Rhyolites in the Kimberly Drill Core, *Project Hotspot*: First Intracaldera Ignimbrite from the Central Snake River Plain, Idaho?

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Introduction

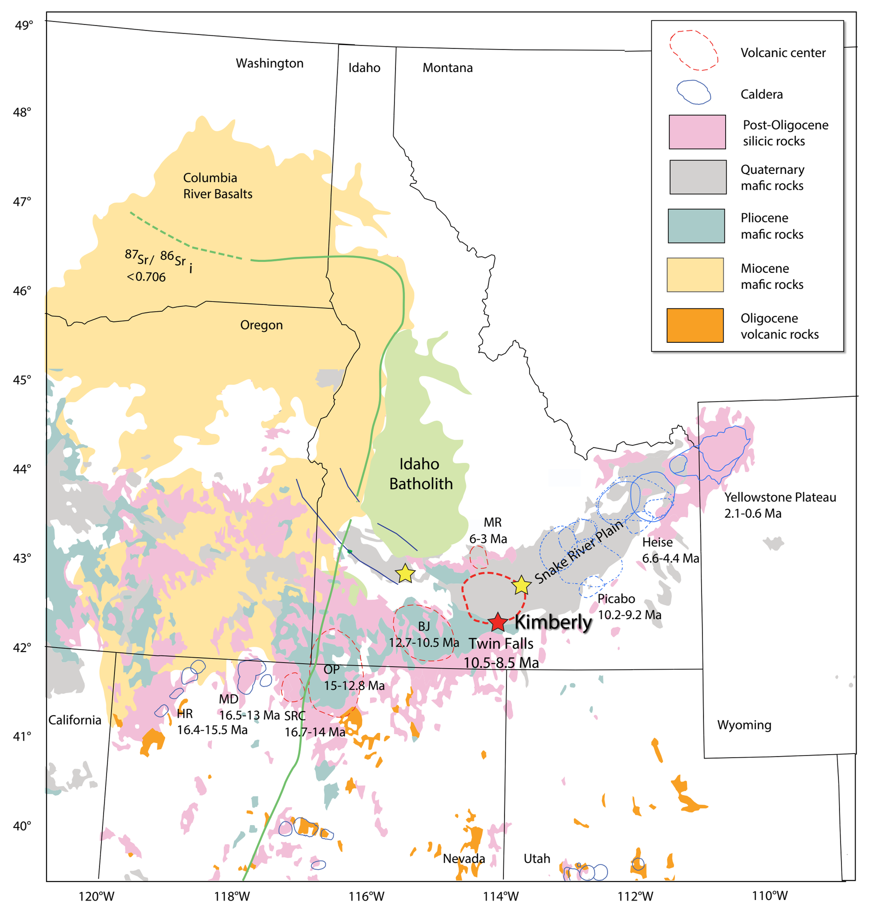
The rhyolites on the track of the Yellowstone hotspot are the classic examples of continental hotspot volcanism. The study of surface outcrops is maturing rapidly. However, in the central part of the track, where silicic volcanism is most voluminous, compositionally distinctive, and isotopically most anomalous, study of these large magma systems has been hindered because eruptive sources are buried. The 2 km Kimberly core helps fill that gap; it penetrates through surficial basalt, deep into the rhyolitic underpinnings on the southern margin of the province. The Kimberly core is dominated by thick sections of rhyolite lava and welded ignimbrite, with basalt-sediment intercalations between 241 m and 424 m depth. We tentatively interpret the core to include a thick intracaldera tuff--making this the first identification of a caldera in the Central Snake River Plain.

Our preliminary studies suggest that there are only three major rhyolite units in the core. Rhyolite 3, the uppermost unit, is a nearly 130 m thick, low-silica rhyolite. Rhyolite 2 is the most highly evolved with ~75% silica and distinctively resorbed quartz.

