

Geologic Field Guide to Riley Ranch Nature Reserve and the Deschutes River Trail to Tumalo State Park.

by
Bob Jensen

Geologic Overview

The Deschutes River canyon between Bend and Tumalo State Park exposes a window into Central Oregon's geologic history, with volcanic units ranging in age from about 65,000 years ago ($ka = 1,000$ years ago) to more than 5 million years ago ($Ma = 1,000,000$ years ago). The wide variety of volcanic and erosional features within the Riley Ranch Nature Reserve makes it the most geologically interesting park in the Bend Park & Recreation District. The Deschutes River Trail extends north from the Reserve to Tumalo State Park and reveals more of the geologic history of the area.

Ash-flow Tuffs of Bend area

Several pyroclastic eruptions of Pleistocene age are recorded by deposits exposed near Bend and in adjacent parts of the Cascade Range. From oldest to youngest, the major deposits are the Desert Spring Tuff, the Bend Pumice and Tumalo Tuff (tephra-fall and ash-flow deposits of a single magmatic episode), and the Shevlin Park Tuff.

The Desert Spring, Tumalo, and Shevlin Park Tuffs were erupted from volcanic centers west of Bend, on the basis of their distribution and diminished welding outward from the proposed source area. Various vents have been suggested between Triangle Hill and Broken Top.

Only the Desert Spring Tuff and Tumalo Tuff are exposed at Riley Ranch and Tumalo State Park. For more information on the ash-flow tuffs west of Bend check out the Field Guide for Shevlin Park.

Deschutes River changes

Over the last half million years the Deschutes River has been forced to cut a new channel multiple times due to eruptions originating from the Cascades to the west and Newberry Volcano to the south. Prior to about 350,000 years ago the paleo Deschutes River occupied a channel east of Bend and Redmond (Figure 1A). This paleo channel was filled by the basalt of Crooked River Gorge which was erupted about 350,000 years ago from a buried vent on the north flank of Newberry Volcano (Figure 1B). The river established a new channel which was still to the east of Bend but it cut a canyon through the Redmond area.

In the Bend area a major change in the river's location occurred about 64,500 years ago with the eruption of the basalt of Bend, which underlies much of Bend east of the river (Figure 1C). The vent for this

eruption (now buried by younger flows) was located on the north flank of Newberry in the Mokst Butte area and the flows extend northward to the south edge of Redmond. A about a 500 years later another eruption produced the basalt of Lava Top Butte from multiple vents (Figure 1D). The flows from these two eruptions filled and obscured the paleo Deschutes channel all the way to Redmond. In Redmond the basalt of Lava Top Butte partially filled the paleo channel leaving today's flat floored Dry Canyon. The Deschutes River had to establish a new channel near the western margin of the basalt of Bend.

The final eruption which affected the Deschutes was the eruption of Lava Butte and its flows which resulted in Benham, Dillon, and Lava Island Falls (Figure 1E). This eruption filled over eight miles of the post basalt of Bend channel.

Megaflow

This section is a rough draft only.

There are multiple locations where large boulders have been identified along a 14 mile stretch of the Deschutes River from Meadow Day Use to Tumalo State Park (see map on last page). Over 500 boulders have been inventoried, of which about 450 boulders have at least one dimension exceeding 9 ft. The volume of these large boulders begin at about 15 cy and reach as much as 130 cy with corresponding weights of 40 to 330 tons.

In addition to the large boulder deposits there are five areas where erosional channels and features have been cut across the basalt of Bend in addition to the current river channel. These additional erosional channels appear to represent excess river volume finding other routes.

The boulders and channels require a greater river flow volume than normal river flows can provide. Prior to about 15,000 years ago, glacial conditions prevailed and the volume of flow of the Deschutes River was larger than today. Under these glacial conditions the river would have been able to erode and transport larger material than today, but most of the large boulders are still too big to have been moved even under those higher flow conditions.

Outburst floods related to natural dam breaches can provide the flow velocity and volume necessary to move large boulders. The emplacement of the basalt of Bend not only caused the relocation of the route of the Deschutes River but also created a dam which caused a lake to form upstream in the Sunriver area. There are still questions to be resolved but the breaching of this lake is a likely source for the flood through Bend.

South of Meadow Day Use Area evidence of a flood has been buried by the younger Lava Butte eruption 7 ka years ago. From Meadow Day Use Area to Farewell Bend Park the river canyon is largely cut into lava flows coming from the Cascades with the basalt of Bend only being exposed in roughly half of the eastern canyon rim. Generally the boulders at the various locations can be linked to sources a short distance upstream (generally less than 2 miles). Most boulder sites are at slightly wider canyon locations where stream velocity drops. At the final location near Farewell Bend Park the river emerges from a narrow canyon to deposit boulders over a large part of the Woodriver subdivision south of the park.

From Farewell Bend Park to Drake Park there are no boulder deposits but a large area adjacent to the river was flooded by water and gravels were deposited.

At the northern end of Drake Park the river enters the basalt of Bend which it is in or adjacent to all the way to Tumalo State Park. The river canyon is fairly shallow (less than 40 feet) until Sawyer Park. From Sawyer Park until the river exits the narrow canyon in Riley Ranch the canyon continues to deepen and at the canyon exit it is 150 feet deep.

Just upstream of Canyon Hill in Riley Ranch Nature Reserve, the river had to cross a lobe of the basalt of Bend which had flowed up a stream channel along the northwest side of Awbrey Butte. After crossing this lobe,

the river widened and began dropping large boulders but still had sufficient energy to cut into the gravels and pyroclastic flow downstream.

Riley Ranch Nature Reserve contains the largest collection of large boulders along the Deschutes River through Bend. The gravels and boulders along the Canyon Loop trail are primarily basalt of Bend and basalt of Awbrey Butte plus occasional boulders of Desert Spring Tuff. Compared to the basalts the tuff is relatively soft and tends to break up in transport so tuff boulders in the deposit tend to occur only a short distance downstream from Desert Spring exposures.

Rimrock exposures of the basalt of Bend show that it tends form flow units that are 10 to 30 feet thick resulting in large blocks. Exposures of the basalt of Awbrey Butte show that it tends to produce thin flow units (less than 5 feet) which results in smaller blocks.

The two basalts are distinctly different in hand specimens. The basalt of Bend (Figure 2) has a fine granular texture (diktytaxitic) with olivine while basalt of Awbrey Butte (Figure 3) is porphyritic with phenocrysts of feldspar.

At the northern end of Riley Ranch Nature Reserve the river again enters a deep canyon which it exits just above Tumalo State Park where the final large boulder deposit is located.

The timing of this flood event is a big question. Some evidence seems to point to a significant canyon at



Figure 2 - Basalt of Bend.



Figure 3 - Basalt of Awbrey Butte.

Table 1 - Summary of Geologic Events

Age	Event
0 ka	Today
7 ka	Eruption of Lava Butte and its flows
11.7 ka	Holocene Epoch - Pleistocene Epoch boundary, end of the last major glacial period.
	Cutting of new Deschutes River channel following eruption of basalt of Bend. The cutting of a new channel included a major flood event leaving boulder deposits along river from southern Bend to Tumalo S.P.
~64 ka	Eruption of basalt of Lava Top Butte from multiple vents on Newberry Volcano.
	Deposition of fine gravels overlying basalt of Bend, source Tumalo Creek.
~64.5 ka	Eruption of basalt of Bend from Newberry Volcano.
~65 ka	Caldera forming eruption at Newberry Volcano.
~260 ka	Eruption of Shevlin Park Tuff.
	Eruption of basalt of Skyline Ranch Road from High Cascades.
	Eruption of basalt of Johnson Road from High Cascades.
~345 ka	Eruption of basalt of Crooked River Gorge from Newberry Volcano.
	Development of erosional surface across Tumalo Tuff and deposition of gravels beneath basalt of Bend.
~440 ka	Eruption of Tumalo Tuff / Bend Pumice from High Cascades.
~530 ka	Earliest eruptions of Newberry Volcano.
~600 ka	Eruption of Desert Spring Tuff from High Cascades.
2.6 Ma	Pleistocene Epoch - Pliocene Epoch boundary.
> 4 Ma	Eruption of multiple mafic flows of the Deschutes Formation.
> 5 Ma	Eruption of basalt of Awbrey Butte.

the time of the flood while other evidence seems to suggest the opposite.

