On Trail

Special Feature »

Exploring Washington's Geology

In this feature, we'll help you interpret the landscapes you hike through. Learn a little bit about geology, and you'll realize that every rock can tell a story. Prepare to have your sense of time and scale stretched. The geologic events that have led Washington to look the way it does now have been a long time in the making.

A Grand Geologic Tour

Colorful columnar basalt in Moses Coulee

In the 18th century, young aristocrats would embark on what came to be known as "The Grand Tour" of the major sights of Europe. In that spirit, we'd like to take you on a Grand Tour of Washington, a natural and geological wonderland composed of "physiographic provinces," landscapes that are distinct from one another, with unique landforms, plants, soils and climate in each.

As a hiker with boots on the ground, you can appreciate how geological forces created what you see as you explore. And, as there is still so much that is not fully understood or adequately explained, you can speculate next time you go out for a hike and see interesting shapes to the land or rocks underfoot.

Before we embark, let's spend a few minutes on the "big picture." One thing that makes Washington both geologically interesting and great for hiking and scenery is the fact that the ice age was so recent (relatively speaking, of course). Our state was right at the edge of the action as the ice was advancing and retreating. All that ice had a dramatic effect, especially near the Canadian border and on the high peaks in the South Cascades. A vast sheet of ice repeatedly flowed south out of Canada to scour out the Strait of Juan de Fuca and Puget Sound. Near where the ice sheet finally ended, three huge lobes of ice followed the lowlands between the mountain ranges, carved out wide basins, and left behind hills and valleys of glacial drift, loose and unsorted rock debris scattered by glaciers and glacial meltwaters. The Puget Lobe formed Puget Sound and the surrounding lowland between the Olympics and Cascades, while the Okanogan and Pend Oreille lobes had similar effects in valleys east of the Cascades. The Cascade and Olympic Mountains were also covered by their own ice caps that formed as glaciers came together and grew to fill valleys. These ice caps radiated from the high peaks and carved out the "alpine" scenery we find so picturesque, including horn-shaped peaks and broad U-shaped valleys.

All right, ready to go?

SPECIAL THANKS to Annaliese Eipert, Phil Fenner, Lee Whitford, "Hig" Higman, Eli Boschetto, Scott Babcock, Bob Carson and the Ice Age Floods Institute for their help with this feature.

MORE GEOLOGY COMING SOON!

Next Issue >> VOLCANOES and GLACIERS

Above: Orcas Island is made of some of the older rocks in Puget Sound. Photo by Doug Diekema.

Center: Hiker en route to Sahale Arm. These spiky peaks are typical of the North Cascades, caused by resistant rock and intense glaciation. Photo by Scott Means.

By starting in the northwest, with our backs to the Pacific Ocean, we'll come first to the Olympic Peninsula, with miles of coastline surrounding the **Olympic Mountains**, which rise to almost 8,000 feet, encompass about 60 small glaciers, and are home to some of the world's densest temperate rain forest. The rocks here form tilted wedges as bits and pieces of sea floor piled up against the continent. Look for "pillow lavas" on the pennisula. These pillow-like structures formed from magma erupting underwater, in this case far out under the Pacific, and plate movement gradually carried them to where they are today. Too bad they can't double as camp cushions! More seafloor scrapings piled up here, including sandstone that also started out far out in the ocean. You won't find fresh volcanoes like Mount Rainier in the Olympics because the subducting oceanic crust underneath is not at great enough depth. *(See graphic on page 22)*.

South of the Olympics, the **Chehalis River** flows through a vastly oversized valley, one that carried an ice-age super-river formed from all the rivers of the east Olympics and west Cascades and the meltwater from the Puget Lobe itself out to Grays Harbor, until the ice receded northward past the Strait of Juan de Fuca and Puget Sound filled with salt water.

Just south of the Chehalis River, you'll find the **Willapa Hills**, an area of lower, rolling topography. The area is underlaid by submarine basalt flows and sediments, then a huge flow of the same basalt that is found in central Washington invaded from the vicinity of today's Blue Mountains. Since then, the area has been eroded gradually by streams and rivers and has escaped glaciation.

