# FIELD TRIP GUIDE TO THE GEOLOGY OF THE BOISE VALLEY

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# FIELD TRIP GUIDE TO THE GEOLOGY OF THE BOISE VALLEY

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## LOCATION AND GEOLOGIC SETTING

The Boise Valley refers to the lower valley and terraces of the Boise River that extend from the mountains across the western Snake River Plain to join the Snake River west of Parma (Figure 1). The Boise River heads in the Sawtooth and Smokey Mountains of central Idaho. It drains an extensive area of mountainous terrain before it exits the mountains near Lucky Peak Dam southeast of the city of Boise (Figure 1). The Boise Foothills lie along the northwest-trending mountain front that separates the western plain from the central Idaho mountains (Figure 1).

The western Snake River Plain has little relief compared with the surrounding mountains, but the Boise Valley, as well as other major river valleys in the plain, is incised about 150 meters (500 feet). The western plain thus appears as broad uplands between major river valleys. It lacks prominent features, but reveals a fairly complete record for reconstructing late Cenozoic geologic and geomorphic history (Figure 2).

The Boise Foothills and the uplands and high terraces of the plain are broken by many small faults typically striking parallel to the northwest-southeast trend of the western plain (Othberg and Stanford, 1992). The adjoining river valleys, although broad and low in gradient, generally are benched with terraces (Figure 3). The most complete terrace sequence is near the south side of the city of Boise (Figure 4).

The western Snake River Plain is both a northwest-trending physiographic

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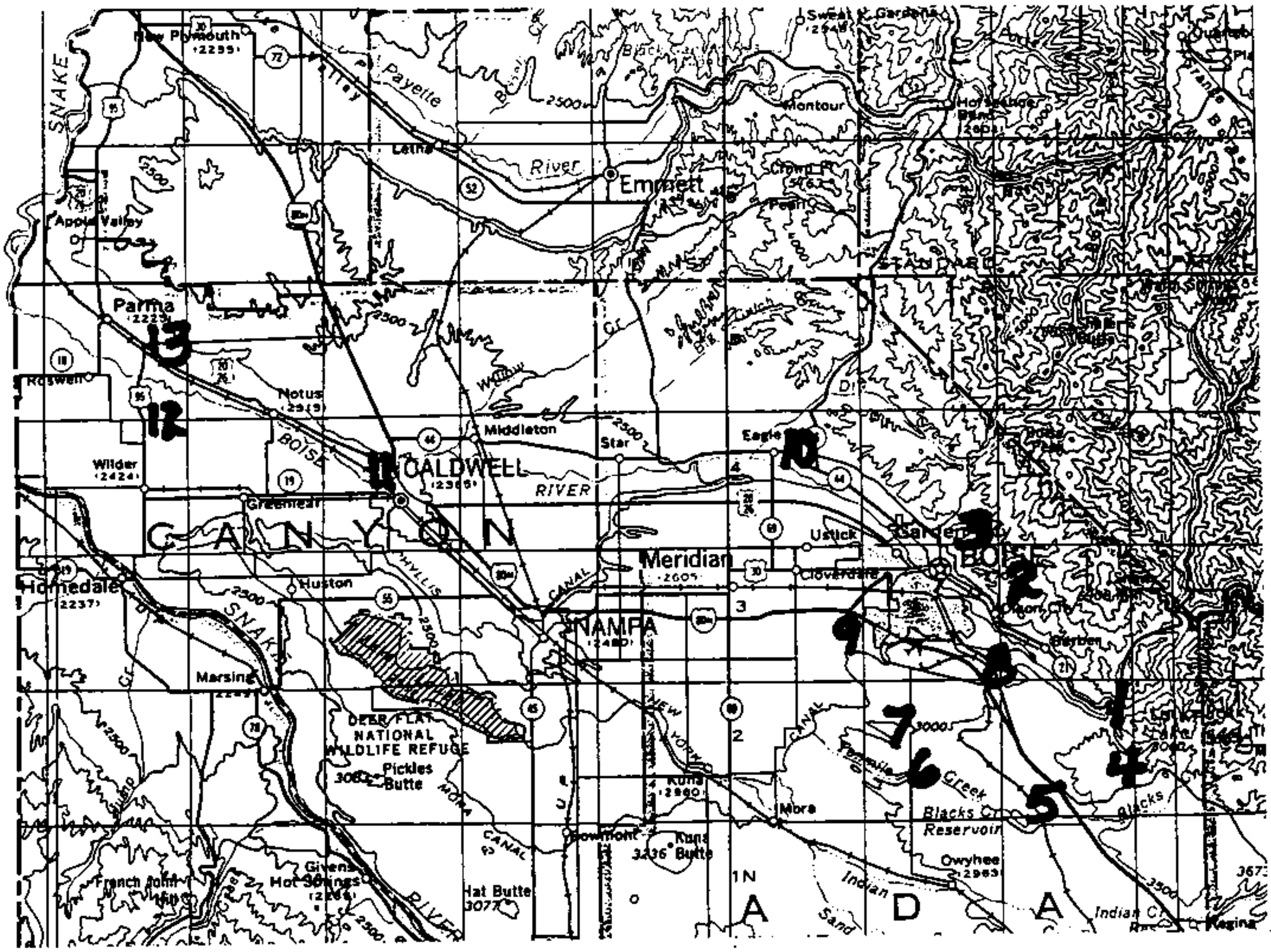