Sherrod, D.R., Taylor, E.M., Ferns, M.L., Scott, W.E., Conrey, R.M., and Smith, G.A., 2004, Geologic Map of the Bend 30- x 60-Minute Quadrangle, Central Oregon: U.S. Geological Survey Geologic Investigations Series I-2683, scale 1:100,000, <https://pubs.usgs.gov/imap/i2683/>

References

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Geologic Guide to Riley Ranch Trails

by
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Miles

0.00—[Elev. = 3492 ft. N 44.09900° E 121.32550°]
Riley Ranch Trailhead. Note location on Figure 4. As with most of Bend east of the Deschutes River, the Riley Ranch Trailhead is located on the basalt of Bend. The basalt of Bend was erupted

about 65 ka (one ka = 1,000 years ago) and is one of a group of large volume, highly fluid basalt flows that covered large areas on the low north and south flanks of Newberry Volcano over the last 400 ka. The vent for basalt of Bend eruption

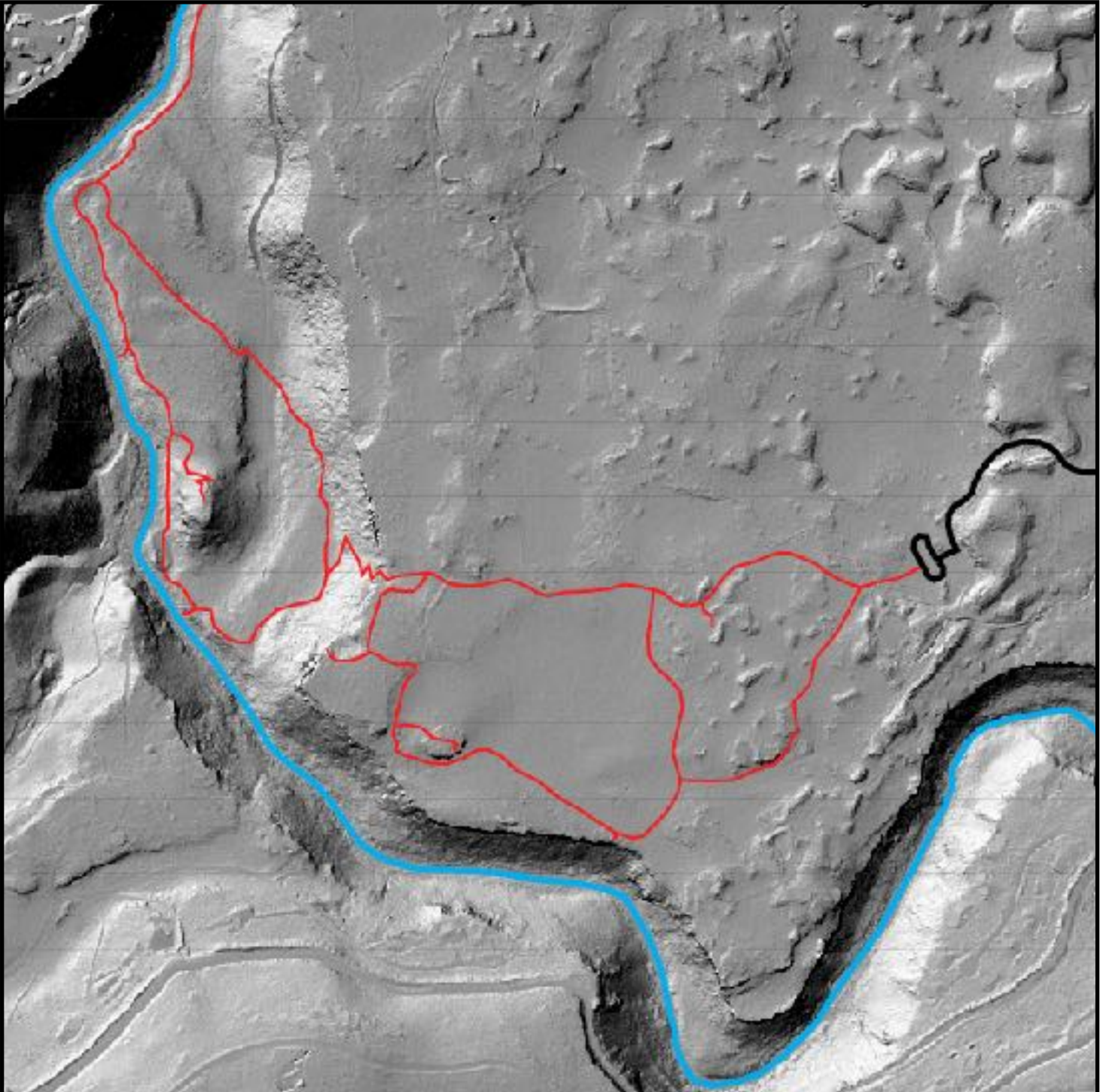


Figure 4 - Lidar image of Riley Ranch Nature Preserve area. Trailhead and Glen Vista Road in black. Trails in red, river in blue.

(now buried by younger flows) was located on the north flank of Newberry in the Mokst Butte area and the flows extend west to the Deschutes River and northward to the south edge of Redmond, a distance of nearly 30 miles (48 km). The flows cover an area of about 90 square miles (230 sq km). Based on detailed paleomagnetic studies of a similar set of flows at Medicine Lake volcano in northern California the basalt of Bend was probably erupted over a period of less than 100 years. Based on eruption rates that have been observed in Hawaii the entire eruption of the basalt of Bend could have occurred in less than a year if there was a constant supply of magma.

— Head west on Juniper Loop Trail.

- 0.03**—View of Mt. Bachelor ahead. The Middle Sister and North Sister are also visible off to the right ahead. (For information on the Cascade volcanoes see Appendix A.) Over next mile various peaks are intermittently visible to west, some of the views are noted in the trail log.
- 0.05**—[Elev. ~3493 ft. N 44.09874° E 121.32632°]
Trail Junction.
— Turn left on Juniper Loop Trail.
- 0.13**—[Elev. ~3495 ft. N 44.09773° E 121.32698°]
Bench—Lt. Typical basalt of Bend flow surfaces. Rocky highs with intervening lows covered by a soil of wind blown material. Also a view of Mt. Bachelor.
- 0.19**—[Elev. ~3489 ft. N 44.09692° E 121.32731°]
Bench—Rt Another area of typical flow surfaces near a flow lobe margin.
- 0.23**—[Elev. ~3478 ft.] To the right is a typical flow margin edge (Figure 5), compare what you see here with the edge at mile 0.58.
- 0.26**—[Elev. ~3476 ft] View of Black Crater and Mt. Washington ahead to right. Also a view of South Sister. (For information on the Cascade volcanoes see Appendix A.)
- 0.31**—[Elev. = 3474 ft. N 44.09634° W 121.32943°]



Figure 5 - Flow margin at mile 0.23.

Trail Junction. From this junction the view includes the volcanoes from Ball Butte to Mt. Jefferson (top). (For information on the Cascade volcanoes see Appendix A.) Trail to right ties through to log mile 2.97.

— Turn left from Juniper Loop Trail onto Sage Flat Loop Trail.

- 0.39**—[Elev. ~3465 ft. N 44.09575° W 121.33036°]
Trail Junction.

— Turn left on spur trail to River Viewpoint.

- 0.40**—[Elev. ~3465 ft. N 44.09558° W 121.33045°]
River Viewpoint. This Overlook is located on canyon rim of basalt of Bend about 125 feet above the Deschutes River at river mile 162.0 (Figure 6).

With the eruption of the basalt of Bend more than 10 miles of the Deschutes River channel was buried and the Deschutes was forced to find nearly 40 miles of new channel to the west of the basalt of Bend.

The view south shows the canyon cut by the Deschutes River along the contact between Awbrey Butte lavas and the basalt of Bend. Everything across the river is from Awbrey Butte. On this side of the river the basalt of Bend forms the capping rimrock (about 30 feet thick), but lower in the canyon wall lavas from Awbrey Butte are exposed.

As the river began to establish this new route along the margin of the basalt of Bend waters may have spread fine gravels along the route. These fine gravels (3" max. size) are found in scattered locations on the basalt of Bend from here downstream for about a quarter mile (Figure 7).

— Return to Sage Flat Loop Trail.

- 0.41**—[Elev. ~3465 ft. N 44.09575° W 121.33036°]
Trail Junction.
— Turn left on Sage Flat Loop Trail.
- 0.45**—About a hundred feet to the left is a rock-cut basin (or plucked-bedrock pit) formed by a kolk (an



Figure 6 - View from River Viewpoint.

underwater vortex). A kolk spins pebbles and cobbles rapidly which erodes out a basin from the abrasive action. This rock-cut basin is oval in shape (11" x 14") and about 12" deep (Figure 8). There are additional examples along this early drainage route.

0.47—The shallow draw to left was part of early river channel system. Also there are views of the Three Sisters in this area.



Figure 7 - Fine gravels and sand.



Figure 8 - Rock-cut basin.

0.50—About two hundred feet to the left is a large rounded boulder (about 5' in dia.).

0.53—[Elev. ~3459 ft.] Trail turns to left as it enters an early drainage channel.

0.58—[Elev. ~3456 ft.] The vertical rock face to the right is the result of flowing water scouring away the edge of this flow margin (Figure 9), compare this with the edge you previously looked at (mile 0.23). This channel was eroded shortly after the river began working to establish a new channel.

0.61—[Elev. ~3455 ft.] Trail begins climb out of channel. Note that eroded flow margin begins to change to a normal flow margin. This channel is the northern margin of the gravels mentioned at mile 0.40.

To the west below the rim is the southernmost exposure of Tumalo Tuff in the Riley Ranch Area. The canyon is about 130 feet deep and the top of the welded tuff is about 60 feet below the rim. The basalt of Bend rimrock is about 25 ft thick. Above the welded tuff is unwelded tuffaceous materials which grade upward into reworked tuffaceous sediments.