Head back north and east and you'll reach the **Puget Lowland**, with Puget Sound at its center. Now the urban center of the state, it was once covered by a sheet of ice about five times thicker than the height of Seattle's Space Needle. The lobe of the continental ice sheet that flowed south from Canada during the last ice age went further south here in Puget Sound than anywhere else in the state. Deepening the basin, it created an inland arm of the sea, interspersed with islands and channels. Have you noticed that these channels and islands are generally longer in the north-south direction? That is the direction the ice lobe followed in its advance and retreat. The **San Juan Islands** in the northern Sound are made of much older rocks than those found in the south Sound.

The **Cascade Range** divides the state from north to south. The **North Cascades** are made of older rocks exposed by intense uplift. Large portions are pieces of oceanic crust and island arcs known as "exotic terranes," rafted-in by subduction of the Kula plate and piled up here. Think of it as a sort of "terrane-wreck"—a huge pile of debris that can be hard to sort out. If you're interested in geology, the North Cascades have some of the most complicated geology anywhere, with two volcanoes (Mount Baker and Glacier Peak) over 10,000 feet to boot. The northern mountains were uplifted more, exposing their crystalline core of more resistant rocks, then they were more severely glaciated in the ice age than the southern Cascades—a formula for spectacular scenery. Many peaks in the North Cascades are still glaciated, adding to their scenic beauty.

Phil Fenner

Phil is an amateur naturalist and a WTA member. He majored in history and geology at Whitman College.

Younger, more easily eroded volcanic and sedimentary rocks are exposed at the surface of the **South Cascades.** Here, the range was not uplifted as much as in the north, so the overlying mantle of these less-resistant rocks remains. Many of the sedimentary rocks here came from volcanic mudflows and erosion of other volcanic rocks. The South Cascades volcanoes are the highest in the range, with Mount Rainier topping out at 14,410 feet and Mount Adams at 12,276 feet. The only Washington volcano to erupt recently, Mount St. Helens, is found here as well.

It would be hard to imagine how the lands east of the Cascades could look more different, as we leave steep, wet and forested for arid, flat and rolling. Dominating the central part of the state, the **Columbia Plateau** was formed by vast lava flows, known as the Columbia River basalts, which primarily erupted between 16 million and 13 million years ago. The land is flat and barren, interrupted by river gorges and long, folded hills and valleys. Some of the largest floods to have ever taken place on earth happened here near the end of the last ice age, carving out huge canyons in the basalt as they repeatedly roared through after an ice dam periodically broke in northern Idaho. *(Read more about the unflatteringly named Channeled Scablands on page 25.)* With the Cascades holding back moist air masses from the Pacific, the dry side often beckons to hikers and those who hike here find a spectacular landscape and ecosystem.

The northeast portion of the state is geologically an extension of the Rocky Mountains and the Intermontane Superterrane known as the **Okanogan Highlands**. It is high, rugged country that was mostly covered by the continental ice sheet. Remote, lonely pathways await the few hikers who venture here. If you like hiking in the Rockies, you can hike the same sort of landscape with a lot less travel time.

The **Blue Mountains** rise in the southeast corner of the state. Here, the Columbia River basalt flows were pushed up and folded into a rolling mountain range that extends into northeast Oregon and up to heights over 6,000 feet. The topography can get steep, but it was not carved by glaciers so it's generally rounded rather than peaky.

One feature that cuts across the state is known as the "**Olympic-Wallowa lineament**," and may be a fault like the San Andreas in California. Whenever you take the northwest-southeast route of Interstate-90 from Seattle to Ellensburg, you are roughly following this feature. You can see a rough line pattern to the land forms beginning in the upper left of a state map, with the angle of the Strait of Juan de Fuca, continuing along the route over Snoqualmie Pass, then running east of and parallel to the Yakima Valley, through Pasco and into northeastern Oregon, ending in the northern front of the Wallowa Mountains. In some areas the land southwest of the line is raised or uplifted, while lands to the northeast are often lowered. This feature of our state's geology is not fully understood and remains one of the puzzles that geologists are striving to solve! ♦

Anxious to learn more? Phil's " I-90 Geology Tour" is online at www.mtsgreenway.org/newsandpublications.

