A Geologist's View of the Region around Arco, Idaho

The region around Arco is a geological wonderland. To the south is a vast volcanic plain with varied kinds of volcanic rocks, eruptive structures ranging from fissures to huge buttes, and rocks produced in styles ranging from oozing flows of lava to some of the most explosive and gigantic eruptions in Earth's history. To the north are mountains made of layers of sediment deposited on the seafloor hundreds of millions of years ago and subsequently broken and mangled to give structures that look like spaghetti. Atop those sedimentary rocks, volcanic rocks were erupted, but very different ones from those of the Snake River Pain, and by-products of their eruption included mineral deposits that inspired mining in the mountains and construction of the valley's railroad. All these rocks to the north were faulted to give the mountains that we see today, and since then they have been sculpted by glaciers and streams to give peaks and chasms. At least once, a vast catastrophic flood has come down the valley and left huge boulders on the volcanic plain to the south. Today, a river comes down the valley and does a peculiar thing: most rivers flow across the continents to the oceans, but this one sinks into the volcanic plain and is "Lost". Meanwhile, up the valley, huge earthquakes continue to build the mountains and lower the valleys. What a landscape!

The paragraph above is organized geographically. The rest of this document is organized chronologically, from formation of the region's oldest rocks to its youngest rocks and processes. It is a story of several hundred million years, and although it ends with the present, it looks to the future too.

Hundreds of millions of years ago (the Paleozoic and Mesozoic)

The mountains on each side of the Big Lost River and Little Lost River valleys consist largely of rocks that are the solidified remains of sediments deposited on ancient seafloors 500 to 300 million years ago. Most commonly they are limestones, which consist of calcium carbonate and form from the fossils of the seas' plants and animals. The hillsides above Arco consist of limestone, and one commonly finds fossils in the rocks there. Most geologists would point to the seafloor around the Bahamas as a modern place where limestone is forming today, but the Bahamas provide only a geographically small example compared to the vast expanses of limestone deposited hundreds of millions of year ago. (See the top panel of Figure 1.)

In addition to limestones, sandstones formed hundreds of millions of years ago where sand like that of the rivers of eastern North American reached the sea and settled onto the

A very simplified geologic history of the Basin and Range region of east-central Idaho