0.65—[Elev. ~3463 ft. N 44.09704° W 121.33419°] **Trail Junction.**

— **Turn right on spur trail to Sage Flat Overlook.**

0.72—[Elev. ~3473 ft. N 44.09673° W 121.33322°] **Sage Flat Overlook.** View across Sage Flat.

Early in the settlement history of the Riley Ranch Nature Reserve area the Sage Flat Area was cleared of native vegetation for agricultural and grazing purposes.

This viewpoint features informational signs listing plants and animals you might see here in the Reserve. There are also directional markers for Summer Solstice, Winter Solstice, and East.

— **Return to Sage Flat Loop Trail.**

0.79—[Elev. ~3463 ft. N 44.09704° W 121.33419°] **Trail Junction**

— **Turn right on Sage Flat Loop Trail.**



Figure 9 - Flow margin at mile 0.58.

0.87—[Elev. ~3476 ft. N 44.09790° W 121.33466°]
Trail Junction.

— **Turn left on spur trail to Canyon Overlook.**

0.88—View of ahead to Mt. Bachelor and Tumalo Mtn.

0.90—[Elev. ~3476 ft. N 44.09774° W 121.33516°]
“Canyon Overlook” geology sign.

0.92—[Elev. ~3476 ft. N 44.09792° W 121.33546°]
Canyon Overlook This Overlook is located on canyon rim of basalt of Bend about 165 feet above the Deschutes River at river mile 161.65 (Figure 10).

Prior to the emplacement of the basalt of Bend, this area was covered by pyroclastic and fluvial deposits and a shallow drainage off Awbrey Butte passed near here. As the basalt of Bend flooded into the area, flows were pushed up the drainage. In general the river established a new channel along the margin of the basalt of Bend, but here the river had to cut across the flow lobe which filled the drainage leaving a remnant of the basalt of Bend isolated on the west side of the river. From this viewpoint four homes across the river are located on the isolated remnant and a fifth home at a lower level is located on the underlying Desert Spring Tuff.

Upstream the river was confined by the basalt of Bend and Awbrey Butte basaltic lavas resulting in a deep, narrow canyon. After crossing the basalt of Bend lobe, the river was no longer confined by basalts and could cut a wider channel in the pyroclastic and fluvial deposits. As the channel deepened the canyon walls beneath the basalt of Bend were over steepened and would

periodically collapse resulting in a slope of massive talus blocks. At this location the rimrock is broken by a series of deep, open fractures parallel to the rim, that are the result of the last collapse here.

The Desert Spring Tuff fills an old channel of Tumalo Creek. Tumalo Creek then established a new channel slightly to the north which subsequently was filled by the Tumalo Tuff. Tumalo Creek again established a new channel which was subsequently filled by the basalt of Skyline Ranch Road which forms the ridge line to west.



Figure 10 - View from Canyon Overlook.

Table 2 - View from Canyon Overlook.

Direction	Distance	Summit	Feature
S 60.6° W	10.2 miles	6,619 feet	High point, unnamed cinder cone
S 64.9° W	19.4 miles	9,065 feet	Mt. Bachelor
S 67.3° W	16.6 miles	7,775 feet	Tumalo Mtn.
S 86.8° W	18.2 miles	9,175 feet	top of Broken Top
N 88.8° W	21.6 miles	10,358 feet	top of South Sister
N 83.4° W	0.2 miles		Desert Spring Tuff across river
N 44.3° W	0.2 miles		Boulder capped “Canyon Hill”. The hill is cored by Desert Spring Tuff and capped by gravels including boulders to 15 feet. The gravels include materials from both Awbrey Butte and the basalt of Bend.
N 43.5° W	36.5 miles	7,841 feet	Three Fingered Jack
N 35.4° W	25.7 miles	6,436 feet	Black Butte
N 29.8° W	46.0 miles	10,497 feet	Mt. Jefferson
N 11.5° W	89.7 miles	11,239 feet	top of Mt. Hood visible above home above junction of Tumalo Creek and Deschutes River.

The view here includes peaks from Mt. Bachelor to Mt. Hood, see Table 2. (For more information on the visible Cascade volcanoes see Appendix A.)

— Return to Sage Flat Loop Trail.

0.97—[Elev. ~3476 ft. N 44.09790° W 121.33466°] Trail Junction

— Turn left on Sage Flat Loop Trail.

0.98—[Elev. ~3476 ft.] Old closed bulldozer road down into canyon (see mile 1.26).

1.01—[Elev. ~3476 ft. N 44.09842° W 121.33459°] Bench—Rt. Limited view across river to the Desert Springs Tuff.

1.06—[Elev. = 3473 ft. N 44.09878° W 121.33385°] Trail Junction

— Turn left from Sage Flat Loop Trail on to Robin's Run Trail.

1.08—[Elev. ~3462 ft.] Trail begins steep descent into canyon at low point between two flow lobes. Trail descends through talus deposits with no exposures.

1.11—[Elev. ~3440 ft.] Trail switchbacks to right. Approximate base of basalt of Bend.

1.12—[Elev. ~3434 ft.] Trail switchbacks to left.

1.13—[Elev. ~3420 ft.] Trail switchbacks to right.

1.15—To the left is boulder of basalt of Bend which was cut in half during construction of the trail. Offers a good look at a fresh exposure.

1.16—[Elev. ~3378 ft.] Trail switchbacks to left.

1.19—[Elev. ~3348 ft. N 44.09892° W 121.33542°] Trail Junction Bottom of descent into canyon.

— Turn left from Robin's Run Trail on to Canyon Loop Trail.

The trail follows base of a massive talus slope to left and high terrace to right. The talus slope is made up of large blocks of basalt of Bend from the collapse of the basalt rim as the canyon deepened and under cut the rimrock as mentioned at mile 0.92.

1.22—[Elev. ~3354 ft.] High point on Canyon Loop Trail.

1.25—[Elev. ~3346 ft.] Old closed bulldozer road comes down slope on left (see mile 0.98). The Canyon Overlook (Elev. ~3476 ft.) is visible above.

1.29—[Elev. ~3340 ft.] The trail leaves base of massive talus slope as it turns right along high terrace, about 35 feet above river. This terrace is a remnant of a high, wide channel as the river down cut. The river was actively moving across the full width of the canyon floor. Roughly equivalent to the surface at mile 1.85.

Across the river is the rimrock of the isolated basalt of Bend remnant which overlies Desert Springs Tuff and basalts from Awbrey Butte.

1.31—[Elev. ~3333 ft. N 44.09802° W 121.33711°] Bench—Lt. Good view to rear up river canyon (Figure 11).

1.32—Boulder RR-294—Lt. Exposed is the top of buried porphyritic boulder of unknown size.



Figure 11 - View up canyon.

1.33—Boulder RR-001—Lt. A 17x8x8 ft basalt of Bend boulder. Volume of about 40 cy and an estimated weight of 100 tons.

Trail begins descent into a lower channel. Note other large boulders along channel edge.

1.35—Boulder RR-003—Lt. A 12x8.5x7.5 ft basalt of Bend boulder. Volume of about 28 cy and an estimated weight of 70 tons.

The trail starts across head of an old channel, which is about 15 feet above current river level. At the time this channel was active on the east side of "Canyon Hill" (informal name) there was a second channel on the west side of the hill. The western channel became the dominant channel and eventually deepened and cut off water to the eastern channel.

1.36—[Elev. ~3317 ft. N 44.09849° W 121.33761°] Trail Junction.

— Turn left on river access trail.

1.38—[Elev. ~3302] River edge at high water at river mile 161.55. Here the river is flowing in a bedrock channel cut into a Deschutes Formation age basalt flow.

— Return to Canyon Loop Trail.

1.40—[Elev. ~3317 ft. N 44.09849° W 121.33761°] Trail Junction .

— Turn left on Canyon Loop Trail.

Optional side trip also starts at this junction.

0.00—Jct at 1.40

0.01—Optional route begins following old road northward.

0.05—Exposure of pre-Desert Springs basalt—Lt.

0.06—Boulder RR-072—Rt. A 15x11x9 ft basalt of Bend boulder. Volume of about 55 cy and an estimated weight of 140 tons.

Desert Spring tuff block—Lt.

0.09—Last exposure pre-Desert Springs basalt—Lt.??

0.10—Boulder RR-087—Rt. A 20x16x11 ft basalt of Bend boulder. Volume of about 130 cy and an estimated weight of 330 tons.

- 0.13—Boulder RR-089—Rt. In addition there is rock-cut basin cut into it. A 17x11x3 ft basalt of Bend boulder. Volume of about 21 cy and an estimated weight of 53 tons.
- 0.14—Another rock-cut basin—Lt. Channel widens.
- 0.15—Group of rock-cut basins beyond boulders—Rt. Return to mile 1.41 or continue down draw and rejoin field guide route at mile 2.40.
- 0.25—Jct with Canyon Loop at mile 2.40.
- 1.42—[Elev. ~3313 ft.]** Begin descent to river level.
- 1.44—[Elev. ~3304 ft.]** Trail crosses the head of a small, dry channel. Prior to the construction of Wickiup and Crane Prairie Reservoirs this channel was probably active during high spring flows. The trail exposures of an older flow. View across river of Desert Springs Tuff and this older flow beneath it (Figure 12).
- 1.45—**“Canyon Hill” ahead (to right) is cored with Desert Spring Tuff with a bouldery cap.