Figure 1. Location map of the field trip area.

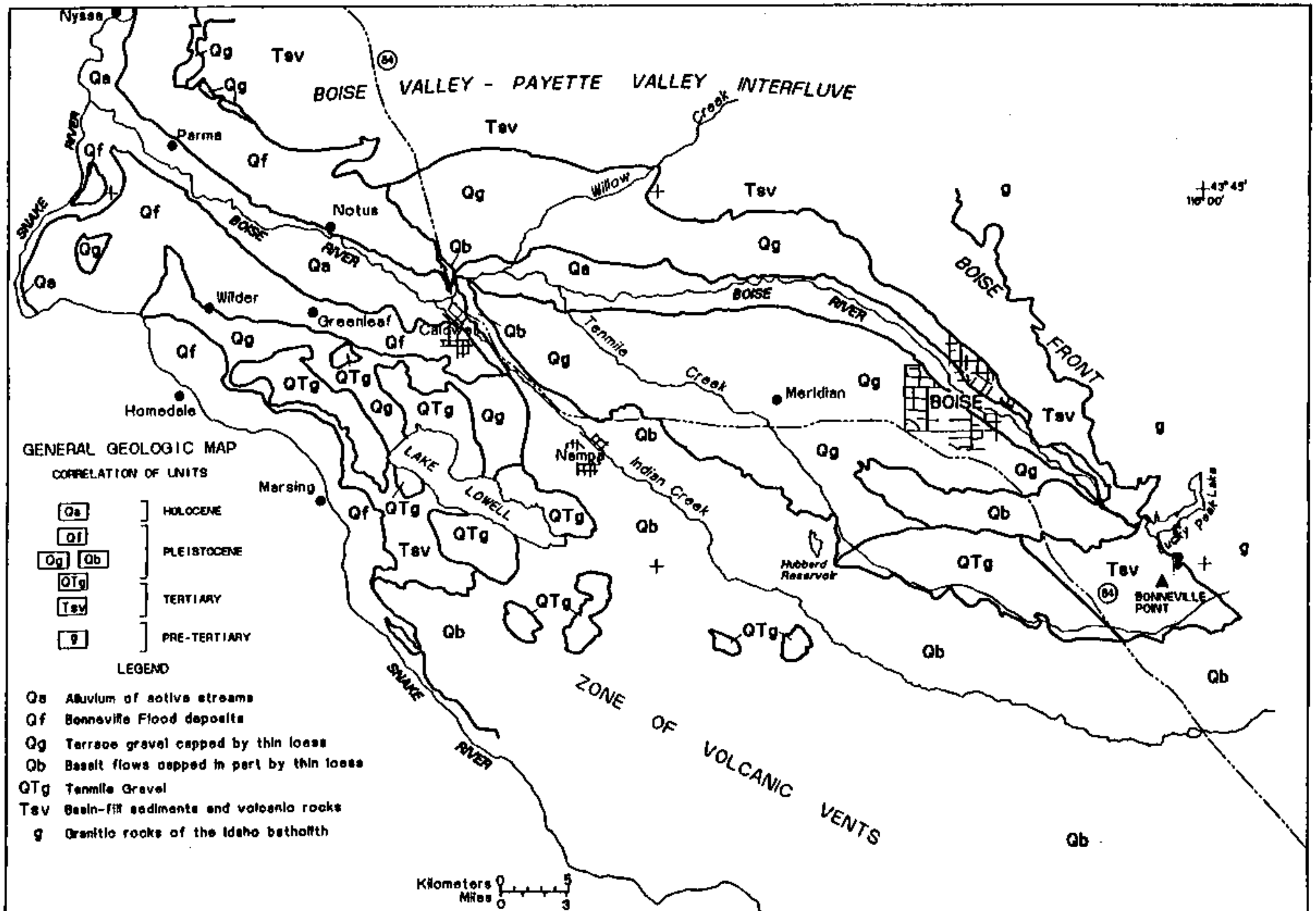


Figure 2. General geologic map of the Boise Valley and adjoining areas.

lowland and a great structural graben separating the Cretaceous Idaho batholith of west-central Idaho from batholith outliers in southwestern Idaho. The volcanic rocks of the eastern Snake River Plain probably formed by plate movement to the northeast over a hot spot presently active in the Yellowstone National Park area. The western plain, however, is a structural graben with features similar to continental rifts (Mabey, 1982; Smith and others, 1985; Wood, 1994). The basin is a well-defined graben but structural downwarping is also present along its margins. Numerous marginal faults trend northwest-southeast with movements down toward the center of the basin (Malde, 1959, 1991; Wood and Anderson, 1981; Wood, 1989, Wood, 1994). Vertical displacement along the northern faults may be as much as 2,744 meters (9,000 feet). Much faulting took place in the early to middle Pliocene, but deformation probably began in the Miocene and continued into the Pleistocene. Late Miocene and Pliocene rocks of the Boise Foothills overlie the Idaho batholith (Figure 2) (Othberg and Stanford, 1992; Clemens and Wood, 1993). These sedimentary and volcanic rocks are displaced downward toward the center of the basin and form a thick graben fill overlying middle Miocene volcanic basement rocks (Wood, 1994).

The western Snake River Plain graben can be classified as a tectonic continental rift (Othberg, 1994; Wood, 1994). The rift began to open after eruption of the Columbia River flood basalts and passage of the early stages of the eastern Snake River Plain hot spot. The late Tertiary geologic history of the western plain has been controlled by this