Origin of Lava Benches and Upper and Lower Mesa Falls in the Henrys Fork and Warm River Canyons, Island Park, Idaho

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Abstract

The headwaters of the Henrys Fork River—including Warm River—lie in the Island Park area of eastern Idaho. In southern Island Park, these rivers form deep canyons through the flank of the Yellowstone I caldera, then join and flow west onto the Snake River Plain. The Henrys Fork and Warm River canyons contain lava benches formed when local basalt lava flows entered the canyons, solidified, and were later incised.

We correlate lava benches inside the canyons to local basalt lava fields using field relations, petrography, remanent magnetization, and chemical composition. The five lava-bench remnants in Henrys Fork River canyon are from the Warm River (~835 ka), Elk Wallow Well (~743 ka), Highway 20 (~737 ka), Survey Draw (~450 ka?), Hatchery Butte (~81 ka), and Pinehaven (~29 ka) lava fields. The three lava-bench remnants in Warm River canyon are from the Warm River, Survey Draw, and Hatchery Butte lava fields.

The Henrys Fork River canyon contains Uppper and Lower Mesa Falls and other small falls and cascades. We use density variations in the Mesa Falls Tuff in the Henrys Fork River canyon to infer that these falls result from high-density/highly-welded zones in the Mesa Falls Tuff. Changes in gradient of the top of the Pinehaven, Hatchery Butte, and Survey Draw lava benches suggest that Upper and Lower Mesa Falls existed downstream from their current locations in the past. The migration of the falls was halted at least three times by lava. The density profile of the Mesa Falls Tuff suggests that at least three ash deposits built the Mesa Falls Tuff, as follows: a layer over 150 feet thick was emplaced at about 800 °C; after a break of months to years and before the lower layer had finished welding, a layer about 140 feet thick was deposited, also at about 800°C; then, following a break of at least days, a layer 135 feet thick was emplaced at about 630 °C; finally, after a break of days to months, a 50 feet thick layer at about 700 °C capped the unit.

Research Questions

- How did the lava benches form?
- How did Upper and Lower Mesa Falls form?

Methods

- We use field relations, petrography, paleomagnetic orientation and chemical composition to correlate lava benches
- We use core samples of the Mesa Falls Tuff to calculate density variation within the unit.

Collecting core samples by rappeling down the Upper Mesa Falls cliffs.