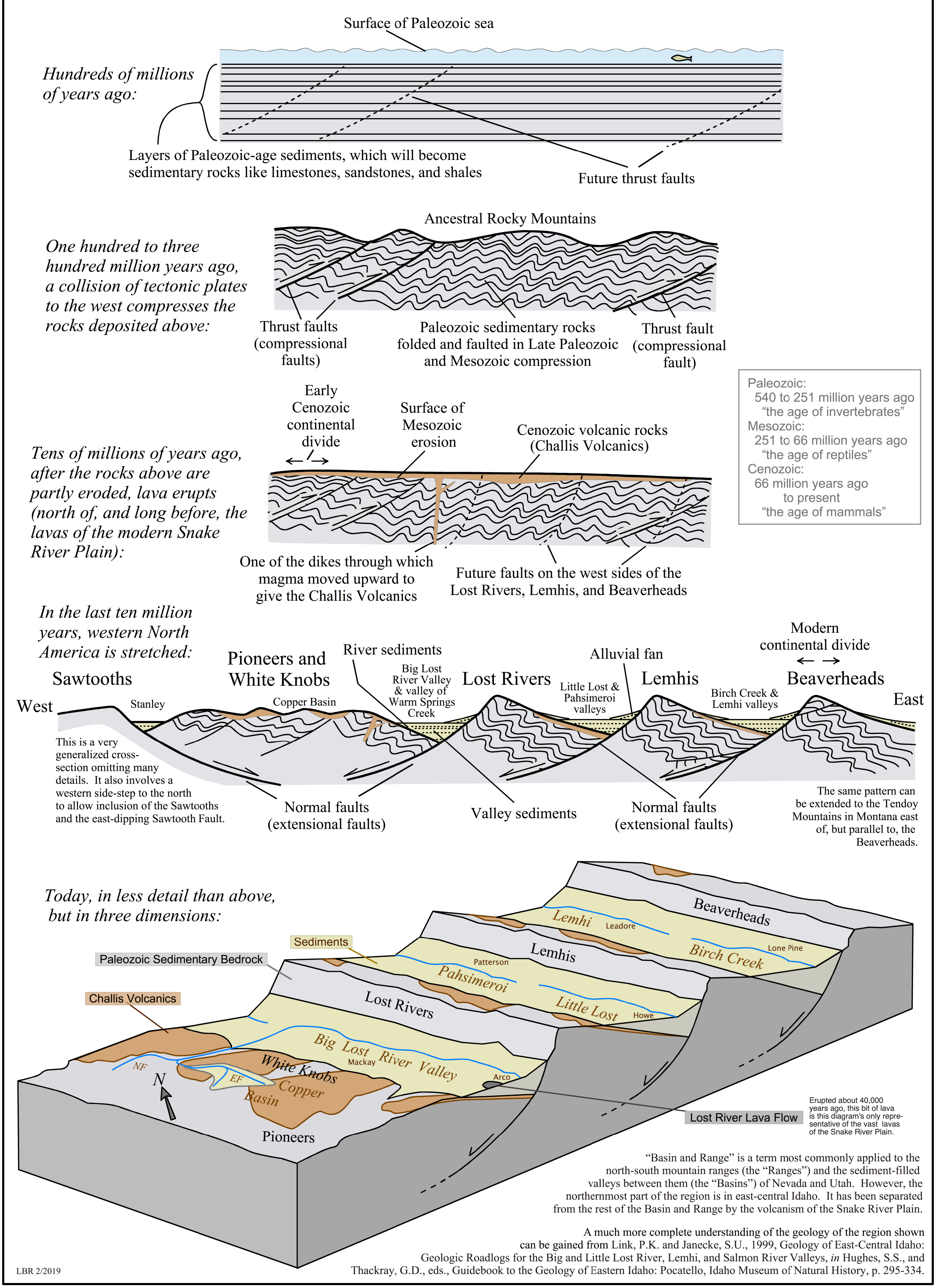

Figure 1. Sketches illustrating the geologic history of the Lost Rivers region of eastern Idaho. The right side of the block diagram at the bottom and the panel just above it (the fourth from the top) represent much the same transect from west to east.

seafloor. The white sandstones of Elbow Canyon are a good example. In a few times, coarser sediments were carried to the edges of seas to give rocks with coarser rounded particles, rocks called "conglomerate" because they are agglomerations of pieces of rock. These are found in the uplands of Antelope Canyon and generally on the west side of the Big Lost River valley.

All of the sediments discussed above were deposited in flat-lying layers and then solidified into layers of solid rock. However, collisions of small bits of continent with western North American generated compressive forces that, over millions of years and at the warm temperatures of Earth's interior, squeezed those layers into folds or squeezed the layers so much that they broke along faults (second panel of Figure 1). The result is the goulash of upturned and swirling layers of rock visible in the hills above Arco, in the spur of Appendicitis Hill that reaches out to Moore, and in the mountains to the east in the northern part of the Big Lost River Valley. Atop their collective mass would have been an eroding mountainous landscape over which dinosaurs roamed and pterosaurs flew. However, even their remains would have been eroded before the next big event in the history of this landscape.

Fifty million years ago (the Paleogene, or specifically the Eocene)

About fifty million years ago, magma (molten rock material) began to move up through Earth's interior into this region, oozing its way up through cracks in the sedimentary rocks discussed above. Most of this was erupted to give lava flows and deposits of volcanic ash that are collectively called "the Challis Volcanics". Challis is indeed near the center of their present area, but they blanketed a vast area of the sedimentary rock discussed above (see third panel of Figure 1). For example, they can be found southward to areas east and west of Arco, and they would cover the hills above Arco had they not been eroded away in the last tens of millions of years.

