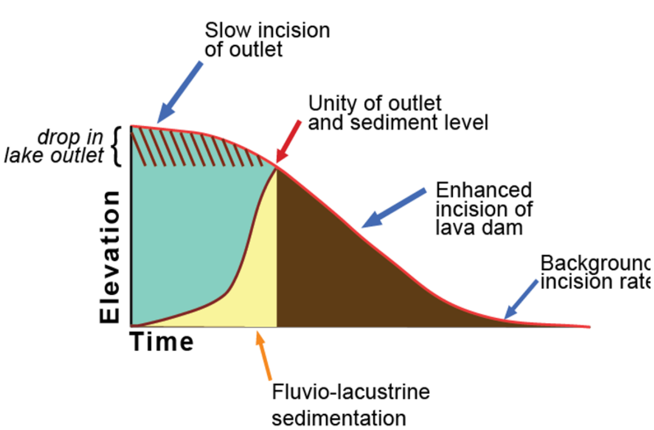
This didn't start out as a dogleg bend. 70,000 years ago, the river's course was around a gentle bend 165 feet above today's river channel, on top the West Crater lava blockage. As the river incised through the lava blockage, its course gradually moved to the outside of the bend, creating the dogleg, and leaving behind boulder-covered stairsteps called "strath terraces" on the riverbank.

The strath terraces are a way to date the lava dam removal process. Geologists used surface-exposure-dating techniques to determine how long the river boulders have been exposed on the surface of each terrace, and thus the terrace's age.

It wasn't until after the reservoir behind the dam had filled up with sediment that incision began. The sediment-filling stage took about 25,000 years. It then took another 30,000 years for the river to cut down through the lava to its pre-dam elevation. That job was completed only about 15,000 years ago.

Once the river water contained sediment, incision took off and quickly started creating the terraces, averaging about 1 mm/year (the thickness of a credit card or 10 sheets of printer paper each year), which seems slow but is about 10x faster than the river's average incision rate over the last 2 million years.

Geologists explain that new lava dams start off with a slow rate of incision because the dam overflow water has lost most of its abrasive power. Abrasive particles suspended in the incoming river water don't make it to the dam outlet, they settle out in the calm waters of the lake behind the dam, slowly building up layers of lakebed sediment. Enough time must pass for the lakebed sediment to reach the height of the dam outlet and then be picked up by the overflow water. Once that happens, the dam overflow water becomes abrasive, the rate of dam incision increases dramatically, and it quickly (in geological time) incises through the blockage.



Simplified Lava Dam Incision/Removal Model

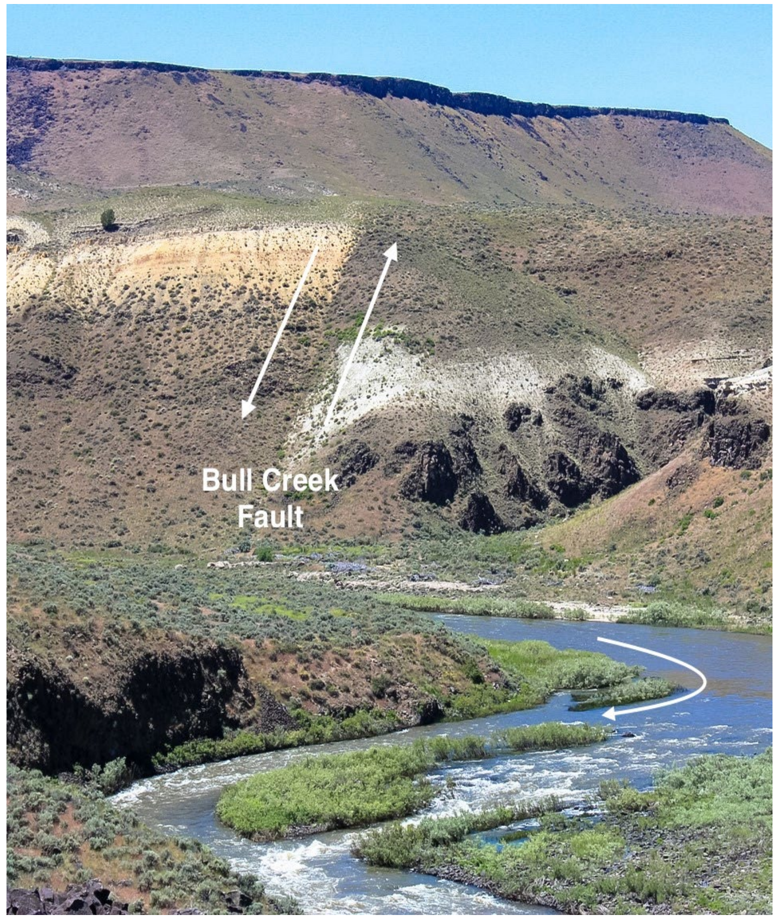
Sources: (Ely, et al., 2012), (Brossy, 2006), (Orem, 2010),

Bull Creek fault (mile 29.3)

At Dogleg Bend, observe the misaligned light-colored sedimentary layers in the canyon wall on river-left (west). This marks the Bull Creek fault. The fault moved upward to the north (right side in the photo), uplifting the strata on the right by over 100 feet relative to the left.

Other faults cross the river upstream near Pruitts Castle and another crosses the river downstream at Hoot Owl Creek (at the north end of Whistling Bird Canyon). The Hoot Owl Creek fault has about 130 feet of offset. Like the Bull Creek fault, its downstream strata are uplifted relative to upstream.

The combined uplift of the Bull Creek and Hoot Owl Creek faults is about 230 feet. This amount matters because it exposes older rock layers, making them visible. The striking volcanic rhyolite and tuff formations that appear around the next turn are prime examples.



Mile 29.3: Bull Creek fault. Strata on the right are uplifted over 100 feet relative to the strata on the left. (Looking upstream from Dogleg Bend.

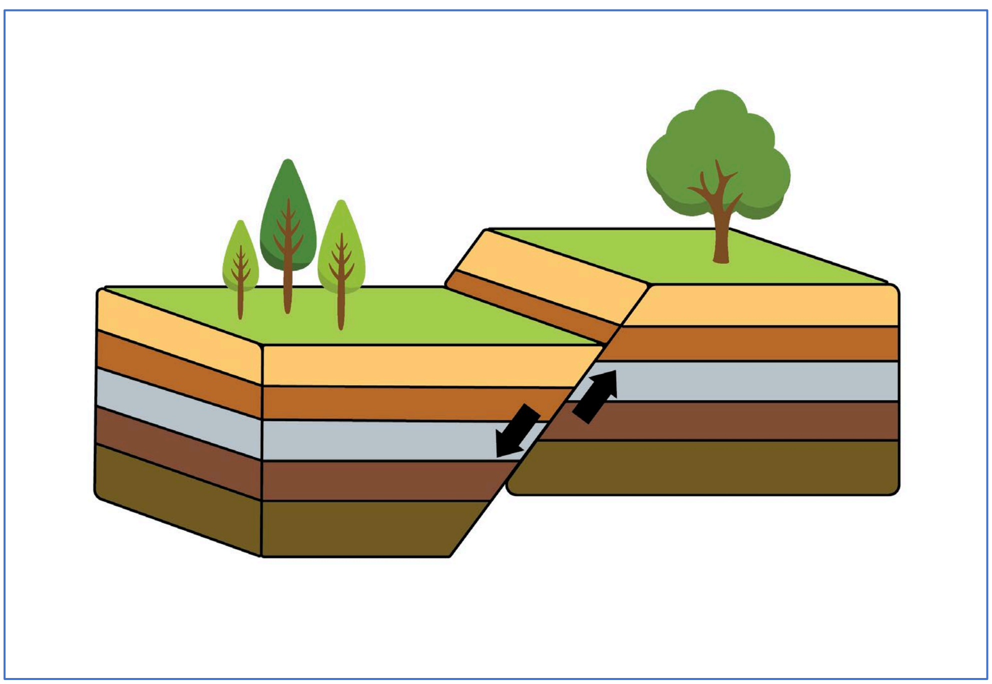
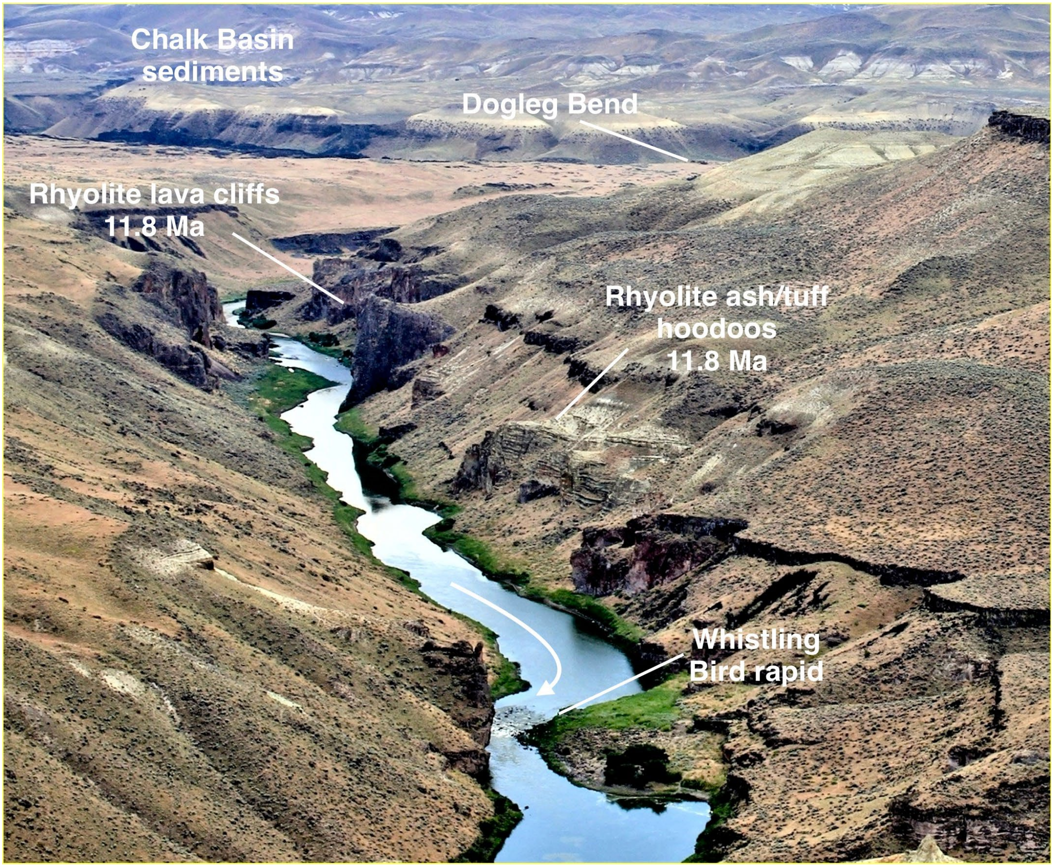


Illustration of a normal fault with strata uplifted to the right. Bringing old underlying strata into view. Source USGS.

Chapter 8—Whistling Bird Canyon (mile 30–32)

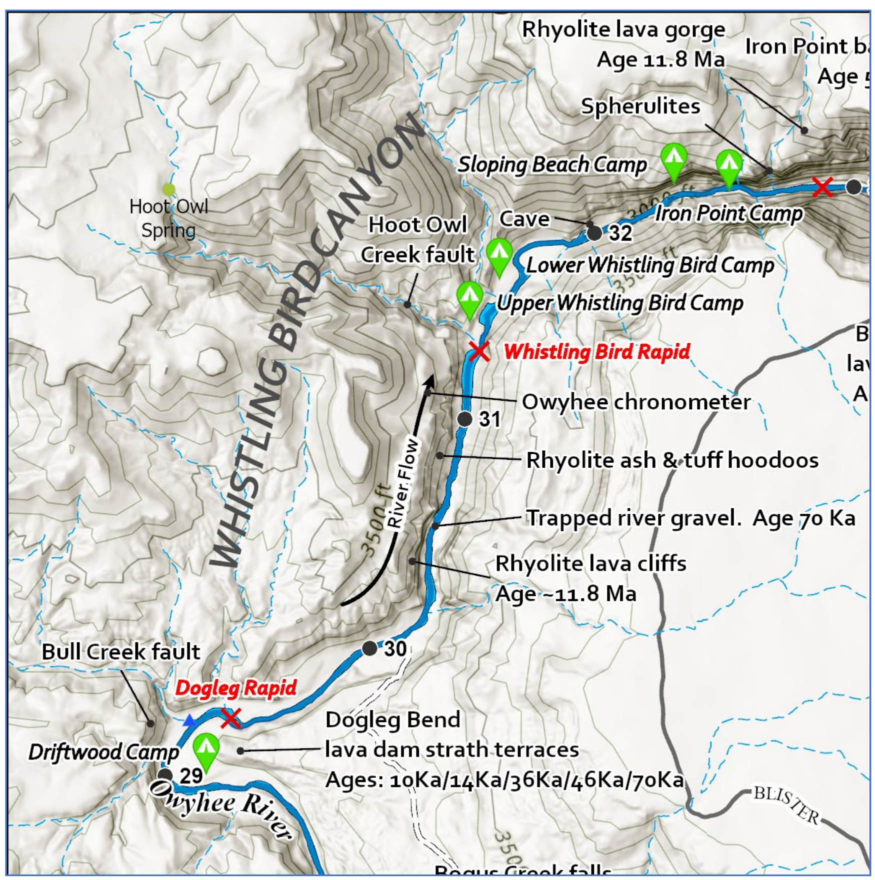


Mile 30: Whistling Bird Canyon cuts through rhyolite lava and pyroclastic deposits from a volcanic eruption about 11.8 million years ago.

Cliffs of rhyolite lava, ash & tuff

In Whistling Bird Canyon, the river incised through strata from an ancient volcanic eruption, exposing long-buried layers of rhyolite ash and tuff, and intermittent formations of hard rhyolite rock. The relatively soft layers of ash and tuff have eroded into orange-colored hoodoos and caves lining the valley walls. The hard erosion-resistant rhyolite rocks form eye-catching, orange-colored vertical cliffs at the water's edge.

Age and Source: Researchers think the rhyolite rocks here were created 11.8 million years ago by a volcanic eruption that also created the 1,100-foot-thick rhyolite lava dome in Sleeping Dragon Gorge just two miles downstream. Geologists have collectively named all the rhyolite in Whistling Bird Canyon and in



Mile 30: Pinnacles of rhyolite ash and tuff, capped by basalt lava colonnade. Age 11.8 million years.

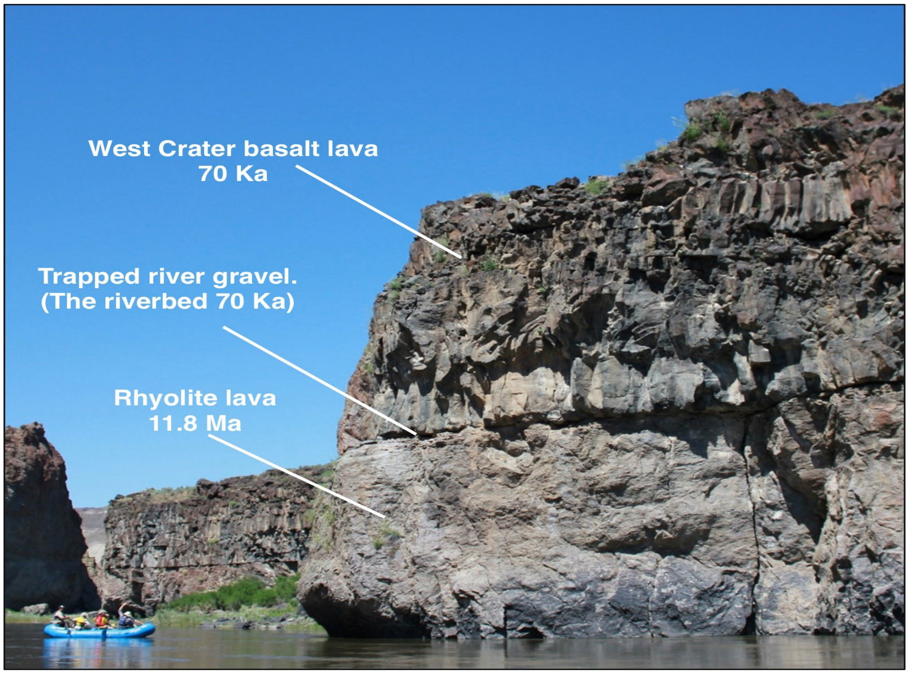
Sleeping Dragon Gorge the "rhyolite of Iron Point", named for the highest basalt rimrock above Sleeping Dragon gorge.

The volcano's explosive phases spread a thick layer of pyroclastic materials over the area. Embedded in the rhyolite tuff bluffs are assorted fragments of rhyolite and basalt rocks, indicating the volcanic tuff was deposited by turbulent pyroclastic flows along the ground, not by air-fall deposits. An explosive gas eruption probably ripped rocks from the volcano's vent walls and ejected the fragmented rocks, along with huge quantities of ash, into the air, and descended to form a ground hugging chaotic pyroclastic flow that later lithified (solidified) into the volcanic tuff here.

Overlying strata: After the eruptions ended, the layers of rhyolite were covered with almost a thousand feet of interbedded sediment and basalt lava flows—the layers we see upstream at Chalk Basin.

Faulting and uplift: Basin and Range extension then stretched the crust and uplifted the strata here in Whistling Bird Canyon at least 100 feet relative to the strata upstream at Chalk Basin. Consequently, as the Owyhee River carved the present canyon, it eroded into the underlying layers of ancient rhyolite rock upon passing Dogleg Bend and its associated fault. For further information, refer to Bull Creek Fault in Chapter 7.

Mile: 30: 150-foot-tall rhyolite lava cliffs.



Mile 30.5: West Crater lava flow overlies a rhyolite riverbed strath. Horizontal seam 28 feet above river marks riverbed location 70,000-years ago. Raft for scale.

70,000-year-old riverbed (mile 30.5)

Researchers discovered remnants of the West Crater intracanyon lava flow here in Whistling Bird Canyon. The lava overlies a distinctive rhyolite riverbed strath with trapped river gravel between them, only 28 feet above the water. This easy-to-see rock formation shows the river has not changed its course here in the last 70,000 years.

Whistling Bird Rapid (mi. 31.2)

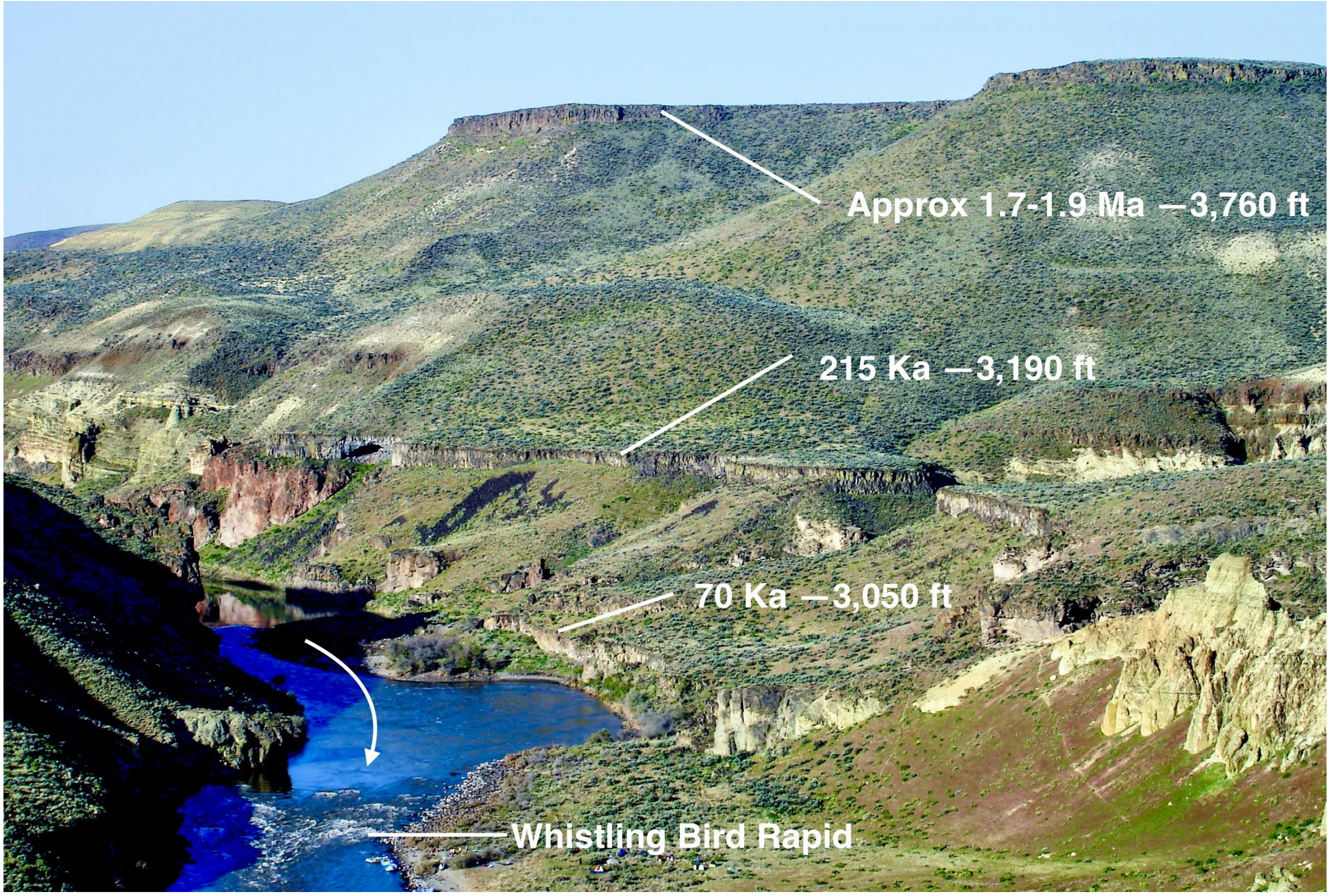
One of the Owyhee's most challenging rapids, Whistling Bird Rapid was created when rock debris from a flooding tributary on river-left redirected the river against the cliff on the right, eventually undercutting the rhyolite rock cliff face and triggering a rock-fall, creating the "rock sieve" that now blocks that side of the river. Rafters must carefully thread between the dual hazards of the boulders on river-left and the rock sieve on river-right.

Cave (mile 32)

Notice the large cave in the rhyolite cliff on river left. We can see large fragments of rhyolite land basalt rocks embedded in the cave walls, suggesting the volcanic tuff in this location was deposited by turbulent pyroclastic flows along the ground, not by air-fall.

Mile: 32: Large cave in rhyolite tuff. Numerous large pieces of erupted rhyolite rock are embedded in its walls.

Mile 31.2: Whistling Bird rapid at low water. The cliff is an erosion-resistant rhyolite intrusion (or lava flow).



Mile: 31.3: View upstream of "Owyhee Chronometer" in Whistling Bird canyon. At this location, three different intracanyon lava flows are visible in the canyon wall, each one marking the riverbed's former elevation and age.

Owyhee Chronometer (mile 31.3)

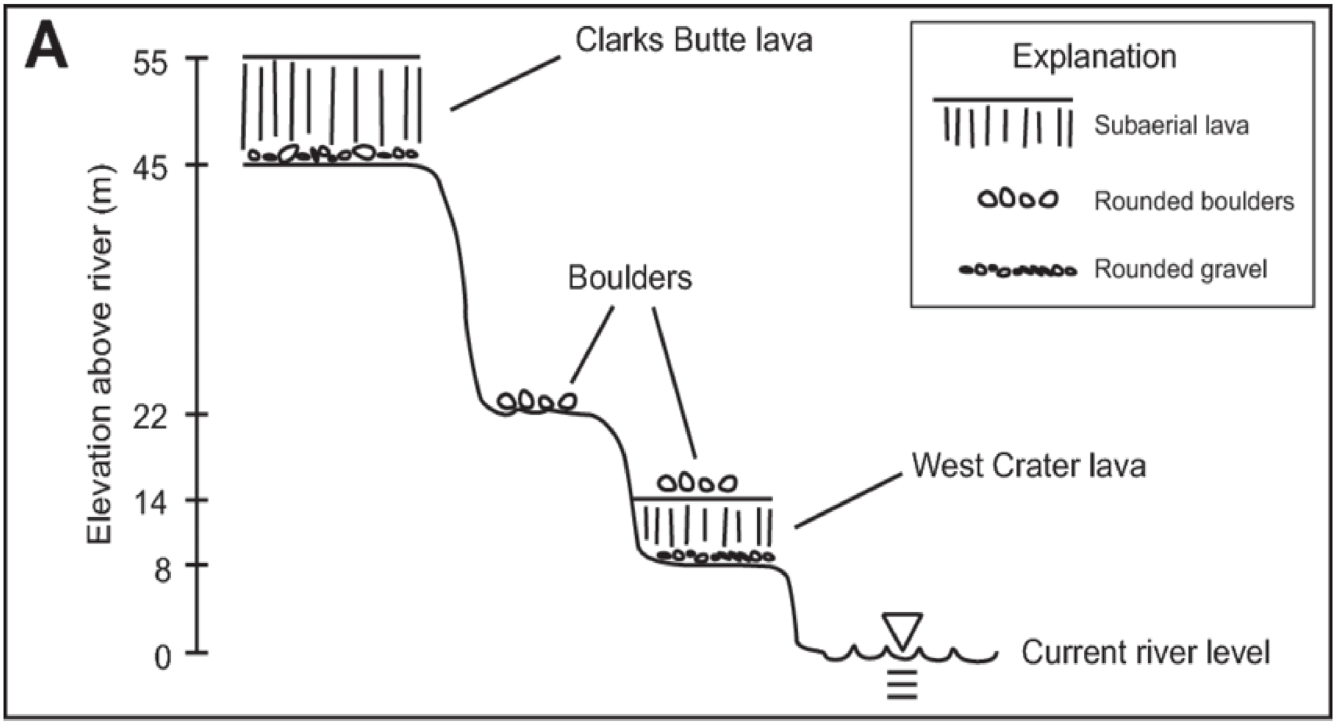
The "Owyhee Chronometer" contains lava remnants from three different valley-filling lava flows showing where the riverbed was located 70,000 years ago, 215,000 years ago, and 1.7 to 1.9 million years ago. Researchers used this information to reconstruct the river channel immediately prior to the date of each eruption and to calculate the river channel incision rate between eruptions. (These are the "West Crater", "Clarks Butte" and probably "Bogus Rim" lava flows, from youngest to oldest.)