Origin of Lava Benches

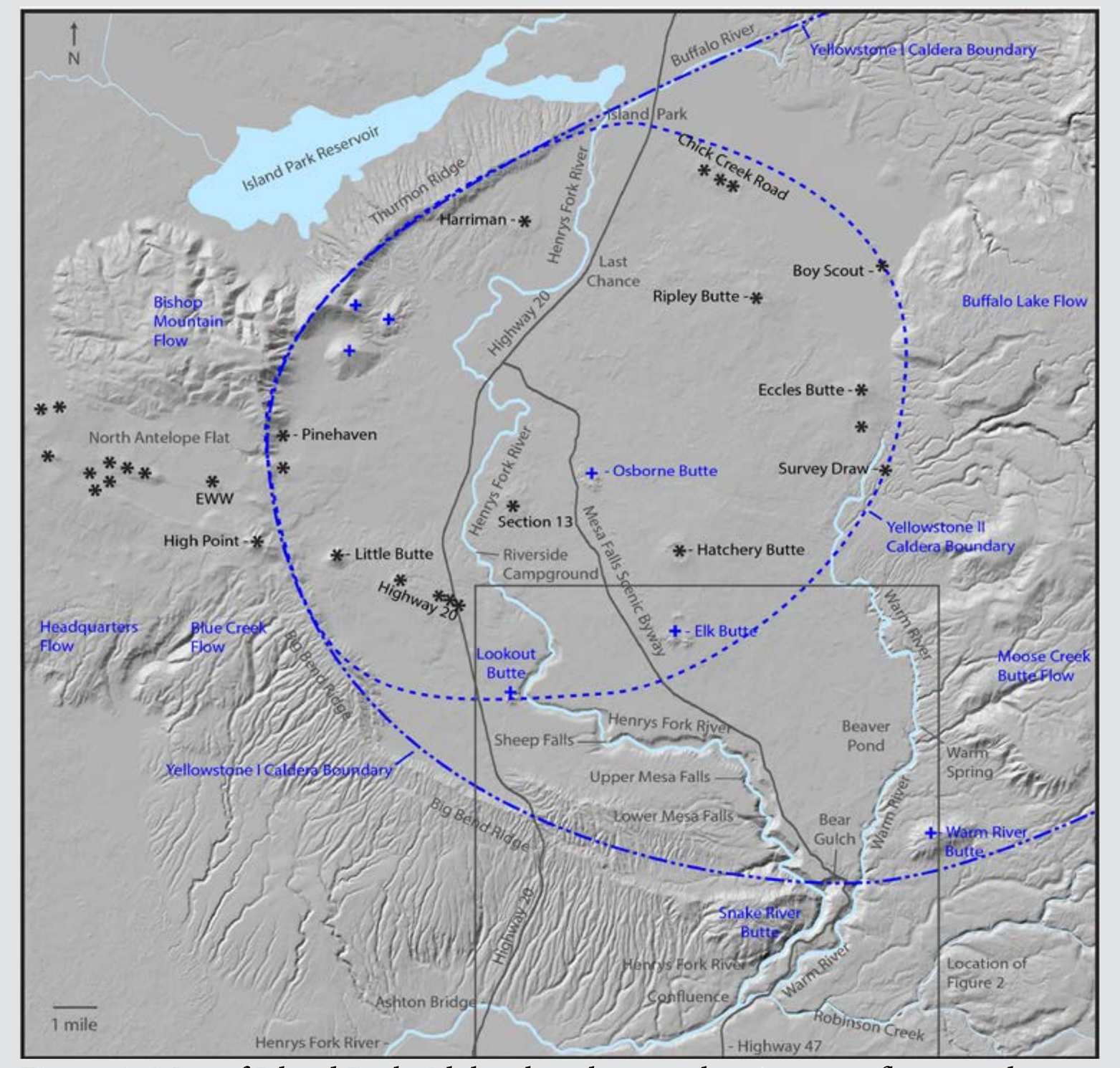

Figure 1. Map of Island Park, Idaho that shows volcanic vents, flows, and caldera boundries. The gray box shows the location of Figure 2.

Volcanic Events	$^{40/39}$Ar Ages (ka)
Pinehaven basalt lava field	29 ± 9
Unnamed and undated basalt lava field; the vent is just south of the Pinehaven vent	Older than Pinehaven basalt
Ripley Butte basalt lava field	77 ± 24
Hatchery Butte basalt lava field	81 ± 13
Buffalo Lake rhyolite lava flow	106 ± 3
Section 13 basalt lava field	443 ± 26
Survey Draw basalt lava field	Older than Hatchery Butte basalt; younger than Lava Creek Tuff; loess cover similar to Eccles Butte basalt. 450 ± 100?
Harriman Ranch basalt lava field	457 ± 17
Eccles Butte basalt lava field[α]	466 ± 22
Lava Creek Tuff	640 ± 2
Boy Scout basalt lava field	Older than Eccles Butte basalt and the obsidian gravel deposits
Highway 20 Basaltic Andesite	737 ± 5
Elk Wallow Well Basalt	743 ± 5
Warm River Basalt	835 ± 17
Bishop Mountain rhyolite lava flow	1200 ± 10
Moose Creek Butte rhyolite lava flow	1220 ± 10
Warm River Butte rhyolite lava dome	1240 ± 20
Mesa Falls Tuff	1292 ± 50
Blue Creek rhyolite lava flow	1770 ± 20
Headquarters rhyolite lava flow	1820 ± 10
Huckleberry Ridge Tuff	2053 ± 6
Snake River Butte rhyolite lava flow *	1990 ± 20

Basalt flow names and ages are from Kuntz and others (this volume), except for the age of the Warm River basalt reported by Adedini (2009). Rhyolites ages are from Christiansen (2001).

[α] This flow field includes flows erupted from vents to the south (in Section 2) and to the northwest (near Chick Creek Road).

* The Snake River Butte rhyolite is older than the Huckleberry Ridge Tuff: it is cut by the ring fracture of the Yellowstone I caldera and underlies the Huckleberry Ridge Tuff.

Table 2. $^{40/39}$Ar ages of selected units in Island Park. Basalt lava fields are highlighted in gray; those that formed intracanyon benches are in bold. Rhyolite lava flows and domes are shown with no highlight.