rifting which caused eruptions of subaerial and subaqueous basalts. Sedimentation began shortly after a thick, basal volcanic basement was formed. The sediments were deposited in lake, stream, and alluvial fan environments (Middleton and others, 1985; Smith and others, 1985; Jenks and Bonnichsen, 1989; Wood, 1994).

The rock record shows widespread filling of the basin by both sediments and basalt from the late Miocene through the late Pliocene. A Tertiary drainage outlet believed to exist to the west through eastern Oregon probably was interrupted by periods of volcanism there (Kimmel, 1982; Malde, 1991). Although basalt eruptions continued into the Pleistocene and coarse sediments were transported from the mountains onto the plain during Quaternary glaciations, the filling of the western Snake River Plain was replaced by incision in the latest Pliocene or earliest Pleistocene and incision of the valleys has continued to the present.

## STRATIGRAPHY

### Cretaceous (144-65 my[3] ago)

In the Boise Foothills, granodiorite of the Cretaceous Idaho batholith provides a "basement" under the younger rocks (Figure 2). Outcrops of biotite granodiorite found in the higher elevations of the foothills are part of the southern portion of the Atlanta lobe of the Idaho batholith, of which most of central Idaho is composed. The Atlanta lobe is 170 miles (275 km) long and 80 miles (130 km) wide. It consists of six main rock types: tonalite, hornblende-biotite granodiorite, porphyritic granodiorite, biotite granodiorite, muscovite-biotite granite, and leucocratic granite (Johnson and others, 1988). The Idaho batholith ranges in age from 65 to 95 my. The most common unit, the biotite granodiorite, is 75 to 85 my old based on K-Ar radiometric ages (Lewis and others, 1987; Johnson and others, 1988).