These hikers in the Goat Rocks Wilderness are enjoying typical south Cascades geology, rounded peaks of less resistant rocks in the foreground and a looming volcano (Mount Adams) in the distance. Photo by Judy Roberts.

A view of the rounded hills of the Palouse, toward Kamiak Butte, in southeastern Washington. Photo by Robert Tetzlaff.

The Tortoise of Geologic Time

by Annaliese Eipert

Blank stares. Silence. "How did these fossils get all the way up here, a mile above sea level?" he asked again. A group of us had hiked up Hurricane Hill near Port Angeles as part of a week-long environmental science and outdoor adventure program, and were now gathered around a small fragment of rock.

I took in my teacher's explanation of colliding tectonic plates moving towards each other at the barely discernable rate of 3 to 4 centimeters per year, and patiently tried to imagine a timeline that would allow rocks once part of the sea floor to transform into mountains large enough to influence weather patterns in Seattle, sustain a glacier with the volume of a trillion ice cubes, and keep most people from dreaming of ever standing on top of them.

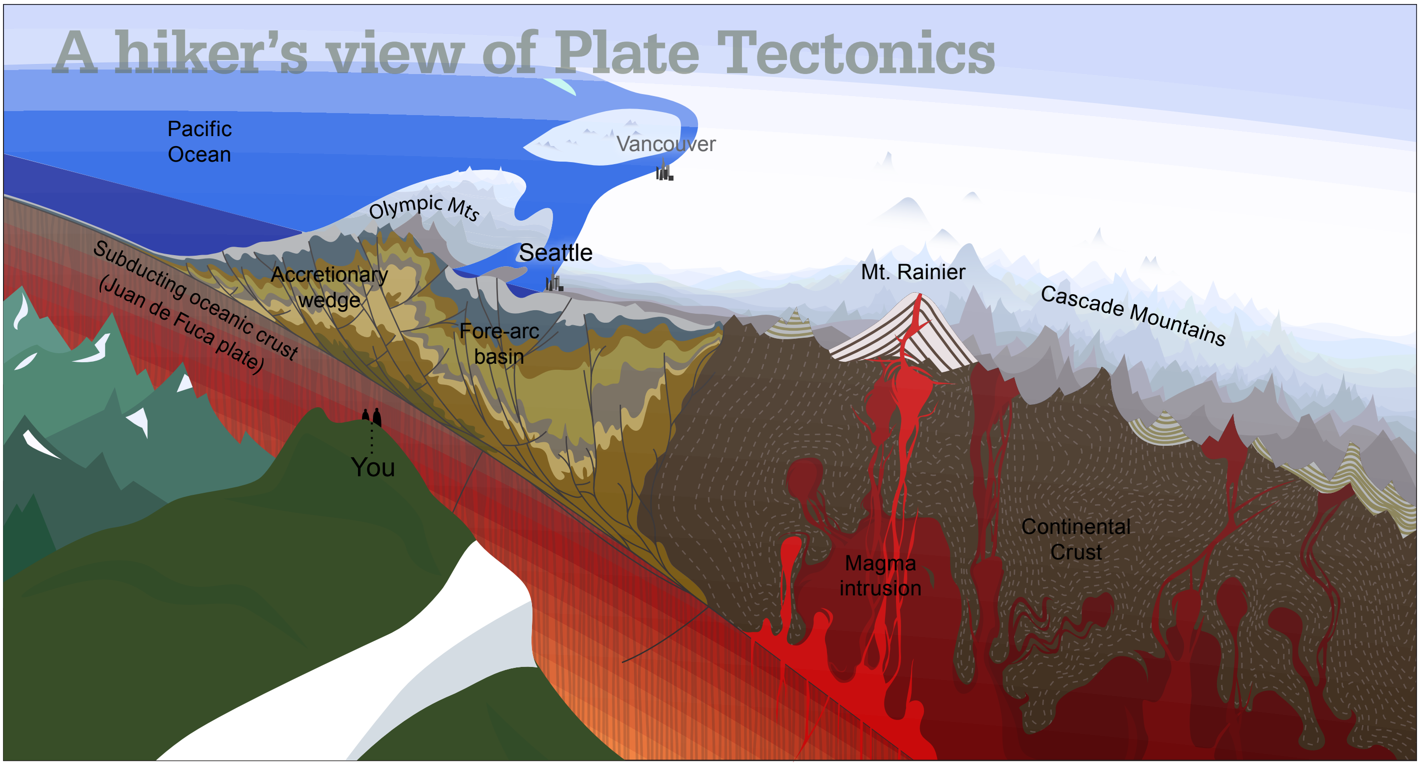
That was ten years ago. I've since become a geologist and have sought answers in hundreds of rocks (often finding only blank stares and silence), but I still feel the same sense of awe at the bigness of geology and the slow, patient tortoise of geologic time. Underneath all the sediments and water and rocks we can see hiking, the crust of our Earth is made up of dozens of shifting plates that never stop moving.