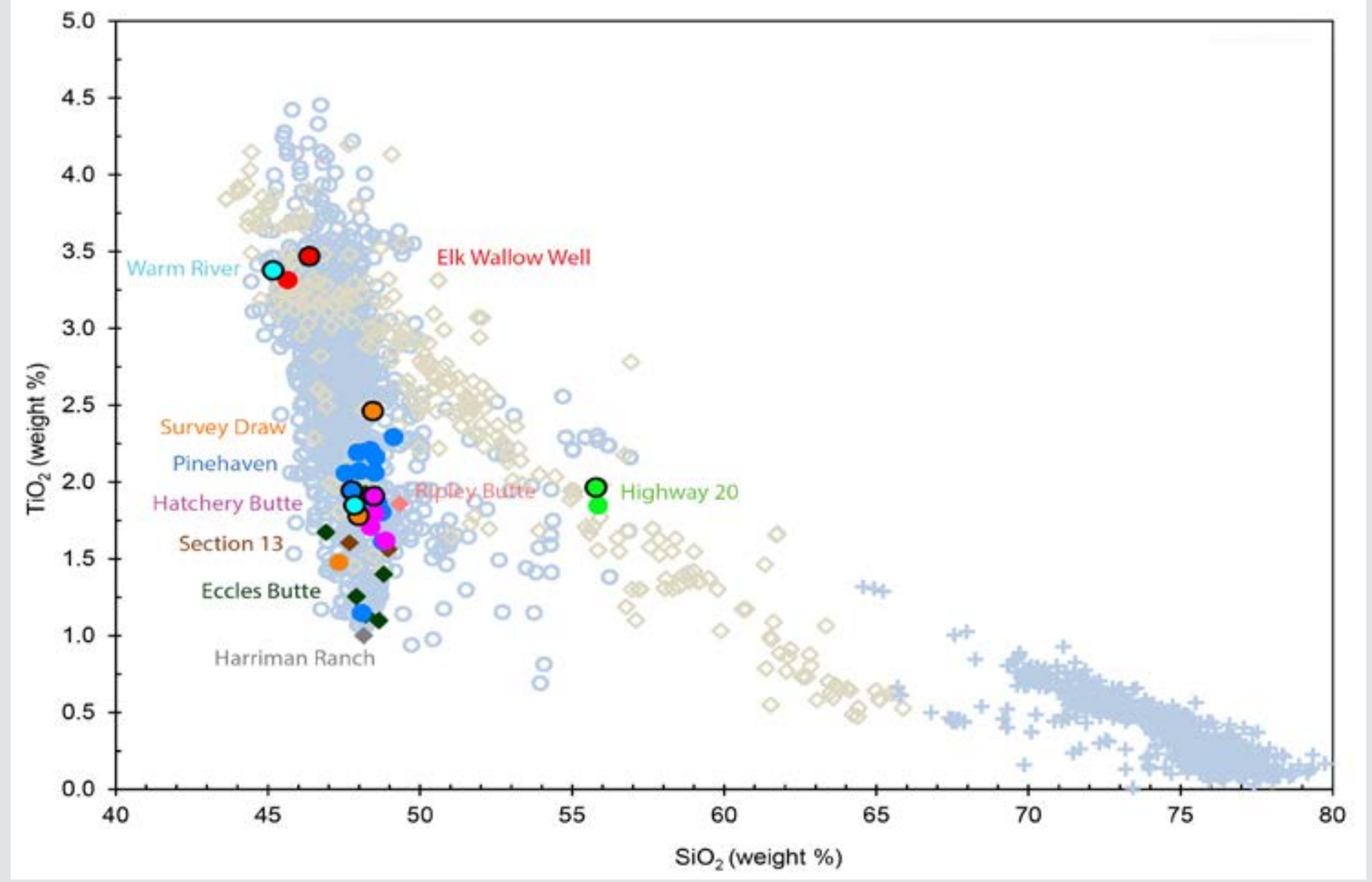

Figure 4. Harker variation plot of SiO_2 versus TiO_2 for Island Park lava fields.