If we return to the magma "oozing its way up through cracks in the sedimentary rocks", we find that interesting things happened there. Magma ascends very hot, very depleted in oxygen as we know it (the O_2 of air), and either a little bit acidic or at least not alkaline. As it enters near-surface rock like limestone, it reaches an environment cooler, more oxidizing, and more alkaline (because limestone readily neutralizes acid). The result is that some elements dissolved in the magma become insoluble and form solid minerals where magma meets limestone. The "some elements" include zinc, copper, silver, gold, and lead. In a region extending from Galena (lead-sulfide) Summit in the west to Copper Basin near the middle to Leadore in the east, one sees the geologic and economic effects of the magma's interactions. The results included the Lava Creek and Champagne Creek mining districts to the west, Copper Basin to the northwest, the Alder Creek mining district and Mackay's Empire Mine in the Big Lost River Valley, and other if less successful mining ventures to the east. Discoveries above Houston (for latecomers, above Mackay) were (or at least seemed) so large that they inspired the Union Pacific Railroad, in the guise of its Oregon Short Line, to build a railway from Blackfoot to Mackay, with huge implications for everything in between.

Twenty million years ago (the Neogene)

Our account above left a landscape of volcanic rocks, the Challis Volcanics, blanketing a substrate of folded and faulted ancient sedimentary rocks. This landscape slowly eroded for about thirty million years. About twenty million years, the entire American west from southwest Montana to southern Nevada west began being stretched from east to west. The region was broken into north-south mountain ranges separated by north-south valleys (reversing the order of those two, it's called the "Basin and Range"). This process occurred in the Lost Rivers country (see fourth and fifth panels of Figure 1). For an analogy, imagine facing north while looking at a bookshelf half-filled with books (their tops will collectively be our landscape above). Now remove the bookend at the books' left (western) end and let the bottoms of the books slide to the left. The boundaries between the books are newly formed faults that dip to the west. The tops of the books are our landscape, now chopped into segments that slope steeply on their western sides (the exposed book covers, or the fault surfaces) and slope less steeply to the east (the tops of the books, or the now east-dipping old landscape) (Figure 2). The movements along those faults were experienced by the region's ancient animals as earthquakes. The Borah Peak earthquake of 1983 is the most recent example, and it continued the uplift to the east and down-drop to the west along the Lost River Fault.

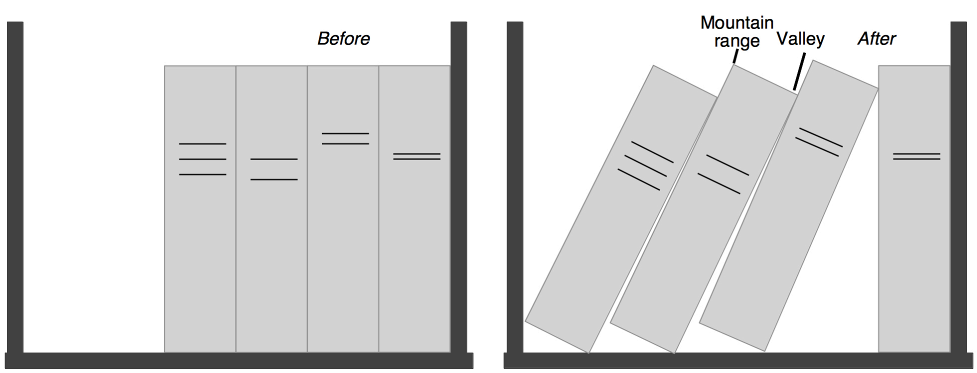

Figure 2. A very simple "bookshelf" model of the faulting that generated the Lost River, Lemhi, and Beaverhead Mountains, as shown more technically in Figure 1. The top of the sketch is a useful visualization; the bottom is not.