Fresh biotite granodiorite is typically a light-grey, medium-grained rock composed principally of plagioclase, quartz, potassium feldspar, and 2-8% biotite. It is locally porphyritic with potassium-feldspar phenocrysts up to an inch in length (Johnson and others, 1988). Small cross-cutting dikes of coarse-grained quartz-feldspar-muscovite pegmatites are common in the Boise Foothills.

The Idaho batholith, along with the Sierra Nevada batholith in California and the Coast Range batholith in British Columbia, formed above a long-lived Mesozoic (245 to 65 million years) subduction zone along the western margin of the North America. It was similar to the present-day west coast of South America, where the Pacific Ocean plate is subducting under the less dense continental plate. Lines of volcanoes, earthquakes, and a subsurface zone of molten rock or magma are generated by the heat and stresses above the subduction zone. The magma that formed the batholith crystallized slowly at depths of 8-15 km and temperatures of 600-800°C.

### Tertiary (65-1.6 my ago)

Evidence of the early Tertiary rocks is absent in the Boise Valley and the Boise Foothills. After a long hiatus, igneous activity in the Boise Valley erupted in a series of Miocene (24 to 5 million years) and younger volcanic rocks. The

[3]For convenience, "my" is used for "million years."

earliest of these, the Columbia River Basalt, erupted from about 17 to 14 my ago. These extensive flood basalts are exposed in western Idaho from Weiser north to Coeur d'Alene, and may form the "basement" rocks under the western Snake River Plain (Mabey, 1982).

Southwestern Idaho hosts a diverse suite of Cenozoic silicic volcanic rocks, exposed over much of Owyhee County and along the margins of the western Snake River Plain (see Bonnichsen and Breckenridge, 1982 for many articles on Cenozoic vulcanism in Idaho). Two groups of Cenozoic rhyolites have been distinguished (Malde and Powers, 1962; Armstrong and others, 1975, 1980; Clemens and Wood, 1993). Group 1 includes the 15-16.4 my old precious-metal mineralized, hydrous mafic mineral-bearing tuffs and flows such as the Silver City and Jarbidge rhyolites of Owyhee County. Group 2 comprises the 9-14 my old unmineralized, relatively anhydrous Idavada Group volcanics of southwest and south-central Idaho. Although debate continues over many details, the Group 2 rhyolites are probably related to the younging-eastward progression of the eastern Snake River Plain hotspot, now centered under Yellowstone (Armstrong and others, 1975; Rodgers and others, 1990; Clemens and Wood, 1993; Geist and Richards, 1993). Rhyolites exposed in the Boise Valley, as well as in the Mount Bennett Hills and at Twin Falls, fit in the Group 2 category.

Lindgren, 1898, provided the earliest description of rhyolites in the Boise Quadrangle. Lindgren interpreted the rhyolite in Quarry View City Park as a "laccolith in miniature." A laccolith is a shallow intrusive which domes up the overlying strata. More modern work interprets the "Castle Rock" exposure at Quarry View Park as an extrusive rhyolite or rhyodacite flow(Wood and Burnham, 1987; Clemens and Wood, 1993). Faulting and warping can easily account for the tilt of the younger sandstone which overlies Castle Rock (Wood and Burnham, 1987). The Quarry View Park rhyolite is similar to rhyolites exposed in Rocky Canyon along Cottonwood Creek (Field trip STOP 2) and in the South Fork of Willow Creek north of Eagle. The rhyolites are faulted against and lie unconformably over the much older granodiorite. Potassium-argon ages of the Quarry View rhyodacite and Cottonwood Creek rhyolite are 11.8 $\pm$ 0.6 my and 11.3 $\pm$ 0.3 my, respectively (Clemens and Wood, 1993).

Overlying the rhyolites is a complex sequence of basaltic volcanics, referred to by early workers as the Banbury Basalt (Malde and Powers, 1962; Armstrong and others, 1975). Radiometric ages of the basaltic flows and tuffs range from 9-10 my old (Armstrong and others, 1980). Othberg and Burnham (1990) and Burnham and Wood (1992, in review) mapped these rocks in the Boise South and Lucky Peak quadrangles as part of a volcanic assemblage which includes basaltic and palagonite tuff, flow basalt, tuffaceous and arkosic sediments, and local rhyolitic ash. The basaltic tuffs contain expansive clays and can cause slope failures and engineering problems for buildings and roads. Thick exposures of the volcanic assemblage outcrop to the east and southeast of downtown Boise.