Rhyolite 1 is at least 1,340 m thick (the base was not cut by the core), has no apparent flow contacts or cooling breaks, and may represent a single, thick intracaldera ignimbrite. Paleomagnetic inclinations form a curious V-shaped profile, shallowing by about 18° between 700 and 1700 m depth but similar at the top and bottom. We interpret this to be the result of slower cooling of the mid-part of the intracaldera tuff. The unit is a low-silica rhyolite with high concentrations of Fe and Ti—among the highest of any known ignimbrite on the SRP. It is chemically distinct from the upper units, very homogeneous, not vertically zoned, and lacks multiple populations of phenocrysts. It resembles the regionally extensive 8.9 Ma tuff of McMullen Creek. However, this is one of several large, petrologically similar ignimbrites exposed in the Cassia Mountains south of the hole, so further work is needed.

Like most rhyolites from the Snake River Plain, all 3 units have the characteristics of A-type rhyolites with high concentrations of alkalies, high Fe/Mg and TiO_2/MgO ratios, as well as high concentrations Nb, Y, Zr and Ga.

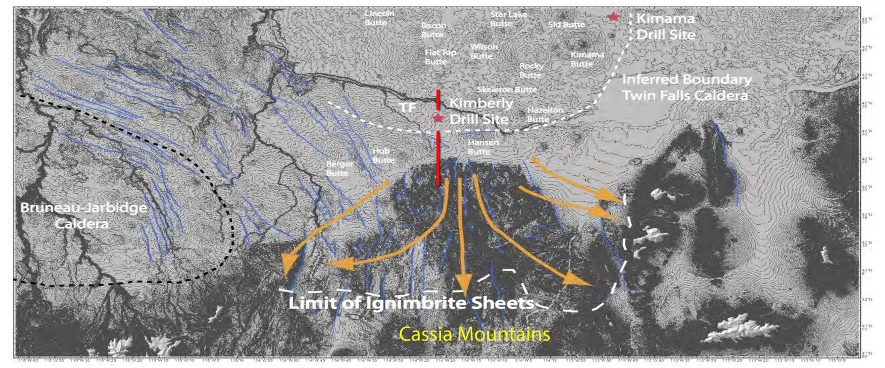
Initial analyses of plagioclase, clinopyroxene, and quartz show that all three units are low δ18O rhyolites, like most from the Central Snake River Plain-- $\delta^{18}O$ in feldspar ranges from 1‰ in Rhyolite 1 to 3‰ in Rhyolites 2 and 3. In the thick lower ignimbrite, whole-rock δ18O increases systematically from the base upward (0.5‰ to as much as 9‰ in the altered top and δD ranges from -140 to -180‰). Whole rock variations correlate with water content, and are apparently controlled by secondary clay. We suggest that these characteristics were largely imposed by their derivation from partial melting of basaltic sills and surrounding older crust. The low 18O values reflect recycling of hydrothermally altered crustal rocks and indicate progressive incorporation of more hydrothermally altered material into the younger magmas.



Geology of the Snake River Plain-Yellowstone region.
Simplified geologic map of the northwestern United States. Rhyolitic volcanic centers and calderas related to the Yellowstone hotspot are generally younger to the northeast. Basalts overlie older rhyolites.

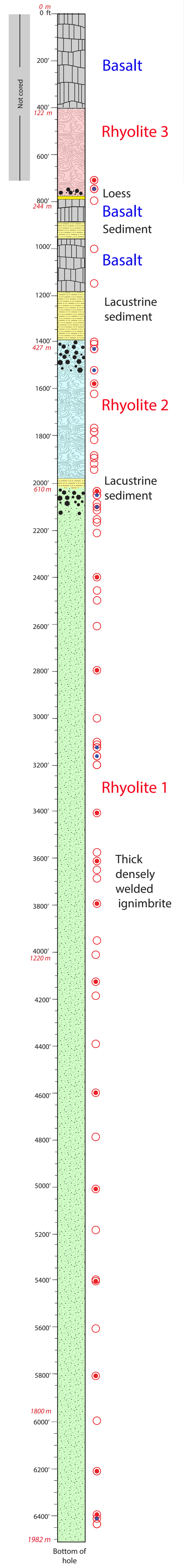
Stars show the location of the Project Hotspot drilling sites; the Kimberly well is in red.