The results of all this movement were the Lost River Mountains, the Lemhis, and the Beaverheads, each with steep west faces and more gently-sloping east sides. Between them, sediments began to fill the valleys to the west of each new range, giving the Big Lost River Valley, the Little Lost River Valley, and the valley of Birch Creek. (Those flow south; to the north are Willow Creek, the Pahsimeroi River, and the Lemhi River). Within the mountain ranges themselves, the upturned west sides are commonly cut by streams into gorges like the narrows of Pass Creek, whereas the east sides of the mountain ranges commonly have gently slopes like those of Wet Creek.

Those mountain ranges (and the valleys between) presumably continued to the southeast, connecting with ranges in northeastern Utah, far southeastern Idaho, and southwestern Wyoming. However, the next chapter in this history changed all that.

The last few million years

About sixteen million years ago, another kind of volcanism began that would move south of Arco, as opposed to the much older Challis Volcanics that had been erupted to the north. This new volcanism began in southeastern Oregon with a huge explosive eruption, or series of eruptions, sixteen million years ago. If one looks just at a map of western North America, the location of these eruptions appears to have moved northeast up the Snake River Plain, reaching the area southwest of Twin Falls about thirteen million years ago, erupting in the area between Arco and American Falls about ten million years ago, erupting in the area around Idaho Falls six to four million years ago, erupting northeast of St. Anthony about a million years ago, and erupting in Yellowstone during the last few hundreds of thousands of years. If, on the other hand, one knows that North America has drifted to the southwest, the location of the eruptions hasn't moved at all, and instead North America has moved over the source of the eruptions, somewhat like slowly moving a large sheet of solid plastic over a blowtorch. The metaphorical blowtorch is the geologist's "hotspot", a stationary source of heat and magma over which a plate of Earth's surface moves (Figure 3). The eruptions produced vast amounts of rhyolite, a silica-rich volcanic rock, that fill much of the Snake River's valley and are exposed at its edges, as at Picabo, Champagne Creek, and Howe Point (Figure 4).

After the Snake Plain had passed over the hotspot, lesser eruptions of magma occurred sporadically. This magma was less rich in silica and more rich in iron and magnesium, producing the black volcanic rock called "basalt" that any traveller of the Arco Desert has seen. Basalt commonly erupts in a flowing liquid style, spreading across the landscape as lava flows and producing low volcanoes like Wildhorse and Sixmile Buttes south of Arco. Occasionally, more viscous or sticky rhyolite magma erupted and would not flow, producing piles like the Big Butte and the eastern of the Twin Buttes (Figure 5). The most recent eruptions of basalt occurred at Hell's Half Acre west of Idaho Falls and Blackfoot, and even more recently at Craters of the Moon. The result is the vast and largely uninhabited Snake River Plain of basalt to the south of Arco.