Figure 12 - Desert Spring Tuff.



Figure 13 - Desert Spring Tuff.

- 1.48—[Elev. ~3303 ft.]** The trail again crosses the dry channel. Trail enters Desert Springs Tuff and leaves the older basalt below the tuff.
- 1.48 to 1.52—**Cliffs of Desert Spring Tuff exposed in side of hill to right (Figure 13).
- 1.49—**To left across river the drainage off Awbrey joins the Deschutes.
- 1.50—**Large block of Desert Spring Tuff adjacent to trail on right.
- 1.53—[Elev. ~3312 ft.]** The Desert Spring Tuff is exposed in trail backslope and a large block of Desert Springs Tuff exposed in slope above trail.
- 1.57—[Elev. ~3338 ft. N 44.10054° W 121.33803°]**
Trail Junction.
— Turn right to “Canyon Hill”.
- 1.59—[Elev. ~3348 ft.]** Trail makes sweeping turn to right.
- 1.61—[Elev. ~3353 ft.]** Steps as trail begins to climb.
- 1.62—[Elev. ~3357 ft.]** Trail switchbacks to left. Note top of welded Desert Spring Tuff—Rt.
- 1.64—[Elev. ~3374 ft.]** Large boulders—Lt. & Rt.
 Boulder RR-018—Rt. A 8.5x7x6 ft basalt of Bend boulder. Volume of about 13 cy and an estimated weight of 33 tons.
 Boulder RR-019—Lt. A 11x9x7.5 ft basalt of Bend boulder. Volume of about 27 cy and an estimated weight of 71 tons.
 Boulder RR-020—Lt. A 12x9x7.5 ft basalt of Bend boulder. Volume of about 30 cy and an estimated weight of 76 tons.
 Boulder RR-021—Rt. A 9x9x5.5 ft basalt of Bend boulder. Volume of about 16 cy and an estimated weight of 43 tons.
- 1.65—[Elev. ~3385 ft.]** Trail switchbacks to right with steps.
- 1.66—[Elev. ~3392 ft.]** Stack of boulders to left (Figure 14).
 Boulder RR-023. A 12.5x8x6.5 ft basalt of Bend boulder. Volume of about 24 cy and an estimated weight of 61 tons.
 Boulder RR-024. A 7x5x4.5 ft basalt of Bend boulder. Volume of about 6 cy and an estimated weight of 15 tons.
 Boulder RR-025. A 13.5x8x5 ft basalt of Bend boulder. Volume of about 20 cy and an estimated weight of 51 tons.
- 1.67—[Elev. ~3395 ft.]** Trail turns to left.
- 1.68—[Elev. ~3405 ft. N 44.09984° W 121.33763°]**
Trail Junction. Trail reaches summit.
— Continue straight on summit loop.
- 1.69—[Elev. ~3407 ft.]** On the left edge of the trail is another rock-cut basin formed by a kolk as discussed at mile 0.45 (Figure 15). In boulder RR-33, a 12x6x3 ft basalt of Bend boulder. Volume of about 8 cy and an estimated weight of 20 tons.
- 1.695—[Elev. ~3408 ft. N 44.09967° W 121.33757°]**
— Turn right to summit viewpoint.
- 1.70—[Elev. ~3409 ft. N 44.09963° W 121.33748°]**
Viewpoint. Bench at summit of “Canyon Hill”.



Figure 14 - Stack of boulders on Canyon Hill.



Figure 15 - Rock-cut basin on top of "Canyon Hill."

This hill is cored by Desert Springs Tuff and is capped by a deposit of boulders about 15 feet thick. Between the tuff and gravels there are traces of a white pumice deposit, could be a remnant of Bend Pumice.

— Return to summit loop.

**1.705—[Elev. ~3408 ft. N 44.09967° W 121.33757°]
Trail Junction**

— Turn right on summit loop.

1.715—[Elev. ~3408 ft.] Boulder RR-026—Rt. A 16x13x11 ft basalt of Bend boulder. Volume of about 85 cy and an estimated weight of 216 tons. The back underside of this boulder has water carved surface.

**1.72—[Elev. ~3405 ft. N 44.09984° W 121.33763°]
Trail Junction.**

— Turn right and return to Canyon Loop Trail.

**1.83—[Elev. ~3338 ft. N 44.10054° W 121.33803°]
Trail Junction.**

— Turn right on Canyon Loop Trail.

1.84—[Elev. ~3341 ft.] Trail reaches top of gravel bar on downstream side of "Canyon Hill".

1.86—At rotten log, note rounded boulders removed during trail construction, both basalt of Bend and basalt of Awbrey Butte.

1.88—View to rear up slope of gravel bar toward "Canyon Hill" to south.

**1.91 — [Elev. ~3312 ft. N 44.10132° W 121.33877°]
Trail Junction**

— Turn left on river access trail.

1.915—Boulder RR-113—Lt. at steps in trail. A 13x5x5 ft Desert Spring Tuff boulder. Volume of about 12 cy and an estimated weight of 20 tons. The gravel bar is primarily make up of boulders and gravels of the basalt of Bend and basalt of Awbrey Butte, but there are occasional boulders of Desert Spring Tuff like this one.

1.93—[Elev. ~3287] River edge at high water at river mile 161.30.

Boulder RR-114—Rt. A 15x8x8' ft basalt of Bend boulder. Volume of about 36 cy and an estimated weight of 91 tons.

Here the river is flowing in a bedrock channel cut into a Deschutes Formation age basalt flow. At low water there are several modern rock-cut basins near the low water channel (Figure 16).

— Return to Canyon Loop Trail.

**1.95—[Elev. ~3312 ft. N 44.10132° W 121.33877°]
Trail Junction.**



Figure 16 - Modern rock-cut basin.

— Turn left on Canyon Loop Trail.

- 1.96**—Additional smaller boulders of Desert Spring Tuff off to left.
- 1.98**—Old power line crossing to other side of river.
- 2.00**—[Elev. ~3306 ft.] Trail begins decent off gravel bar level. Boulder RR-147 down slope—Lt. A 14x10x10 ft basalt of Bend boulder. Volume of about 52 cy and an estimated weight of 132 tons.
- 2.05**—[Elev. ~3293 ft.] Trail reaches a low river terrace level.
- 2.06**—At ponderosa pine on right, note the rounded boulders to left removed during trail construction, include both basalt of Bend and basalt of Awbrey Butte.
Across river note the large power line at top of canyon wall. There is a large quarry beyond the power line. The quarry started in gravel deposits but has been deepened into the underlying basaltic bedrock.
- 2.13**—[Elev. ~3285 ft. N 44.10371° W 121.33952°] **Trail Junction.** Riley Ranch Trail to left goes 2 miles downstream to Tumalo S.P. See Geologic Guide for Riley Ranch-Deschutes River Trail (below).

— Turn right and continue on Canyon Loop Trail.

- 2.16**—[Elev. ~3291 ft.] South Cabin ruins to right (Figure 17). Two room cabin constructed prior to 1900.
- 2.17**—[Elev. ~3292 ft.] Leave channel bottom.
- 2.22**—[Elev. ~3303 ft.] On gravel bar.
- 2.26**—[Elev. ~3304 ft.] Boulder RR-153—Rt. A 10x6x4 ft basalt of Bend boulder. Volume of about 9 cy and an estimated weight of 23 tons.
- 2.27**—[Elev. ~3306 ft.] Just beyond old power line crossing, note rounded boulders removed during trail construction, both basalt of Bend and basalt of Awbrey Butte.
- 2.33**—[Elev. ~3308 ft.] Leave gravel bar.
- 2.35**—[Elev. ~3298 ft.] Edge of channel.

- 2.37**—[Elev. ~3296 ft.] **Bench—Lt.** Cross old road which follows channel bottom. This is the same channel discussed at mile 1.36 to 1.40.
- 2.39**—[Elev. ~3298 ft.] Edge of channel.
- 2.42**—[Elev. ~3311 ft.] Large alluvial blocks litter this surface. Top of ascent out of channel.
The canyon wall to the left is about 150 feet high. The capping rimrock of basalt of Bend is about 15 feet thick. Under the basalt is about 25 feet of gravels. Then about 20 feet of welded Tumalo Tuff. Then another 90 feet of talus slope, the upper part shows Pumice from unwelded Tumalo Tuff or the underlying Bend Pumice.
- 2.43**—[Elev. ~3315 ft.] Large broken talus basalt block (8x6x6 ft) and smaller broken tuff block (8x6x4 ft) to left. Big snag on right. In place Tumalo Tuff occurs at an elevation of about 3410 feet (top and base not exposed). Here the top of the rim is at an elevation of about 3450 feet, with about 10 feet basalt of Bend forming the rim. Between the basalt of Bend and Tumalo Tuff there are 20 to 30 feet of gravels. Beneath the Tumalo Tuff is the Bend Pumice (air fall pumice preceding the pyroclastic flow which formed the Tumalo Tuff)
- 2.45**—[Elev. ~3319 ft.] Large talus block (8x5x4 ft) of Tumalo Tuff at trail edge to left, more blocks visible up slope.
- 2.47**—[Elev. ~3325 ft.] Large talus block (10x8x8 ft) of Tumalo Tuff at trail edge to left, more blocks visible up slope.
- 2.49**—[Elev. ~3330 ft.] Two talus blocks (13x12x28 ft & 15x14x13 ft) of basalt to left, one shows an impression of the flow base. Above this point the rimrock of basalt of Bend thickens to about 30 feet thick here, much thicker than the 10-foot thickness north of here. The thicker rimrock resulted in larger blocks in the talus south of here.
- 2.52**—[Elev. ~3337 ft.] To the left, massive talus blocks cover the slope up to the rim (Figure 18).
- 2.53**—[Elev. ~3339 ft.] Block of Tumalo Tuff (4x3x2 ft) to left.