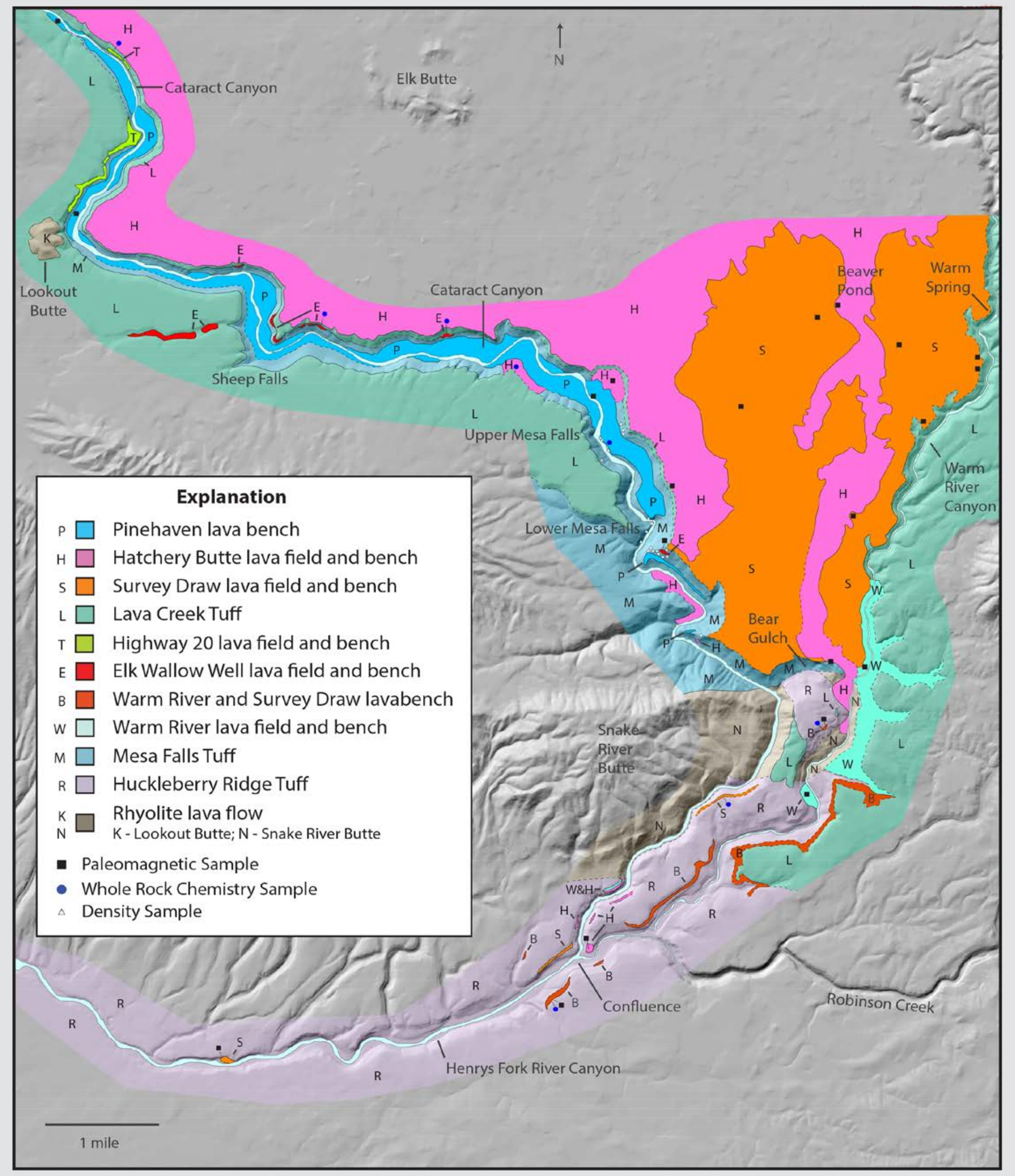

Figure 2. Geologic map of the Henrys Fork and Warm River Canyons and nearby areas.