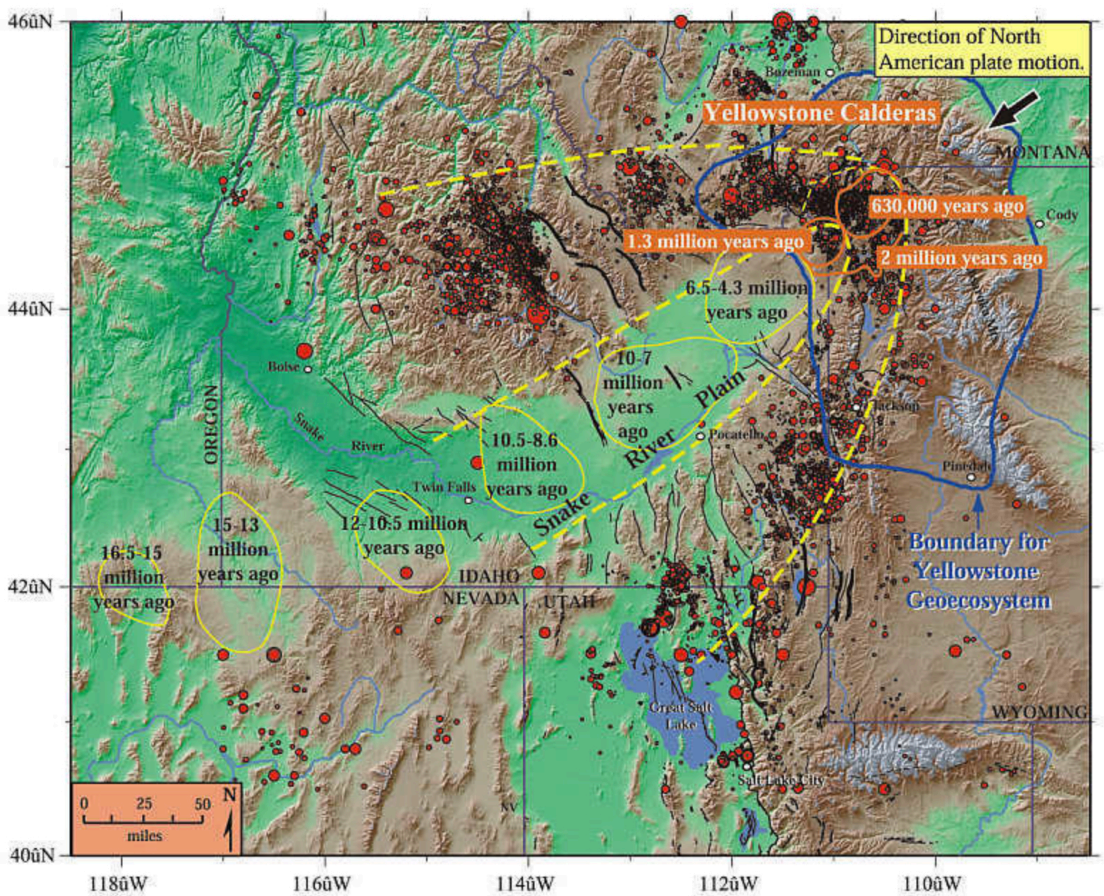

Figure 3. A US Geological Survey public-domain document illustrating the track of the Yellowstone hotspot as western North American migrated over it. The image is accompanied by this USGS text: "Yellow and orange ovals show volcanic centers where the hotspot produced one or more caldera eruptions- essentially "ancient Yellowstones"- during the time periods indicated. As North America drifted southwest over the hotspot, the volcanism progressed northeast, beginning in northern Nevada and southeast Oregon 16.5 million years ago and reaching Yellowstone National Park 2 million years ago. A bow-wave or parabola-shaped zone of mountains (browns and tans) and earthquakes (red dots) surrounds the low elevations (greens) of the seismically quiet Snake River Plain. The greater Yellowstone "geoecosystem" is outlined in blue. Faults are in black. Used with permission from "Windows into the Earth, The Geologic Story of Yellowstone and Grand Teton National Park", Robert B. Smith and Lee J. Siegel, Oxford University Press, 2000." The source is https://www.usgs.gov/media/images/map-showing-path-yellowstone-hotspot.