Figure 17 - South Cabin.

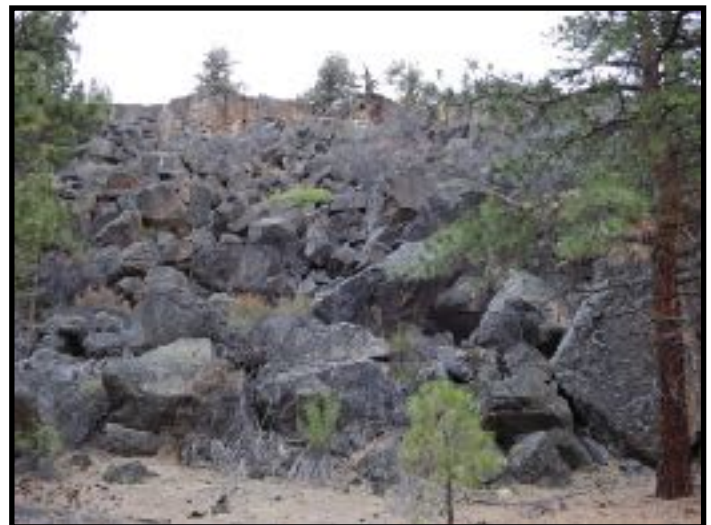


Figure 18 - Massive talus slope.

2.53 to 2.55—The ground surface is littered with small fragments of tuff.

2.57—[Elev. ~3348 ft. N 44° 05.935' W 121° 20.128']
Trail Junction

— **Turn left from Canyon Loop Trail on to Robin's Run Trail.** Start climb out of canyon.

2.58—[Elev. ~3357 ft.] Tumalo Tuff block (4x4x2 ft) in edge of trail to left.]

2.60—[Elev. ~3378 ft.] Trail switchbacks to right. Large block of Tumalo Tuff (10x6x4 ft) in talus, about 15 feet to left. No Tumalo Tuff blocks or exposures are known south Robin's Run Trail.

2.63—[Elev. ~3420 ft.] Trail switchbacks to left.

2.64—[Elev. ~3434 ft.] Trail switchbacks to right.

2.65—[Elev. ~3440 ft.] Trail switchbacks to left.
Approximate base of basalt of Bend.

2.68—[Elev. ~3462 ft.] Top of steep ascent out of canyon.

2.70—[Elev. ~3473 ft. N 44.09878° W 121.33385°]
Trail Junction

— **Turn left from Robin's Run Trail on to Sage Flat Loop Trail.**

2.83—[Elev. ~3473 ft. N 44.09868° W 121.331515°]
Bench—Lt. View right across Sage Flat to Awbrey Butte. Also to rear there is a view of Broken Top and South Sister. (See list of volcanoes visible from Riley Ranch Nature Reserve.) Over next 0.4 miles various peaks are intermittently visible to west.

2.92—[Elev. ~3481 ft. N 44.09881° W 121.32986°]
Trail Junction Trail to right ties through to mile 0.31.

— **Continue straight from Sage Flat Loop Trail on to Juniper Loop Trail.**

2.95—[Elev. ~3486 ft. N 44.09861° W 121.32948°]
Bench—Lt. View of Cascades, similar to view at mile 2.97. (See list of volcanoes visible from Riley Ranch Nature Reserve.)

2.98—[Elev. ~3492 ft. N 44.09857° W 121.32899°]
Trail Junction.

— **Turn right on spur trail to Ben Newkirk Mountain Overlook.**

3.00—[Elev. ~3492 ft. N 44.09822° W 121.32884°]
Ben Newkirk Mountain Overlook.

The familiar snow-clad peaks (Figure 19) of the Cascade Range are part of a 800 mile long chain of volcanoes, which extends from northern California to southern British Columbia. The volcanoes are the result of subduction (the slow slide of dense oceanic crust as it sinks beneath North America), which releases water and melts overlying rock. The Cascade Range began forming about 36 million years ago, but the major peaks that rise up from today's volcanic centers were born within the last 1.6 million years (Pleistocene). This volcanic zone contains the well-known landmark volcanoes and approximately 3,000 other known volcanic vents, ranging from small cinder cones (like Pilot Butte)

to substantial shield volcanoes (like Newberry Volcano).

The view here includes peaks from Mt. Bachelor to North Sister, see Table 3. (For more information on the visible Cascade volcanoes see Appendix A.)

— **Return Juniper Loop Trail.**

3.02—**Trail Junction** [Elev. ~3492 ft. N 44.09857° W 121.32899°]

— **Turn right on Juniper Loop Trail.**

3.14—[Elev. ~3495 ft. N 44.09902° W 121.32696°]
Bench—Lt. View of Three Sisters to rear. Also a view of Three Creeks Butte.

3.18—[Elev. ~3493 ft. N 44.09874° E 121.32632°]
Trail Junction.

— **Turn left and return to Trailhead.**

3.23—[Elev. ~3492 ft. N 44.09900° E 121.32550°]
Riley Ranch Trailhead Parking Lot.



Figure 19 - View from Ben Newkirk Mountain Overlook.

Table 4 - View from Ben Newkirk Mountain Overlook.			
Direction	Distance	Summit	Feature
S 45.0° W	0.6 miles		northwest flank of Awbrey Butte
S 61.4° W	15.3 miles	6,619 feet	High point, unnamed cinder cone
S 65.4° W	19.7 miles	9,065 feet	Mt. Bachelor
S 67.7° W	16.9 miles	7,775 feet	Tumalo Mtn.
S 72.8° W	9.1 miles	5,635 feet	High point, unnamed cinder cone
S 82.8° W	17.3 miles	8,091 feet	Ball Butte
S 83.1° W	11.3 miles	6,471 feet	Bearwallow Butte
S 85.6° W	2.0 miles	3,885 feet	Tumalo Butte
S 86.8° W	18.4 miles	9,175 feet	Broken Top
N 89.6° W	10.5 miles	6,415 feet	Triangle Hill
N 89.0° W	21.9 miles	10,358 feet	South Sister
N 81.1° W	22.8 miles	10,047 feet	Middle Sister
N 77.7° W	22.5 miles	10,985 feet	North Sister

Geologic Guide for Riley Ranch-Deschutes River Trail

Riley Ranch to Tumalo S.P.

by
Bob Jensen

Miles

0.00—[Elev. ~3285 ft. N 44.10372° W 121.33952°]
Trail Junction See mile 2.13 on Geologic Guide to Riley Ranch Trails and on Figure 4.

— Go north on Riley Ranch Trail.

0.00 to 0.03—Trail crosses an old channel bottom. This is the same channel discussed at mile 1.36 to 1.40 and mile 2.41 on the Riley Ranch Trails guide.

0.04—[Elev. ~3290 ft.] Old rock wall to right as trail climbs on to terrace.

0.05—[Elev. ~3296 ft.] Trail on bouldery terrace surface.

0.06—[Elev. ~3297 ft.] Rail fence around North Cabin Site (Figure 20). Cabin constructed prior to 1900 for stock or storage of supplies.

0.10—[Elev. ~3289 ft.] Trail crosses another old channel bottom, then climbs back up to terrace.

0.11—Boulder RR-202—Lt. A 4x4x3 ft tuff boulder. Volume of about 2 cy and an estimated weight of 3.5 tons.

0.12—[Elev. ~3293 ft.] Trail on terrace surface. View of house on rim ahead.

South of the house, an old road descends to the canyon floor exposing some of the canyon wall geology (Figure 21). The canyon wall is about 150 feet high. The rim capping basalt of Bend is 10 to 15 feet thick over a gravel deposit which is about 20 feet thick. The gravel deposit lies on a nearly horizontal erosion surface cut across the Tumalo Tuff/Bend Pumice. At the upper (left) end of the Tumalo Tuff/Bend Pumice exposure the road cuts across the air fall Bend Pumice which mantles the underlying topography of Deschutes

Formation basalts. To the south along the exposure, the Bend Pumice seems to dip to the south while the overlying Tumalo Tuff thickens to south.

Boulder RR-203—Lt. A 13x9x3 ft basalt of Bend boulder. Volume of about 13 cy and an estimated weight of 33 tons.

0.13—Boulder RR-204—Rt. A 14x6x4 ft basalt of Bend boulder. Volume of about 12 cy and an estimated weight of 30 tons.