Names of volcanic fields (red) and calderas (blue): HR - High Rock, MD - McDermitt, SRC - Santa Rosa-Calico; OP - Owyhee Plateau; BJ - Bruneau-Jarbidge, MR-Magic Reservoir Boundaries are dashed where less certain or buried. (Anders et al., 2013; Morgan and McIntosh, 2005; Coble and Mahood, 2012; Bonnichsen, 1982)



Shaded relief map of the Twin Falls, Idaho, area with 10 m contours. Arrows show the flow directions of ignimbrites and the dashed white line marks the southern extent of the tuffs in the Cassia Mountains south of the Kimberly drilling site (McCurry et al., 1996). Blue lines are faults and lineaments. Speculative boundary for the Twin Falls caldera is shown along with the location of the Bruneau-Jarbidge volcanic field. From Shervais et al. (2012).

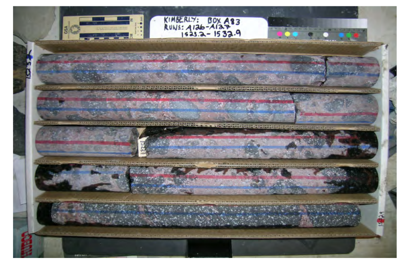
The Core



Core boxes from the Kimberly core.
Each slot is 2 feet or 0.6 m long.

A. Vitrophyre at base of Rhyolite 3 in contact with red loess at ~775 feet deep.

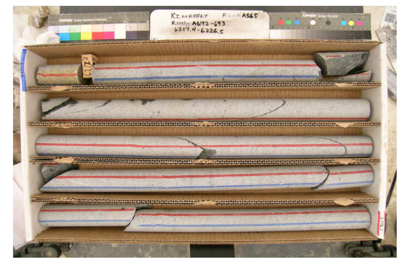
B. Finely laminated marly lake sediment above Rhyolite 2 from a depth of 1320 feet.



C. Vitrophyre clasts in flow breccia at top of Rhyolite 2 at a depth of 1530 feet.

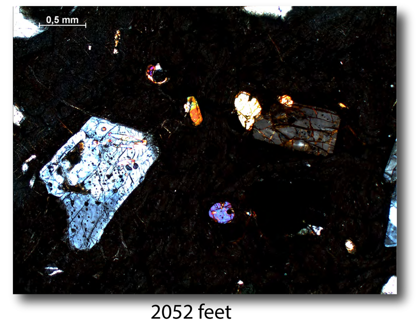
D. Vitrophyre at base of Rhyolite 2 at 1950'. Sediment in bottom slots of core box .

E. Breccia facies at top of lower ignimbrite (Rhyolite 1) at a depth of about 2200 feet.

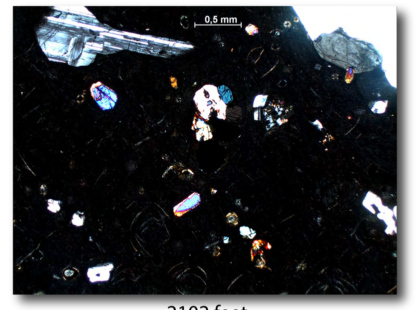


F. The lower unit is a homogeneous porphyritic ignimbrite with phenoclasts of plagioclase, sanidine, pyroxene, and oxides shown here at a depth of 6220 feet.