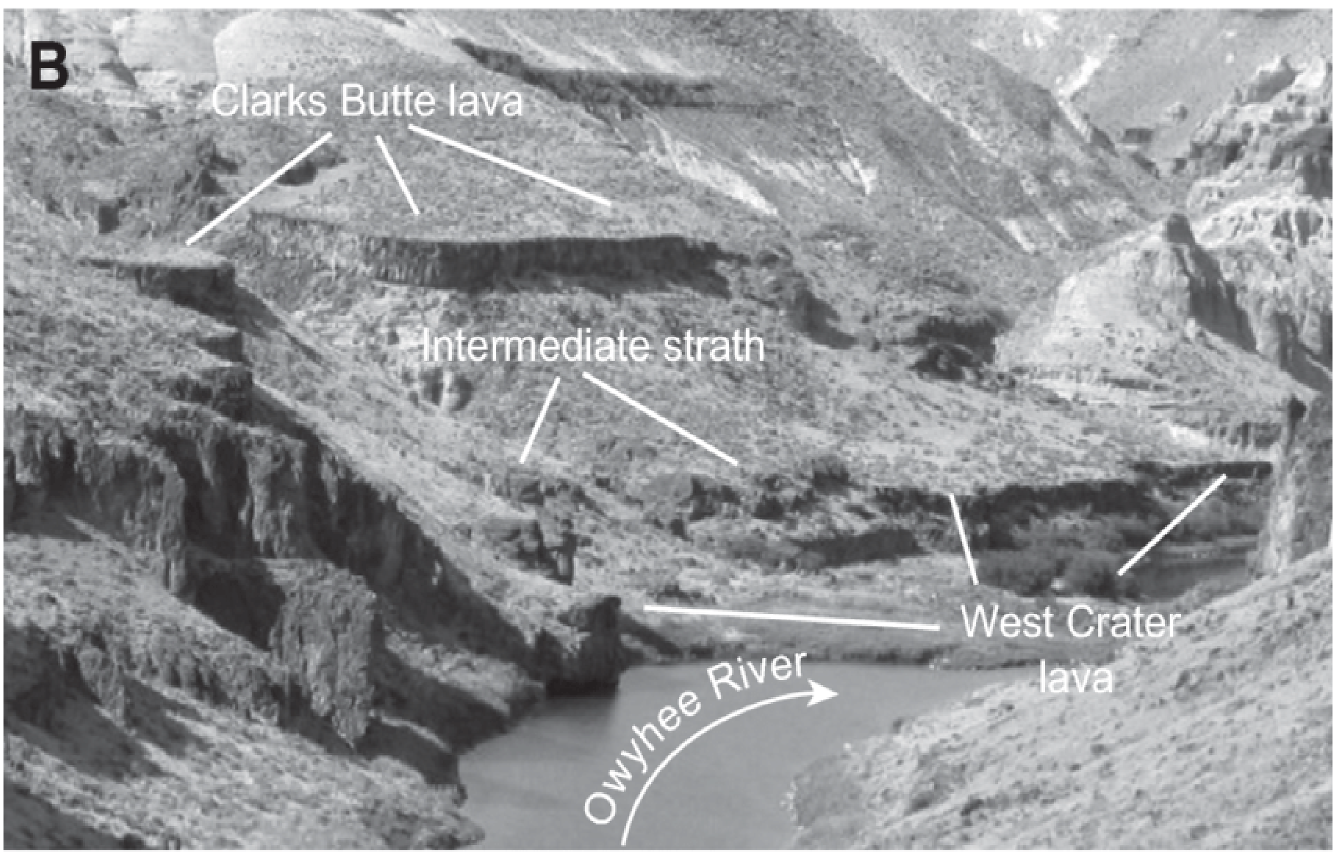
The two lowest lava flows have a thin layer of trapped Owyhee river gravel at their base, evidence that the river course at this location has remained unchanged for at least 215,000 years, despite the disruptions caused by lava flows twice completely blocking the river channel. Researchers believe the river has little ability to change its course in this reach of the canyon because it is constrained just one mile downstream to pass through a narrow erosion-resistant rhyolite canyon, "Sleeping Dragon Gorge".

Measured over the past 1.7 million years (from the topmost lava flow), the Owyhee Canyon has grown deeper at an average rate of 6.4 inches per 1,000 years, about the thickness of one or two sheets of paper each year.

This is typical of other western rivers, though incision rates vary widely. However, data from intervening lava flows show that short-term incision rates can be very high, incision rates jumped 69 percent after the Clarks Butte lava flow, before returning to just below the long-term average during the most recent 70,000 years. Studies here and at other locations in the canyon have been instrumental in understanding factors that affect river canyon incision rates.

Source: (Ely, et al., 2012), (Brossy, 2006), (Ferns & Evans, 1993), (Plumley, 1986), (Swenton, et al., 2022),





Mile 31.1
(Figure A) Profiles of two former lava dams in Whistling Bird Canyon with vertical scale.
(Figure B) View downstream of the lava dam remnants perched on the canyon wall.

Each lava flow overlies 1–3 feet of river gravels that rest on rhyolite strath surfaces (the former Owyhee riverbed.) Rounded boulders rest on the lower lava flow and an intermediate strath surface not covered by a lava flow.

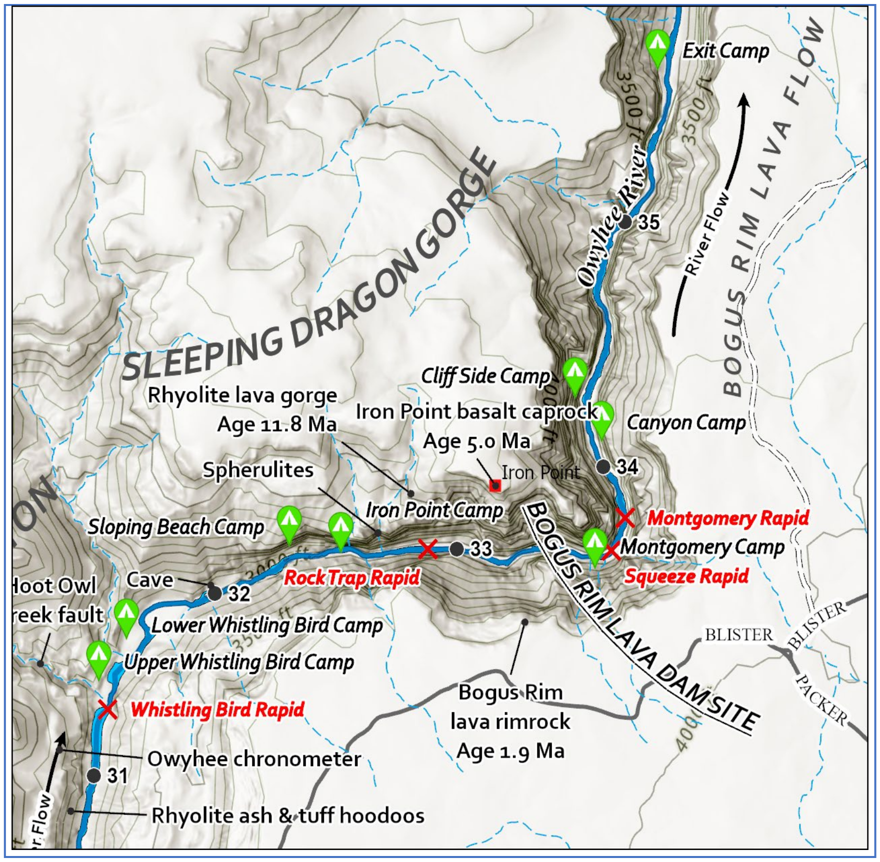
From: Ely, et al., 2012

Chapter 9—Sleeping Dragon Gorge (mile 32–36)

Rhyolite lava gorge (mile 32)

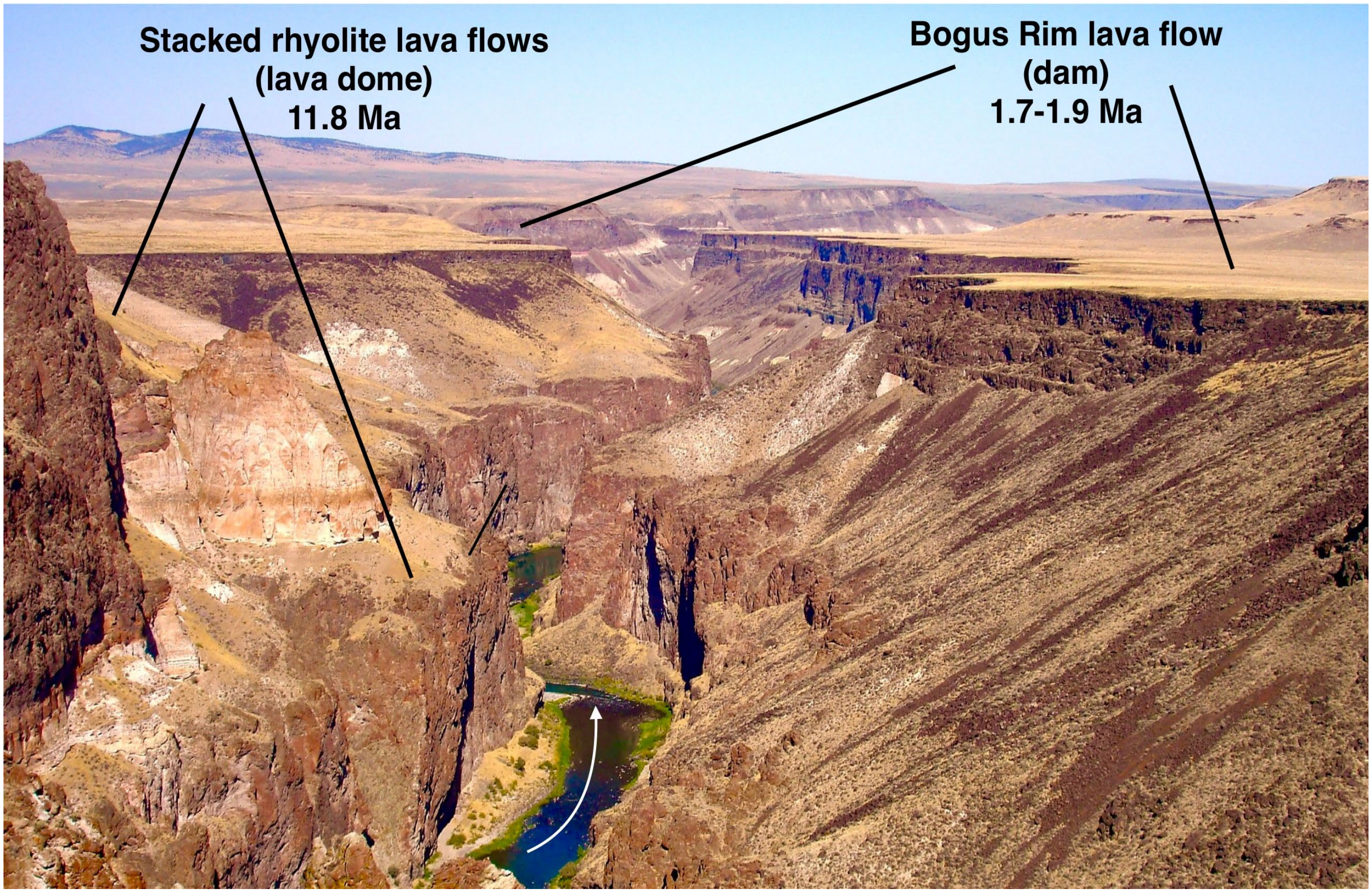
Sometime between 2 and 5 million years ago the Owyhee River began carving Sleeping Dragon Gorge, informally named for the striking dragon profile visible from the rimrock. One of the deepest canyons on the Owyhee River; it measures 1,300 feet deep from the tip of Iron Point to water level. It grows deeper each year by fractions of an inch, about the thickness of a sheet of paper. The canyon walls are rhyolite lava, a hard erosion-resistant rock that forms narrow, vertical canyon walls and weathers to a soft orange color.

In this canyon you pass through the cross-section of an 11.8-million-year-old rhyolite volcanic eruption, probably a lava dome. The flowing lava from the eruption left two thick layers of rhyolite lava exposed in the gorge walls, a lower layer 720 feet thick and an upper layer 360 feet thick, separated by a thin layer of pyroclastic material.



Mile 33: Sleeping Dragon Gorge. Vertical cliffs are rhyolite lava, age 11.8 Ma. View downriver. Photo: James Parsons.

Chapter 9—Sleeping Dragon Gorge (mile 32–36)



Mile 33.5: 1,300-foot-deep Sleeping Dragon Gorge cuts through a dome of 11.8-million-year-old rhyolite lava. Looking downriver/north.

Lava dome: Flowing rhyolite lava is extremely viscous and does not travel more than a few miles before solidifying into rock, usually covering only a small area. Based on exposures in the gorge, it is thought that these lava flows originally covered a roughly circular area, approximately four miles in diameter—a dome. The edge of the flow lobes can be traced along the walls of the gorge where the flows gradually thin and then abruptly end.

Rhyolite volcanic eruptions often alternate between flowing lava and air-fall ash and rock. The explosive phases of the eruption left hundreds-of-foot-thick layers of ash and tuff upstream at the gorge entrance (Whistling Bird Canyon) and downstream at the gorge exit (Tanager Canyon). Geologists call everything the "rhyolite of Iron Point."

Age: The rhyolite is laboratory-dated as 11.8-million-years old. Nearby Sacramento Butte, only 5 miles away to the northwest, is the same age, suggesting a possible connection between the two eruptions. Both occurred near the beginning of a 2.5-million-year-long pulse of rhyolite volcanism when at least twenty-four different rhyolite volcanic centers were active in this corner of Oregon.

The basalt plateau ("Iron Point") that overlies the rhyolite dome is dated as 5.0-million-years old.

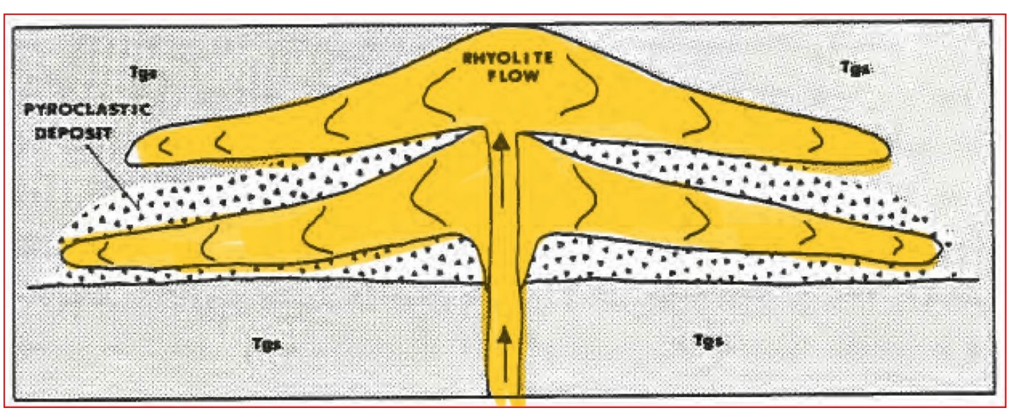


Diagram of a rhyolite lava dome. (Source Plumley 1986.)

Spherulites (mile 32.5)

As you enter the narrow gorge by boat, watch the rock wall on river-left and try to spot the group of basketball-sized spherulites as you pass by. (It's not possible to stop in the current.) While small spherulites less than an inch in diameter are abundant in rhyolite rocks, large spherulites like these are uncommon.

Recent research shows that large spherulites, like small ones, grow from crystals that form in molten lava as it cools to its "glass transition temperature" (about 1,350 to 1,560 degrees F), at which point growth halts. Calculations show it takes decades to grow large spherulites of this size, so these spherulites are evidence of an unusually slow lava cooling rate. (Some geologists explain these features as mineral-filled gas bubbles.)

The research also shows that spherulites expel water as they grow (crystalize) and the excess water often chemically alters the surrounding lava into clay-sized minerals. The odd-looking rock surrounding these spherulites is likely the original rhyolite lava now altered into different minerals by the expelled water.

Mile 32.5: Basketball-sized spherulites surrounded by clay minerals in canyon wall on river-left at gorge entrance.

Possible buried caldera

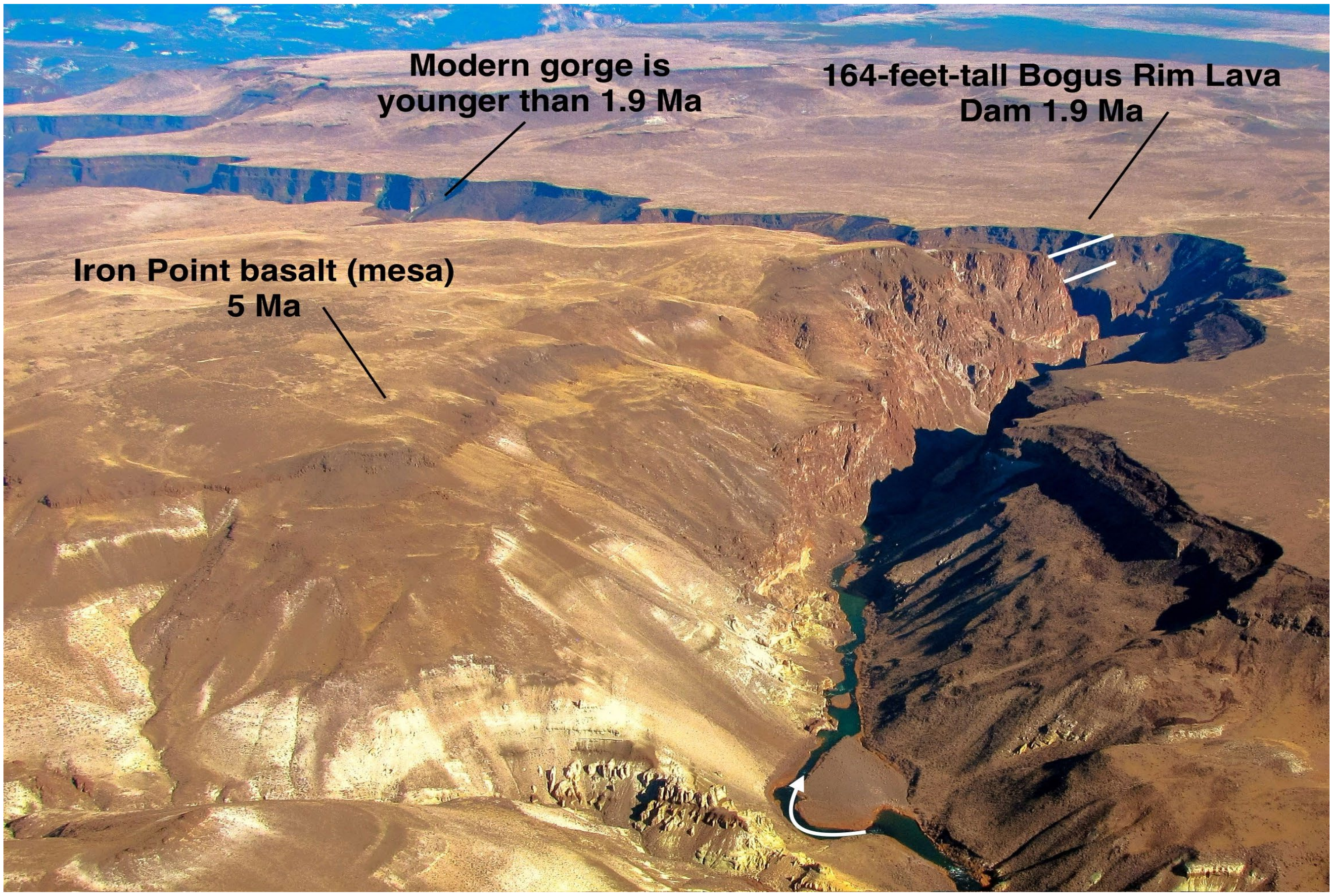
Geologists have proposed that a buried volcanic caldera may be located nearby based on a gravity survey conducted in 1986-87 by the USGS. The survey identified a semi-circular area of low-density rock extending for 15 miles across the Owyhee River Canyon, with a nadir located about 2 miles northwest of Sleeping Dragon Gorge. A possible explanation for the low-density rock is a concealed older caldera complex containing low-density rhyolite caldera fill.

If so, the eruption that created the rhyolite in Sleeping Dragon Gorge and nearby Sacramento Butte may be a part of a much bigger picture. Much more field evidence needs to be found to prove it did happen.

The "sleeping dragon" (mile 33)

If you stand on the south rimrock 1,000 feet above the river, you can look across the canyon and see the silhouette of the sleeping dragon rock formation for which Sleeping Dragon Gorge is informally named. The views are breathtaking, but access is difficult—on a rough, 2-track, 4-wheel drive road, across the high lava plain from US-95.

The sleeping dragon silhouette for which the gorge has been informally named. View from south rimrock looking across the canyon. The summit of the dragon's back is "Iron Point," a 5-million-year-old basalt lava flow overlying the 11.8-million-year-old rhyolite lava dome.



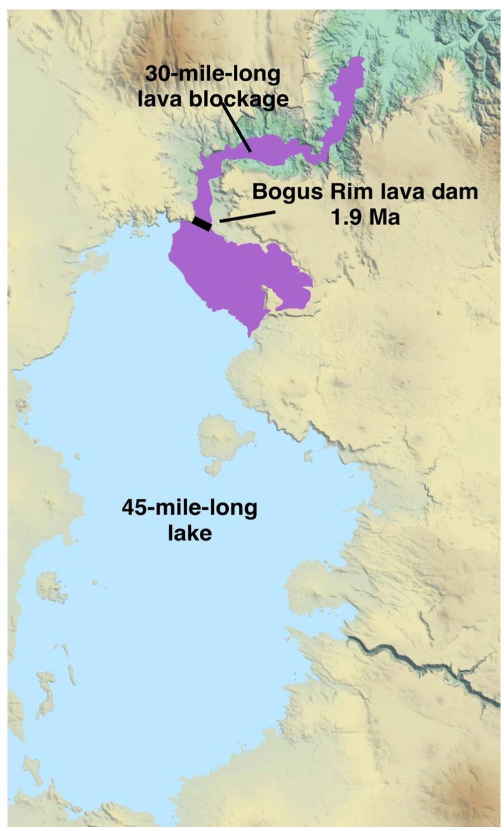
Sleeping Dragon Gorge looking downstream (NE). Site of the nearly 2-million-year-old Bogus Rim lava dam. The riverbed was then wide and shallow and located high above today's river. View upstream/northeast.

Bogus Rim lava dam (mile 33.5)

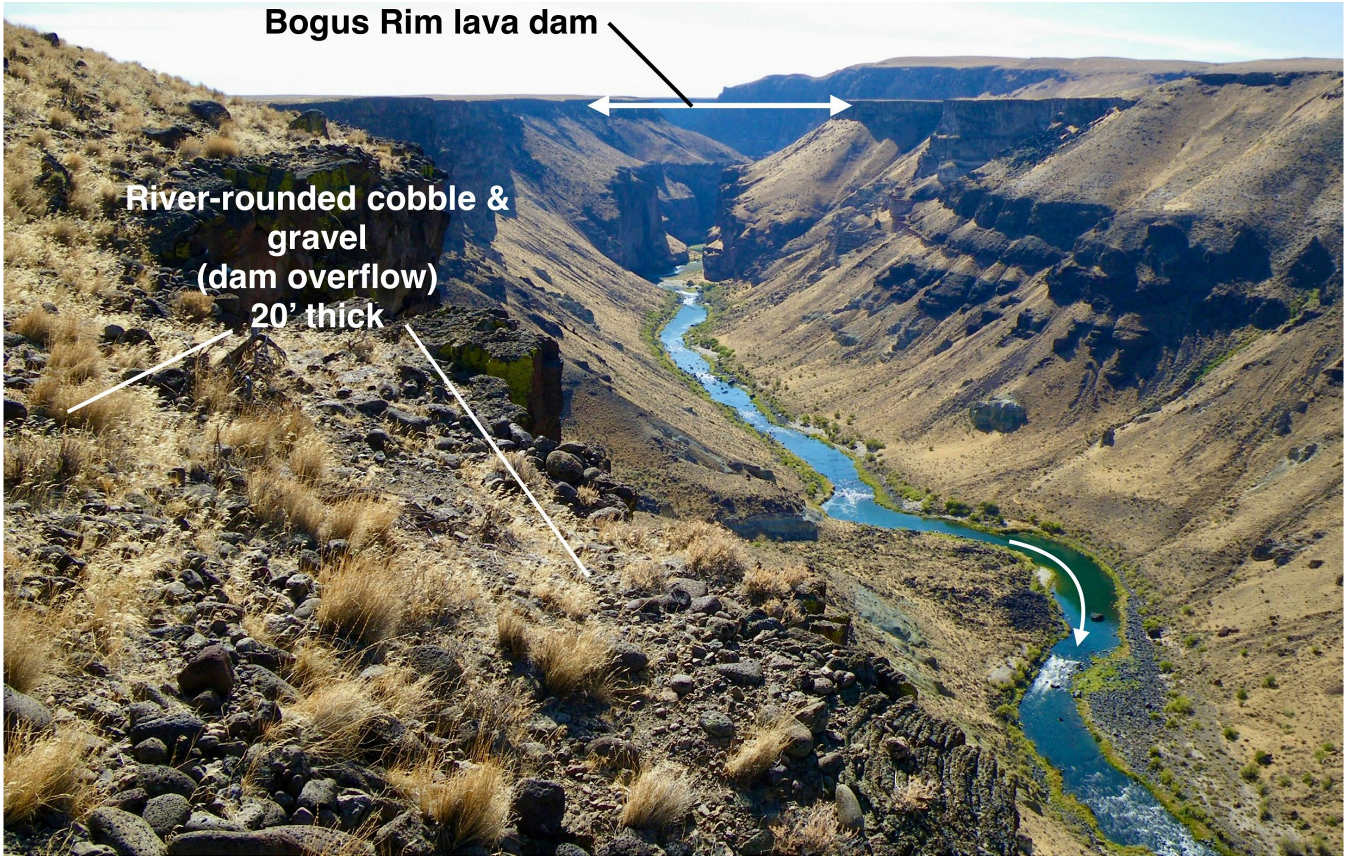
In the early 2000s, a team of researchers investigating ancient lava dams on the Owyhee discovered evidence here of the largest known lava flow and lava dam in the Owyhee River corridor—the Bogus Rim lava dam. This event occurred almost two million years ago, before the modern deep and narrow Sleeping Dragon Gorge existed.