The work of tectonic plates can be seen and felt all over Washington, from Cascade volcanoes to earthquakes in Seattle to the Olympic Mountains—the accumulated rock and sediment scraped off the subducting Juan de Fuca Plate as it pulls eastward under the North American Plate. Over the past 50 million years, enough material has moved through this subduction zone conveyor belt to build up into an extensive mountain range.

Tectonic plates are constantly recycling—during subduction a denser oceanic plate melts into magma as it descends into the Earth, where heat and pressure buoy it upward and it begins to melt the overlying North American Plate. Lava erupts through the surface and quickly cools to form the andesite of Mount Baker or the rhyolite of Mount St. Helens. Or, the magma cools more slowly underground in a pluton, where minerals in the melt separate into distinct crystals as seen in the tonalite of Vesper Peak or the granite of Copper Ridge. These plutonic rocks will one day be exposed, after all the overlying rock and sediment has eroded and been deposited in the lowlands or washed into the sea, where they will perhaps be subducted and remelted into magma with the downgoing slab, or perhaps will be accreted into the Olympic Mountains.

What better testament to the slow-but-steady tortoise than the mountains of geologic time? ♦

Created exclusively for *Washington Trails* readers, this illustration provides a hiker's eye view of the geologic forces which shape our landscape. Graphic by Ground Truth Trekking.



What if the earth were sliced in half across the width of Washington? Imagine climbing to the edge of the cut on a peak in the Cascades, looking across the yawning gulf to see the other half of the earth, its insides exposed for your study. You could see the Juan de Fuca oceanic plate subducting under the land, building a wedge of scraped-off sediments into the Olympic Mountains. Faults fragment the edge of the continent, and magma oozes up through the crust to form the volcanoes of the Cascade range.

5 Amazing Geology Hikes

Check out these geological wonders this summer.

Recommendations and photos by Eli Boschetto.

Hoh Melange – Beach Three

Take an easy stroll along Olympic's Third Beach to witness some truly mangled rock formations. At one time part of the Juan de Fuca Plate's sea floor, these sandstones, shales and cherts were ground up, then thrust vertically back above the surface.

The brown seeps coming from the rocks are from organic material that was subducted with the rocks and changed into petroleum.

Glaciated Granite – Asgaard Pass

Referred to as the "Yosemite of the Northwest" and varying greatly from the distinctive volcanic features of the state, the Alpine Lakes Wilderness is a glaciated granite wonderland. Replete with ice-carved arêtes, spires and ridges, all surrounding pristine lake basins and beautiful creekside meadows, this landscape invites hikers, backpackers and climbers to immerse themselves in a landscape of rugged alpine perfection.

Sky-High Seafloor – Hurricane Hill

Fifty million years ago, the rocks composing most of the Olympic Range were actually miles under the ocean as part of the Pacific sea floor. Over time, these rocks were subducted more than 15 miles below the surface, then thrust a mile above the surface, forming the Olympic Mountains as we know them now. Hike the 3-mile Hurricane Hill Trail to view submarine sandstones, shales, pillow lavas and turbidites.