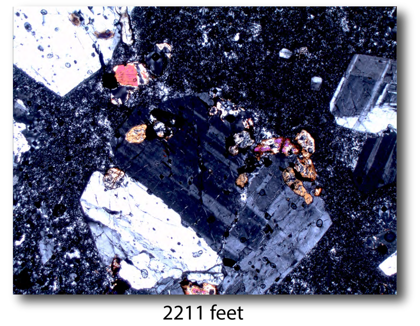
Rhyolite 1



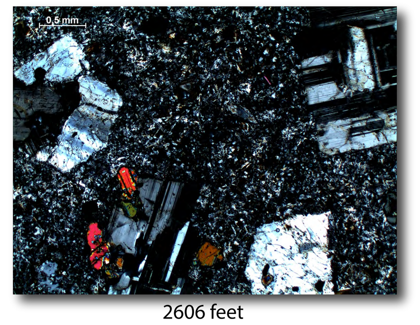
2052 feet



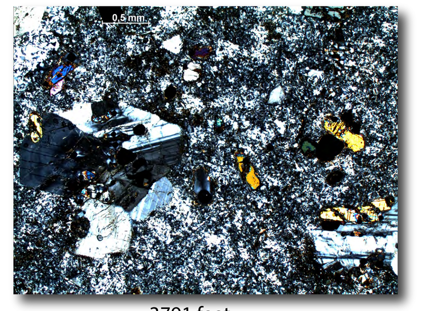
2102 feet



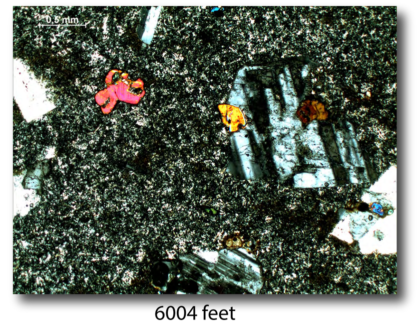
2211 feet



2606 feet

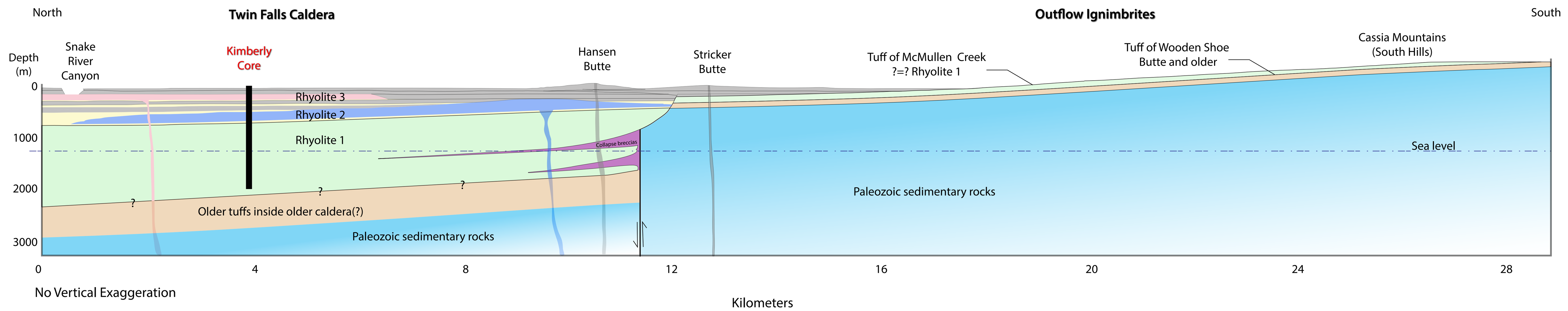


3791 feet

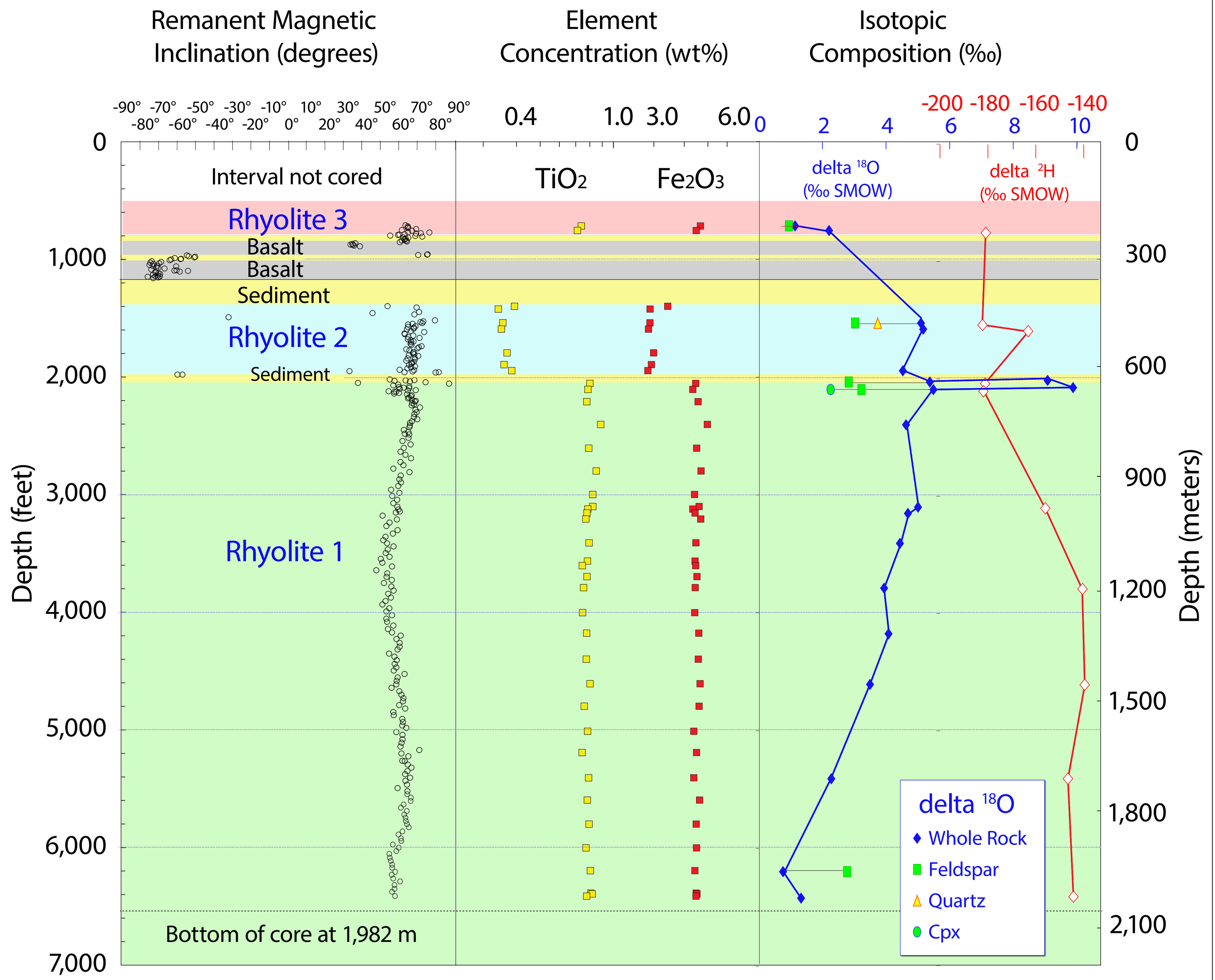


6004 feet

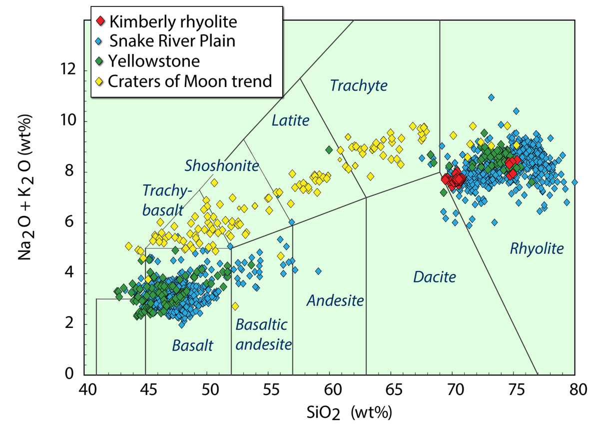
6414 feet

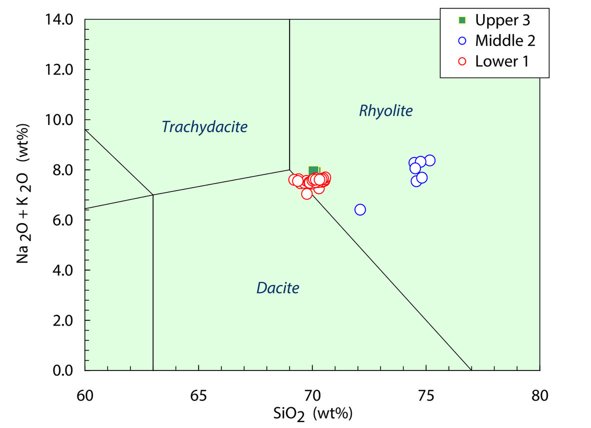


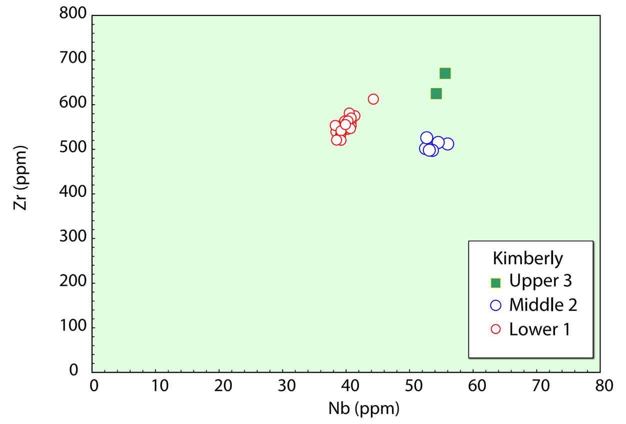
Speculative cross section drawn through the Snake River Canyon, the Kimberly drill core, and into the Cassia Mountains (South Hills). The tuff of McMullen Creek (8.9 Ma) is the youngest of the tuffs exposed in the Cassia Mountains (Williams; et al., 1991, 1999; Mytton et al. 1990) and is thus the most likely correlative with the thick intracaldera tuff encountered in the drill hole. The outflow