Size: The lava dam was 164 feet tall, and its base was about 852 feet above today's water level, marking the location of the riverbed at that time. The crest of the dam was about 1,016 feet above today's river. Behind the lava dam, a huge lake formed that would have extended about 45 miles upstream and flooded the surrounding landscape, covering everything up to an elevation of 3,970 feet!

Source: The lava dam consists of up to four different overlapping basalt lava flows (collectively called the Bogus Rim lava), the first one occurred about 1.9 million years ago. The lava erupted from a shield volcano on the high lava plateau east of the river and spilled into the river channel just upstream of Sleeping Dragon Gorge (aka Iron Point). The lava flowed downstream for 30 miles, covering an almost 1-mile-wide swath (in places) of the river corridor



An immense lake formed behind the Bogus Rim lava dam. The lake was over 45 miles long and the lava blockage about 30 miles long.



Mile 36.5: The rimrock is covered with a 20-foot-thick layer of river-rounded cobble and gravel deposited when the river flowed over the top of the lava dam. In the distance is the exit of Sleeping Dragon Gorge. (Looking upstream/south.)

with erosion-resistant basalt rock up to 400 feet thick.

Duration: The lava flows filled up so much of the canyon that they may have effectively halted river channel incision here for hundreds of thousands of years. In comparison, the other Owyhee River lava dams survived for only tens of thousands of years. Geologists attribute the longevity of the blockage to the massive thickness and length of the Bogus Rim lava flow, and the immense lake that formed behind the dam required much more time to fill with sediment before effective incision of the dam could begin. Research is currently being carried out to determine exactly how long the lava dam lasted.

Mile 31: Lava pillows and foreset beds 1,000 feet above modern river where the Bogus Rim lava flow encountered river water as it built the dam. (Clipboard for scale.)

Source: (Plumley, 1986), (Evans, et al., 1990), (Ferns, et al., 1993), (Cummings, et al., 2000), (Ely, et al., 2012), (Swenton, et al., 2022), (Breitkreuz, et al., 2021), (Orem, 2010), (Brossy, 2006), (Ely, et al., 2012),

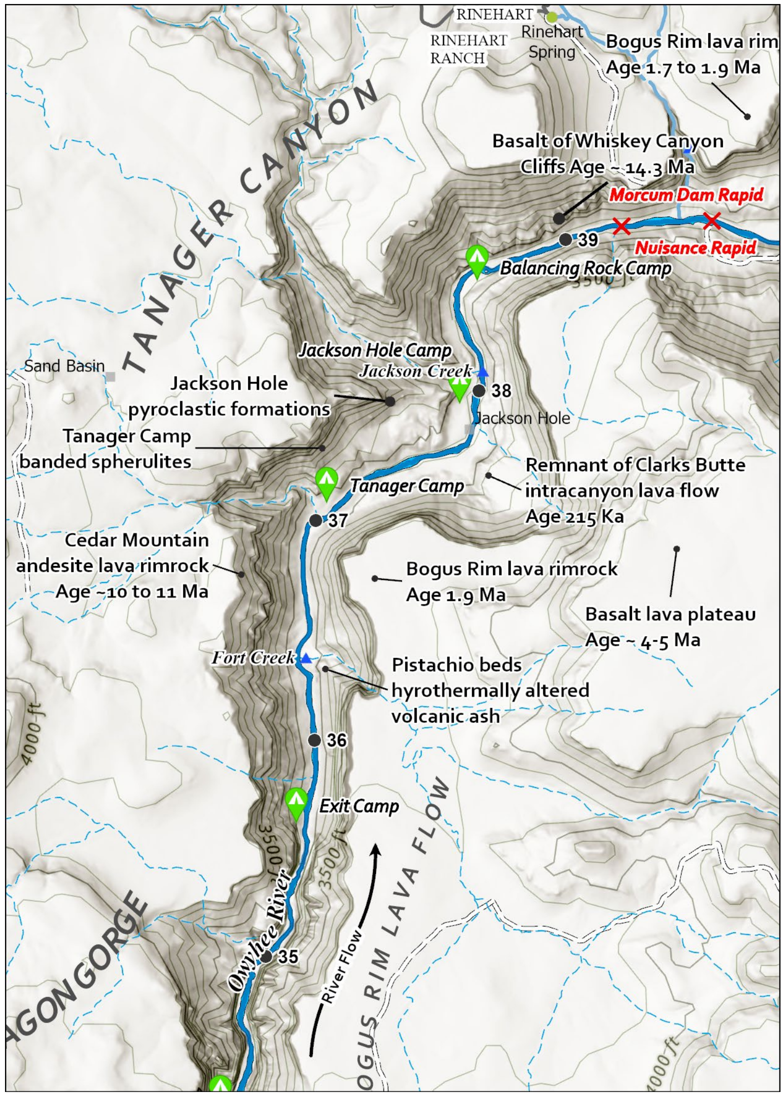
Chapter 10—Tanager Canyon (mile 35–39)

Tanager Canyon (mile 35.5)

The 900-foot-deep Tanager Canyon reveals volcanic events back to about 14.3 million years ago, the oldest so far in this guidebook. The bottom 450-foot strata in the 4-mile-long canyon are colorful ash, tuff and volcanistic sediment. These layers of volcanic ash and tuff interfinger with the rhyolite lava flows of Sleeping Dragon gorge, evidence they were probably produced by the same 11.8-million-year-old rhyolite eruptions. There are excellent geology hikes into the ash and tuff formations from Tanager camp and Jackson Hole camp.

Bogus Rim Lava rimrock (mile 36)

The imposing canyon rimrock that dominates the right (east) side of the river is the Bogus Rim lava that flowed into and dammed the river channel 1.7 to 1.9 million years ago. (Some remnants are visible on the left (east) side.) The age and location tell us when the deep and narrow modern Owyhee River canyon was formed. We can look up at the lava rimrock and readily see the bulk of the modern canyon lies below it. We also know the ancient river channel was much wider and shallower than today because portions of the ancient canyon topography are visible beneath the rimrock. (See Chapter 9 “Bogus Rim lava dam” for description of the Bogus Rim lava flow and the dam it created.)



Mile 36: The rimrock that dominates the east side of the river is a thick layer of Bogus Rim lava 1.7 to 1.9 Ma. Some remnants are visible on the west side. (Looking downstream.)

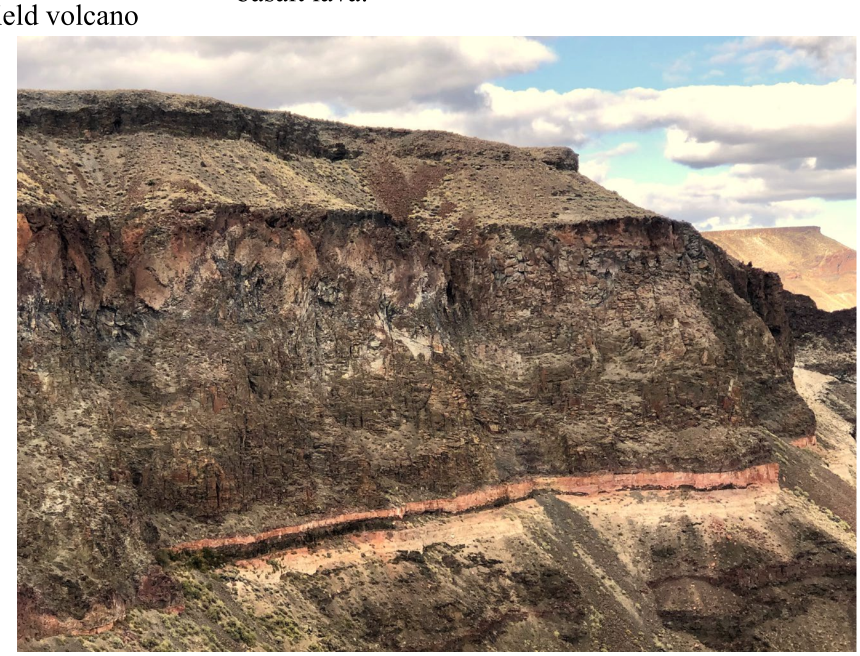
Chapter 10—Tanager Canyon (mile 35–39)

Mile 35.5: Looking downstream (north) into 4-mile-long Tanager Canyon from the rimrock near Sleeping Dragon Gorge. Cedar Mountain shield volcano is about 5 miles away.

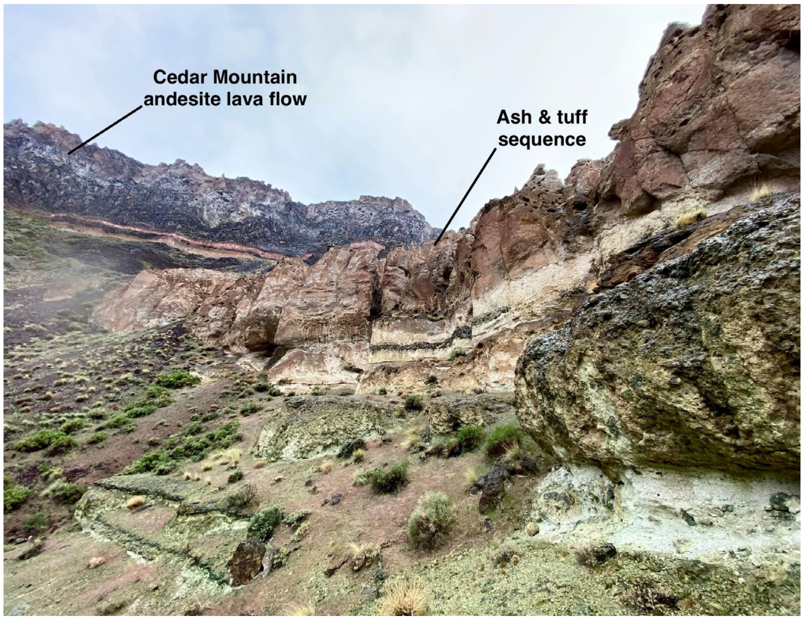
Cedar Mountain lava (mile 36.5)

From river level, the skyline on the left (west) side of Tanager Canyon is dominated by a dark-colored, 300-foot-tall cliff with a thin, horizontal, orange-pink line in the middle. The cliff consists of a series of andesite and basalt lava flows that likely erupted from Cedar Mountain, a large shield volcano about 5 miles to the northwest, collectively known as the "Cedar Mountain lava". The extensive lava flows covered an area of about 300 square miles to a depth of as much as 300 feet. The Cedar Mountain lavas are undated but were estimated to be 10 to 11-million-years old as of 1992, the most recent study. This was many millions of years before the Owyhee River existed. Several other large andesite shield volcanos were active in the Lake Owyhee region during that time.

The distant orange-pink line is a layer of sediment that was baked brick-red and fused by the heat of the thick overlying andesite lava flow. This shows that enough time elapsed between eruptions of lava for layers of sediment to accumulate between the flows. Above the orange-pink line is a single andesite lava flow almost 200 feet thick covered with a layer of reddish scoria (rocks filled with large gas bubbles). Beneath the orange-pink line is another 120-foot-thick formation consisting of 5 to 6 individual flows of basalt lava.



Closeup of Cedar Mountain andesite lava flow about 10 to 11-million-years-old. The orange-pink line is layer of baked sediment.



Mile 37: Colorful sequence of ash and tuff beds and a killer view above Tanager camp.

Green Pistachio Beds (mile 36.2)

The green pistachio-colored formation at mile 36.2 is an example of hydrothermal alteration from a magmatic geothermal system (circulating hot water).

This was a lake basin during much of the several million years that it took to accumulate the strata in the canyon walls. Many pyroclastic layers show evidence of being deposited into water, and enough time elapsed between eruptions that layers of sedimentary rock (sandstone and mudstone) sometimes accumulated between the layers of volcanic ash, tuff, and lava flows.

Because of the lake water environment, the ash and tuff layers have undergone extensive chemical weathering and alteration, and the rocks do not have their original color, texture, or hardness. Rhyolite ash is inherently unstable, and, over time, reacts chemically with water, gradually altering its atomic structure to clay minerals.

Tanager Camp hike (mi. 37.2)

Tanager camp is a terrific spot to stop and hike to colorful beds of ash, tuff and volcanistic sediment. Examine unusual beds of baseball-sized soft spherulites embedded in pyroclastic deposits and enjoy a killer view of the Cedar Mountain andesite lava rimrock. One bed contains concentrically banded spherulites, the other contains solid (unbanded) spherulites. (Note: These spherulites are soft and will crumble into pieces if moved or handled.)

Like any other spherulite, they were probably rock-hard 11 to 12 million years ago when they crystallized out of hot ash or tuff. Afterwards they were probably chemically altered into soft clay-like minerals by long-lasting immersion in the lake that existed here then, or from local hydrothermal alteration. The beds of volcanic ash and tuff surrounding the spherulites have also been chemically altered into clay minerals.

Mile 36.2: "Pistachio rocks"—Green-colored tuff chemically altered after burial by local hydrothermal activity.

Mile 37: Bed of volleyball-sized banded spherulites above Tanager Camp.

Mile 37: Closeup of banded soft spherulite above Tanager camp. (~10-inch diameter)

Mile 38: Best example of baked river gravel and sediment on the river! Trapped beneath a 215,000-year-old Clarks Butte lava flow. (See Clarks Butte lava geology hike.)

Clarks Butte lava geology hike (mile 37.8)

Besides the campsite hikes, there is a good geology hike across the river from Jackson Hole campsite. You can see an excellent exposure of Owyhee River gravel that was trapped beneath a 215,000-year-old flow of the Clarks Butte lava. The trapped river gravel marks the location of the river channel at that time as being about 150 feet above today's elevation. The river sediment and gravels beneath the lava were baked into a strongly consolidated mass by the overlying hot basalt. There are no clear indicators of any lava-water interaction, this suggests that when the lava flow reached here, the river-water was already blocked off somewhere upstream by a lava dam.

The trail continues upslope to a spectacular view from the top of the Bogus Rim lava rimrock.

Jackson Hole Camp geology hike (mile 38)

A short hike upslope from Jackson Hole brings you to colorful formations of volcanic ash, tuff and lakebed sediment. Some of the formations are a brick-red color from hydrothermal alteration. An easy trail up Jackson Creek leads to several interesting sites.

Mile 38: Colorful rhyolite ash, tuff, and lakebed sediment at Jackson Hole Camp.

Mile 39: "Basalt of Whiskey Canyon" lava forms these ancient riverside cliffs near Nuisance Rapid. It caps the western side of Hole in the Ground and part of the eastern side. A useful age marker estimated about 14.3-million-years old.

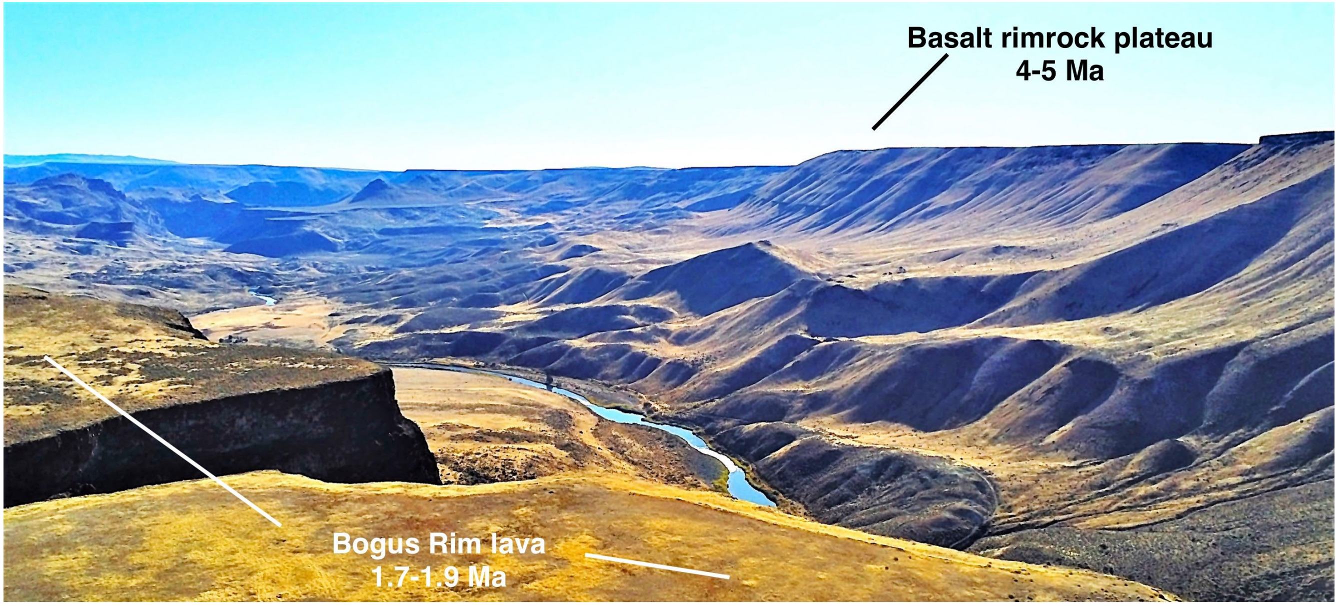
Basalt of Whiskey Canyon (mile 39)

The oldest rock formation exposed in Tanager Canyon is the riverside lava cliff that begins behind Jackson Hole camp and continues down-river, past Nuisance Rapid and into The-Hole-in-the-Ground. The riverside rock formation consists of a series of lava flows collectively named Basalt of Whiskey Canyon. Its correlative with the well-known 14.3-million-year-old Owyhee Basalt found throughout the Lake Owyhee Volcanic Field. The formation here is about 500 feet thick and consists of multiple individual lava flows interbedded with layers of sediment and siltstone. Lava pillows and other features indicate the lava flows entered lake water, evidence that a lake basin existed here as long ago as 14.3 million years.

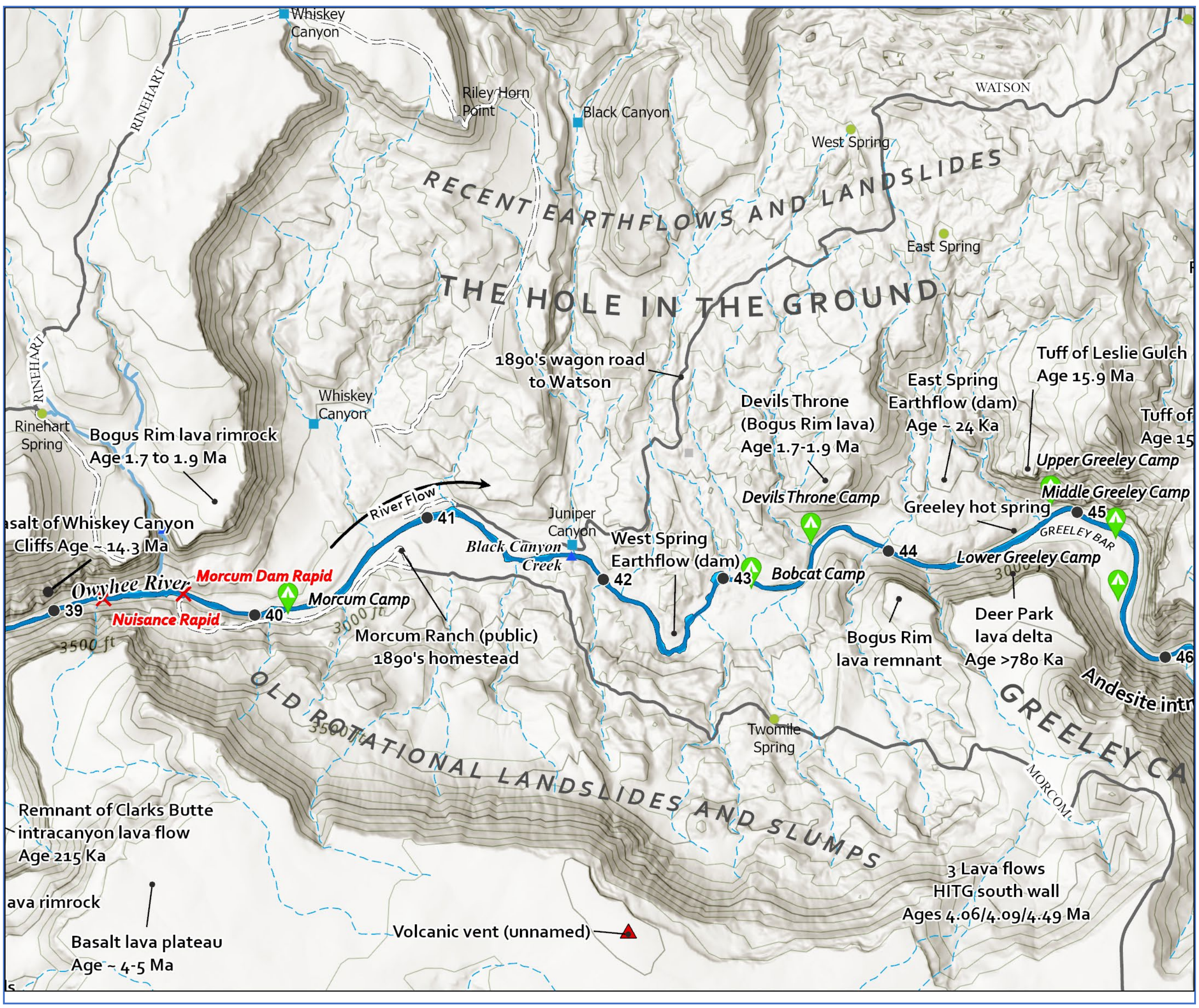
The Basalt of Whiskey Canyon lava is a useful 14.3-million-year-old age marker. The strata below are older, and everything above is newer. The lava flow was originally laid down horizonal, but faults and uplift have now tilted the formation and its surrounding strata noticeably upward about 3 to 5 degrees to the north (downriver). This means that as you go downstream, the strata exposed along the river gets older. Because of the uplift, the Basalt of Whiskey Canyon lava now caps the western side of Hole in the Ground and some of the eastern side.

Sources: (Swenton, et al., 2022), (Cummings, et al., 2000), (Ferns, et al., 1993), (Ferns & Evans, 1993), (Plumley, 1986), (Breitkreuz, et al., 2021), (Breitkreuz, 2013)

Chapter 11—The Hole in the Ground (mile 39–44)



Mile 40.5: The Hole in the Ground is the widest and deepest part of the Owyhee Canyon. Extensive landslides line both sides of the river. Looking downstream (east) from Bogus Rim.



Chapter 11—The Hole in the Ground (mile 39–44)

Mile 42.5: Remnants of earthflow dam on both sides of the river. Looking downstream.

The Hole in the Ground (mile 40)

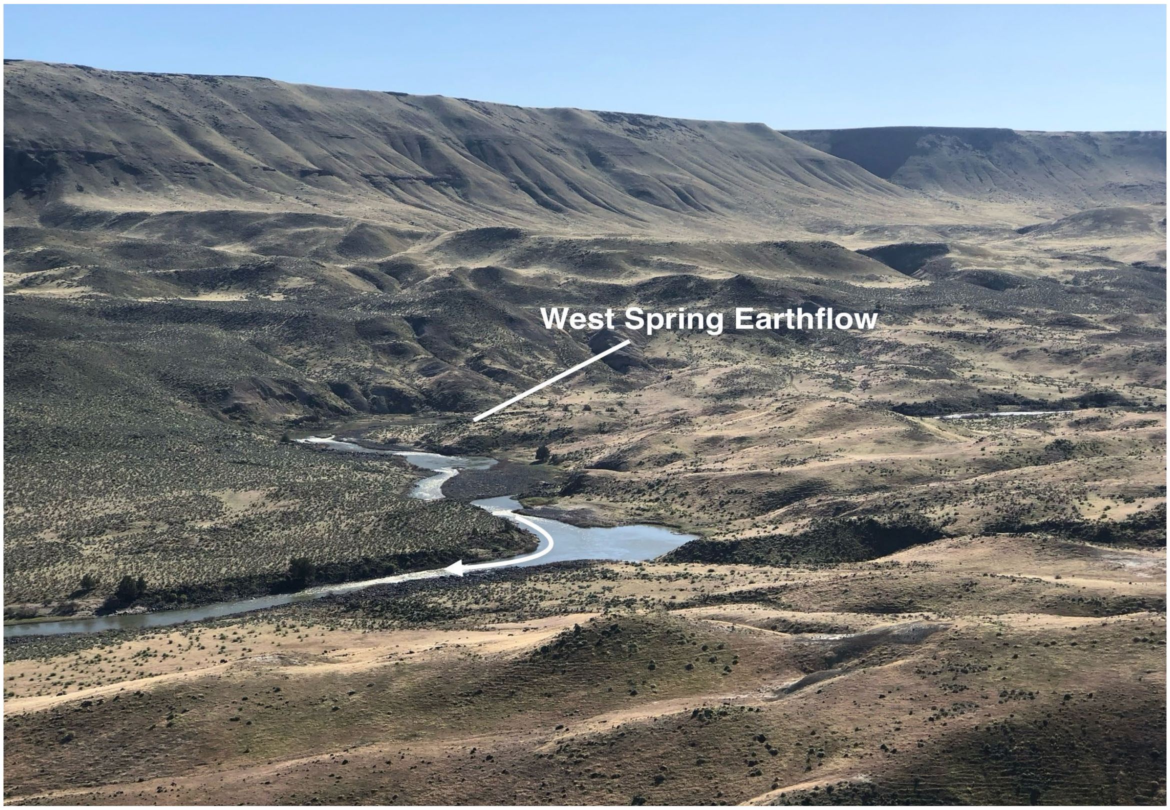
Aptly named The Hole in the Ground (not to be confused with Oregon's other "Hole-in-the Ground") is the widest and deepest part of the Owyhee Canyon, five miles wide and 1,700 feet deep at its north and south rims. It grew to its present size because of repeated and extensive landslides, The rolling hills and depressions covering the valley floor are remnants of the landslides and the S-shaped bends in the river channel are where the river was blocked and redirected.

This vast valley may have begun forming up to five million years ago, with the last six hundred feet excavated in the past two million years. The elevation of the valley floor about two million years ago is marked by the base of 600-foot-tall Devils Throne, a remnant of the well-studied Bogus Rim intracanyon lava flow.

The strata in the distant canyon walls are tilted upward to the northeast, indicating that basin-wide uplift was occurring throughout the millions of years it took for the basin to fill with sediment. The river traverses almost two million years of geological history in about 6 river-miles as it flows downstream (eastward). Starting from the cliffs of 14.3-million-year-old "Basalt of Whiskey Canyon" at Jackson Hole camp to the cliffs of 16-million-year-old "Tuff of Leslie Gulch" at Greeley Bar. (It traverses about sixteen million years if you include the river's deposits and landslides.)