0.14—[Elev. ~3292 ft.] Trail on terrace surface. Deschutes Formation basalt in canyon wall to right. Trail location now on Figure 22.

0.15—Boulder RR-209—Lt. A 11x8x4 ft basalt of Bend boulder. Volume of about 13 cy and an estimated weight of 33 tons.

0.18—[Elev. ~3285 ft. N 44.10563° W 121.33771°] **Trail Junction** River access trail to left.

— Turn left on river access trail.

0.195—[Elev. ~3275] River edge at high flow. River is flowing in bedrock floored channel with numerous basalt of Bend boulders

— Return to Riley Ranch Trail.

0.21—[Elev. ~3285 ft. N 44.10563° W 121.33771°] **Trail Junction** with Riley Ranch Trail

— Turn left on Riley Ranch Trail.

0.22—Boulder 224—Lt at trail edge. A 9x8x1.5 ft basalt of Bend boulder only partially exposed. Volume of about 4 cy and an estimated weight of 10 tons.

0.23—Boulder 223—Rt at trail edge. A 11x9x5 ft basalt of Bend boulder. Volume of about 18 cy and an estimated weight of 45 tons.



Figure 20 - North Cabin site.



Figure 21 - Gravel / Tumalo Tuff / Bend Pumice exposure.

- 0.24—An old road approaches trail from right and is paralleled by the Reserve boundary fence.
- 0.26—Boulder RR-222—Lt. at river edge. A 15x12x11 ft basalt of Bend boulder. Volume of about 73 cy and an estimated weight of 185 tons.
- 0.27—The old road crosses trail here to former bridge site at river mile 160.9. Long term plan is for footbridge here which will connect via a new trail to the current end of the existing Deschutes River west side of river.
- 0.28—Elev. ~3284 ft. N 44.10641° W 121.33735°]
Riley Ranch North Trailhead [Trail sign with map.] Trailhead is at river mile 160.9 and at a river elevation of about 3275 ft.

Large quarry at top of canyon wall across river.

—Riley Ranch Trail ends here, continue north on Deschutes River Trail.

- 0.30—[Elev. ~3283 ft.] The Reserve boundary fence turns up slope to end against the Deschutes Formation basalt cliff.
- 0.36—[Elev. ~3283 ft.] Deschutes Formation basalt cliff to right
- 0.40—[Elev. ~3278 ft.] To right the older Deschutes Formation basalt is exposed below the capping basalt of Bend.
- 0.42—[Elev. ~3278 ft.] Trail passes through a group of talus boulders.

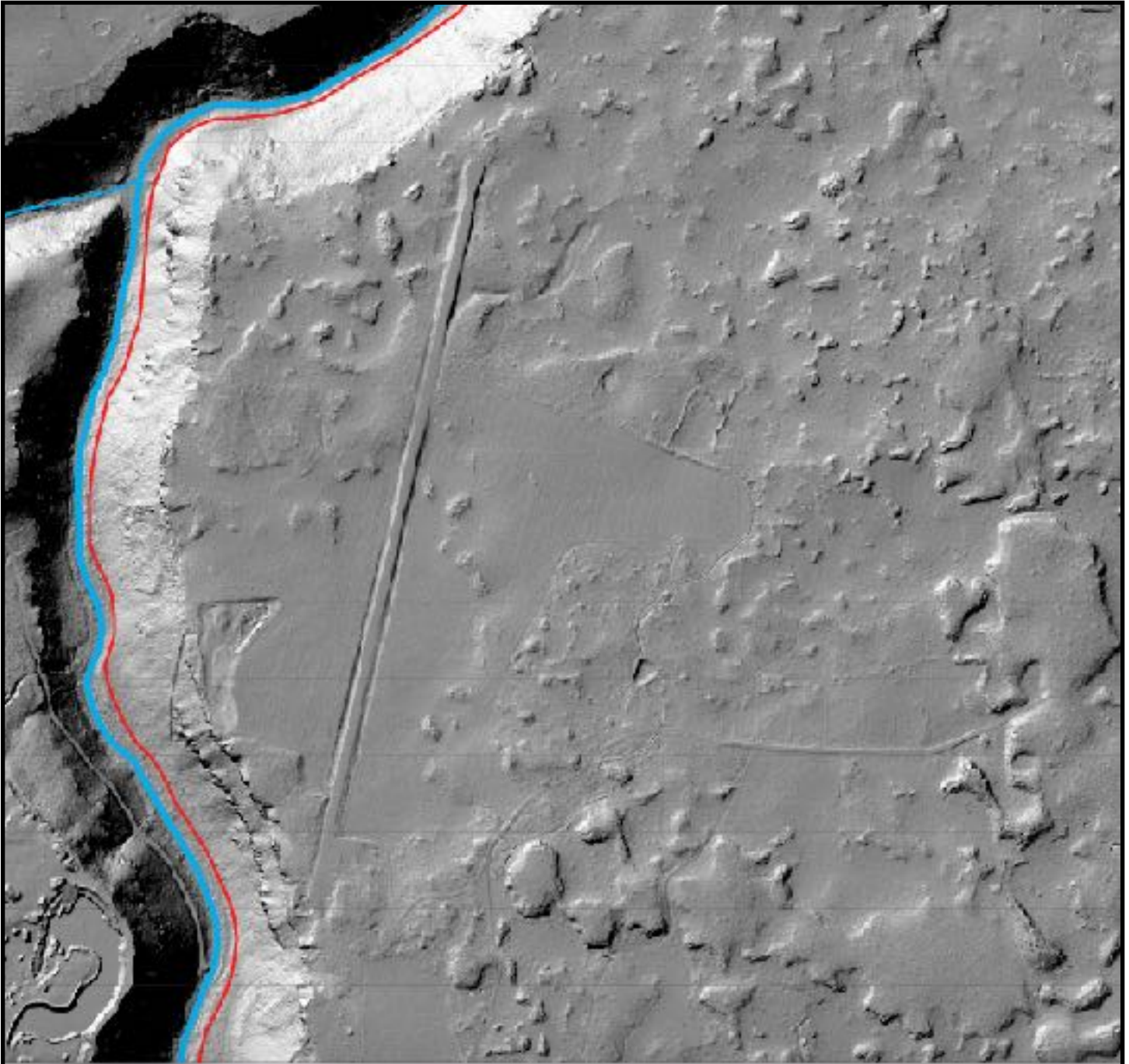


Figure 22 - Lidar image of Deschutes River Trail from Riley Ranch Nature Reserve to Tumalo Creek. Trail in red, river in blue.



Figure 23 - Pillow basalts at base of basalt of Bend.



Figure 24 - Mouth of Tumalo Creek.

0.47—[Elev. ~3274 ft. N 44.10881° W 121.33836°] To right an old cat road goes up to rim. The Deschutes Formation flow is exposed again to right. Across the river is northern end of the large quarry.

0.00—Trail

0.01—Fence, enter private property.

0.08—Base of exposed Deschutes Formation lavas

0.09—Top of Deschutes Formation lavas

0.11—Base of basalt of Bend (bbe) on gravels.

0.13—[Elev. ~3460 ft.] Top of bbe at canyon rim. Cat road enters old gravel quarry where 10 to 15 feet of gravels overly bbe.

0.48—[Elev. ~3273 ft.] The Reserve boundary fence comes down slope to trail from the Deschutes Formation basalt cliff.

0.51—[Elev. ~3271 ft.] Boundary. Trail enters Tumalo State Park lands and leaves Riley Ranch Nature Reserve.

0.52—[Elev. ~3270 ft. N 44.10947° W 121.33892°] End boundary fence. The canyon bottom widens.

0.52 to 0.60—Short wider canyon segment with flood deposits to left of trail. Some larger boulders along river edge.

0.61—[Elev. ~3267 ft.] The canyon bottom narrows, trail now on talus slope. In this area there are a few feet of gravels above the basalt of Bend which forms the rimrock. These gravels contain a large component of silicic material indicating a source to the west in the Cascades via the Tumalo Creek drainage.

0.63—[Elev. ~3268 ft.] Trail is near river but well above it. Ahead across the river is a rimrock formed by the basalt of Bend which flowed up a drainage. There are pillow basalts (Figure 23) at the base of basalt indicating that it flowed into water.

0.64—[Elev. ~3269 ft.] Some round gravels in talus slope.

0.70—[Elev. ~3267 ft.] A view head shows basalt of Bend rimrock above older basalt, on both sides of river.

0.74—[Elev. ~3263 ft. N 44.11213° W 121.33975°] Trail near river level at river mile 160.5. The two large boulders to left may be flood boulders. In narrow areas like this it can be difficult to flood boulders from talus boulders.

0.78—[Elev. ~3271 ft.] A good view to west of rimrock of basalt of Bend.

0.82—[Elev. ~3261 ft.] At a low point the trail starts up across rocky talus slope.

0.85—[Elev. ~3265 ft.] Thick Deschutes Formation basalt on both sides of river.

0.87—Large boulder in river is probably a flood boulder.

0.91—[Elev. ~3268 ft.] High point on trail across rocky talus slope.