tuffs dip northward to the axis of the Snake River Plain as a result of post eruptive subsidence of the SRP. No caldera collapse breccias were found in the core; consequently, the wall of the caldera probably lies to the south in between the drill site and the first outcrops of outflow tuff to the south. The sediments are interpreted to have formed in intracaldera lakes and they envelope intracaldera rhyolite and basalt lavas (Rhyolite 2). We interpret these flows to be between 8.9 and 6 Ma (Othberg et al., 2012) based on a tentative correlation of the upper rhyolite (Rhyolite 3) with the rhyolite lava of Shoshone Falls. The caldera probably filled with basalt below Rhyolite 3. Subsequent eruption of the Tb and the Hansen Butte basalt buried the caldera and the rhyolite domes by about 2 Ma.

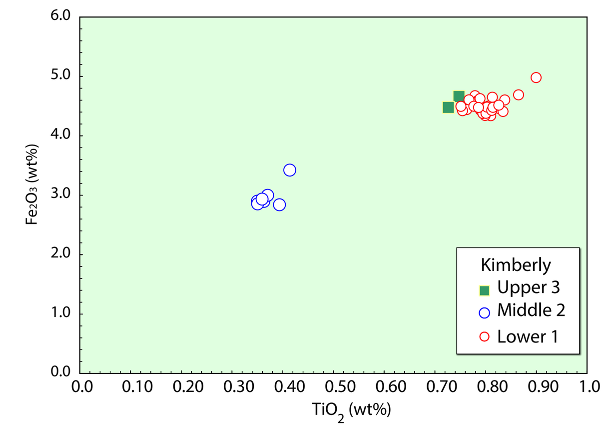


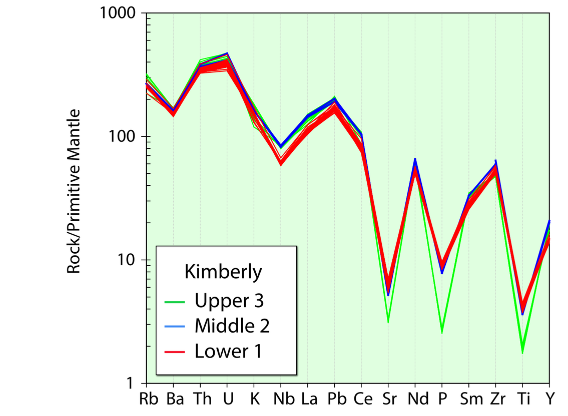
Paleomagnetic inclinations and composition of the rhyolites in the Kimberly core suggest there are at least 3 eruptive units in the core. Other units may be found during detailed logging and geochemical and paleomagnetic investigations. For example, paleomagnetic data suggest a thin volcanic layer lies within sediment at about 600 m (2000') and the upper part of Rhyolite 1 shows small changes that might mark another unit. Oxygen and hydrogen isotopic compositions show that quartz, feldspar, and clinopyroxene have retained their magmatic values in spite of alteration of the groundmass. Feldspar (=magmatic) delta 18O ranges from 1‰ (in Rhyolite 3), to 3‰ (in Rhyolites 1 and 2). Note feldspar has same 18O in the upper and lower parts of Rhyolite 1, even though whole-rock O-isotope ratios systematically decline and H-isotope ratios increase with depth.