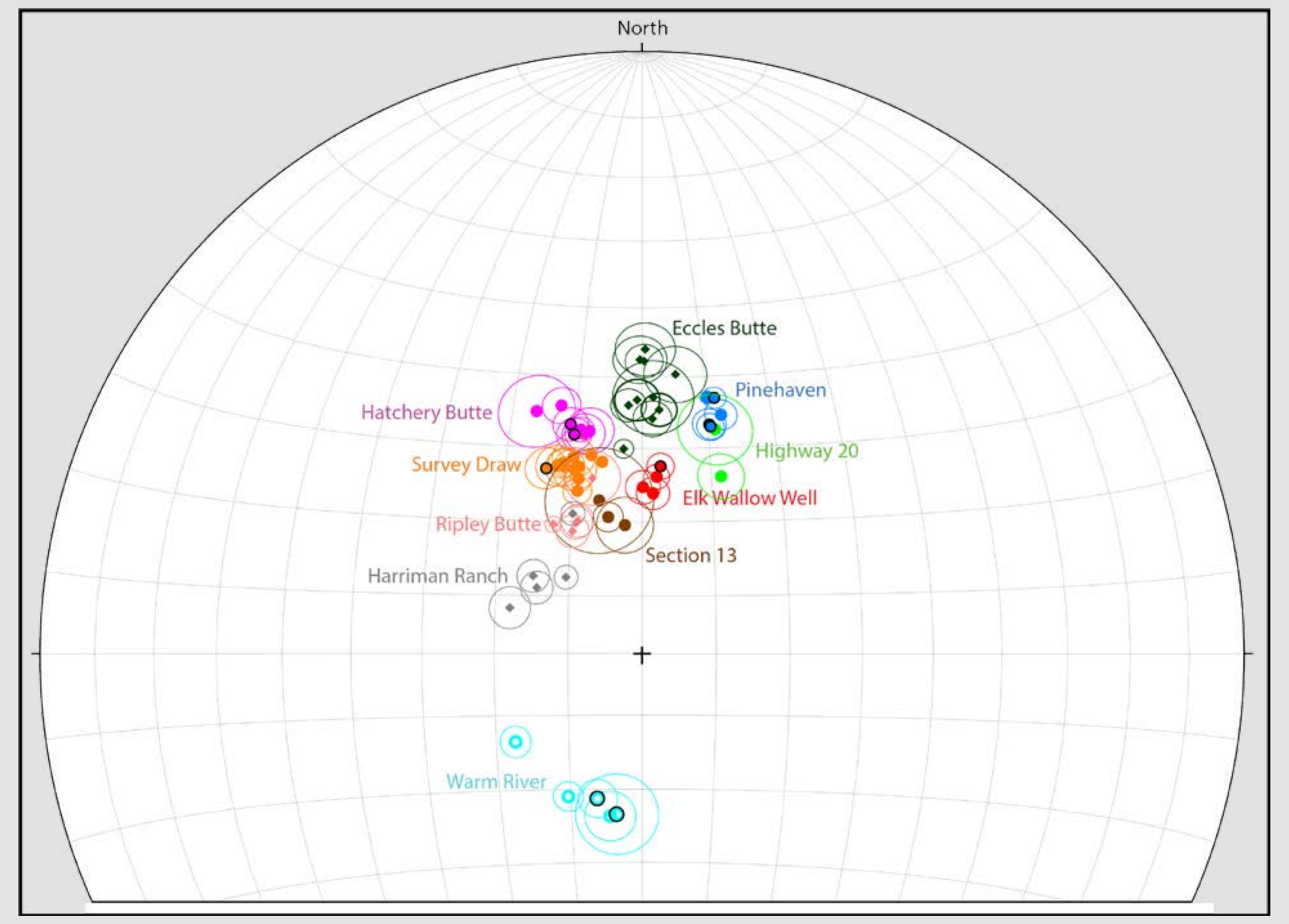

Figure 5. Stereonet plot of remanent magnetization orientations of Island Park lava fields