Sediments of the Idaho Group compose most of the Boise Foothills and overlie the basaltic rocks (Figure 2). Similar sediments form the low-lying hills from Boise to Weiser along the northeast margin of the western Snake River Plain (Othberg and Stanford, 1992). Arkosic sand dominates, with common sandstone, siltstone, claystone, and lesser conglomerate, oolitic sandstone, and mudstone layers. Two newly named units, the Pierce Gulch sand and the Terteling Springs Formation, were mapped in the Boise South, Eagle, and Lucky Peak quadrangles (Othberg and Burnham, 1990, Othberg and others, 1990, Burnham and Wood, 1992, in review). The most spectacular exposures of the sands (such as at Table Rock and Field trip STOP 3) exhibit large-scale cross beds deposited in a deltaic setting where rivers from the mountains north of Boise entered a large lake, Lake Idaho, that occupied the subsiding graben that was forming the western Snake River Plain.

Within the Boise Valley, the Idaho Group sediments have been dropped 800 to 1000 feet below the surface along the Boise range-front fault zone. These deep sediments constitute the Boise aquifer, the city's main source of drinking water. The sediments fine from course alluvial fan gravels in the east to fine sands and mudstones in the west, toward the center of the ancient lake. Recharge and hydrologic parameters of the aquifer are controlled by the sedimentary facies and structure within the Idaho Group sediments (Squires and others, 1993).

Ages of the Idaho Group sediments are elusive, but they probably correlate somewhat with the Glenns Ferry Formation and Poison Creek Formations exposed on the southwest margin of the Snake River Plain. Clemens and Wood (1993) obtained a $9.5 \pm 0.6$ my date on the Aldape Park Basalt flow, a dense, olivine basalt flow within sandstone and siltstone of the lowermost Terteling Springs sediments in Boise. Thus, sedimentation began earlier than had been previously thought (Wood and Burnham, 1987), as Lake Idaho must have already been accumulating sediments by 9.5 my ago. An upper age limit on the Idaho Group sediments in the Boise foothills is not known, but evidence from fossils and radiometric dating near the western Boise Valley along the bluffs of the Snake River suggest the Glenns Ferry Formation and the Tenmile Gravel were deposited at the very end of the Pliocene (5 to 1.6 million years) (Othberg, 1994; Othberg and others, in press).

Boise hosts the oldest geothermal heating district in the United States. Houses along Warm Springs Avenue and elsewhere along the fault-bounded Boise Front still are heated by the 66°C (172°F) water (Wood and Burnham, 1987). Deeply circulating waters traveling through the faulted and fractured rock are heated along the graben margin. Remnants of an earlier hot spring system are evidenced by the silicified butte called Table Rock, a local landmark, and by other silicified sands at Castle Rock behind the Old Penitentiary and north of Eagle. The hot springs may have existed at the same time as Lake Idaho, as well as today. Hot waters carrying dissolved silica permeated through the loose sands of the Idaho Group sediments where the sands lay above or near faults. The dissolved silica precipitated between the grains as a quartz cement, binding them tightly together like glue (Wood and Burnham, 1987). The resulting hard, massive sandstone became one of the most prized building stones of the early settlers of the Boise Valley. Convicts at the Old Territorial Penitentiary quarried the stone to construct their own prison. The stone also graces the old Assay Office in Boise, the Idaho Statehouse and buildings as far away as San Francisco and Denver.

## Quaternary (1.6 my ago to present)

The Tertiary Idaho Group includes the lake and stream sediments and volcanic rocks that partly filled the rifting, subsiding basin of the western Snake River Plain. The basin continued to subside until the late Quaternary, but the infilling by sediments was replaced by incision shortly after Hells Canyon was cut in the late Tertiary and the Snake River began flowing north. This initiated the present physiography of broad upland remnants of the basin fill separated by terraced river valleys. The Quaternary sediments and volcanic rocks of the Boise Valley have formed in this essentially modern setting (Othberg, 1994).