The flat-lying basalt lavas in the rimrocks arrived long after the basin was filled with sediment and uplifted. In 1982, geologists collected rock samples from three southern canyon wall lava flows, dating them at 4.06, 4.09, and 4.49 million years old.

Aerial view of The Hole In The Ground looking downstream towards Greeley Canyon. The historic Morcum Ranch is visible in center foreground on the right riverbank.



Mile 42.5: Chaotically mounded landscape at The Hole in the Ground was formed by repeated landslides. The West Spring Earthflow blocked the river with a dam over 24,000 years ago. (View upstream/west.)

Outburst flood boulder on riverbank downstream of West Spring Earthflow. Note percussion marks on boulder. Geologist yellow notebook for scale.

Landslides

The geology story here is heavy on landslides. The north side of the basin (river-left) is particularly susceptible to earthflows; liquid-like flows of mixed sediment and rocks that can quickly transport large amounts of accumulated debris and weathered material away from the rimrock down to the valley floor.

The most recent one, East Spring Earthflow, occurred only about 24,000 years ago. The sediment on the north side of the basin contains an unusual 600-foot-thick bed of slick, gooey bentonite clay deposited in a lake that was here before the river existed. It swells when wet and can absorb up to10x its own weight in water. Heavy rainfall onto the clay sediment triggers new earthflows and reactivates old ones. The presence of this localized lake deposit may explain why The Hole in the Ground exists—instead of a narrow canyon.

A different type of landslide occurs on the south side of the river, in part because that canyon wall appears to have a lower concentration of bentonite clay sediment. The landslides there are old, inactive rotational style landslides (slumps) with a highly weathered and filled-in topography.

West Spring Earthflow (mile 42.5)

West Spring Earthflow diverted the river and created the distinctive horseshoe bend in the river about two miles downstream of the historic Morcum ranch buildings. It descended from the north rim and completely blocked the river with an earth dam, remnants of which are visible today, and created a long-lived upstream lake that eventually filled up with sediment, resulting in fine-grained fill-terraces along the modern riverbank. The dam is undated, but it likely occurred over 24,000 years ago, before the East Spring Earthflow.

Devils Throne (mile 43.5)

Devils Throne is the impossible-to-miss columnar basalt mesa on river-left (north), standing almost six hundred feet above the river. This now-isolated rock formation is a small remnant of the massive Bogus Rim lava flow(s) that 1.7 to 1.9 million years ago filled about thirty miles of the river channel with a thick layer of basalt lava. At the tower's base we can see orange-colored sediment baked by the heat of the overlying lava.

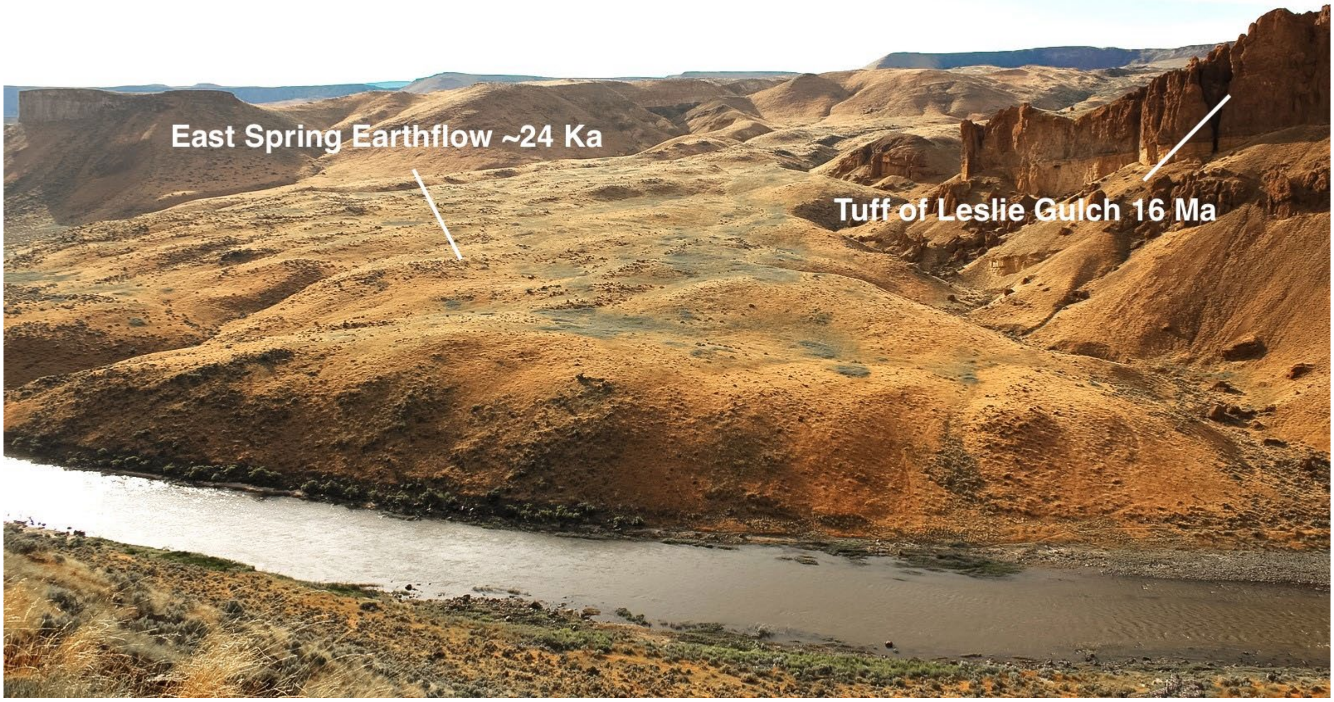
Another remnant of the same lava flow is visible on the opposite side of the river just one quarter mile downstream. Look for the prominent basalt rimrock close to the river. Judging by the distance between the two lava remnants, the Bogus Rim lava flow once bridged a roughly one-mile-wide swath of the basin floor.

While it lasted, the thick layer of lava was a buttress that protected the basin from landslides and erosion. But once the Owyhee River incised through the lava, erosion quickly removed all evidence of the once-extensive lava flow other than these few remnants. The valley-widening landslides resumed and created the huge valley called The Hole in the Ground.

Mile 43.5: Devils Throne. This columnar basalt lava rimrock is a small remnant of Bogus Rim lava flow 1.7–1.9 million-years-old.

Devils Throne looking north. It's surrounded by geologically recent earthflows. (Aerial view.)

Mile: 44: Rimrock in foreground is a remnant of the same lava flow as Devils Throne in distance. Together they mark the valley floor location almost 2 million years ago.



Mile 44: East Spring Earthflow descended 1,300 vertical feet and 2.5 miles from the rimrock. It blocked the river with a 70-foot-tall earth dam. The outburst flood created Greeley Bar downstream. (View to river-left/north.)

East Spring Earthflow (mile 44)

The largest and most recent landslide in The Hole in the Ground, named East Spring Earthflow, completely blocked the river with a 70-foot-tall earth dam about one half mile long, located immediately downstream of Devils Tower. The steep, 70-foot-high riverbank on the left (north) side of the river near Greeley hot spring is where the river incised through the dam. The earthflow originated 1,300 feet above from the north canyon wall and flowed about 2.5 miles to the basin floor, where it pinned the river against the right side of the canyon. The earthflow dam persisted for many years, long enough for thick layers of sediment to accumulate in the lake behind the dam and form extensive fill terraces upstream along the riverbank.

The East Spring Earthflow dam eventually failed catastrophically, causing an outburst flood that formed Greeley Bar, a large downstream boulder bar. Geologists studied the flood boulders on Greeley Bar and determined they were deposited there about 24,000 years ago.

Excellent views of the East Spring Earthflow's path can be had by hiking upslope from Greeley campsite. The field of undulating hills and 10depressions on the gently sloping hillside are the earthflow's toe, and the earthflow extends uphill, out of sight, to its distant source at the base of the canyon rimrock. Another good hike is to the top of Devils Throne.

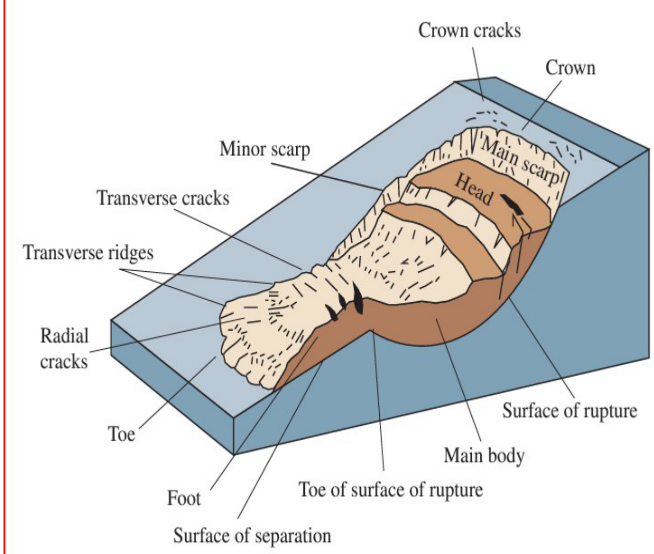


Figure 1. An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide.

Diagram of an earthflow. (Source: USGS.)

Source: (Othus, 2008); (Cummings, et al., 2000); (Ferns, et al., 1993); (Ely, et al., 2012); (Plumley, 1986); (Orem, 2010), (Shoemaker, 2004)

Chapter 11—The Hole in the Ground (mile 39–44)

Mile 40.8: 1890s Morcum Ranch at The Hole in the Ground. (View downstream.)

History note: Morcum Ranch (mile 40.8)

Ranching began here in the 1890s when Riley Horn claimed 160 acres that became known as the Hole in the Ground ranch. By 1898 Riley had a house, irrigated field, rock dam, and irrigation ditch here. He built the rock dam across the river at the upper end of the flat. The dam was breached by the record 1993 flood. (See Chapter 1 "Ice age outburst flood enters Rome valley") Remnants of the dam now create the Morcum Dam Rapid. The first house was probably built of stone since there were no trees in the canyon other than juniper. Riley was granted a homestead "patent" (title) in 1901.

According to Owyhee historian Bill Crowell, access was by pack train or horsedrawn wagon until the 1930s when new owners Conley Davis and his wife Stacia blasted and bulldozed a rough, rocky, 2-track road from the south canyon rimrock to the ranch, 1,500 vertical feet below. This road is the only way to access the remote site today. On the opposite (north) side of the river is an old wagon road that went to the pioneer community of Watson (now covered by Lake Owyhee), about 10 to 15 miles away.

The ranch is now named after J.T. Morcum, who owned it from 1944-72. In 1985 a fire destroyed most of the ranch buildings and the remaining buildings give little sense of the size of the original ranch complex—and the grove of cottonwood trees is now gone. The BLM bought the ranch in 1993, and it is now part of the Lower Owyhee Canyon Wilderness Study Area.

Mile 40.8: ca 1930s ranch house.

Mile 40.8: Pioneer stone root-cellar.

Sources: (Crowell, 2022), (BLM General Land Office Records Search, 2024)

Petroglyph at The Hole in the Ground consisting of a carved (etched) motif in Great Basin Abstract style. Substantial regrowth of rock varnish suggests great age.

Petroglyph in Tanager Canyon consisting of pecked (the dots) and etched (the figure) motifs. Possibly made by two different people at separate times. Limited regrowth of rock varnish suggests younger age.

History note: prehistoric petroglyphs.

Humans have been living on Oregon's high-desert plateau for about the last 18,000 years according to a recent study at the Rimrock Draw Rockshelter west of Burns, Oregon. We know that almost 7,000 years ago people lived along the Owyhee River four miles downstream near Birch Creek Ranch. Other research shows that almost 10,000 years ago, people were living upstream near Three Forks at the Dirty Shame Rockshelter. (See Chapter 13, "History note: prehistoric site".)

These people left abundant evidence of their presence throughout the Owyhee Canyon by etching enigmatic images, known as petroglyphs, into the weathered surface of basalt boulders—mostly outburst flood boulders near the river. Most archeologists believe that petroglyphs were meant to be seen and are usually found located near prehistoric camp sites, seasonal hunting and gathering sites, and along well-traveled routes.

Tanager Canyon and The Hole in the Ground contain petroglyphs of varying ages (based on patina), evidence that ancient people were present multiple times, and may have lived here, though no other archeological evidence has been discovered.

The people were hunter-gatherers—they lived in groups of a few dozen people that consisted of several families. They moved seasonally from place to place and did not have a year-round settlement. The Birch Creek archeological site downstream was only occupied in the winter when conditions were too harsh on the high plateau.

The petroglyphs in the Owyhee Canyon are undated. In general, petroglyph ages must be inferred from circumstantial evidence because carbon dating only works on organic material, not on rocks. Petroglyphs are found throughout the world and range in age from about 46,000 years ago to the recent past – the practice was brought to North America by its first people. Similar petroglyph-covered boulders at Celebration Park (Idaho) on the Snake River have estimated dates ranging from about 11,200 years ago to 1,400 years ago, according to a study using a new experimental rock varnish dating method. Two of North America's oldest scientifically confirmed petroglyph sites are Winnemucca Lake (Nevada), dated at 10,500 to possibly 14,800 years old and Long Lake (near Lakeview, Oregon) dated at over 8,850 years old. Large petroglyph sites usually contain a mix of young and old panels created by different people at different times, spanning hundreds to thousands of years. The darkest and most weathered petroglyphs may be thousands of years old. Light-colored ones are newer, perhaps only hundreds of years old.

Studies show that petroglyphs have meaning to the people who created them, but it is not a writing system, and no one today can interpret them with certainty. Within a given geographic region, petroglyphs share a common, easily recognizable style. Here the style is Great Basin Abstract, consisting of curvy lines, circles, spirals, dots, star patterns, triangles, and squiggles. As well as scattered circular depressions, a few centimeters wide and deep, called pit-and-groove. Stick-figure humans and lizards, deer, and mountain sheep rarely occur. This style is found throughout the Snake River Plain, southeast Oregon, Nevada, and Oregon's Columbia Plateau – where the ancient hunter-gatherer culture survived the longest.

Source: (Aikens, 2022), (Nevada Rock Art Foundation, 2015), (Shock, 2002), (Benson, et al., 2013), (Davis, 2019), (Fisher, 2010), (Kaestle & Smith, 2001), (Loring & Loring, 1996), (Andreae & Andreae, 2022)

Chapter 12—Greeley Canyon (mile 44–48)

Tuff of Leslie Gulch (mile 45)

Beginning at Upper Greeley camp and continuing downstream three miles, the river passes through a spectacular canyon up to 1,500 feet deep. At sunset, the canyon walls light up with a beautiful orange glow, resulting in terrific photos. These orange-colored cliffs are made of rhyolite tuff, part of the well-studied Tuff of Leslie Gulch, named for the location where it was first identified. At almost sixteen million years old, this is the oldest strata in the canyon walls of this fifty-mile stretch of the river.

The individual layers in the canyon wall are from different volcanic eruptions spread out over many thousands of years. Some are well-defined air-fall deposits and others are jumbled pyroclastic flows and surges caused by collapse of the eruption columns. Still others are local mud flows (lahars) and reworked tuff sediment (volcanoclastic) deposited between eruptions.

The volcanic ash and tuff erupted from Mahogany Mountain Caldera, only fifteen miles to the east and one of the oldest and most explosive volcanic eruptions in the region. It created a huge caldera estimated to be about 10 to 15 miles diameter, now filled with sediment, rhyolite tuff, and lava flows. Recent high-precision rock dates show the eruptions began 15.9 million years ago and continued for tens of thousands of years. The ongoing eruptions blanketed the surrounding landscape with thick layers of rhyolite tuffs and lavas, some layers near the caldera are up to 2,000 feet thick. (For more details see Chapter 14–Owyhee Breaks.)

Mile 44.8: Cliffs are rhyolite tuff almost 16 million years old View downstream from Upper Greeley Camp.

Chapter 12—Greeley Canyon (mile 44–48)

Mile 45: Greeley Canyon. (View from rimrock to NE.)

Greeley hot spring (mile 44.7)

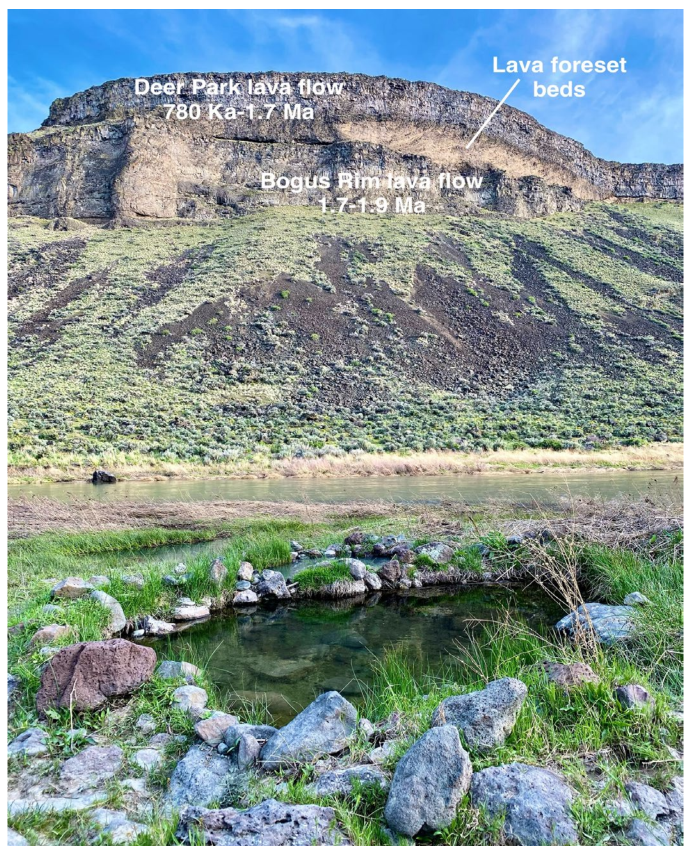
Greeley hot spring is located a short walk upstream of Greeley camp where a tub has been excavated in the riverbank for soaking. At high-water, the hot spring is flooded and not usable. The wetland between the hot spring and river edge is protected toad habitat.

Hot springs are evidence of volcanic heat below the earth's surface. The water is ordinary rainwater that seeps into fractures, circulates deep underground, and comes to the surface again in faults. In recently active volcanic areas, hot rock is unusually close to the surface. The source of the hot spring may be from one of the two nearby north-south faults mapped by geologists.

Deer Park lava delta (mile 44.7)

Take a dip in Greeley hot spring and look across the river at the rimrock. You are looking at a valley-filling lava flow (Deer Park lava) that spilled into the canyon between about 1.7 million and 780,000 years ago. Interaction of the molten lava with river water left a tell-tale layer of brown/orange-colored slanting foreset beds (the lava delta), easily seen in the rimrock.

The rimrock is a layer-cake of different lava flows with a clear dividing line visible between them. The top layer (with the lava delta) is the Deer Park lava flow, a small flow that only filled in about 3 miles of the canyon. The bottom layer consists of at least two different flows of 1.7 to 1.9-million-year-old Bogus Rim lava, which filled the canyon with a 30-mile-long lava blockage. (See Chapter 9, "Bogus Rim lava dam".)



Mile 44.5: Greeley hot spring tub with view across the river to Deer Park lava foreset beds in layer-cake rimrock.

Chapter 12—Greeley Canyon (mile 44–48)

Mile 45: Remains of small rock "cabin" on 1909 homestead at Greeley Bar, named for Andrew Greeley.

Mile 45: The riverside cliff below Upper Greeley Camp is an intrusion of andesite, a "sill". (View upstream.)

Greeley Bar (mile 45)

Greeley Bar, a large boulder bar deposit at the river bend, was created by outburst floods from failed upstream landslide dams. A 2006 study shows that boulders near the river were likely deposited about 22 to 24 thousand years ago by the failure of the East Spring Earthflow dam less than a mile upstream. (See Chapter 11 "East Spring Earthflow".) Boulders farther away may be from older floods.

History note: Greeley homestead

Greeley Bar is named for Andrew Greeley who in 1909 obtained an original homestead patent (title) for 160 acres bordering both sides of the river, stretching from Greeley Bar, across the river to the hot spring and up the hillside onto the rolling hummocks created by the East Spring Earthflow. Access to the homestead was probably by packhorse on a primitive trail that once ran three miles downstream to Birch Creek ranch, portions of the trail still exist today. The remains of a small rock cabin and corral on Greeley Bar are probably nominal improvements made to "prove up" the homestead to obtain title, after living on it for five years. There is no evidence of year-round residence, likely the homestead was used for seasonal grazing of livestock. The property is now owned by the BLM

Geology hikes

From Upper Greeley camp: Hike up the ravine behind camp, past layers of rhyolite tuff and a thick sequence of fine-grained lakebed sediment, ending at an interesting andesite lava flow with large vesicles (air bubbles) filled with white quartz. (Note: The upper part of this hike is a scramble over loose rock.)

An easier but longer hike is to go upstream over the landslides to the summit of Devils Throne and enjoy a killer view of The Hole in the Ground.

At low water you can walk downstream from camp to a 50-foot-high cliff of dense, hard andesite. This is magma that horizontally intruded the overlying rhyolite strata millions of years ago—a "sill".

From Middle & Lower Greeley camps: Hike west through the sagebrush to a 100-foot cliff perched on the valley wall. From its top you have good views of the landscape and downstream to the andesite intrusions discussed later in this chapter.

Walk to the downstream end of Greeley Bar and connect to an old trail along the riverbank that takes you to the andesite intrusions.

High above Upper Greeley Camp. In the foreground is fine grained sediment deposited in a lake that once existed here. In background are rolling hummocks of East Spring Earthflow.

Mile 45.7: The river cut through an andesite intrusion in lower Greeley Canyon. Photo by Kathy Cashman.

Intrusive sills and dikes (mile 45-47)

This canyon is a good place to see the different shapes that intrusive andesite magma can take.

The 50-foot-high cliff immediately downstream from Upper Greeley Camp (you can walk to it from camp) is andesite that intruded the overlying rhyolite strata millions of years ago. It's called an andesite "sill", a sheet-like intrusion parallel to existing rock layers.

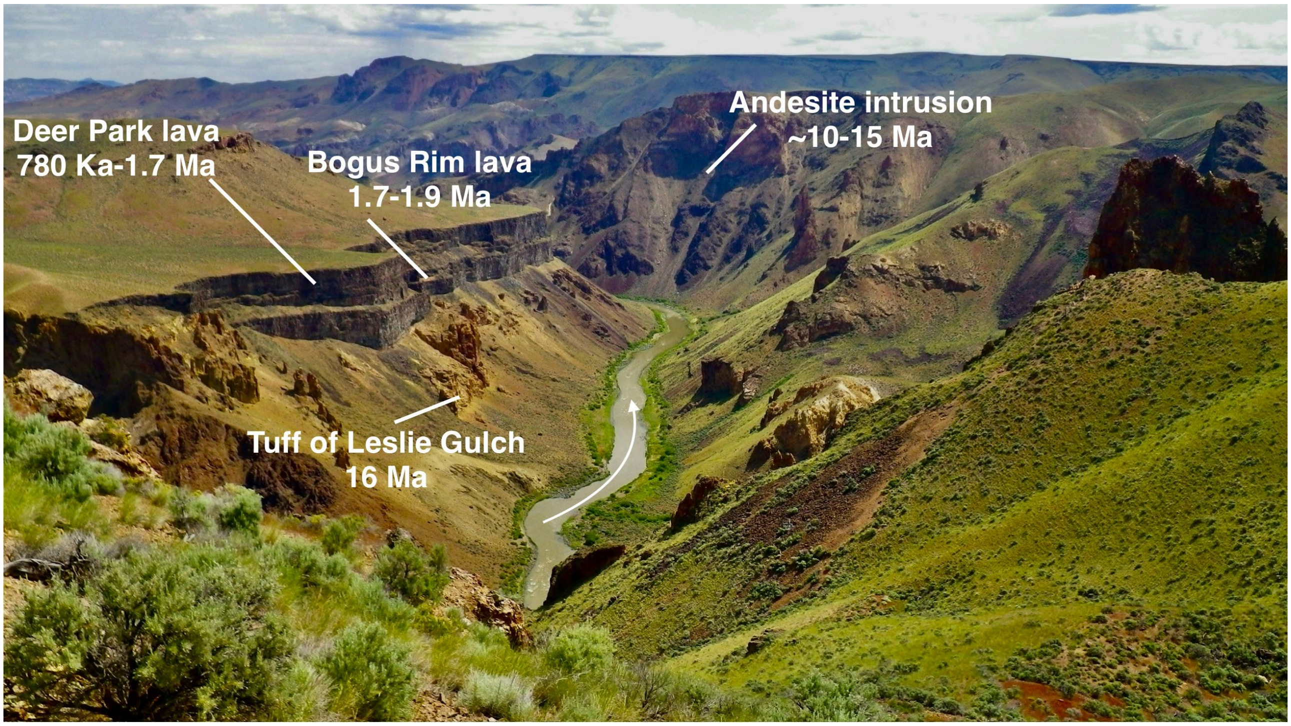
You can see several vertical andesite intrusions in the rhyolite canyon wall across from the middle Greeley Bar camp. They cut upwards through the rhyolite strata from river level and then branch off into smaller intrusions. These are andesite "dikes", vertical or steeply inclined intrusions that cut across rock layers. Dikes are often conduits through which magma once traveled to the surface to feed lava flows. Unfortunately, the canyon walls are broken by so many faults that it's not possible to trace the dikes to the surface. (The dikes are easiest to see at sunset, binoculars help.)

Downstream of Greeley Bar the river cuts through two massive, irregularly shaped intrusions of dark andesite lava, each one located at a 90-degree bend in the river. Each intrusion is about half a mile across and hundreds of feet thick.

The intrusions formed millions of years ago when molten andesite rose from a magma chamber deep underground and penetrated the overlying Tuff of Leslie Gulch formation. It did not reach the surface and cooled underground into these solid masses of rock. Millions of years later, the Owyhee River incised through the overlying rhyolite tuff and encountered the buried andesite rock, creating a deep and narrow canyon. The river stripped most of the overlying rhyolite tuff from the hard, erosion-resistant andesite canyon walls, but in a few places, it left distinctive, orange-colored pinnacles standing along the river.

The intrusions are undated, but it's plausible they occurred between 10 and 15 million years ago. Studies show that after the nearby Mahogany Mountain Caldera collapsed, andesite dike swarms emerged along active faults that fed numerous andesite flows.