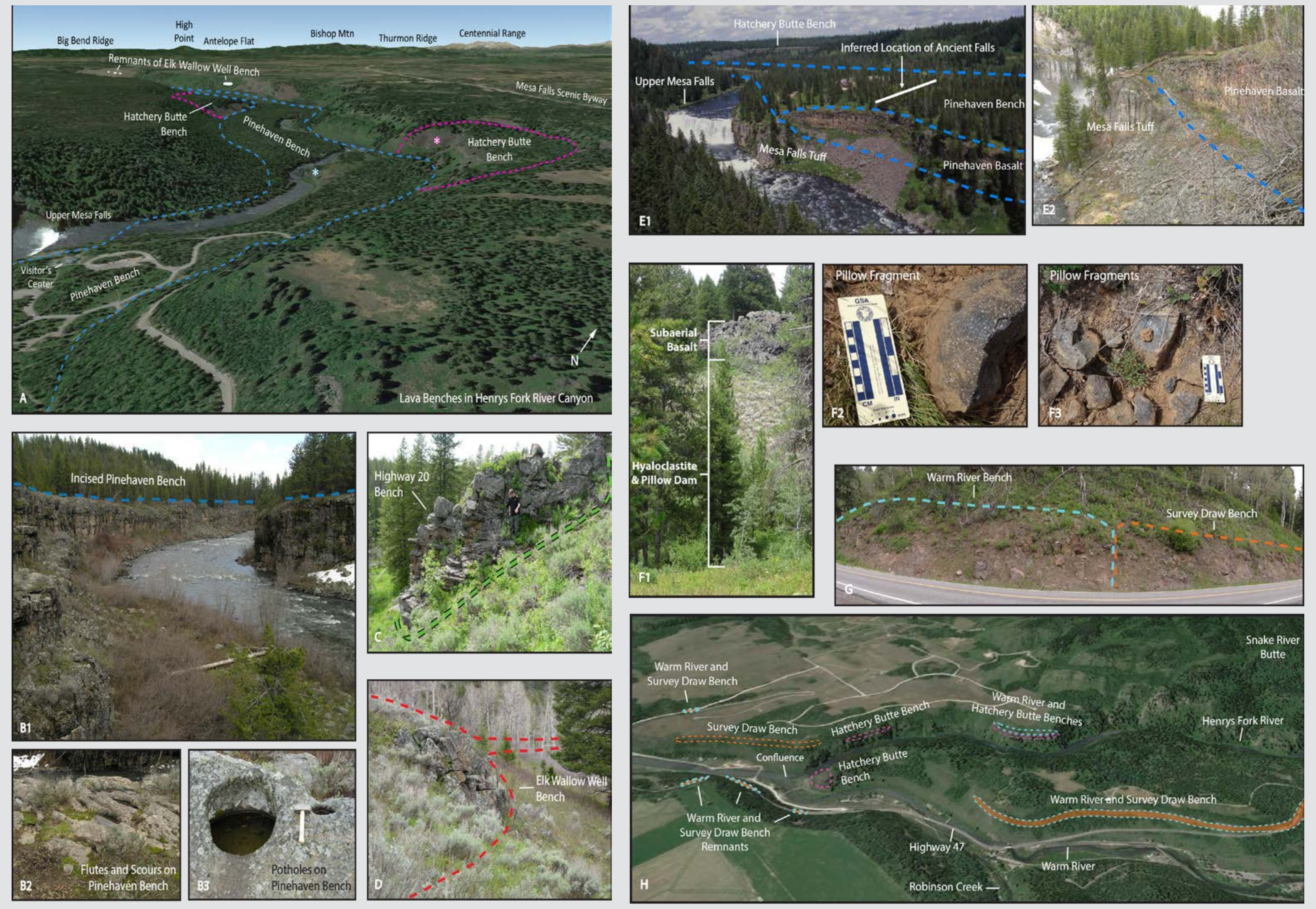

Figure 3: **A**) Upper Mesa Falls area showing the distribution of lava benches. **B)** Pinehaven lava bench near Upper Mesa Falls. **C)** Highway 20 bench near Lookout Butte. **D)** Elk Wallow Well bench near Lower Mesa Falls. **E)** Pinehaven basalt and Mesa Falls Tuff at Upper Mesa Falls. **F)** Hatchery Butte lava bench 0.5 mi upstream from Upper Mesa Falls. **F1**) Hatchery Butte bench showing a hyaloclastite and pillow dam under a subaerial basalt flow. **G)** Lava bench along highway 47 just south of Bear Gulch. **H)** Confluence of the Henrys Fork and Warm Rivers - distribution of lava benches