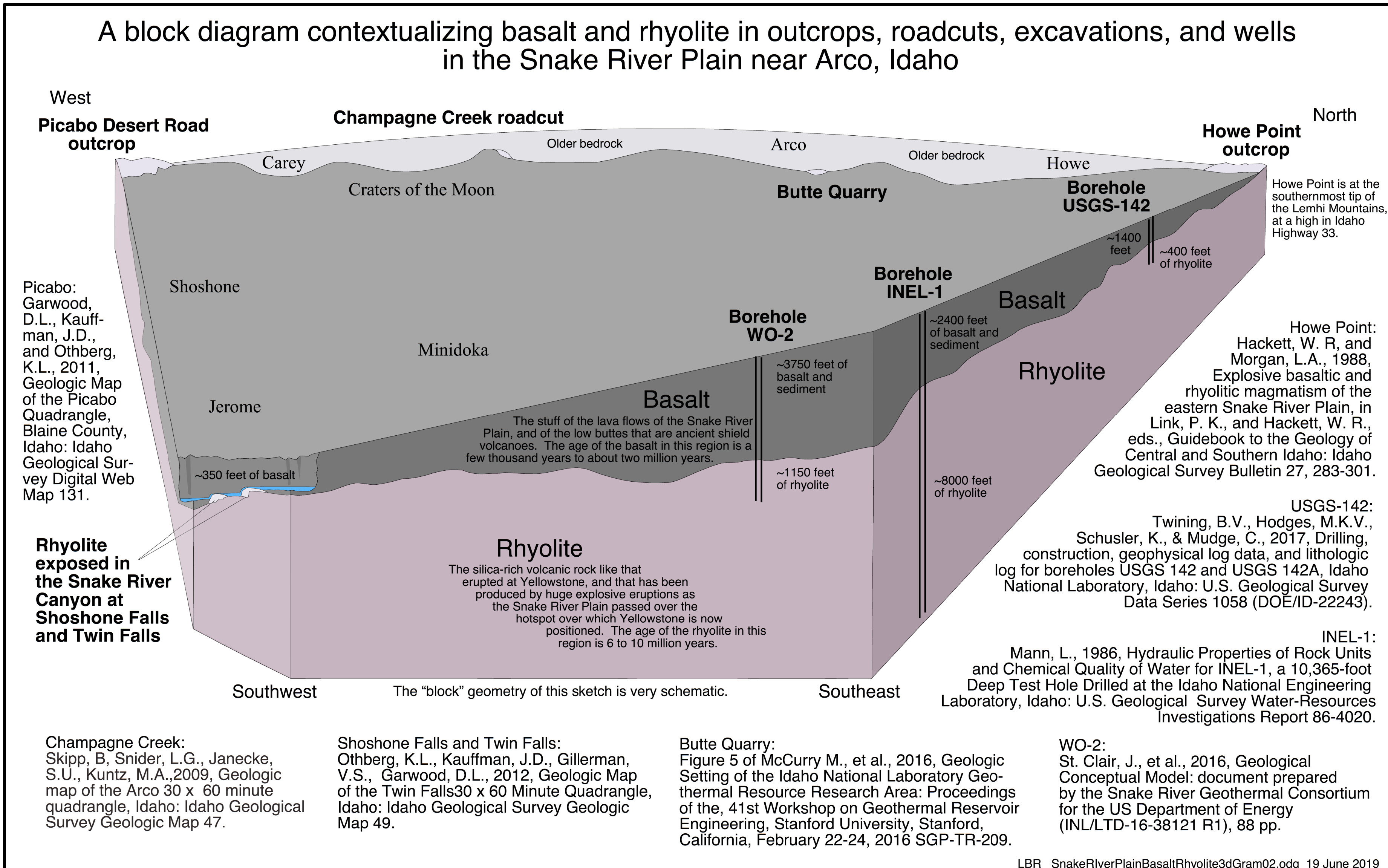

Figure 4. A block diagram showing the relative thickness of surficial basalt and underlying rhyolite in the Snake River Plain. The most telling evidence is Borehole INEL-1, which encountered a vast thickness of rhyolite under the basalt.