Mile 45.7: Pinnacles of rhyolite tuff were left standing on the eroded surface of an andesite intrusion. (View upstream.)



Mile 46-47: Looking downriver (east) into lower Greeley Canyon. The rimrock marks the downstream location of the Deer Park lava dam, formed 0.8 to 1.7 million years ago, almost 600 feet above the modern river.

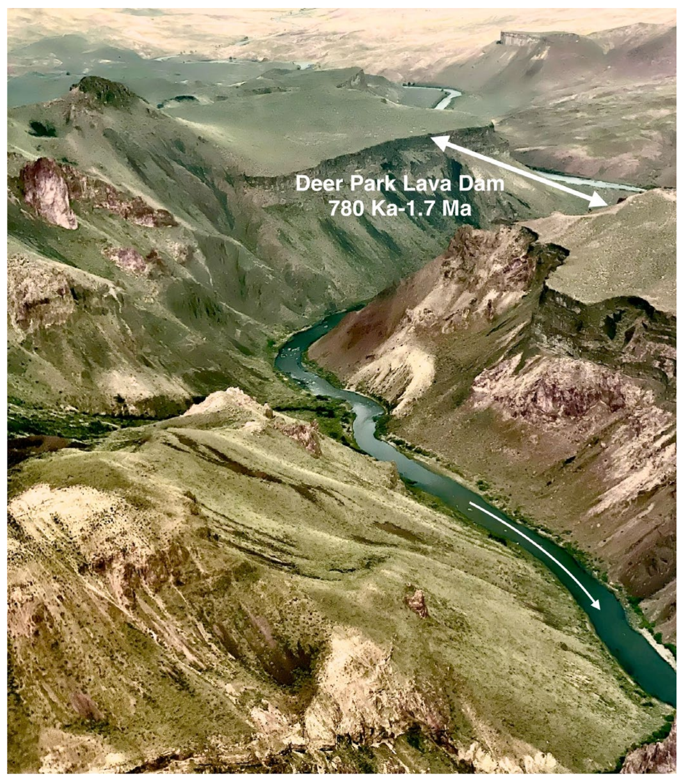
Deer Park lava dam (mile 46-47)

In the 2000s, the team of researchers investigating ancient lava dams on the Owyhee discovered evidence of another lava dam here, the Deer Park lava dam, the second oldest identified, located almost 600 feet above today's water level. It was dated then as 780,000 years old based on a rock sample taken on the plateau at the vent location. Recent field studies indicate that several lava flows originated from the vent, and the lava dam—though currently undated—is probably older than 780,000 years.

At just 3 miles long, it had the shortest footprint of any lava dam along the river and probably did not persist long. The remnants of the dam form today's basalt lava rimrock lining the river downstream of Greeley Bar. From river level, we get little sense of the original extent of the lava dam.

Though small and probably short-lived, this lava dam is particularly important to researchers because it formed on top of a preexisting dam, the Bogus Rim lava dam, dated 1.7 to 1.9 million years old, creating a layer-cake basalt rimrock that we can easily see from river level. Lava foreset beds and other evidence show that the Bogus Rim dam was still intact and blocking the river here when the Deer Park lava flow arrived.

The fact that the old lava blockage (dam) was still present in the river channel when the new Deer Park flow arrived is very significant. Once we know the exact date of the Deer Park lava dam, the age difference between the old and new dams will tell us how long the Bogus Rim lava dam persisted. Was it hundreds of thousands of years, an extraordinarily long time, or only tens of thousands of years, like the other lava dams studied by geologists on the Owyhee River?



Mile 45-46: Arrows mark location of Deer Park lava dam. When the lava flow arrived, the river channel was about 600 feet above the modern river. View upriver to NW.

Mile 46.8: A layer of Owyhee River gravel is trapped beneath the Bogus Rim lava flow. This marks the location of the Owyhee riverbed almost 2 million years ago. Geologists for scale. (~350 feet above the river—a dangerous hike!)

Ancient riverbed gravel (mi. 46.8)

As you go around the 90-degree bend in the river at mile 46.8, look up to the rimrock on river-left and find the 20-foot-thick layer of Owyhee River gravel, sand and mud stranded 350 feet above the modern river, trapped under the bottom layer of lava. This layer of gravel and mud marks the course and elevation of the ancestral Owyhee River channel when the Bogus Rim lava flow(s) arrived 1.7 to 1.9 million years ago and blocked the river channel. At this location, the modern river has changed its course little in the last nearly 2 million years.

Mile 46.8: Closeup of ancient ripple marks in thick layer of Owyhee river mud trapped beneath the Bogus Rim lava flow. The heat of the overlying lava baked the mud into "brick". This is at the rimrock site pictured above. Geologist for scale.

Mile 47.2: The Lava Castle marks the location of ancestral Owyhee River almost 2 million years ago. The layer-cake lava flows are perched on a colorful formation of 16-million-year-old Tuff of Leslie Gulch. (View downstream/north.)

The Lava Castle (mile 47.2)

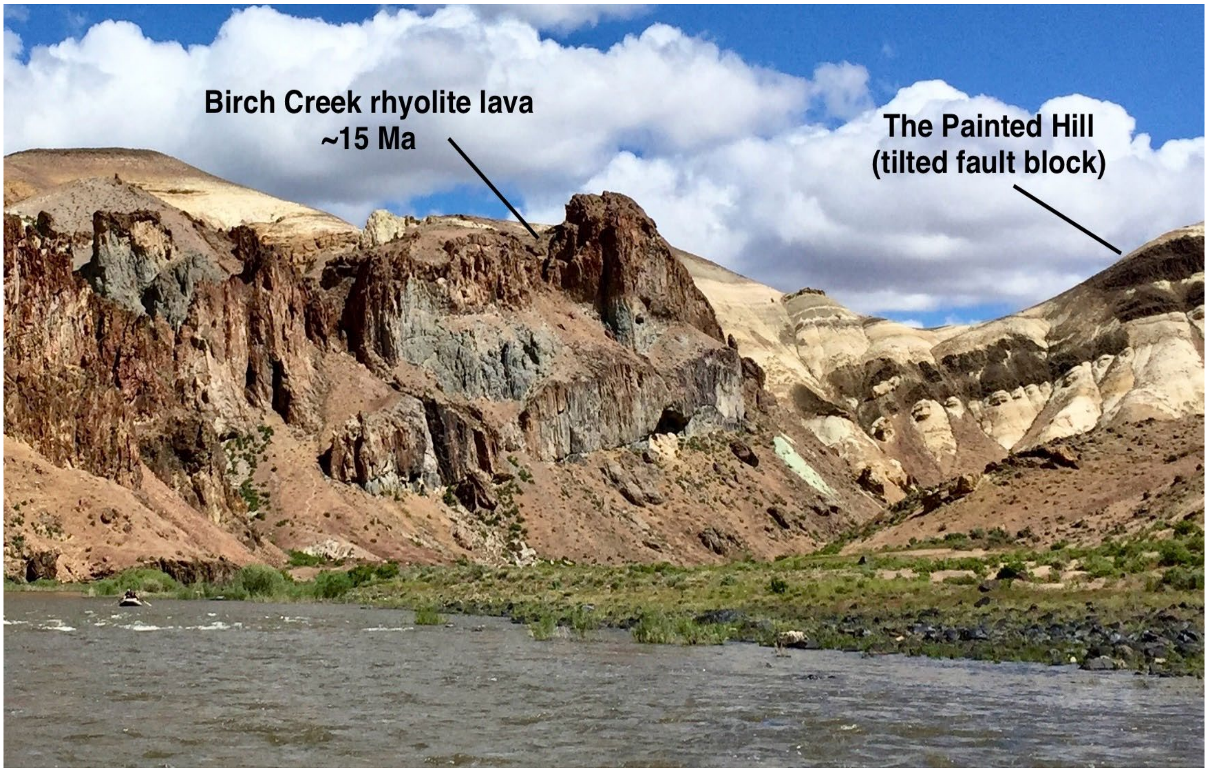
Approximately a quarter mile downstream from the 90-degree bend in the river lies an impressive geological structure, informally referred to as The Lava Castle, situated on a cliff well above the riverbank. From the river it's easy to see the 20-foot-thick layer of Owyhee river boulders and gravel trapped under the base of the bottom lava flow.

This marks another location of the ancestral Owyhee River almost 2 million years ago. We can also see a segment of the ancient valley wall preserved beneath the protective lava; its gentle curve suggests the ancient river valley was wider and shallower than today's.

The lava castle is perched on Tuff of Leslie Gulch, about 16-million-years old. The castle consists of two layer-cake basalt lava flows, a top layer of over 780,000-year-old Deer Park lava and a base layer of 1.7 to 1.9-million-year-old Bogus Rim lava.

SOURCES: (Swenton, et al., 2022), (Black, 2021), (Benson & Mahood, 2016), (Ely, et al., 2012), (Cummings, et al., 2000), (Ferns, et al., 1993), (Vander Meulen, et al., 1990), (Vander Meulen, 1989), (Plumley, 1986)

Chapter 13—Birch Creek Ranch (mile 48–51)



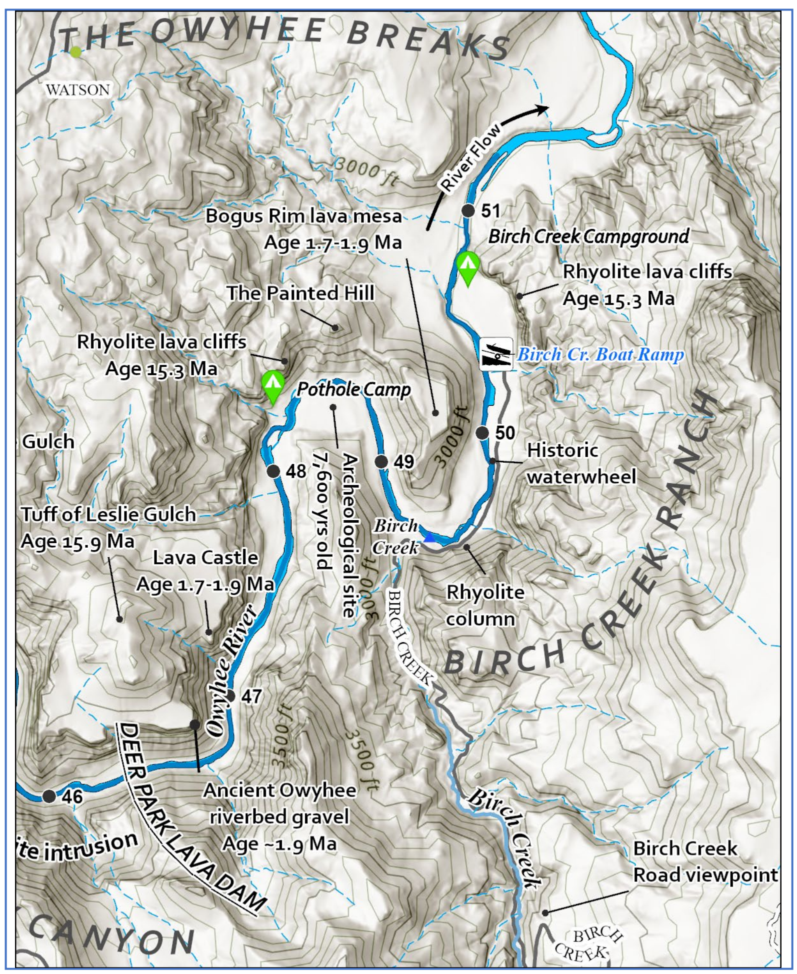
Mile 48.2: Near Pothole Camp, the river flows into the Owyhee Breaks and the cliffs change to rhyolite lava.

Faulting (mi 48.2)

Near Pothole Camp, the canyon widens to reveal a fractured landscape of tilted sediment and lava blocks. Extensive faulting and uplift occurred in this region following the violent eruption of the Mahogany Mountain Caldera about 5 to 10 miles to the northeast. (For full details, see Chapter 14—Owyhee Breaks & Mahogany Mountain Caldera.)

Several faults intersect the canyon here, exposing a variety of rock layers. The movement caused by faulting and uplift has tilted the pale sedimentary layers at uneven angles, with adjacent strata shifted by several hundred feet. As a result of the uplift, solid rhyolite lava replaces the softer Leslie Gulch Tuff at this bend in the river.

Birch Creek Lava: The rhyolite cliffs downstream of the faults are Birch Creek Lava, 14.9 to 15.5 million years old. Several crevices, including Pothole cave, are visible in the cliffs. Additional details regarding the Birch Creek Lava flow are available in the "Rhyolite lava cliffs" section further on in this chapter.



Chapter 13—Birch Creek Ranch (mile 48–51)

Mile 48.5: The Painted Hill, an ancient, tilted fault-block. Volcanic sediments are interlayered with two columnar-basalt lava flows near the summit. The basalt layers are cut by a fault that offsets them about 150 vertical feet.

The Painted Hill (mile 48)

The dramatic painted hill near Pothole camp exemplifies the Owyhee Breaks' rugged terrain and is popular with photographers. It's also visible from across the river at the Birch Creek Ranch alfalfa field.

Slanted fault-block: The hill sits atop a small, slanted fault-block that has sunk hundreds of feet in comparison to the surrounding terrain.

Geologic history: About 14 to 15 million years ago, layers of basalt lava and sediment accumulated horizontally in low-lying areas near the eruptive Mahogany Mountain Caldera. These new sediments and lavas settled above the thick deposits of rhyolite tuff and lava produced by previous eruptions.

Over millions of years, faulting and subsidence lowered the basin floor 2,000 feet below the canyon rim, breaking it into numerous small, tilted blocks. The Owyhee River carved its canyon through these blocks, exposing tilted and varied rock strata along its course.

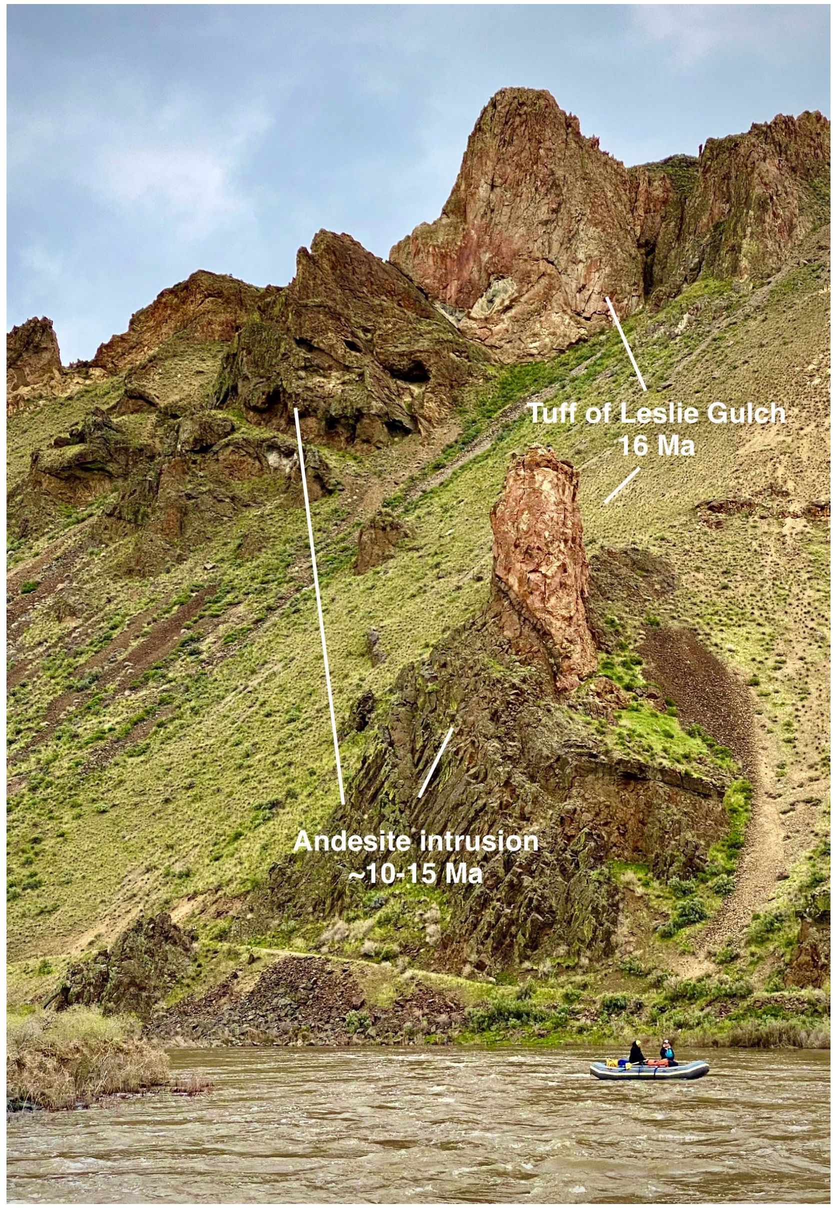
Visible faults: From Pothole camp, two faults that caused the hill's subsidence are visible. The most noticeable fault is in the hilltop; it shifts the dark horizontal layers of basalt lava by about 150 feet. A larger, less visible fault lies upstream in the canyon wall, where the Painted Hill meets the pink rhyolite cliff of Birch Creek Lava, separated by a vertical seam of compacted conglomerate rock.

Geology hikes: Although you can hike to Pothole cave from camp, the steep, unstable rocky slope poses a hazard—it's probably not worth it. A better hike is up the steep ravine behind camp to the rimrock for a killer view overlooking the canyon.

Mile 48.2: Pothole cave in Birch Creek Lava rhyolite cliff. Note tiny hikers on hazardous slope.

Archeological site: Prehistoric people lived for millennia on the flat river terrace (now a field) opposite the Painted Hill. For details see "History note: Prehistoric site" later in this chapter.

Closeup of cooling zone between hot andesite magma and cold overlying tuff.



Mile 49.5: Pinnacle of 16-million-year-old Tuff of Leslie Gulch standing on base of intrusive andesite rock. Roadcut to boat launch is visible along riverbank. View downriver/north.

Rhyolite pinnacle (mile 49.5)

Near the historic waterwheel and boat ramp access road, a striking orange pinnacle of 16-million-year-old Tuff of Leslie Gulch rests atop dark intrusive andesite.

This spot highlights the contact zone between intruding hot andesite magma and cold rhyolite tuff. Similar formations are visible in the canyon walls 2-3 miles upstream. See Chapter 12, Greeley Canyon, for a detailed explanation of rhyolite pinnacles and intrusive andesite.

The pinnacle is not easily seen from the gravel road that leads to the boat launch. Because the road is narrow and lacks pullouts, stopping during rafting season is challenging, and limited visibility further restricts views.

Source : (Ferns, et al., 1993), (Plumley, 1986)

Historic waterwheel (mile 49.8)

The waterwheel once provided irrigation water to the Morrison Ranch. It is believed to be one of only three pioneer waterwheels still surviving in the state of Oregon as of 1997. Local historian Bill Crowell notes that over a dozen waterwheels once operated along the Owyhee from Rome to Leslie Gulch, with homesteads occupying nearly every flat spot by the river. Materials for each waterwheel were brought in by wagon and assembled onsite.

This waterwheel measures about 30 feet in diameter and is an "undershoot" design where the water hits the wheel from beneath instead of dropping from above. It's designed specifically for irrigation purposes to lift water from a stream where the water level is low and does not have a high vertical drop (head). The wheel is equipped with paddles and buckets along the circumference of the wheel that rotates when the water strikes the bottom of the wheel.

The design is relatively simple and cost-effective, making it a popular solution in historical and rural irrigation systems without access to electric power. They generally fell into disuse once power became available.

You can find another half-buried waterwheel at the abandoned pioneer Island Ranch, 3 to 4 miles downstream on river-right, before Lake Owyhee begins.

Mile 49.8: ca 1890s waterwheel that once supplied irrigation water to Morrison Ranch.

Mile 50: Boat ramp at Birch Creek Historic Ranch.

Owyhee River take-out (mile 50.5)

The Birch Creek boat ramp is located approximately a quarter mile downstream from the waterwheel, within BLM's Birch Creek Historic Ranch Site.

Source: (Crowell, 2022), (National Register of Historic Places, 1997),

Chapter 13—Birch Creek Ranch (mile 48–51)

Rhyolite lava cliffs (mile 50)

A unique rhyolite cliff with hoodoo formations is a short walk from the boat ramp, marking an ancient rhyolite lava flow exposed by river erosion. The site showcases flow-banded rhyolite, featuring swirling patterns formed by viscous lava. The cliffs extend for about two miles downstream from Birch Creek's mouth, with additional eroded lava outcrops visible along Birch Creek Road as you drive in/out of the canyon

This volcanic formation, largely unexplored, is named "Birch Creek Lava." In 2022, researchers acquired high-precision age determinations of 14.94 and 15.52 million years from two collected rock samples.

The lava likely originated from the Mahogany Mountain Caldera, a rhyolite eruption that lasted about 250,000 years between 15.75 and 16 million years ago. This eruption formed a buried caldera roughly 15 miles wide, with its rim about four miles away. For details, see Chapter 14, Owyhee Breaks & Mahogany Mountain Caldera.

Unlike the smooth vertical walls in upstream rhyolite gorges, these cliffs have weathered into hoodoo-like formations with steep scree slopes and loose, angular rocks. Regional tectonic activity may have created stress fractures after the lava solidified, enabling this distinctive erosion. Many faults cross the area, and sections of the canyon floor have dropped by as much as 2,000 feet, suggesting powerful forces were at work that led to extensive cracking.

Mile: 50: The cliffs at Birch Creek are a flow of rhyolite lava dated 14.9 to 15.5-million-years old, during the aftermath of the Mahogany Mountain Caldera eruption. (Looking SE.)

Birch Creek Road viewpoint looking NW. The road climbs 1,700 vertical feet through orange-colored rhyolite tuff and lava that erupted 15 to 16 million years ago.

Birch Creek Road

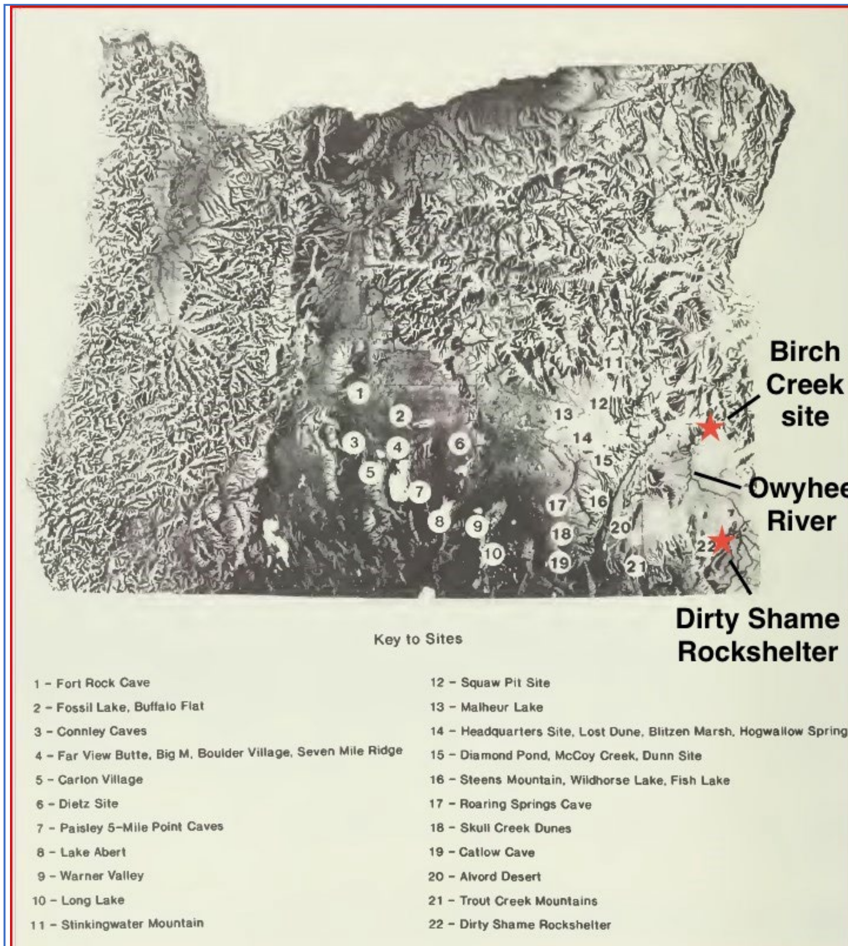
Birch Creek Road ascends 1,700 feet from the Owyhee Canyon on a narrow, rocky route, emerging at 4,600 feet elevation onto a 5-million-year-old basalt plain—similar in elevation to highways over Oregon's Cascades. Pullouts along the road provide views of the Owyhee Breaks, a faulted and eroded volcanic landscape shaped by eruptions and collapse of ancient volcanoes in the Lake Owyhee Volcanic Field.

The west side of the road is mostly eroded tuff; the east is primarily lava. Both rock types originated from the Mahogany Mountain Caldera eruption 15–16 million years ago, with the creek and road roughly following their boundary.

SOURCES: (Swenton, et al., 2022), (Black, 2021), (Benson & Mahood, 2016), (Ely, et al., 2012), (Cummings, et al., 2000), (Ferns, et al., 1993), (Vander Meulen, et al., 1990), (Vander Meulen, 1989), (Plumley, 1986)

History note: Prehistoric sites

Birch Creek site: On the river terrace upstream of the rafters' takeout at Birch Creek ranch, Washington State University archeologists uncovered evidence that prehistoric people lived here more than 7,700 years ago. They conducted two excavations over seven field seasons, 1998-2006, resulting in at least six published thesis papers. The site was selected because a scatter of chipped stone was visible in the alfalfa field and charcoal stains were exposed in a cutbank. Today nothing of interest is visible, the archeological excavations were filled in and the surface returned to its present-day condition.



Locations of Great Basin culture archeological sites in Oregon. Source: Aikens, 1993, Archeology of Oregon, a BLM publication.

2,200 to 7,700+ years ago: At the first excavation site, archeologists dug down to a layer of 7,700-year-old Mount Mazama ashfall (a well-known age-marker). Beneath the layer of ash were a few broken artifacts and domesticated dog remains, evidence of brief visits even earlier than 7,700 years ago. Above the layer of ash, they found evidence of an open-camp occupation, and above that they found evidence of a hamlet composed of at least three house pit earth floors. Radiocarbon dates show the site was occupied for at least 5,500 years, from 2,200 to 7,700 years ago, with several gaps in occupation. Analysis of obsidian fragments shows that at least three different groups of people inhabited the site during those 5,500 years, each group had to rediscover where the nearest source of obsidian was located, all which are miles away.