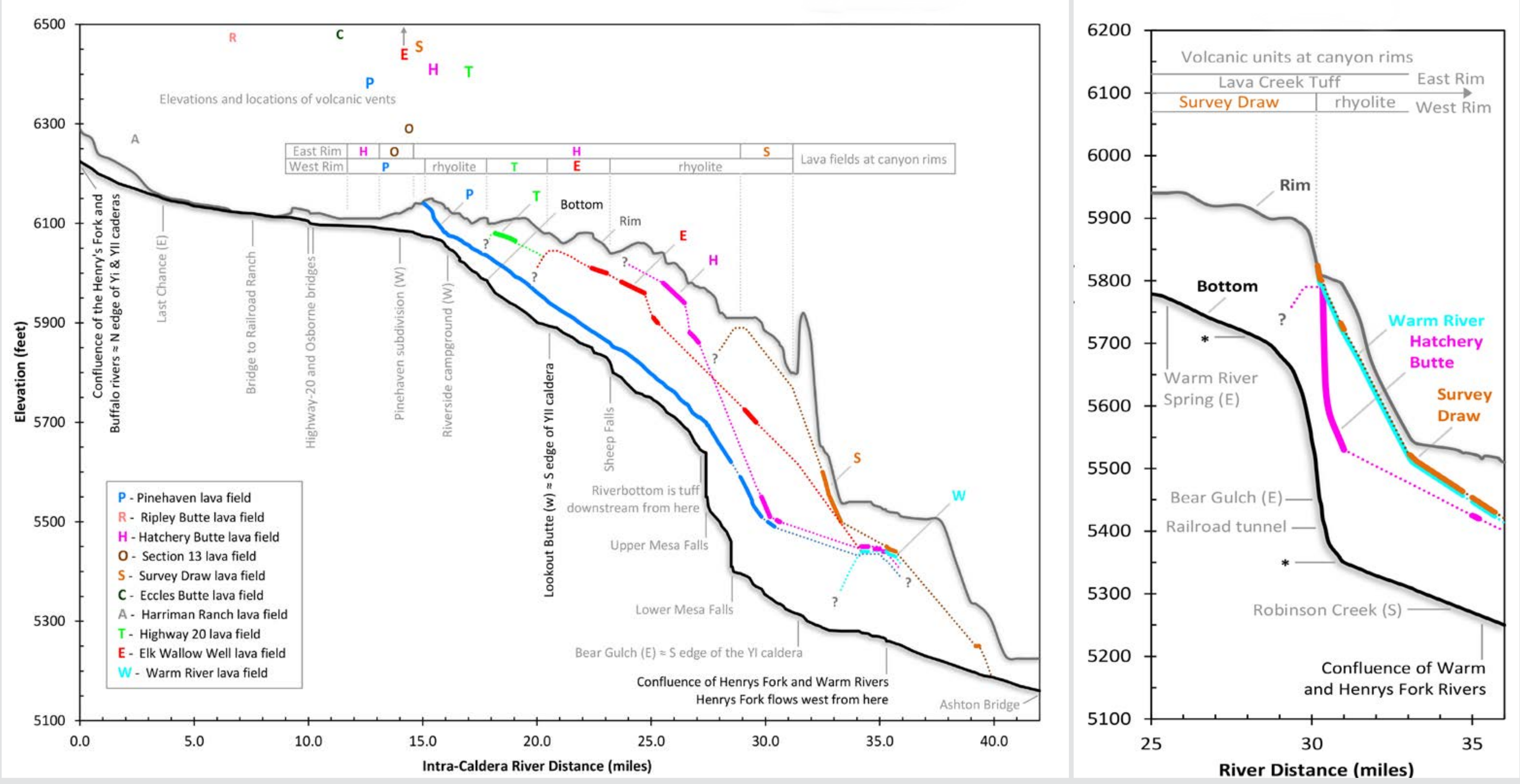

Figure 6 . Longitudinal cross sections of Henrys Fork and Warm River canyons showing qualitative models of the distributions of the tops of lava benches in Henrys Fork and Warm River canyons, expressed as river distance (from north to south) versus elevation. The modeled tops of lava benches curve down upstream of where the lava entered the canyon, simulating the possible distribution of lava dams. Vertical exaggeration is about 110x.