0.93—[Elev. ~3263 ft.] There is a limited exposure of possible Bend Pumice in the slope above the Deschutes Formation basalt.

0.96—[Elev. ~3256 ft. N 44.11512° W 121.33893°] **Boundary** The trail leaves Tumalo S.P. lands and enters a trail easement across private property.

0.98—[Elev. ~3249 ft.] Trail reaches a low point after crossing rocky talus slope. Thick exposure Deschutes Formation basalt to right. Sampled for chemistry.

1.01—[Elev. ~3256 ft.] View left to mouth of Tumalo Creek.

1.04—[Elev. ~3256 ft. N 44.11609° W 121.33863°] **River Junction** Trail begins segment cut across steep slope. View upstream along Tumalo Creek (Figure 24), which enters the Deschutes from the west. Tumalo Creek began cutting this channel following the eruption of the basalt of Bend. Trail location now shows on Figure 25.

1.08—[Elev. ~3254 ft. N 44.11652° W 121.33837°] **Boundary** Trail leaves trail easement across private property and re-enters Tumalo S.P. lands. Across the river the Deschutes Formation basalts (5 to 7 Ma) are capped by a flow out of Cascades,

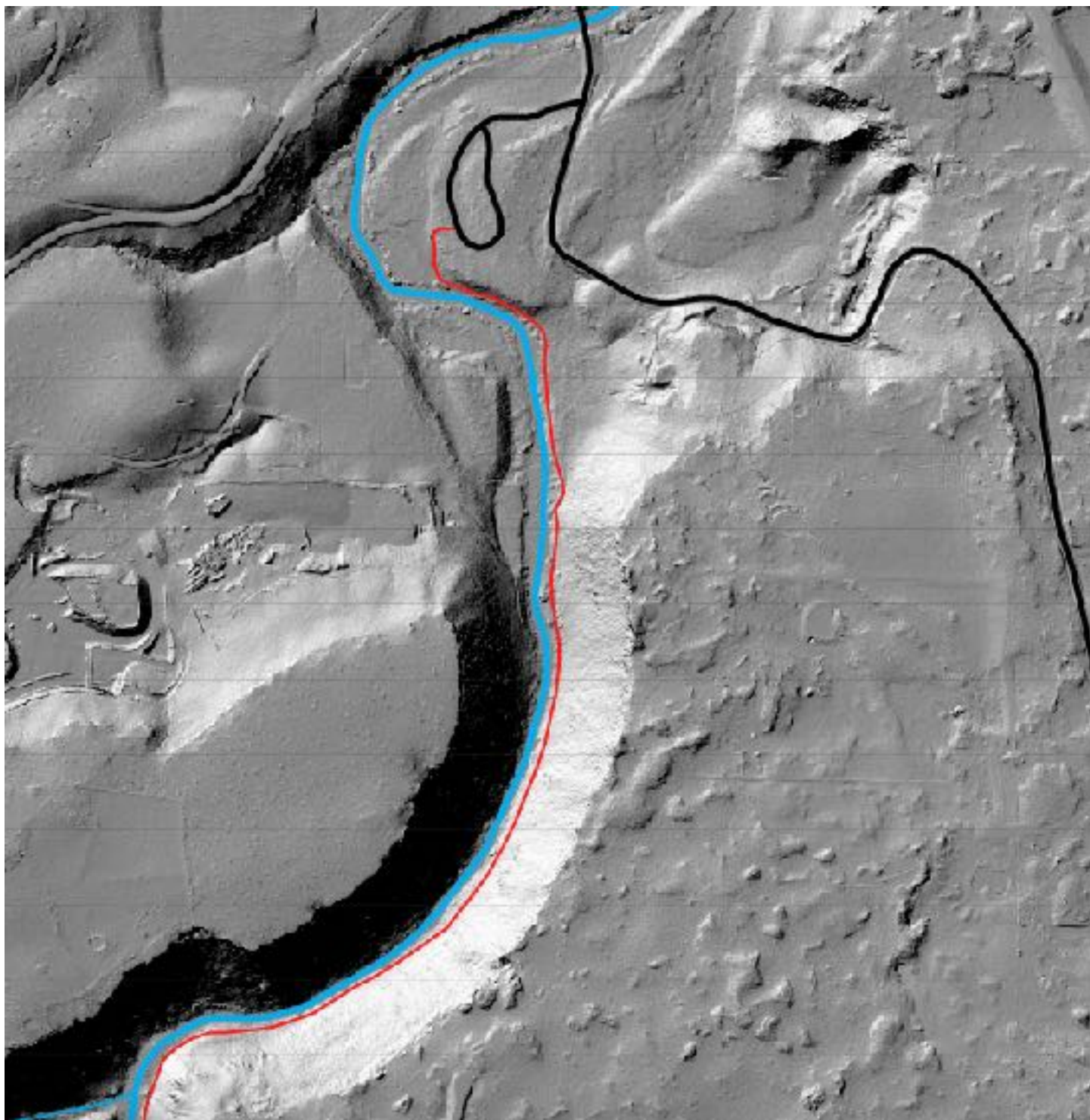


Figure 5- Lidar image of Deschutes River Trail from Tumalo Creek to Tumalo State Park. Trail in red, river in blue, roads in black.

the basalt of Johnson Road. On this side the capping flow is the basalt of Bend (64.5 ka), which farther downstream overlies the basalt of Johnson Road.

- 1.10—[Elev. ~3255 ft.] End trail segment across steep slope.
- 1.13—The house high on the left rim sits on the basalt of Johnson Road.
- 1.20—[Elev. ~3239 ft. N 44.11694° W 121.33641°] **West end of walkway.** The walkway crosses a large block talus deposit (Figure 26).

- 1.24—[Elev. ~3240 ft.] **Viewpoint** On walkway at river mile 160.0. River elevation about 3216 ft.
- 1.26—[Elev. ~3240 ft. N 44.11728° W 121.33552°] **East end of Walkway.**
- 1.28—[Elev. ~3239 ft.] **Trail Junction** River access trail to left.
- 1.30—[Elev. ~3234 ft.] Deschutes Formation basalt above trail.
- 1.37—[Elev. ~3241 ft.] Deschutes Formation basalt just above trail.



Figure 26 - Boardwalk across talus.



Figure 27 - Basalt of Johnson Road (bjr) beneath basalt of Bend (bbe).


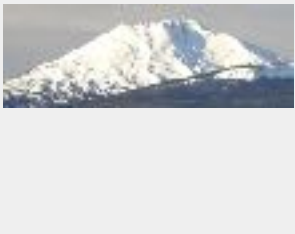








- 1.43—[Elev. ~3231 ft.] **Trail Junction** River access trail to left.
- 1.44—The exposure of Deschutes Formation basalt to right has been sampled for chemistry.
- 1.47—[Elev. ~3231 ft.] End of exposures of Deschutes Formation basalt.
- 1.48—[Elev. ~3230 ft.] First visible exposures of thick welded Tumalo Tuff across river between Deschutes Formation basalts and capping basalt of Johnson Rd.
- 1.53—[Elev. ~3226 ft. N 44.12020° W 121.33220°] **Boundary** Trail leaves Tumalo S.P. and enters trail easement across private property.
- 1.54—[Elev. ~3224 ft.] **Trail Junction** River access trail to left.
- 1.58—**Trail Junction Trail Junction** River access trail to left.
- 1.62—[Elev. ~3229 ft.] **Trail Junction** River access trail to left.
- 1.67—[Elev. ~3229 ft.] **Trail Junction** River access trail to left. Now Tumalo Tuff is visible on both sides of river. At top of canyon on this side the basalt of Johnson Rd is visible under the basalt of Bend (Figure 27).
- 1.69—Good view canyon wall to right shows capping basalt of Bend over the basalt of Johnson Road, which caps rim to left. Tumalo Tuff is also visible about half way down the slope.
- 1.72—[Elev. ~3225 ft.] Outcrop of Tumalo Tuff up slope to right.
- 1.74—Mouth of canyon as the river leaves the confining Deschutes Formation basalts.






- 1.76—[Elev. ~3224 ft.] **Trail Junction** River access trail to left.
- 1.77—[Elev. ~3218 ft. N 44.12340° 07.404' W 121.33188° 19.912'] Trail joins paved road, Trail sign with map.
- 1.82—[Elev. ~3222 ft. N 44.12425° W 121.33177°] **Boundary** Trail leaves paved road and trail easement across private property and enters Tumalo S.P.
- 1.85—Boulder TSP-13—Lt below pine. A 13X8X8 ft basalt of Bend boulder. Volume of about 30 cy and an estimated weight of 76 tons.
- 1.90—[Elev. ~3211 ft.] Old bridge site to left.
- 1.93—[Elev. ~3210 ft.] The low hill to right ahead is Desert Spring Tuff.
- 1.95—[Elev. ~3209 ft.] Boulder TSP-12—Rt. A 14x6x5 ft basalt of Bend boulder. Volume of about 15 cy and an estimated weight of 38 tons.
- 1.95 to 2.04—Trail follow steep slope cut by the river through flood deposits.
- 2.03—Boulder TSP-11—Lt. A 9x9x3 ft basalt of Bend boulder. Volume of about 9 cy and an estimated weight of 23 tons.
- 2.04—[Elev. ~3208 ft.] The trail enters the developed part of Tumalo State Park. Stay right on trail.
- 2.07—[Elev. ~3220 ft. N 44.12683° W 121.33404°] **Deschutes River Trail trailhead** In Tumalo State Park. Trail sign with map.
- 2.09—[Elev. ~3222 ft. N 44.12688° W 121.33372°] **Tumalo S.P. parking lot.** There are a variety of boulders around parking lot, in place and moved by construction of parking lot.