The grain size of the sediments of the Idaho Group coarsened just before or at about the same time that the Hells Canyon route of the Snake River was established (Othberg, 1994). The change from basin filling to valley incision and the coarsening of stream sediments probably both occurred in response to a change in world-wide climate near the end of the Tertiary. Cooler climate led to increased snow packs and mountain glaciations, which in turn produced more coarse sediment and increased river discharges. The change in climate (1) made it more likely that erosion would form Hells Canyon and capture the waters of the western Snake River Plain; (2) caused episodic downcutting of valleys coincident with the periods of mountain glaciation; and (3) caused the glacial and periglacial environments that provided coarse gravel sediments which were subsequently deposited in the valleys (Othberg, 1994). During the Pleistocene (1.6 million years to 10,000 years), there were dozens of periods of glacial climate, providing many opportunities to episodically incise valleys and spread gravel. The result is several hundred feet of incision into the Tertiary basin fill and the formation of river terraces composed of gravel. There is evidence of eight Pleistocene terraces in the Boise Valley (Figures 3 and 4) (Othberg, 1994).

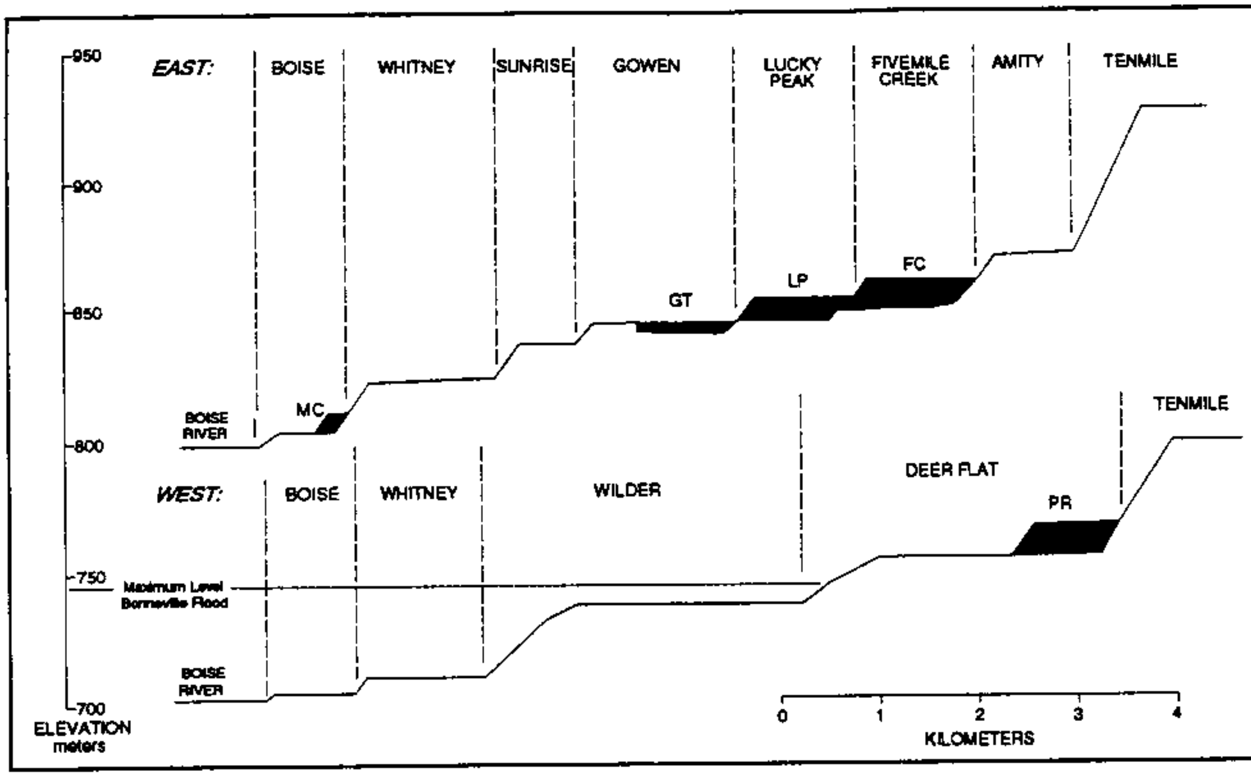


Figure 3. Diagrammatic profiles of the eastern and western Boise Valley terraces and terrace-capping basalt flows. The view in Figure 4 is approximately the same as the eastern sequence except the Lucky Peak terrace is missing in Figure 4. In the western sequence, the Boise, Whitney, and Wilder terraces are mantled with Bonneville Flood sediments, the level of which is indicated. Basalt flows are MC, basalt of Mores Creek; GT, basalt of Gowen terrace; LP, basalt of Lucky Peak surface; FC, basalt of Fivemile Creek surface; and PR, basalt of Pickles rim surface.