Origin of Upper and Lower Mesa Falls

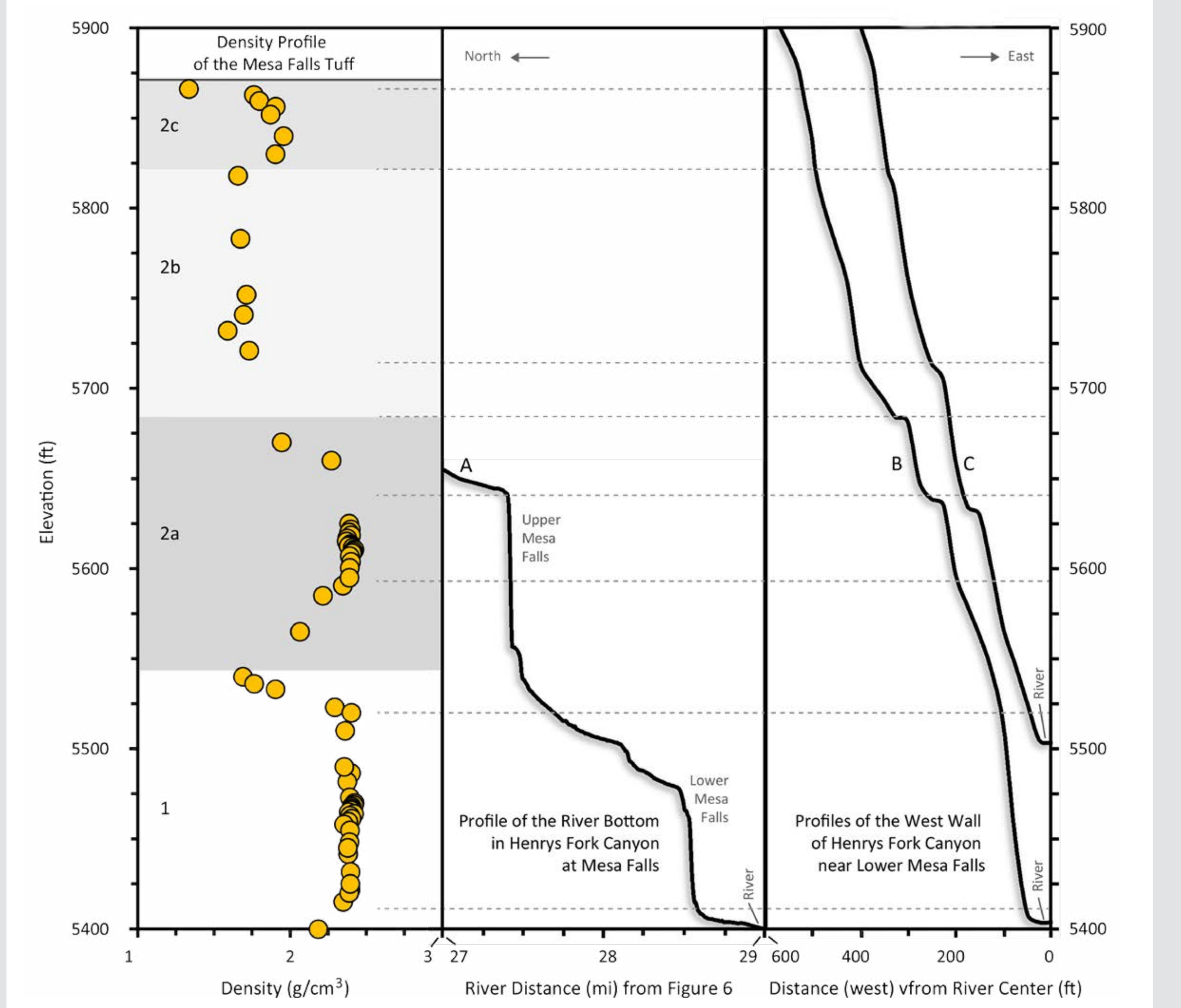

Figure 7. Plot of density versus elevation for the Mesa Falls Tuff in Henrys Fork canyon, relative to topographic profiles of the river bottom and west canyon wall in Henrys Fork canon. Vertical exaggeration is about 60x for river bottom and 4x for canyon walls

Conclusions:

- Density of the tuff is a proxy for the degree of welding, which influences erosion rates.
- The density profile suggests that at least three ash deposits built the Mesa Falls Tuff, as follows:
  - A layer over 150 feet thick was emplaced
  - After a break of months to years and before the lower layer had finished welding, a layer about 140 feet thick was deposited
  - Following a break of at least days, a layer 135 feet thick was emplaced
  - Finally, after a break of days to months, a 50 feet thick layer capped the unit.
- Upper Mesa Falls is shaped by undercutting of the the less-resistant lower section causing blocks of the overlying rock to collapse—which maintains the Upper Mesa Falls cliff.
- Lower Mesa Falls is shaped differently: with no undercutting, the river slowly incises into the resistant rock of Lower Mesa Falls, forming the observed profile.

Upper Mesa Falls

Lower Mesa Falls

Geologic History

Before 2.1 Ma:
- A topographic low draining the hotspot highlands.

2.1 to ~1 Ma:
- The Yellowstone I caldera formed at about 2.1 Ma.
- Caldera filled episodically by glacial ice and may have contained a lake during interglacial times.
- At ~1.3 Ma the Mesa Falls Tuff, which erupted from the Yellowstone II caldera, filled the Yellowstone I caldera moat zone with hundreds of feet of tuff in at least 3 separate ash deposits.
- Erosion deepened the HFR and WR canyons.

~1 Ma to ~400 ka:
- Lava Benches filled the ancient HFR and WR canyons.
- At ~835 ka,WR and HFR canyons were established.
- The precursors to Upper and Lower Mesa Falls first developed.

~400 ka to Present:
- Upper and Lower Mesa Falls migrated upstream, arriving before ~29 ka at their present locations.
- Lava from the Hatchery Butte lava field (81 ± 13 ka) entered both canyons.
- Pinehaven lava field (29 ± 9 ka) formed the Pinehaven bench in the HFR canyon.
- The river eroded through Hatchery Butte flow and continues to erode through the Pinehaven flow today.

Future Research

- Locate lava vent for basalt of Warm River.
- Sample other locations in the Mesa Falls Tuff.
- Create density profiles for the Huckleberry Ridge Tuff and Lava Creek Tuff.

Acknowledgements

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