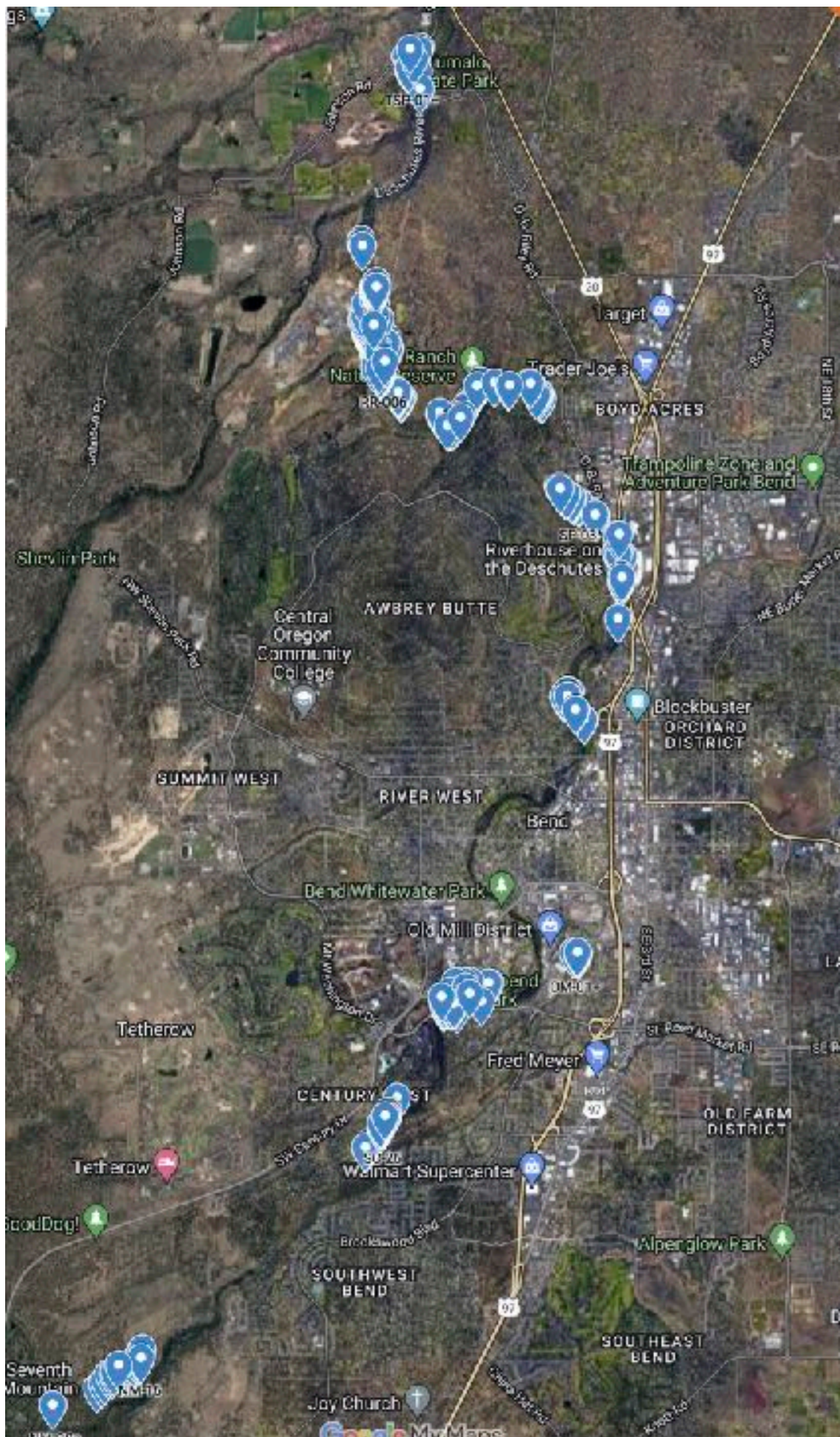
Appendix A

Volcanoes visible from Riley Ranch Nature Reserve

The following named volcanoes (arranged south to north) are all visible from Riley Ranch Nature Reserve, some from many locations, others from only a couple of locations. Many view locations are noted in trail guide.

<p>Awbrey Butte (4,220+ ft). Small shield volcano of porphyritic olivine basalt with normal-polarity magnetization. It is deeply weathered and is overlain by reversed-polarity basalt andesite assigned to the Deschutes Formation. Dates on the Deschutes Formation in the Bend Area range from 6.74 to 4.7 Ma. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>Mt. Bachelor (9,065 ft). Mount Bachelor is the largest volcano in the 15-mile-long, north-south trending, Mount Bachelor volcanic chain, which is composed of numerous cinder cones, lava flows, and shield volcanoes and covers an area of nearly 100 square miles. Eruptions of the chain began during or closely following the retreat of late Pleistocene glaciers, about 18 ka (ka = 1,000 years ago) and ended before the eruption of Mount Mazama (Crater Lake at 7.7 ka), with the main pulse of activity lasting perhaps only 3,000 years. [from USGS Volcano Hazards Program website]</p>	
<p>Tumalo Mtn. (7,775 ft). Small glaciated shield volcano capped by string of cinder cones trending south and northwest from summit. Age between 18 ka and 150 ka; glaciated during Suttle Lake advance (of Cabot Creek glaciation, 18 - 22 ka), and flows overlie an older glacial till thought to be about 150 ka. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>Ball Butte (8,091 ft). Glaciated cinder cone.</p>	
<p>Bearwallow Butte (6,471 ft). Rhyodacite dome, with normal-polarity magnetization and is probably younger than 0.78 Ma. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>Tumalo Butte (3,885 ft). Cinder cone.</p>	
<p>Broken Top (9,175 ft). Broken Top is a long extinct volcano that was active in the middle Pleistocene between about 300 and 150 ka. Eruptive products from Broken Top range from basalt to rhyolite. Its ancient cone has been deeply eroded leaving isolated peaks with little of its original surface intact. [from USGS Volcano Hazards Program website]</p>	
<p>Triangle Hill (6,415 ft). The highest of a group of coalesced cinder cones built on top of a field of rhyolite and rhyodacite domes. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>South Sister (10,358 ft). South Sister, the southernmost and tallest of the Three Sisters, was primarily erupted during the same time frame as Middle Sister. Early eruptions began between 50 to 45 ka, when South Sister produced numerous rhyolite lava flows and domes. Between 37 and 30 ka the broad cone was built of rhyolite to andesite domes and flows, and construction of the cone ended with an explosive eruption that left pyroclastic deposits greater than 200 m (650 ft) thick.</p>	
<p>Three Creek Butte (5,545 ft). Rhyolite dome. Normal-polarity magnetization; younger than 0.78 Ma. [USGS Map I-2683, Sherrod and others, 2004]</p>	

<p>Middle Sister (10,047 ft). Middle Sister formed between 40 and 14 ka, but mostly between 25 and 18 ka, closely in time with South Sister. It has erupted basaltic andesite, andesite, and dacite lavas from its central-vent area, as well as dacites from six flank vents and andesites from three more. An early eruption about 38-ka produced the Obsidian Cliffs lava flow, one of the rare high-silica rhyolites erupted in the Cascades and an important source of obsidian stone tools for Native Americans. Prior to the growth of Middle Sister, there was a period of more than 100,000 years that had little or no volcanic activity. An older, buried edifice of chiefly basalt to andesite lavas that erupted about 180 to 160 ka underlies Middle Sister. Glaciation has removed much of the east half of the volcano, including most of the summit-vent complex, and has sharply steepened its east face. [from USGS Volcano Hazards Program website]</p>	
<p>North Sister (10,985 ft). North Sister is a glacially dissected basaltic-andesite stratovolcano. It has been sufficiently eroded to expose the internal part of the cone, which shows pathways where magma flowed through the edifice in dikes and sills. It is the oldest and longest active volcano of the Three Sisters, and its period of construction from about 120 to 45 ka occurred after the eruptions of Broken Top ended. North Sister lavas show little chemical diversity over the lifetime of the volcano. A north-south chain of mafic vents around Matthieu Lakes erupted intermittently between 60 and 20 ka, cutting across the old North Sister edifice. [from USGS Volcano Hazards Program website]</p>	
<p>Black Crater (7,251 ft). Basaltic andesite lava cone with glacial cirque on northeast side. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>Mt. Washington (7,794 ft). Deeply glaciated basaltic andesite shield volcano with central pyroclastic cone. [USGS Map I-2683, Sherrod and others, 2004]</p>	
<p>Three Fingered Jack (7,841 ft). Deeply glaciated shield volcano.</p>	



Map showing location of over 500 inventoried boulders.