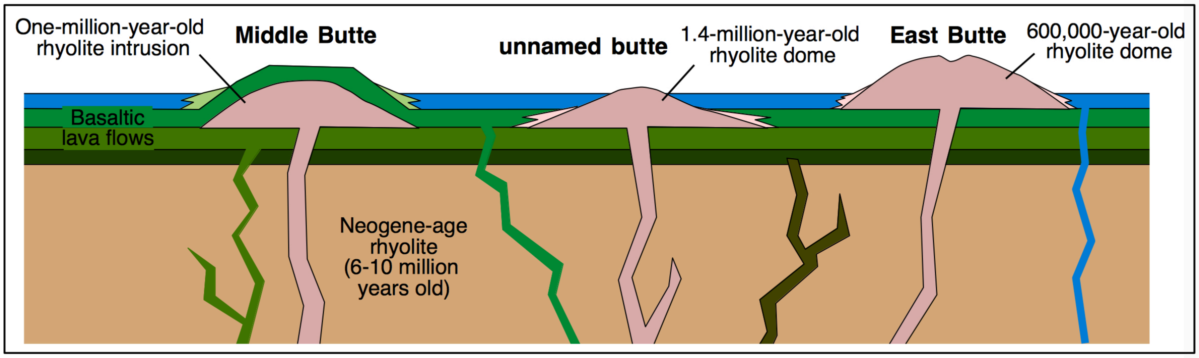

Figure 5. A cross-section suggesting the plumbing in the Snake River Plain with a long sequence of magmas making their way through the older Neogene rhyolite upwards to the surface to form lava flows (green and blue) and rhyolite domes (pink). The sketch is is an elaboration of Figure 16 of Hughes, S.S., Smith, R.P., Hackett, W.R., and Anderson, S.R.,1999, Mafic volcanism and environmental geology of the Eastern Snake River Plain, Idaho, in Hughes, S.S., & Thackray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, p. 143-168.

The last few hundreds of thousands of years (the Pleistocene)

In the account above, the landscape was modified by erosion that was largely performed by rivers and streams. However, for the last two million years, Earth became sufficiently cool that glaciers moved across the high-latitude and high-altitude parts of the planet. In the mountains of this region of Idaho, glaciers cut high bowls called cirques, and three or four cirques together bound high sharp peaks called horns. The resulting topography is perhaps most easily seen on the west and south sides of Copper Basin, but it is spectacularly developed in the high (and thus less easily seen) tops of the Lost River Range (Figure 6).

One short-term phenomenon in regions of glaciers is the damming of valleys by ice, so that lakes form up-valley from the dams. Those dams can give way catastrophically. That seems to have happened about twenty-thousand years ago in the upper reaches of the Big Lost River drainage, releasing a mass of water and ice (henceforth fast-moving icebergs) that swept down the valley and out onto the basalt plain south of Arco. One result is the presence on the basalt plain of huge boulders that consist of rock types only found far up the valley. The exotic or unexpected look of these boulders results in their being called "erratics", and their presence testifies to the huge magnitude of the flood that carried them.