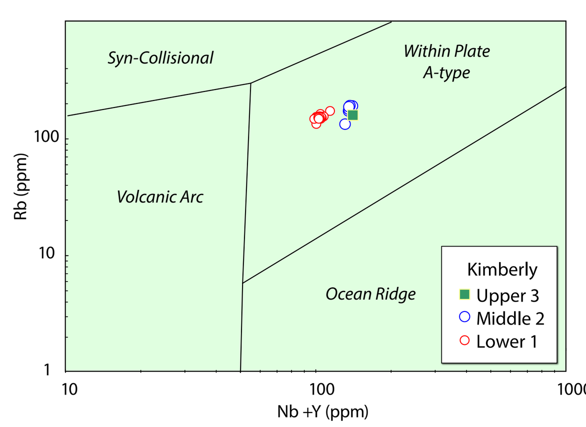












Compositions of rhyolites from the Kimberly core show they are typical of A-type granites elsewhere. (A) IUGS TAS classification. (B) Detail of the TAS diagram for the Kimberly core alone. (C) Zr-Nb concentrations show three distinct compositions that correlate with the lithologic units. Little compositional variety. (D) Fe and Ti concentrations are high in the upper and lower (1) rhyolites compared to the more evolved middle lava (2). (E) Primitive Earth normalized trace element patterns for the three units are similar but each unit has some distinct characteristics. (F) Tectonomagmatic discrimination diagram of Pearce et al. (1984).

Conclusions

Plains basalt
Upper basaltic flows erupted from local shield volcanoes
Several flows of olivine tholeiite erupted from Hansen Butte and other older vents.
This interval was not cored, but is exposed in the adjacent Snake River Canyon.

Rhyolite 3
Rhyolite lava flow
Plagioclase, K-feldspar, pigeonite, augite and Fe-Ti oxides.
Erupted on top of package of sediment/rhyolite lava/basalt lava filling an older caldera.
Tentatively correlated with the rhyolite of Shoshone Falls.

Caldera-filling package of basalt and sediment
Basalt
Multiple basalt lava flows of olivine tholeiite with phenocrysts of plagioclase and olivine.
At least three flows are indicated by the paleomagnetic variation in the upper 100 m thick sequence of basalt.

Sediments
Finely laminated, marly, volcanic ash rich, abundant clay.
Three prominent layers with thickness of 29, 67, and 19 m.
Minor loess compared with Kimama drill core, which penetrates through 6 million years of basalt.
Interlayered with basalt and rhyolite lavas in the upper part of core. Package overlies thick basal ignimbrite.
Accumulated in shallow intracaldera lake formed as a result of collapse associated with rhyolite 1

Rhyolite 2
High-silica rhyolite lava flow
Strongly resorbed quartz, along with plagioclase, K-feldsar, pigeonite, augite and Fe-Ti oxides.
Erupted as an intracaldera lava dome.
Unusually silica-rich for the Central Snake River Plain; no known correlative.

Rhyolite 1
Low-silica rhyolite ignimbrite
Plagioclase, K-feldspar, pigeonite, augite and Fe-Ti oxides.
Densely welded, mostly devitrified, but with glassy upper breccia admixed with sediment.
Paleomagnetic inclinations vary through tuff indicating cooling during secular variation followed by ~5° tilting related to downwarp of Snake River Plain
Thick (1300 m) intracaldera tuff.
Tentatively correlated with the 8.9 Ma tuff of McMullen Creek as late erupted post-collapse tuff.

Acknowledgments

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