Analysis of the chipped stone artifacts, and fragments of bones and shells indicates this was a place of extended occupation—a home. People probably lived here in a small family group in a late fall/winter residence and moved within a 20-to-30-mile radius seasonally to collect seeds, roots, and game, rarely congregating in larger groups. Samples of bone show the occupants consumed large and small mammals, as well as fish and birds. Fragments of pestles and mortars indicate they also collected and processed seeds for consumption throughout the 5,500-year occupation period. Mussels and fish supplied large portions of their diet, along with big horn sheep, deer, bison, coyote, rabbits, marmots, and squirrels.

No bow-and-arrow projectile points were found, indicating these people hunted with the atlatl dart-thrower that had earlier replaced spears, and in turn would be replaced by the bow-and-arrow.

1,100 to 1,300 years ago: At a second excavation site, located about 900 feet farther upstream, archeologists uncovered evidence of 200 years of continuous surface occupation (open-camps), refuse disposal, and possibly one sweat-lodge. It was occupied with no gaps from about 1,100 to 1,300 years ago, before being abandoned. Pollen evidence indicates the 200-year-long occupation period was during an unusually dry period of low river levels; the site was abandoned when flooding occurred and deposited at least two massive layers of sediment over the river bar. Researchers don't know whether this second site was a seasonal camp or a year-round camp.

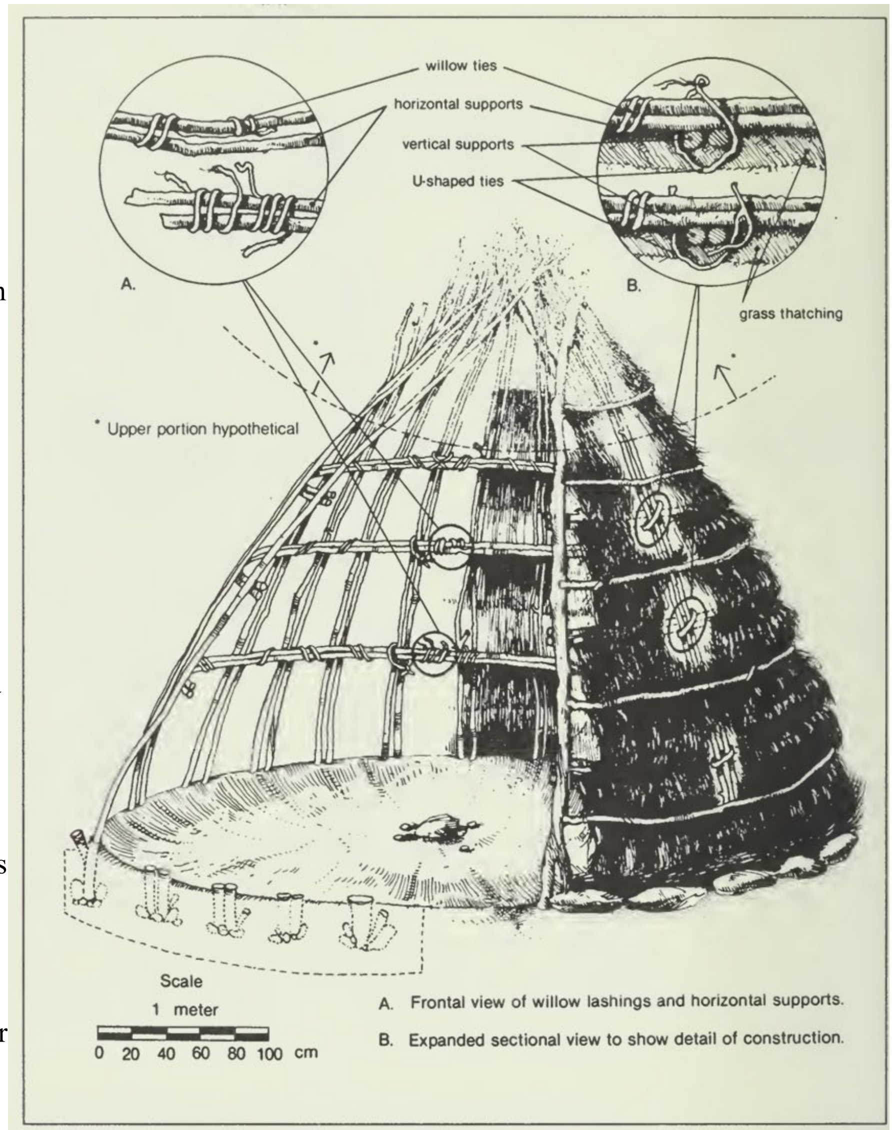
The style of projectile points recovered indicates the inhabitants now used the bow-and-arrow instead of the atlatl (dart-thrower) for hunting. The transition to bow-and-arrow occurred sometime between the two known occupation periods: 2,200 to 1,300 years ago.

Dirty Shame Rockshelter (10,800 years ago): In 1977, University of Oregon researchers studied another prehistoric occupation site on the Owyhee River, the Dirty Shame Rockshelter, located near Three Forks about 50 miles upstream of Birch Creek. (Named for the fact that it was heavily pillaged by artifact collectors before it could be professionally excavated.)

According to archeologist Melvin Aikens, the rockshelter deposits remained dry and thus preserved an exceptionally diverse and well-dated inventory of artifacts and food remains, which portray in rare detail the Great Basin desert culture (hunting-gathering) from the end of the Ice Age into historical times.

The site was occupied from 10,800 to 400 years ago, but with a gap in the dates between about 6,700 and 2,900 years ago when the site saw little or no human occupation for a 3,800-year interval. The break in occupation came at a time of decreasing moisture when apparently the landscape dried and food resources in the area shrank to a level that made travel there unprofitable. Regular use resumed probably because of better environmental conditions.

It's interesting that the 3,800-year break in human occupation at Dirty Shame coincides with the 5,300-year continuous occupation at Birch Creek, 50 miles downstream, a lower elevation site with year-round water.



Artist sketch of house thatched with grass at Dirty Shame Rockshelter. Source: Aikens, 1993, Archeology of Oregon, a BLM publication.

The rockshelter contained well preserved remains of at least five and probably six conical or domed-shaped house structures that were thatched with native grass and willow lashings. There were also woven sandals, soft mats, bags, baskets and cordage, including more than one hundred more or less intact specimens of sandals of the famous Fort Rock type, as well as other sandal varieties. The Fort Rock type sandals and other artifacts indicate the prehistoric people who lived here were the same hunting-gathering culture found throughout the high desert of SE Oregon, at numerous well-studied archeological sites ranging from Fort Rock to Malheur Lake to the Owyhee River.

Aikens states "Perhaps the most arresting conclusion to come from the Dirty Shame study is that the general way of life of its occupants, and much of their technology, changed scarcely at all over the entire period." (About 10,000 years.)

Paiute arrival: At the time of European contact (1850), this area was inhabited by a band of the Northern Paiute tribe named the Tagotoka ("tuber eaters"). The Paiute are thought to have immigrated to this region about 500 to 1,000 years ago from the southern Great Basin. The Paiutes are from the same hunting-gathering, Great Basin desert culture as the earlier prehistoric inhabitants and carried on with the same lifestyle, occupying many of the same living sites and living in similar structures. It remains unclear to archaeologists whether the prehistoric inhabitants of the region departed prior to the arrival of the Paiute, or if they were subsequently displaced, integrated, or assimilated over time.

Source: (Aikens, 2022), (Fisher, 2010), (Cole, 2001), (Noll, 2009), (Kaestle & Smith, 2001), (Davis, 2019), (BLM and Univ of Oregon, 2023), (Aikens, 1993), (Aikens, et al., 2011), (Egan, et al., 2015)

Birch Creek Historic Ranch site is made up of two pioneer homesteads established in the 1890s originally known as the Birch Creek Ranch and the Morrison Ranch.

This dirt road to the Morrison Ranch homesite. It now leads to the BLM boat ramp and campground. (Photo from BLM brochure.)

History note: Birch Creek ranch

Surveyors from the General Land Office reported in 1912 that three established ranches with irrigated fields, gardens, orchards, and cabins were present along a 6-mile stretch of the Owyhee River near Birch Creek. Two of the ranches had waterwheels with flumes and irrigation ditches to distribute water from the river, the other obtained its irrigation water from Birch Creek. These ranches were probably first settled sometime in the mid-1890s as the first wave of homesteaders arrived in the lower Owyhee Canyon.

General Land Office survey maps indicate two wagon roads provided access: today's Birch Creek Road to Jordan Valley, and another road on the opposite riverbank leading about six miles downstream to the now-abandoned community of Watson.

The Watson wagon road frequently crossed the river and became impassable during spring high water. In 1911, Watson was a small community of ranches with 37 residents living along both sides of the river. Between 1898 and 1936, postal services in this rural area operated from ranchers' homes under the name "Watson" rather than a separate post office. The location is now submerged by Lake Owyhee.

The present-day BLM "Birch Creek Historic Ranch" site contains two of the three 1890s homesteads. These two homesteads were originally known as the "Birch Creek Ranch" (located at the mouth of Birch Creek and running upstream), and the "Morrison Ranch" (from the waterwheel to the boat ramp and campground). The two ranches were combined under one owner and sold to the BLM in the 1980s. The third homestead was on the opposite side of the river, downstream from the Morrison Ranch, and was abandoned after being purchased by the government when construction of the Owyhee dam began in 1928.

The water wheel and stone walls date back to the original homesteads and are considered historic. The wooden structures have a hazy history and are probably mid-to-late 1900s vintage, after it was possible to economically transport lumber to this remote site. Trees suitable for milled lumber do not grow in the canyon and it was a long drive by wagon and team on rough roads to the nearest sawmill. Early homesteaders along the river usually built their homes out of local sandstone or volcanic tuff. Even fenceposts were in short supply once the local juniper trees had been harvested, hence the rock walls.

The buildings at the mouth of Birch Creek mark the site of the Birch Creek Ranch homestead. (Photo from BLM brochure.)

Source: (Crowell, 2022), (National Register of Historic Places, 1997), (BLM General Land Office Records Search, 2024)

Chapter 14—Owyhee Breaks & Mahogany Mountain Caldera

Mile 47: The Owyhee Breaks: an ancient, eroded basin filled with faulted and tilted strata. In the distance is Red Butte, an intact remnant of the ancient basin floor. The Mahogany Mountain Caldera (now extinct) location is just out of view, about 5-10 miles NE of Birch Creek Ranch. View from rim of lower Greeley Canyon looking north.

The Owyhee Breaks

The broken landscape near the inflow to Lake Owyhee is known as the Owyhee Breaks. The region is marked by rugged cliffs, rocky outcrops, landslides, gulches, and ridges. Its colorful layers of ancient sediment and volcanic rock are tilted due to intersecting faults and fault blocks.

Mahogany Mountain Caldera

The story of the Owyhee Breaks begins about 16 million years ago when the Yellowstone hotspot passed nearby and left a pool of magma deep in the earth.

Explosive magma eruptions near present-day Owyhee Lake and other sites in SE Oregon covered the area with thick layers of rhyolite tuff and lava. Researchers identified the source of the eruptions as two now buried calderas on the south side of Lake Owyhee.

Mahogany Mountain Caldera erupted first and deposited thick layers of ash-flow and air-fall tuff collectively named the "Tuff of Leslie Gulch". Then, following the collapse of the Mahogany Mountain Caldera, nearby Three Fingers Caldera erupted an ash-flow tuff named the "Tuff of Spring Creek", and it collapsed. Recent research suggests there may be only a single large, buried caldera in the location, not two, that erupted a single type of tuff, the Tuff of Leslie Gulch, in multiple episodes over hundreds of thousands of years. (Not all geologists agree with the single caldera idea.)

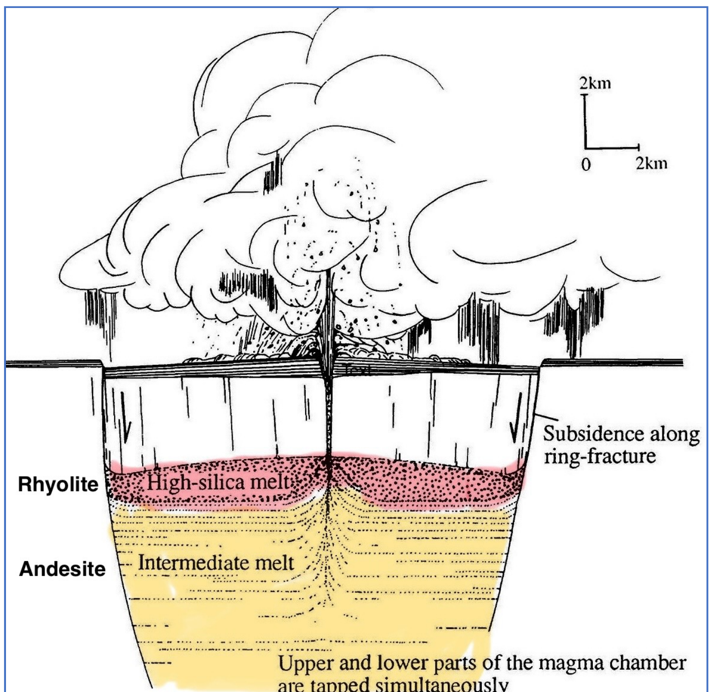
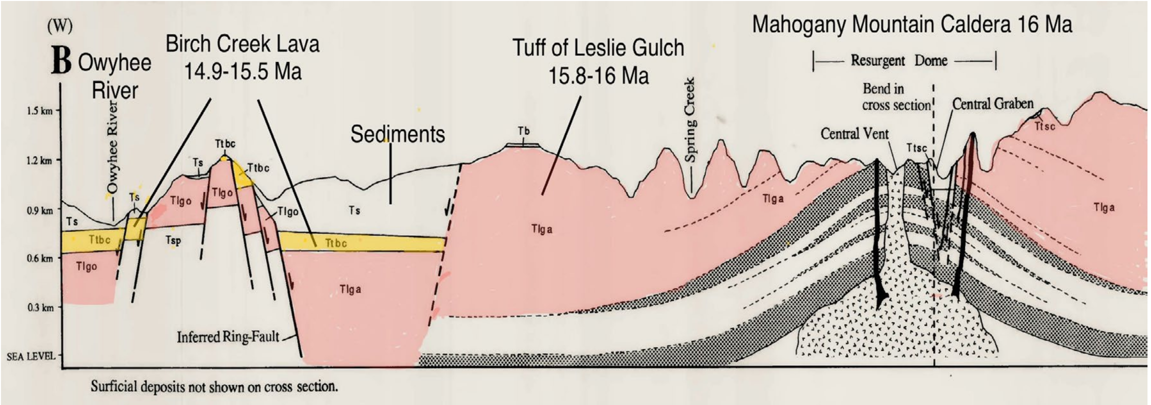
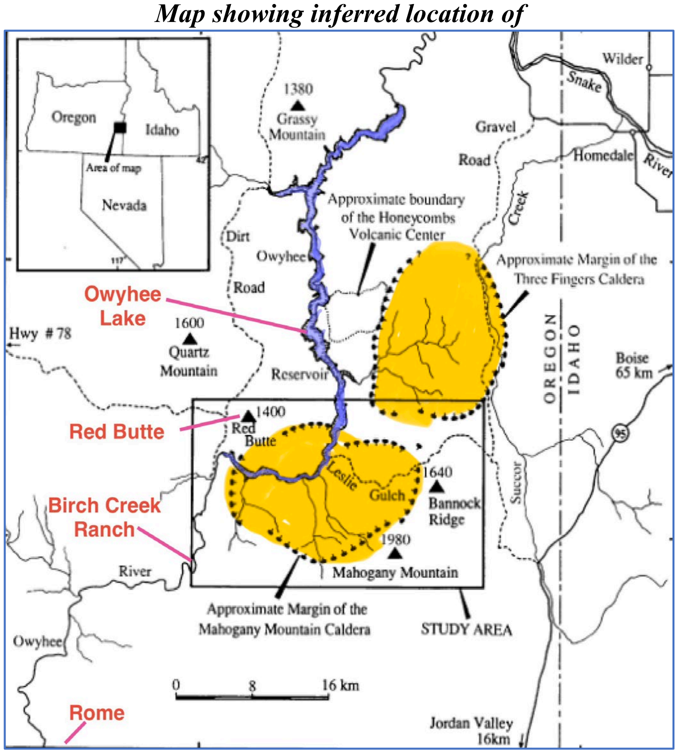


Illustration sketch of Mahogany Mountain Caldera. (From Vander Meulen, 1989, a USGS report.)



Mahogany Mountain Caldera cross-section near Birch Creek. (Adapted from Vander Meulen, 1989, a USGS report.)

Map showing inferred location of



Mahogany Mountain Caldera and Three Fingers Caldera (orange-colored), roughly 10-15 miles in diameter. (Adapted from Vander Meulen, 1990, BLM.)

Age: The Tuff of Leslie Gulch has been studied and laboratory dated many times. Recent research indicates eruptions persisted for 100,000–200,000 years between 15.9 and 15.8 million years ago.

Caldera collapse: During the explosive phase of rhyolite volcanic eruptions, caldera floors collapse, and fracture rings (faults) occur in the earth's crust that provide pathways for molten rhyolite to reach the surface. The subsequent post-caldera lava flows often continue for hundreds of thousands of years (or longer) after the main eruption.

Oregon-Idaho Graben: After the caldera(s) collapsed, the earth's crust fractured into a large down dropped basin (graben), named the Oregon-Idaho Graben. The Owyhee Breaks is in that graben. The graben gradually filled up with multi-colored beds of eroded volcanic sediment, tuff, and basalt lava flows.

At this stage, the Owyhee Breaks were part of a large basin filled with almost 1,000 feet of layered sediment overlying a base of rhyolite lava and tuff up to 1,500 feet thick. The Snake River Plain and ancient Lake Idaho did not yet exist, that region was then probably a topographic highland that served as a source of sediment to the Oregon-Idaho Graben.

Lava plateaus Then uplift and associated faults broke the large graben into smaller sub-basins and tilted the multi-colored strata at various angles. After the sub-basins filled with sediment, numerous small shield volcanoes and vents flooded the landscape with overlapping basalt lava flows, creating a rolling lava plateau high above the present river.

Owyhee River: Then the Owyhee River was born, and it stripped away much of the overlying lava and sediment, leaving today's broken landscape—the Owyhee Breaks.

Red Butte: The distant Red Butte (see photo) is a prominent landmark. It gets its name from the red sandstone and mudstone caprock that millions of years ago was chemically altered by hydrothermal activity (hot springs) into a several-hundred-foot-thick, red erosion-resistant rock.

The hard caprock protected the underlying lakebed sediment from erosion and preserved intact a tiny remnant of the basin floor and underlying strata. The 4,650-foot summit marks the elevation of the ancient basin floor. Red Butte has been well studied and is the subject of at least one thesis. It's about 10 miles north of the Birch Creek takeout.

SOURCES: (Swenton, et al., 2022), (Black, 2021), (Benson & Mahood, 2016), (Ely, et al., 2012), (Cummings, et al., 2000), (Ferns, et al., 1993), (Vander Meulen, et al., 1990), (Vander Meulen, 1989), (Plumley, 1986)

Glossary

Abraded boulders– rocks, typically large ones, worn down by friction with wind, water or ice.

Andesite intrusion– a body of andesite magma that did not reach the surface and solidified within existing rock layers.

Basalt lava– molten rock (lava), rich in iron, low in silica, resulting in highly fluid dark lava

Basaltic tephra– basalt volcanic debris, including ash and rock fragments, ejected during an eruption.

Chert-a hard, fine-grained rock often used by ancient people to make tools.

Fluvial deposits- deposits of sediment moved and deposited by a river or stream.

Foreset beds-inclined layers of sediment or lava deposited at the leading edge of a lava flow or a river where it enters a body of water.

Graben-a block of land that has dropped between two parallel faults, often forming a basin.

Hoodoos-tall, thin spires of rock shaped by erosion, typically topped by harder stone.

Interbedded basalt-basalt lava flows alternating with layers of other rock types in a stratified sequence.

Intrusion- magma that did not reach the surface and solidified within existing rock layers.

Ka- Abbreviation for "kilo-annum", meaning one thousand years.

Lithified- sedimentary rock or other material hardened into stone through compaction and cementation.

Ma- Abbreviation for "mega-annum", meaning one million years.

Magma-liquid or molten rock found beneath Earth's surface.

Mazama Volcano- the eruption that created Oregon's Crater Lake, depositing widespread ash.

Lava pillows-hot lava that solidifies as rounded masses when it enters water and cools rapidly.

Pyroclastic-ash, rock fragments and gases ejected explosively from a volcano.

Rhyolite lava- high-silica viscous lava that forms thick, slow-moving flows, domes, or steep-sided structures.

Rotational landslides-earth slumps that rotate as they slide downhill.

Scoria-gas-filled basaltic lava that cools rapidly, trapping the gas bubbles.

Sedimentary-rock formed when sand, mud or rock fragments or minerals in water turn to rock.

Shield volcano-a broad, gently sloping volcano built by runny lava flowing from a central vent.

Spherulites- circular mineral growths that sometimes occur in silica-rich glassy igneous rock.

Stratigraphy-the study of rock layers (strata) and their order, relative dating and position.

Strath (river)-a flat-bottomed river channel mainly carved in bedrock with thin sediment deposits.

Talus-a pile of angular rock fragments that accumulate at the base of steep rock slopes or cliffs.

Tectonic- the movement and interactions of the Earth's crust (lithospheric plates).

Bibliography of rock ages cited in book

Rock Name	Description	Age	Source	Chapter
Andesite intrusions (dikes/sills/etc)	Andesite	~10.8 to 14.3 Ma	Ferns and Evans (1993) geologic map notes	Chapter 7, 12–13
Artillery Rim lava plateau	Basalt lava	2–5 Ma	Estimate by authors	Chapter 6
Basalt of Whiskey Canyon lavas	Basalt lava	~14.3 Ma	Ferns and Evans (1993) geologic map notes	Chapter 10–11
Birch Creek cliffs	Rhyolite lava	15.3 Ma	Swenton (2022), avg of 2 samples	Chapter 13
Bogus Rim lavas	Basalt lava	1.7 to 1.9 Ma	Ely et al (2012) Table 2	Chapter 8, 9–13
Cedar Mountain lavas	Andesite lava	~11 Ma	Ferns and Evans (1993) geologic map notes	Chapter 10
Clarks Butte lava	Basalt lava	215 Ka	Ely et al (2012) Table 2	Chapter 8, 9–10
Coffeepot Crater lava, (Jordan Craters Volcanic Field)	Radiocarbon dates of underlying organic material	1,300–1,700 yrs	Mehringer (2004)	Key Events
Deer Park lavas	Basalt lava	780 Ka to ??	Ely et al (2012) Table 2	Chapter 12
Devine Canyon Tuff	Rhyolite tuff	9.68 Ma	Jenda Johnson Thesis (1995)	Chapter 7
First Rhyolite Gorge lava	Rhyolite lava	11–12 Ma	Estimate by authors	Chapter 2
Fletcher Point - lava rimrock of abandoned watercourse	Basalt lava	650 Ka	Shoemaker (2004)	Chapter 1–2
Greeley Bar flood boulder deposit	Cosmogenic	24 Ka	Othus (2008) Table 2	Chapter 12
Hells Gate (Artillery) flood boulder deposit	Cosmogenic	10 Ka	Othus (2008) Table 2	Chapter 6
Hole in the Ground - south wall	Bottom lava flow	4.49 Ma	Hart & Mertzman (1983)	Chapter 11
Hole in the Ground - south wall	Middle lava flow	4.09 Ma	Hart & Mertzman (1983)	Chapter 11
Hole in the Ground - south wall	Top lava flow	4.06 Ma	Hart & Mertzman (1983)	Chapter 11
Iron Point basalt rimrock/mesa	Basalt lava	4.99 Ma	Unpublished	Chapter 9
Little Owyhee Butte lava	Basalt lava	1.87 Ma	Bondre (2006)	Chapter 3–4
Mount Mazama tephra	Rhyodacite tuff	7.7 Ka	Egan et al (2015)	Chapter 4, 13
Owyhee Basalt lavas (avg)	Basalt lava	14.3 Ma	Ferns and Evans (1993) geologic map notes	Chapter 10
Owyhee Butte lava	Basalt lava	1.86 Ma	Bondre (2006)	Chapter 3–4
Rhyolite dome North of Iron Point	Rhyolite lava	10.57 Ma	Swenton (2022)	Chapter 2
Rome sediment beds near Arock	Tuff or ash layer	10.76 Ma	Walker et al (1974)	Chapter 1
Round Mountain lava	Basalt lava	1.7 Ma	Unpublished	Chapter 1
Sacramento Butte rhyolite	Rhyolite lava	11.85 Ma	Swenton (2022)	Chapter 2
Saddle Butte lava flow	Basalt lava	145 Ka	Ely et al (2012) Table 2	Chapter 5, 6–8
Saddle Butte rhyolite dome	Rhyolite lava	10.94 Ma	Swenton (2022)	Chapter 2
Sleeping Dragon Gorge lava (aka Iron Point rhyolite)	Rhyolite lava	11.84 Ma	Swenton (2022)	Chapter 8, 9–10
Tuff of Leslie Gulch	Rhyolite tuff	15.9 Ma	Black (2021) & Ferns et al	Chapter 12, 13–14
West Crater lava	Basalt lava	70 Ka	Ely et al (2012) Table 2	Chapter 6, 7–8
Owyhee plateau-wide extension &		~11 Ma to present	Shoemaker and Hart (2002)	

Bibliography

Aikens, C. M., 1993. *Archaeology of Oregon.* s.l.:BLM.

Aikens, C. M., Connolly, T. & Jenkins, D., 2011. *Oregon Archaeology.* s.l.:Oregon State University Press.

Aikens, M., 2022. *Dirty Shame Rockshelter.* [Online]
Available at: https://www.oregonencyclopedia.org/articles/dirty_shame_rockshelter/#.Y5aoIHbMKUk
[Accessed 11 12 2022].

Andreae, M. & Andreae, T., 2022. Archaeometric studies on rock art at four sites in the northeastern Great Basin of North America.

Barlock, et al., 1990. *Mineral Resources of the Blue Canyon and Owyhee Breaks Wilderness Study Areas, Malheur County, Oregon,* s.l.: USGS Survey Bulletin 1741-G.

Benson, L., Hattori, E., Southon, J. & Aleck, B., 2013. Dating North America's oldest petroglyphs, Winnemucca Lake subbasin, Nevada. 40(4466-4476).