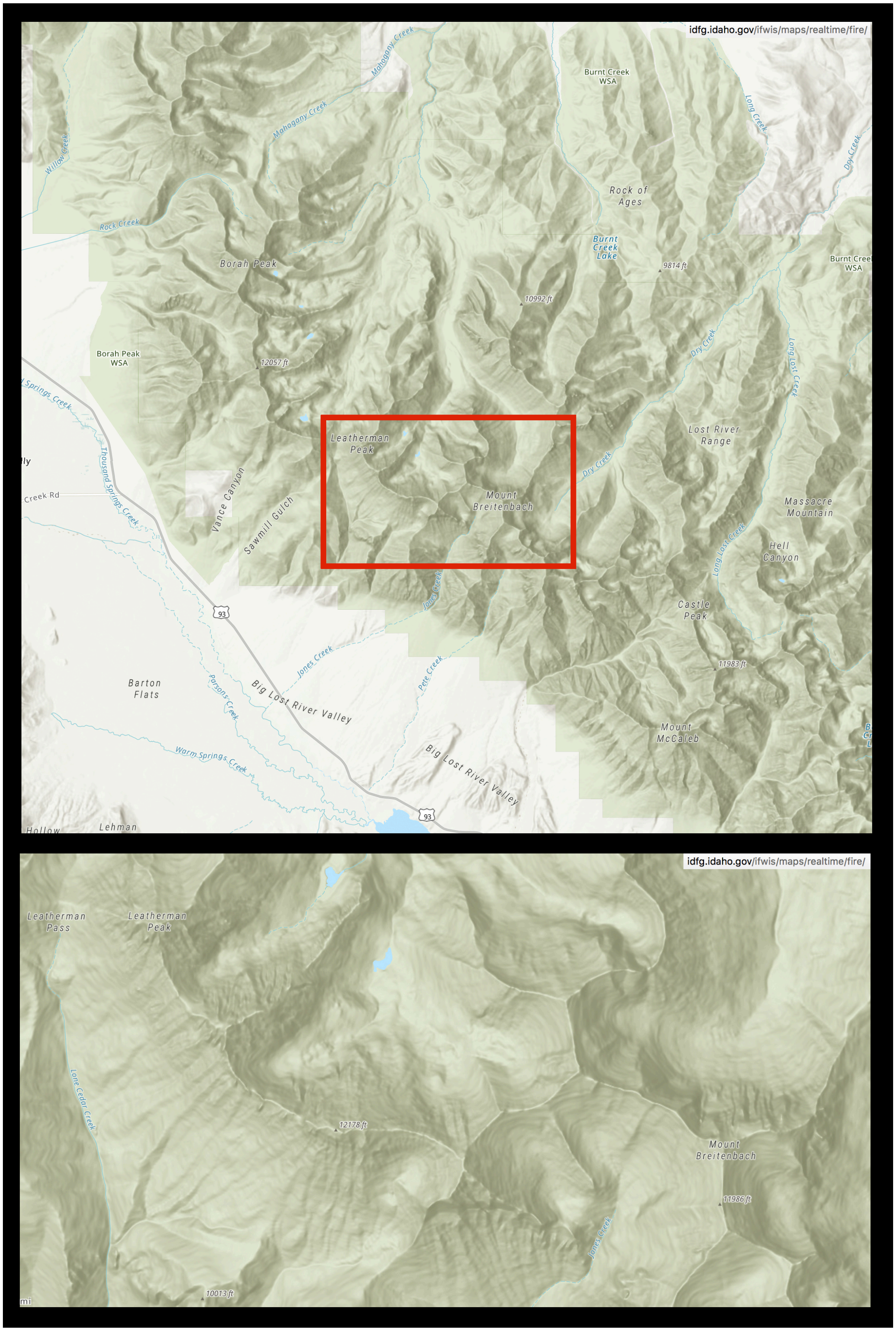

Figure 6. Digital images of the topography of the Lost River Mountains; the lower is the area in red in the upper. In the lower, Leatherman Peak and Mount Breitenbach are the ends of a string of five glacially-sculpted horns; lakes (blue) fill lows in the glacial valleys below those horns.

The last ten thousand years (the Holocene)

The cooling and glaciation of Earth described in the previous section was episodic, cycling from warmer to cooler in roughly 100,000-year cycles. The coolest time of the last glacial cycle was about 20,000 years ago (the Last Glacial Maximum), and by 10,000 years ago Earth had entered a warmer and less glaciated epoch called the Holocene, the epoch in which we live today (unless one sees the recent centuries as so changed that they are a new epoch called the Anthropocene). This warming brought drier conditions to the region, stranding huge deposits of gravel (the alluvial fans at the mouths of canyons) that can only have been deposited in a wetter climate. The lower elevations became the steppe or desert that we know today. The literally burning question is whether future warming will lead to even drier conditions or if some fluke of a warmer Earth will bring wetter weather, or at least bring more winter snowfall that will keep the rivers flowing. This whole document is a story of change, and more is sure to come.

Bruce Railsback, Arco, 2019

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