Plug Volcano – Beacon Rock

Considered a "volcanic plug," Beacon Rock is all that remains of another of the Cascade Range's many volcanoes, the rest of the mountain long since eroded away. The twisted layers and colums of basalt were formed when the ancient volcano's interior magma cooled and hardened into its crystalline form. A 1-mile trail goes to the top of the 840-foot monolith for grand views of the Columbia River Gorge.

Mountain Building – Mount St. Helens

There are few places in the world where you can see geologic processes in action. Mount St. Helens's Monitor Ridge Trail allows hikers to scramble up a jagged lava flow, followed by an ash and pumice slope to the crater rim. From there, peer 2,000' down into the smoldering crater and witness the mountain's rebuilding, as the interior lava dome continues to grow.

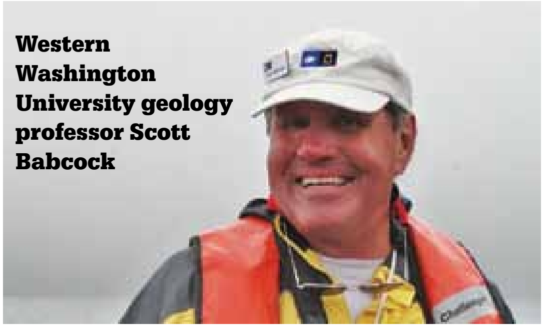
Hikes Highly Recommended

Ape Cave

Chain Lakes

Mima Mounds

Geologist Profile: Scott Babcock, author of *Hiking Guide to Washington Geology*



Western Washington University geology professor Scott Babcock

When did you become a geologist?

Even though I grew up in Wenatchee, which is a kind of geological wonderland with a gold mine and an oil well within a mile of each other on the outskirts of town, I didn't know anything about geology until I took an introductory course my senior year of college. I took the course to satisfy a science requirement, but it ended up changing my life. And the more I learned about geology, the more I realized that it was a profession where hiking and climbing could be part of your job description! It was also an opportunity to spend a few more years taking classes in graduate school before I had to make my entry into the real world.

What is a typical day as a geology professor?

Being a professor has three required elements. The first is teaching and I spend about four to five hours a day either in class or preparing classroom materials. The second is research. This involves another four to five hours daily, plus a large part of summer vacation and other breaks from the teaching schedule, but it is also the part that involves hiking, climbing and traveling to spectacular places on the planet. The third element is service, which can consume one to two hours or all day. Service can consist of seriously tedious time on university committees. Or it can be an opportunity to inform and involve people in the community with geologic topics. Participating in this special issue of *Washington Trails* would be considered service--the kind that I like to do.

How did you come up with the idea to write a hiking geology guidebook?

The Mountaineers had published a book called *Hiking Oregon's Geology* that was surprisingly successful. They decided to do a series of books on geologic hikes in other places. I had previously contributed a chapter to a book called Impressions of the North Cascades, so the editor called to see if I would be interested. I certainly was, but it was obvious that it would take a lot of time and trail miles to get the job done. Finding a co-author was the first thing that crossed my mind. Bob Carson was perfect. He taught at Whitman on the opposite corner of the state, had a different research specialization and, best of all, he had a lot of experience presenting geology to the public. *[Editor's note: The guidebook originally published by The Mountaineers books has been republished under a new name by Keokee Books.]*

What are your personal favorite hikes in *Hiking Guide to Washington Geology*?

That's not an easy choice to make. In fact, it was hard to limit ourselves to the 55 hikes in the book. Someday we may do another book with 55 more hikes that have great geology. If I had to choose just two, I'd pick one short hike and one longer hike, but both easily accessible. The short hike is Ape Caves at Mount St. Helens, which is an absolutely intriguing stroll through the underground plumbing system of a Mount St. Helens lava flow. The longer hike is the Chain Lakes Trail, where you can see everything from recent Mount Baker lava flows to a million year old equivalent of the Crater Lake caldera to 350-million-year-old sea floor deposits that were metamorphosed to greenstone and marble when the Chilliwack terrane smashed into the western margin of North America.