Benson & Mahood, 2016. *Geology of The Mid-Miocene Rooster Comb Caldera and Lake Owhyee Volcanic Field, Eastern Oregon,* s.l.: Elesevier open-access.

Black, C. C., 2021. *Rhyolite Stratigraphy Along Succor Creek: Insights into the Eruptive History of the Three Fingers and Mahogany Mountain Volcanic Field,* s.l.: Portland State University, Thesis.

BLM and Univ of Oregon, 2023. *Testing Yields New Evidence of Human Occupation 18,000 years ago in Oregon,* s.l.: Bureau of Land Management.

BLM General Land Office Records Search, 2024. *Search Documents.* [Online]
Available at: https://glorecords.blm.gov
[Accessed Nov-Dec 2024].

Bondre, N., 2006. *Field and Geochemical Investigation of Basaltic Magmatism From the Western United States and Western India,* Oxford, OH: Miami University Dissertation.

Breitkreuz, C., 2013. Spherulites and lithophysae - 200 years of investigation on high-temperature crystallization domains in silica-rich volcanic rocks. *Springer,* 3 April, Volume Bull Volcano (2013) 75:705, p. 16.

Breitkreuz, C., Gotze, J. & Weibmantel, A., 2021. Mineralogical and geochemical investigation of megasphurlites from Argentina, Germany, and the USA. *Bulletin of Volcanology (2021) 83:14,* 19 February.p. 15.

Brossy, C., 2006. *Fluvial Response to Intra-Canyon Lava Flows, Owhyee River, SouthEastern Oregon,* s.l.: Central Washington University, Thesis.

Campion, K., 1979. *PhD Dissertation "Diagenetic Alteration and Formation of Authigenic Minerals in the Miocene "Rome Beds" SE Oregon".,* s.l.: Ohio State Univ.

Camp, V. & Wells, R., 2021. The Case for a Long-Lived and Robust Yellowstone Hotspot. v. 31(No. 1 January 2021).

Carter, D., Ely, L., O'Connor, J. & Fenton, C., 2005. Late Pleistonce outburst flooding from pluvial Lake Alvord into the Owyhee River, Oregon. Geomorphology 75 (2006) 346-367(doi:10.1016/j.geomorph.2005.07.023).

Cas, R. & Wright, J., 1992. *Volcanic Successions Modern and Ancient.* London: Chapman & Hall.

Cole, C. R., 2001. *Raw Material Sources and the Prehistoric Chipped-Stone Assemblage of the Birch Creek Site (35ML181) Southeastern Oregon,* s.l.: Washington State University, Thesis.

Cressman, L. S., 1937. *Petroglyphs of Oregon.* s.l.:University of Oregon.

Crowell, B., 2022. *Davis Ranch At Hole In The Ground.* [Online]
Available at: https://www.zhuangzismuddytail.com/owyheemarginalia/ranch-at-hole-in-the-ground.html
[Accessed 10 12 2022].

Cummings, Evans, Ferns & Lees, 2000. Stratigraphic and Structural Evolution of the Middle Miocene Synvolcanic Oregon-Idaho Graben. Bulletin Vol 112(No 5, p 668-682).

Davis, e. a., 2019. Late Upper Paleolithic occupation at Cooper's Ferry, Idaho, USA, 16,000 years ago. 365(891).

Egan, J., Staff, R. A. & Blackford, J. J., 2015. A high-precision age estimate of the Holocene Plinian eruption of Mount Mazama, Oregon USA. *ResearchGate*.

Ellison, B., 1968. *Thesis. "Stratigraphy of the Burns Junction - Rome Area, Malheur County, Oregon.",* s.l.: Oregon State Univ.

Ely, et al., 2012. Owhyee River intracanyon lava flows: Does the river give a dam?. Bulletin Published Online(doi: 10.1130/B30274.1).

Evans, C. S., 1986. *The Geology, Geochemistry, and Alteration of Red Butte, Oregon: A Precious Metal-Bearing Paleo Hot Spring System,* Portland, OR: Portland State University.

Evans, J., 1991. Geologic Map of the Lower Owyhee Canyon Wilderness Study Area, Malheur County, Oregon. Volume Misc Field Studies Map MF-2167.

Evans, Turner, Griscom & Sawatzky, 1990. Mineral Resources of the Lower Owyhee Canyon Wilderness Study Area, Malheur County, Oregon. Volume USGS Survey Bulletin 1741-F.

Ferns, Evans & Cummings, 1993. *Geologic Map of the Mahogany Mountain 30x60 Quadrangle, Malheur Co, Oregon, and Owhyee Co, Idaho,* s.l.: Oregon Dept of Geology and Mineral Industries, Map Series 78.

Ferns, M. & Evans, J., 1993. *Preliminary Geologic Map of the Rinehart Quadrangle Malheur County Oregon,* s.l.: ODGMI.

Ferns, M., Streck, M. & McClaughry, J., 2017. Field-Trip Guide to Columbia Flood Basalts, Associated Rhyolites, and Diverse Post-Plume Volcanism in Eastern Oregon.

Fisher, P. R., 2010. *Points In Time: Stone Tool Analysis As An Indication of Group Movement At the Birch Creek Site (35ML181), Southeastern Oregon,* s.l.: Washington State University Thesis.

Fretwell-Johnson, H., 1990. *In Times Past, A History of the Lower Jordan Creek Communities.* s.l.:s.n.

Godchaux, M. & Bonnichsen, B., 2002. Syneruptive Magma-Water and Posteruptive Lava-Water Interactions in the Western Snake River Plain, Idaho, During the Past 12 Million Years. *Tectonic and Magmatic Evolution of the Snake River Plain Volcanic Province: Idaho,* Volume Bulletin 30.

Hart & Mertzman, 1983. "Late Cenozoic volcanic stratigraphy of the Jordan Valley area, southeastern Oregon.". Vol 45(No 2 Feb 1983).

Highland, L., 2004. *Landslide Types and Processes (Fact Sheet 2004-3072),* s.l.: USGS.

Kaestle, F. & Smith, G., 2001. Ancient Mitchondrial DNA Evidence for Prehistoric Population Movement: The Numic Expansion. Volume 115:1-12.

Kittleman, L., 1973. *Guide to the Geology of the Owyhee Region of Oregon,* Eugene, OR: University of Oregon.

Loring, J. M. & Loring, L., 1996. *Pictographs & Petroglyphs of the Oregon Country.* s.l.:Institute of Archaeology, University of California, Los Angles.

Lyons, Glascock & Mehringer, 2003. *Silica from sources to site: ultraviolet fluorescence and trace elements identify cherts from Lost Dune, southeastern Oregon, USA,* s.l.: Journal of Archaeological Science, 30 (2003) 1139-1159.

Markley, C., 2013. *Characterization Mass Wasting Through The Spectral Analysis of LiDAR Imagery: Owhyee River, Southeastern Oregon,* s.l.: Central Washington University, Graduate Thesis MS Geology.

Mehringer, P., 2004. *Radiocarbon dates and microfossil analyses: Upper Cow Lake, Oregon. Progress Report 2 for BLM, Vale District, Oregon.,* s.l.: Secrets of the Past Consulting.

National Register of Historic Places, 1997. *Birch Creek Ranch Historic Rural Landscape,* s.l.: National Park Service Online Database.

Nevada Rock Art Foundation, 2015. *Exploring Great Basin Archaeology,* s.l.: Nevada Rock Art Foundation.

Noll, C. D., 2009. *Last Holocene Occupation of the Birch Creek Site (35ML181), Southeastern Oregon,* s.l.: Washington State University, Thesis.

Oregon Museum of Nat History, U. o. O., 2022. *Dirty Shame Rockshelter.* [Online]
Available at: https://uoregonnaturalhistory.pastperfectonline.com/bysitenumber?keyword=35ML65
[Accessed 11 12 2022].

Orem, C., 2010. *Lacustrin Sediment Record of Multiple Quaternary Lava Dams on The Owhyee River, Southeastern Oregon,* s.l.: Central Washington University, Thesis.

Orr, 1985. *Rivers of the West.* s.l.:Self Published.

Othus, S., 2008. *Comparison of Landslides and Their Related Outburst Flood Deposits, Owyhee River, Southeastern Oregon,* s.l.: Central Washington University, Thesis.

Personius, S. et al., 2007. Late Quaternary Paleoseismology of the Southern Steens Fault Zone, Northern Nevada. 97(No. 5, PP. 1662-1678, October 2007).

Plumley, P. S., 1986. *Volcanic Stratigraphy and Geochemistry of The Hole In The Ground Area, Owhyee Plateau, Southeastern Oregon,* s.l.: University of Idaho, Thesis.

Sheppard & Gude, 1987. "Field trip guide to the Sheaville and Rome zeolite deposits, southeastern Oregon".. 49(No 1 Jan 1987).

Shervais, J., Schmitt, D. & et al, 2013. First Results from HOTSPOT: The Snake River Plain Scientific Drilling Project, Idaho, U.S.A.. Issue March 2013.

Shock, M., 2002. *Rock art and settlement in the Owyhee uplands of southeastern Oregon.,* s.l.: University of Pittsburg, Thesis.

Shoemaker, K. A., 2004. *The Tectonomagmatic Evolution of the Late Cenozic Owyhee Plateau, Northwestern United States,* s.l.: Miami University, Oxford Ohio.

Skilling, I. P., White, J. D. & McPhie, J., 2002. Peperite: a review of magma-sediment mingling. *Journal of volcanology and geothermal research,* Issue 114 (2002) 1-17.

Skinner, 2025. *Skinner Family Northwest (Blog).* [Online]
Available at: http://www.skinnerfamilynw.org/
[Accessed 20 Feb 2025].

Staisch, L. et al., 2022. Major reorganization of the Snake River modulated by passage of the Yellowstone Hotspot. *GSA,* July/Aug.134(no. 7/8).

Swenton, V. M., Streck, M., Miggins, D. & McIntosh, W., 2022. Filling critical gaps in the space-time record of High Lava Plains and co-Columbia River Basalt Group rhyolite volcanism. Volume GSA Bulletin.

Vander Meulen, D., 1989. *Intracaldera Tuffs and Central-Vent Intrusion of the Mahogany Mountain Caldera, Eastern Oregon,* s.l.: USGS.

Vander Meulen, D. B. et al., 1990. *Mineral Resources of the Blue Canyon and Owyhee Breaks Wilderness Areas, Malheur County, Oregon,* s.l.: US Geological Survey Open-File Report 90-0517.

Walker, G., Darlrymple, G. & Lamphere, M., 1974. *Potassium-Argon Ages of Cenozoic Volcanic Rocks of Oregon: Misc Field Studies Map MF-569.* s.l.:USGS.

Walker & Repenning, 1966. Reconnaissance Geologic Map of The West Half of the Jordan Valley Quadrangle, Malheur Co., Oregon. Issue Misc Geological Investigations: Map I-457.

Willsey, S., 2017. *Geology Underfoot in Southern Idaho.* Missoula, MT: Mountain Press Publishing Company.

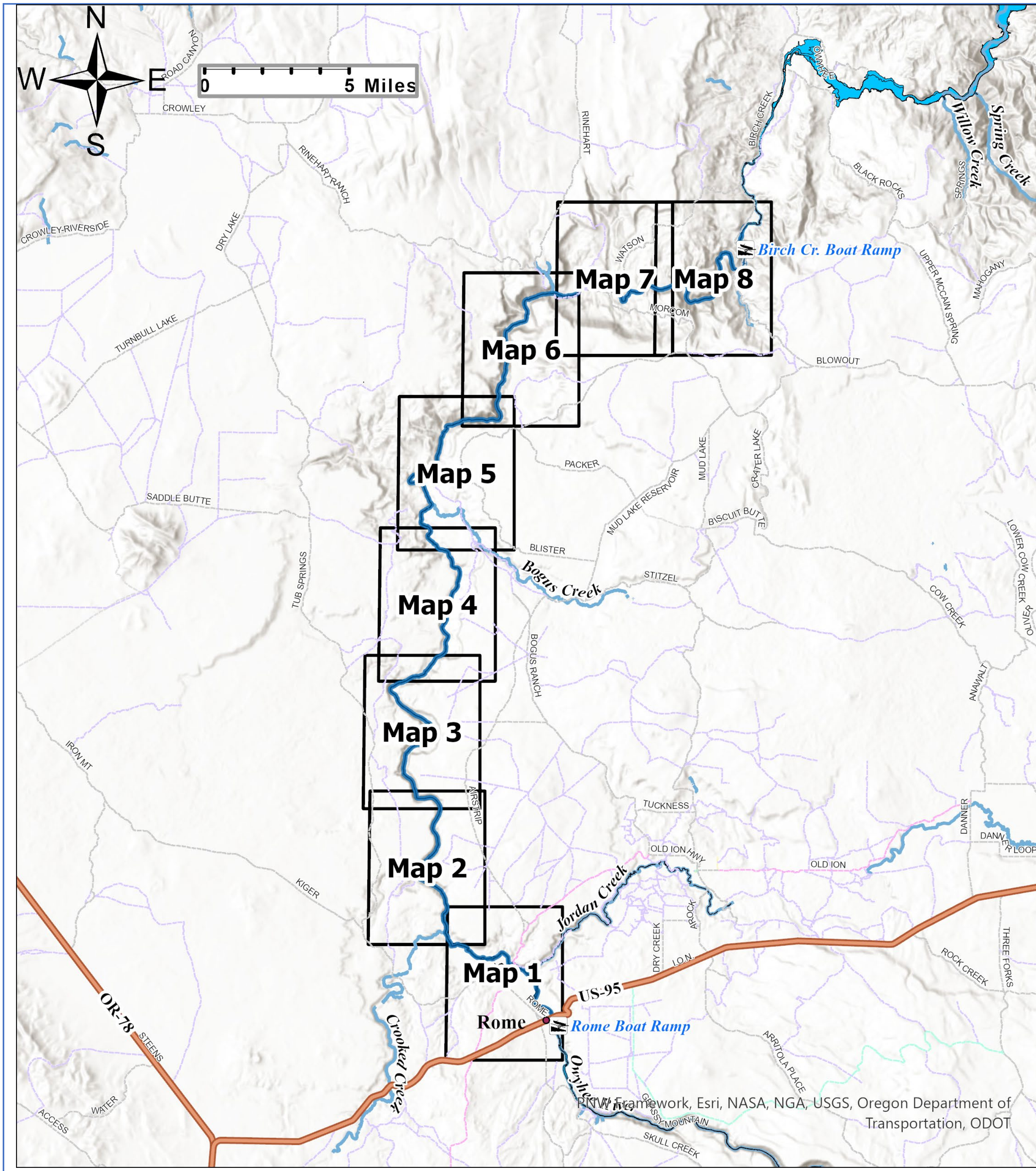
Wilson, J. K., 2007. *Curation and Lithic Technological Organizational Studies on the Owyhee River: A Case Study of the Chalk Basin Site (35ML143), Malheur County, Oregon,* s.l.: Washington State University, Department of Anthropology.

Wolf, K. & Ellison, B., 1971. Sedimentary Geology of the Zeolitic Volcanic Lacustrine Pliocene Rome Beds, Oregon. *Sedimentary Geology,* pp. 271-302.

Wood, S. & Clemens, D., 2002. Geologic and Tectonic History of the Western Snake River Plain, Idaho and Oregon. Volume 30.

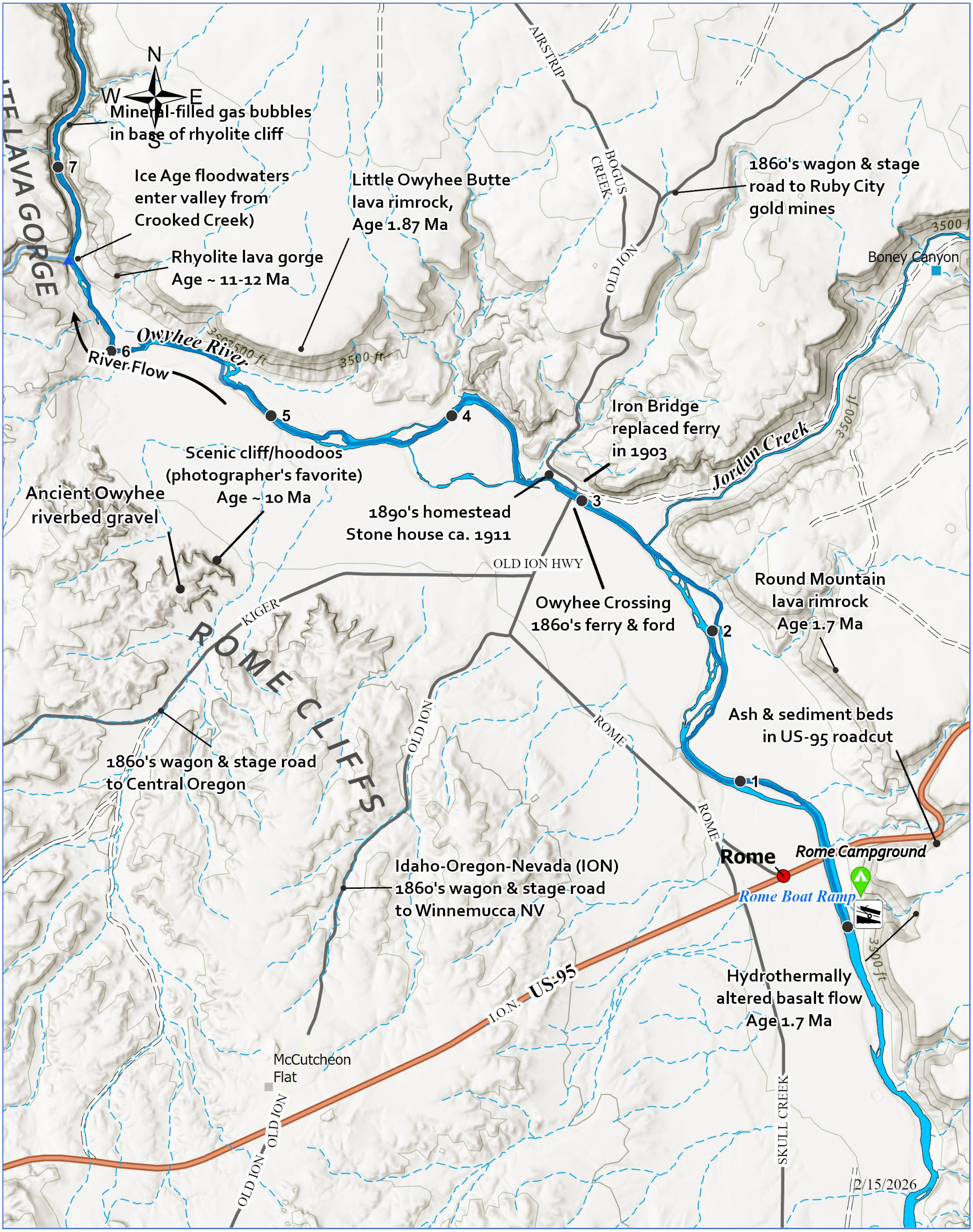
Boating Guide Maps 1–8

The following comprehensive guide maps are for use on the river.