Can you ever take a hike without looking at the geology?

Why would anyone possibly want to hike without checking out some geology? I personally go for the biology and botany as well. Add some human history and you have the perfect hike.

Are scientists really not sure what caused the Mima Mounds?

Well, the latest high-tech study using Lidar imaging favors a glacial origin and even adds a tantalizing new element—sediment filled suncups! I think that it is great that the mounds can still be considered "majorly mysterious" (in the words of one recent blog). We need to have a few natural features that cannot be fully explained by scientific theory—just to keep hiking interesting. ♦

Photographer Alan Bauer scans Steamboat Rock State Park. Photo by Karen Sykes.

The Channeled Scablands

Of the many imposing geological wonders to discover in Washington, the Channeled Scablands outrank all others in magnitude and cataclysmic origins.

Forty or more enormous ice age floods scoured the region, leaving a devastated landscape that extends from the Cascade Range to Spokane and Grand Coulee south between the Columbia and Snake Rivers. As recently as 13,000 years ago, continental glaciers advanced south from Canada and formed ice dams as high as 2,000 feet. Lakes dammed by the ice, such as Glacial Lake Missoula to the east and Columbia Lake to the north, grew to 3,000 square miles and 2,000 feet deep. When rising water breached the ice, huge glacial outburst floods emptied the lakes in a matter of days at speeds reaching 80 miles per hour as the waters raced to the Pacific Ocean. The aftermath of these catastrophic events is visible today throughout this region.

The most striking erosional feature created by the floods is the series of coulees that weave throughout the region. Coulees are steep-walled channels eroded by repeated flooding. Grand Coulee is 50 miles long, 1 to 6 miles wide and 900 feet deep. In the middle, a 743-foot high mesa called **Steamboat Rock** rises out of the artificially made Banks Lake. To the south are **Sun Lakes**, which are basins scoured in the floor of Grand Coulee. The coulee is broken by a stretch of steep cliffs that deep water flowed over during the flooding. Of these, **Dry Falls** is 3 miles wide and 350 feet high. **Moses, Black Rock, Frenchman, Crab Creek** and **Potholes Coulees** all display similar features. Other erosional formations are giant eddy scars, potholes, and pinnacles of hard rock left after the surrounding softer rock washed away.

As glacial floodwaters slowed, sediment was deposited in massive gravel bars that are still visible. Giant ripples 3 to 45 feet high formed by deep, flowing water are evident from both land and air. Granite boulders as large as 21 tons are scattered throughout the Channeled Scablands. These "erratics" were embedded in icebergs and dropped onto the land when the ice melted. Lone rocks are seen today in fields throughout the area.

Currently, the National Park Service and Congress are establishing the first National Geologic Trail, the Ice Age Floods Trail. Soon, new trails and interpretive materials will help us to understand these unique geological wonders found throughout the Channeled Scablands. ♦

— Lee Whitford

Resources That Rock

Dig deeper into this interesting topic by checking out these geology resources.

Publications

Fire, Faults, & Floods: A Road & Trail Guide Exploring the Origins of the Columbia River Basin. Marge and Ted Mueller. University of Idaho Press, 1997

Geology of the North Cascades: A Mountain Mosaic. Rowland Tabor and Raph Haugerud. The Mountaineers Books, 1999

Guide to the Geology of the Olympic National Park. Rowland Tabor. University of Washington Press 1982. Reprinted by Pacific Northwest Interpretive Association,1998

Hiking Guide to Washington Geology. Scott Babcock and Bob Carson. Keokee Books, 2009

Northwest Exposures: A Geologic Story of the Northwest. David Alt and Donald Hyndman. Mountain Press, 1995

On the Trail of the Ice Age Floods, A Geological Field Guide to the Mid-Columbia Basin. Bruce Bjornstad, Keokee Books, 2006

Organizations

Association for Women Geoscientists, Puget Sound chapter - www.awg.org
Geological Society of America - www.gsa.org
Ice Age Floods Institute - www.iafi.org
Northwest Geological Society - www.nwgs.org