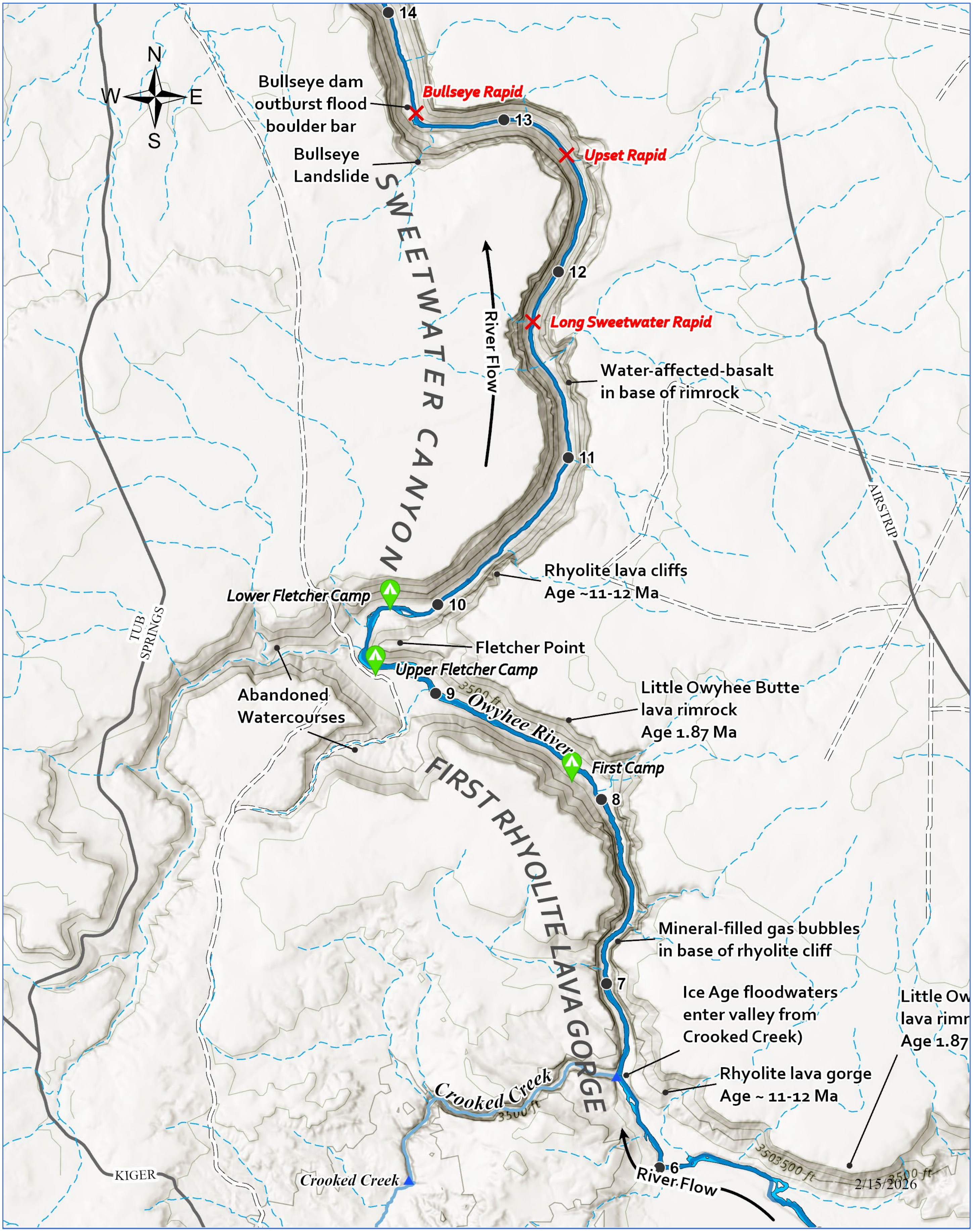


Boating Guide Maps 1–8

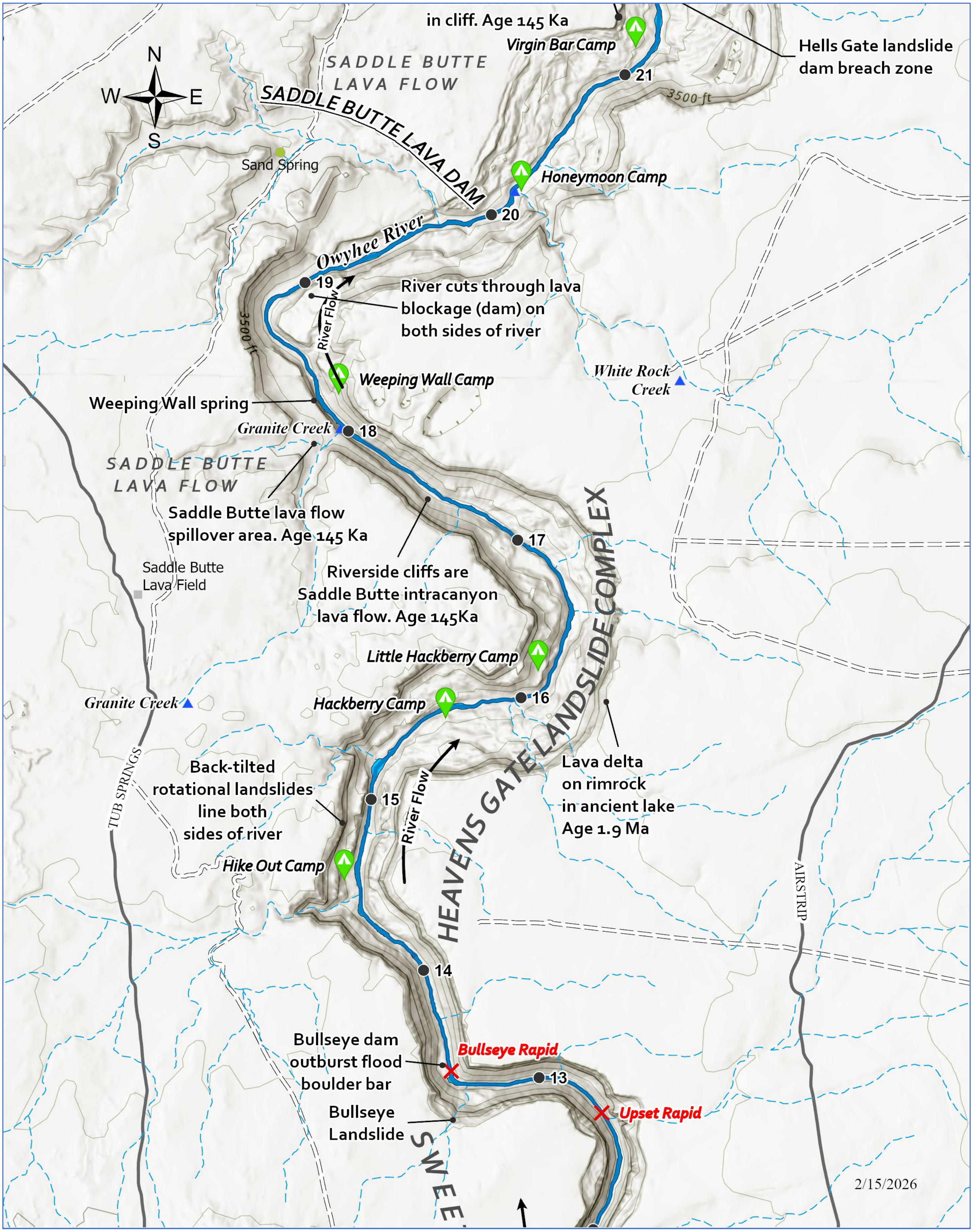
Map 1



Map 2

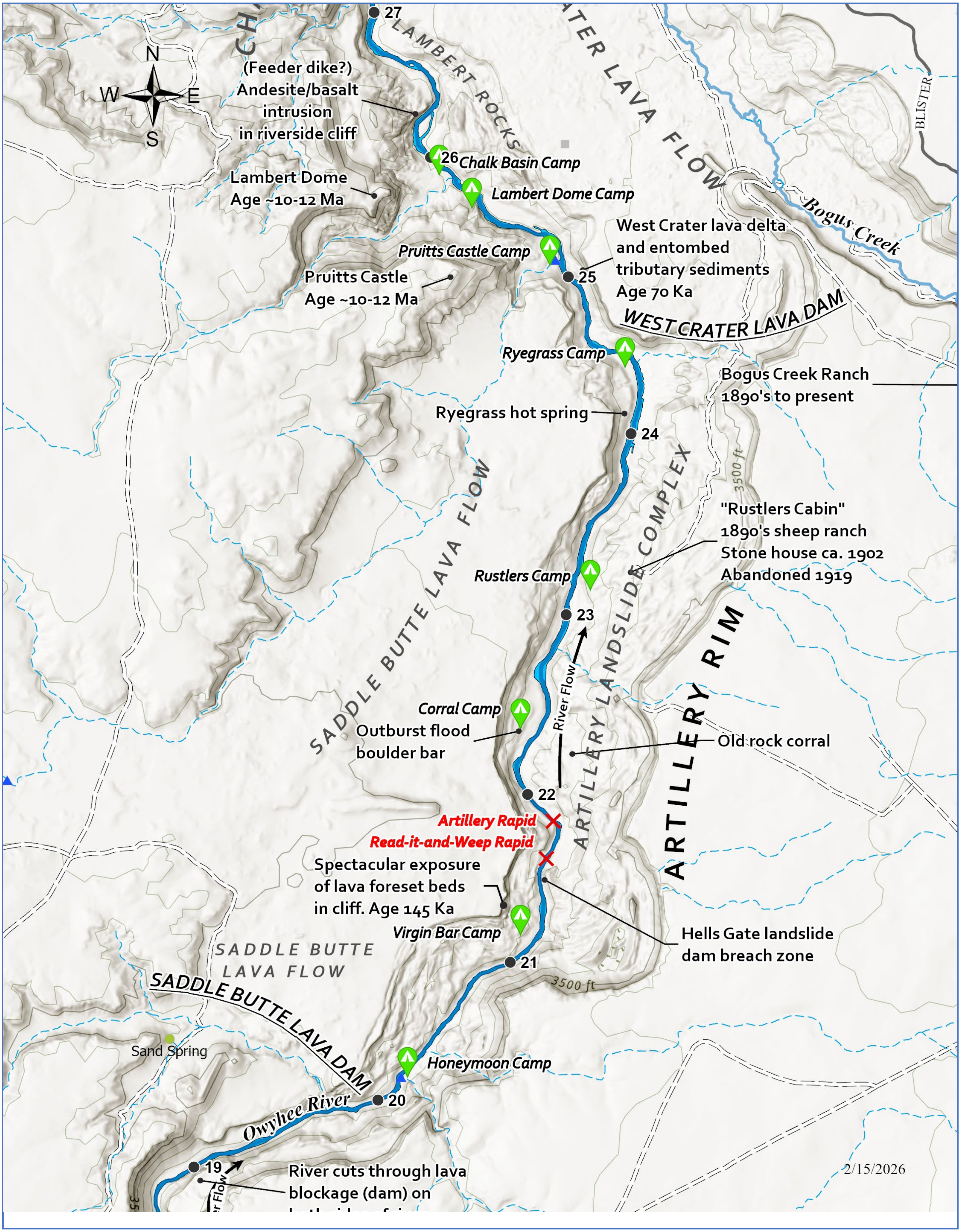

N
W
E
S
14
Bullseye dam
outburst flood
boulder bar
Bullseye Rapid
13
Upset Rapid
Bullseye
Landslide
SWEETWATER CANYON
River Flow
12
Long Sweetwater Rapid
Water-affected-basalt
in base of rimrock
11
Rhyolite lava cliffs
Age ~11-12 Ma
Lower Fletcher Camp
10
Fletcher Point
Upper Fletcher Camp
TUB SPRINGS
AIRSTRIP
Abandoned
Watercourses
9
Owyhee River
Little Owyhee Butte
lava rimrock
Age 1.87 Ma
First Camp
FIRST RHYOLITE LAVA GORGE
8
Mineral-filled gas bubbles
in base of rhyolite cliff
7
Ice Age floodwaters
enter valley from
Crooked Creek)
Little Ow
lava rimr
Age 1.87
Rhyolite lava gorge
Age ~ 11-12 Ma
Crooked Creek
3500 ft
6
River Flow
KIGER
Crooked Creek
2/15/2026

Map 3

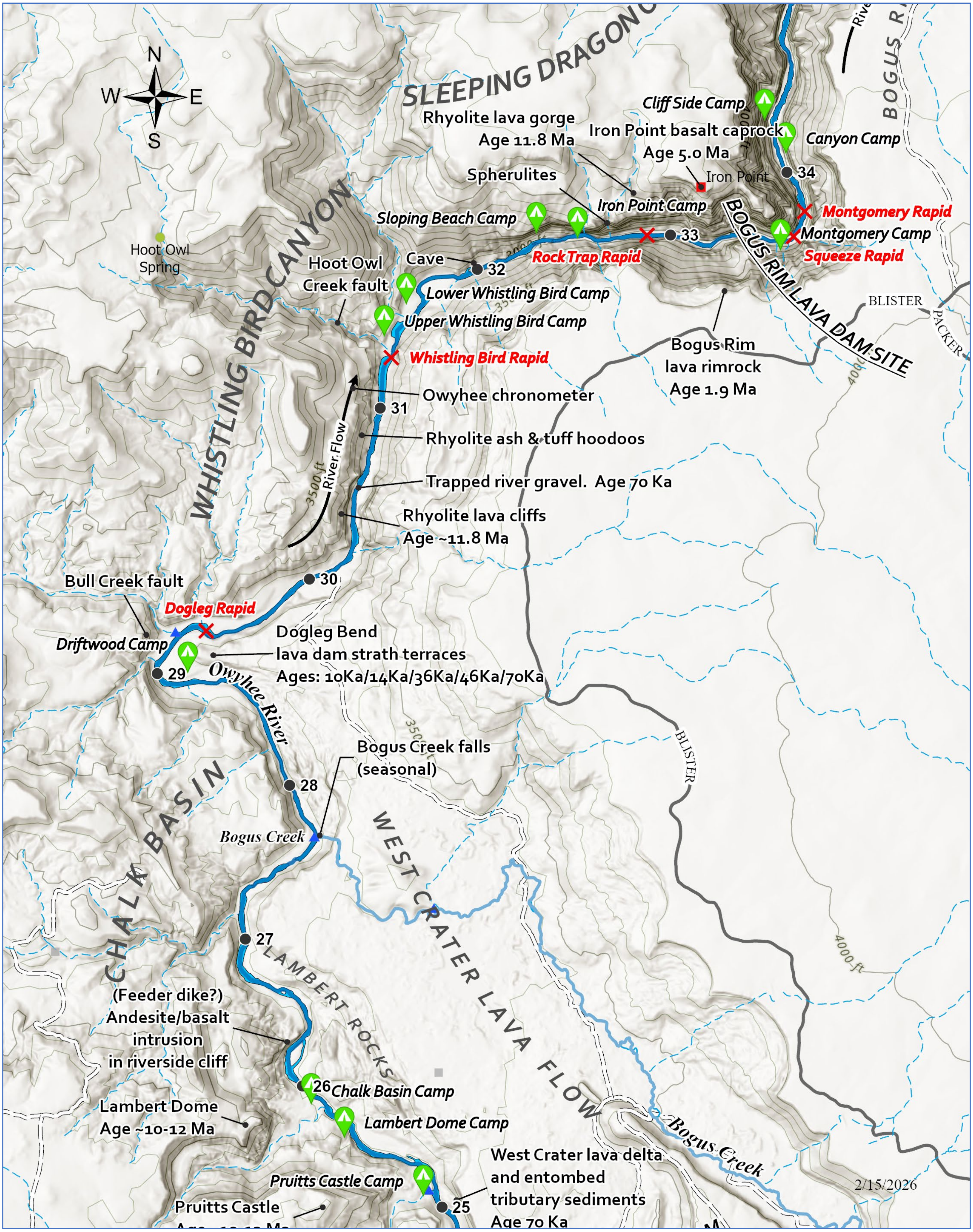


N
W
E
S
in cliff. Age 145 Ka
Virgin Bar Camp
Hells Gate landslide dam breach zone
21
3500 ft
SADDLE BUTTE LAVA FLOW
SADDLE BUTTE LAVA DAM
Sand Spring
Honeymoon Camp
20
Owyhee River
19
River Flow
River cuts through lava blockage (dam) on both sides of river
3500 ft
Weeping Wall Camp
White Rock Creek
Weeping Wall spring
Granite Creek
18
SADDLE BUTTE LAVA FLOW
Saddle Butte lava flow spillover area. Age 145 Ka
17
Saddle Butte Lava Field
Riverside cliffs are Saddle Butte intracanyon lava flow. Age 145Ka
HEAVENS GATE LANDSLIDE COMPLEX
Little Hackberry Camp
Granite Creek
Hackberry Camp
16
Back-tilted rotational landslides line both sides of river
15
River Flow
Lava delta on rimrock in ancient lake Age 1.9 Ma
TUB SPRINGS
Hike Out Camp
AIRSTRIP
14
Bullseye dam outburst flood boulder bar
Bullseye Rapid
13
Upset Rapid
Bullseye Landslide
SWEE
2/15/2026

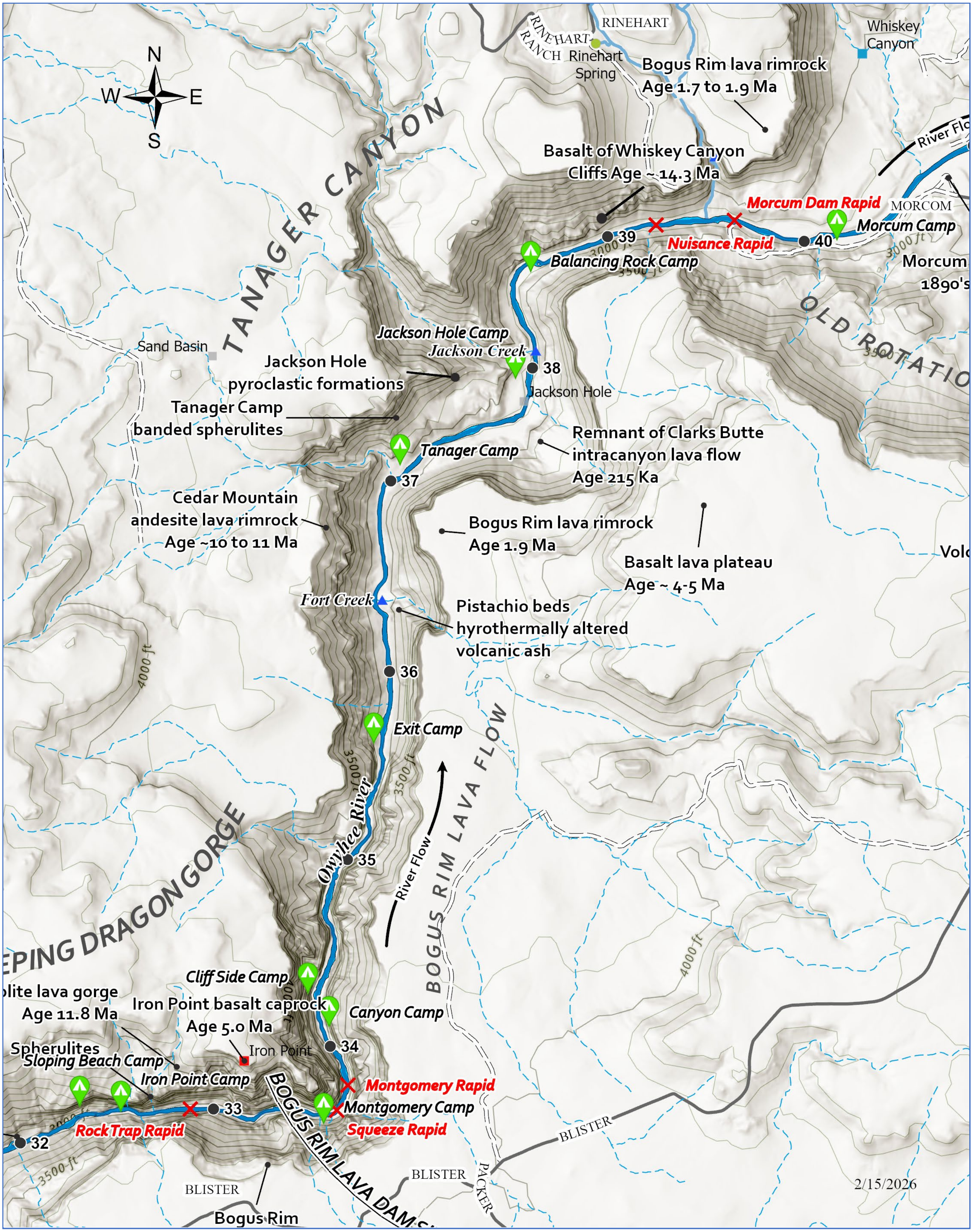
Map 4


27
LAMBERT ROCKS
WEST CRATER LAVA FLOW
N
W
E
S
(Feeder dike?)
Andesite/basalt
intrusion
in riverside cliff
BLISTER
26 Chalk Basin Camp
Lambert Dome
Age ~10-12 Ma
Lambert Dome Camp
Bogus Creek
West Crater lava delta
and entombed
tributary sediments
Age 70 Ka
Pruitts Castle Camp
Pruitts Castle
Age ~10-12 Ma
25
WEST CRATER LAVA DAM
Ryegrass Camp
Bogus Creek Ranch
1890's to present
Ryegrass hot spring
24
3500 ft
SADDLE BUTTE LAVA FLOW
ARTILLERY LANDSLIDE COMPLEX
"Rustlers Cabin"
1890's sheep ranch
Stone house ca. 1902
Abandoned 1919
Rustlers Camp
23
River Flow
ARTILLERY RIM
Corral Camp
Outburst flood
boulder bar
Old rock corral
22
Artillery Rapid
Read-it-and-Weep Rapid
Spectacular exposure
of lava foreset beds
in cliff. Age 145 Ka
Virgin Bar Camp
Hells Gate landslide
dam breach zone
SADDLE BUTTE
LAVA FLOW
21
3500 ft
SADDLE BUTTE LAVA DAM
Sand Spring
Honeymoon Camp
20
Owyhee River
19
River cuts through lava
blockage (dam) on
2/15/2026

Map 5

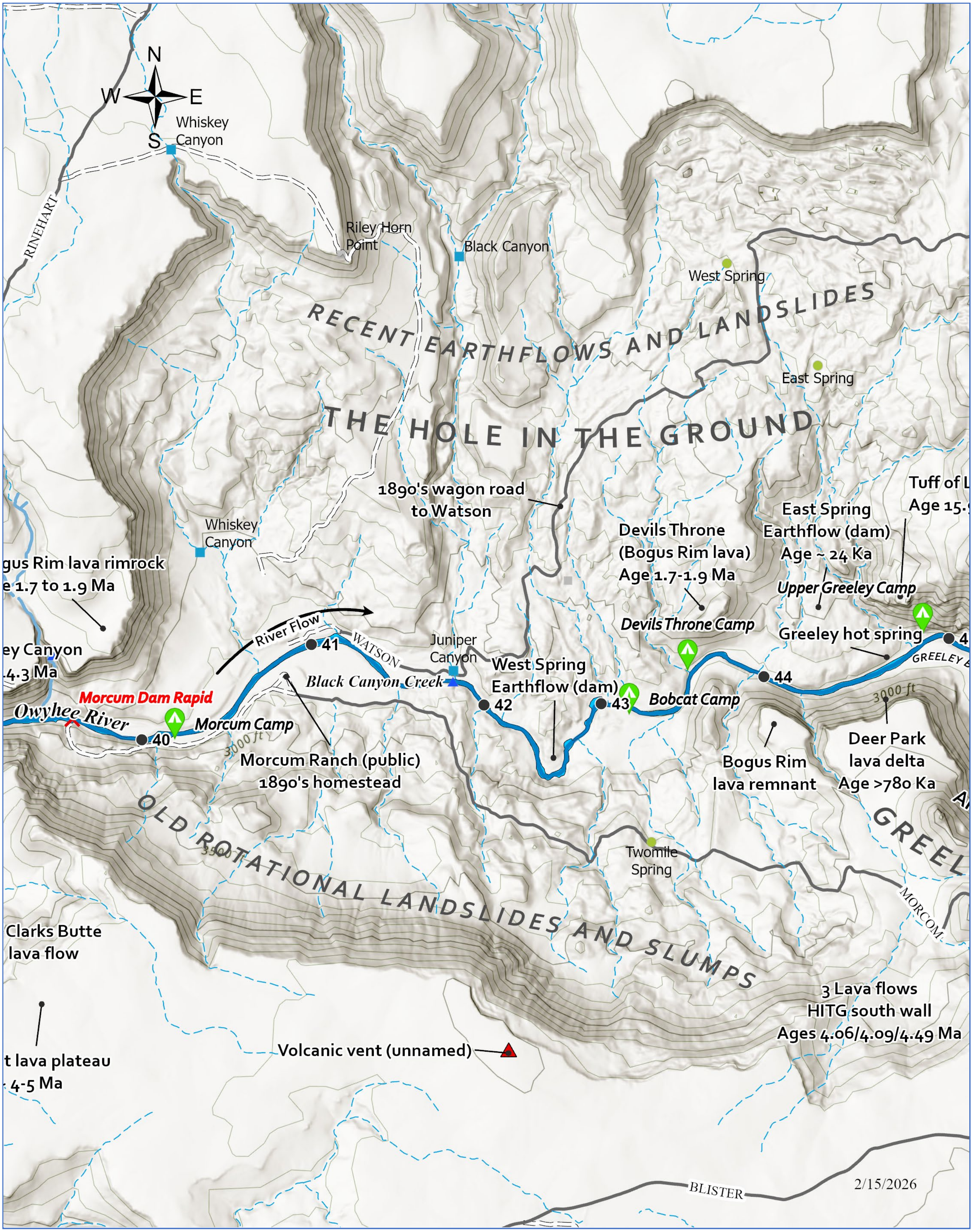

N
W
E
S
SLEEPING DRAGON
WHISTLING BIRD CANYON
Hoot Owl Spring
Rhyolite lava gorge
Age 11.8 Ma
Iron Point basalt caprock
Age 5.0 Ma
Iron Point
Cliff Side Camp
Canyon Camp
34
BOGUS RIM
Spherulites
Iron Point Camp
Sloping Beach Camp
Montgomery Rapid
Montgomery Camp
Squeeze Rapid
33
Rock Trap Rapid
BOGUS RIM LAVA DAM SITE
Cave
32
Hoot Owl
Creek fault
Lower Whistling Bird Camp
Upper Whistling Bird Camp
BLISTER
PACKER
Bogus Rim
lava rimrock
Age 1.9 Ma
Whistling Bird Rapid
Owyhee chronometer
31
Rhyolite ash & tuff hoodoos
River Flow
3500 ft
Trapped river gravel. Age 70 Ka
Rhyolite lava cliffs
Age ~11.8 Ma
30
Bull Creek fault
Dogleg Rapid
Driftwood Camp
Dogleg Bend
lava dam strath terraces
Ages: 10Ka/14Ka/36Ka/46Ka/70Ka
29
Owyhee River
BLISTER
Bogus Creek falls
(seasonal)
28
CHALK BASIN
Bogus Creek
WEST CRATER LAVA FLOW
27
LAMBERT ROCKS
4000 ft
(Feeder dike?)
Andesite/basalt
intrusion
in riverside cliff
26
Chalk Basin Camp
Lambert Dome
Age ~10-12 Ma
Lambert Dome Camp
Bogus Creek
West Crater lava delta
and entombed
tributary sediments
Age 70 Ka
Pruitts Castle Camp
Pruitts Castle
25
2/15/2026

Map 6



RINEHART
RINEHART RANCH
Rinehart Spring
Whiskey Canyon
Bogus Rim lava rimrock
Age 1.7 to 1.9 Ma
Basalt of Whiskey Canyon
Cliffs Age ~14.3 Ma
River Flow
Morcum Dam Rapid
MORCOM
Morcum Camp
Nuisance Rapid
39
40
Balancing Rock Camp
TANAGER CANYON
OLD ROTATIO
Sand Basin
Jackson Hole Camp
Jackson Creek
38
Jackson Hole
Jackson Hole
pyroclastic formations
Tanager Camp
banded spherulites
Tanager Camp
Remnant of Clarks Butte
intracanyon lava flow
Age 215 Ka
37
Cedar Mountain
andesite lava rimrock
Age ~10 to 11 Ma
Bogus Rim lava rimrock
Age 1.9 Ma
Basalt lava plateau
Age ~ 4-5 Ma
Fort Creek
Pistachio beds
hyrothermally altered
volcanic ash
36
Exit Camp
Owyhee River
35
River Flow
BOGUS RIM LAVA FLOW
EPING DRAGON GORGE
Cliff Side Camp
Canyon Camp
olite lava gorge
Age 11.8 Ma
Iron Point basalt caprock
Age 5.0 Ma
Iron Point
34
Spherulites
Sloping Beach Camp
Iron Point Camp
Montgomery Rapid
Montgomery Camp
Squeeze Rapid
33
32
Rock Trap Rapid
BOGUS RIM LAVA DAMS
BLISTER
PACKER
Bogus Rim
2/15/2026

Map 7


N
W
E
S
Whiskey Canyon
RINEHART
Riley Horn Point
Black Canyon
West Spring
RECENT EARTHFLOWS AND LANDSLIDES
East Spring
THE HOLE IN THE GROUND
1890's wagon road to Watson
Tuff of L
Age 15.
East Spring Earthflow (dam) Age ~ 24 Ka
Devils Throne (Bogus Rim lava) Age 1.7-1.9 Ma
Whiskey Canyon
gus Rim lava rimrock
e 1.7 to 1.9 Ma
Upper Greeley Camp
Devils Throne Camp
River Flow
41
WATSON
Juniper Canyon
Greeley hot spring
GREELEY
ey Canyon
4.3 Ma
Black Canyon Creek
West Spring Earthflow (dam)
44
Morcum Dam Rapid
42
43
Bobcat Camp
3000 ft
Owyhee River
Morcum Camp
40
3000 ft
Morcum Ranch (public) 1890's homestead
Bogus Rim lava remnant
Deer Park lava delta Age >780 Ka
OLD ROTATIONAL LANDSLIDES AND SLUMPS
3500
Twomile Spring
GREEL
MORCOM
Clarks Butte lava flow
3 Lava flows HITG south wall Ages 4.06/4.09/4.49 Ma
Volcanic vent (unnamed)
t lava plateau
4-5 Ma
BLISTER
2/15/2026

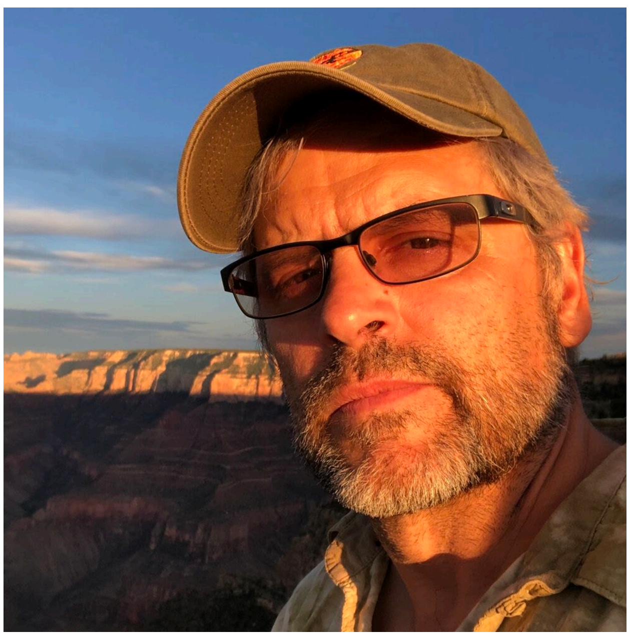
Map 8


N
W
E
S
WATSON
THE OWYHEE BREAKS
Basque Camp
Owyhee River
River Flow
West Spring
LANDSLIDES
East Spring
ROUND
3000 ft
Bogus Rim lava mesa
Age 1.7-1.9 Ma
51
Birch Creek Campground
Rhyolite lava cliffs
Age 15.3 Ma
The Painted Hill
Rhyolite lava cliffs
Age 15.3 Ma
Birch Cr. Boat Ramp
Pothole Camp
50
Historic
waterwheel
49
48
Archeological site
7,600 yrs old
Tuff of Leslie Gulch
Age 15.9 Ma
East Spring
Earthflow (dam)
Age ~ 24 Ka
Tuff of Leslie Gulch
Age 15.9 Ma
Lava Castle
Age 1.7-1.9 Ma
Birch
Creek
Rhyolite
column
BIRCH CREEK RANCH
Upper Greeley Camp
Greeley hot spring
45
Middle Greeley Camp
GREELEY BAR
44
Lower Greeley Camp
47
3500 ft
Deer Park
lava delta
Age >780 Ka
Bogus Rim
lava remnant
46
Ancient Owyhee
riverbed gravel
Age ~1.9 Ma
DEER PARK LAVA DAM
Andesite intrusion
GREELEY CANYON
Birch Creek
Birch Creek
Road viewpoint
MORCOM
BIRCH CREEK
DEER PARK LAVA FLOW
3 Lava flows
HITG south wall
Ages 4.06/4.09/4.49 Ma
BLISTER
Volcanic vents (unnamed)
2/15/2026

The Authors

Kyle House is a professional geologist who has conducted research in the Owyhee Canyon since the early 2000s and leads geology raft trips down the river. Ken Giles (retired) is an enthusiastic amateur geologist who has been rafting the Owyhee River and studying its geology since the early 1970s.

The authors fell in love with the Owyhee River years ago and have long wanted to write a guide explaining its unique geology. They teamed up in 2021 and spent four field seasons researching and writing this book.



Kyle House

Ken Giles