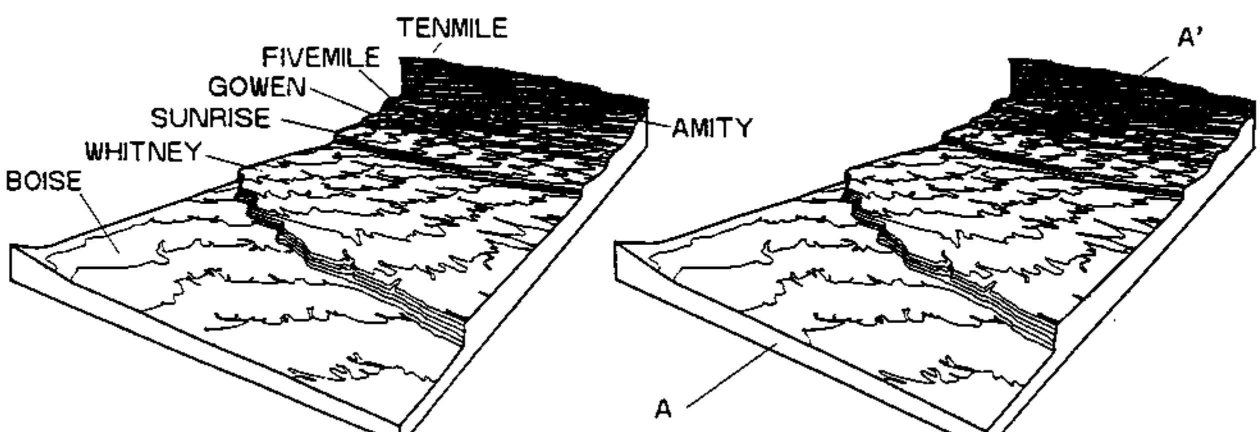


Figure 4. Block diagram of the eastern sequence of terraces in the Boise Valley. Stereopair provided for 3-D viewing (courtesy of L.R. Stanford, Idaho Geological Survey).

# DESCRIPTION OF FIELD TRIP STOPS

## The Boise Foothills

| MILEAGE | DESCRIPTION |
| --- | --- |
| 0.0 | Starting point is the front entrance of the Student Union Building at Boise State University, intersection of University Drive and Lincoln Street. Proceed east on University Drive. |
| 0.4 | Broadway Avenue. Turn south. |
| 2.2 | I-84 underpass and right turn at sign for Federal Way. Follow Federal Way southeast. |
| 4.0 | Intersection of Federal Way and Idaho 21. Turn left onto Idaho 21 and proceed east. |
| 6.7 | Intersection of Warm Springs Avenue and Idaho 21. Turn right and proceed southeast. |
| 11.3 | Discovery Park and view of Lucky Peak Dam. Continue around curve toward the upper part of the dam. |
| 12.4 | Lucky Peak Dam. Turn right and follow road across the dam. |
| 12.8 | Parking area at end of dam. Turn left and park. |

**STOP 1: Lucky Peak Dam.** The top of Lucky Peak Dam provides a 360° view of the geology of the southeast Boise Foothills. Northeast across Idaho 21 are outcrops of the Idaho batholith (Figure 2). The northeastern footings of the dam sit on this granodiorite. Northwest of the dam (the dam is oriented northeast-southwest, 90° to the trend of the range-front), the relatively fresh granodiorite grades into sheared granitic rocks and fault gouge. This marks the upthrown side of a fault (Othberg, 1986; Othberg and Burnham, 1990) which appears to pass directly under Lucky Peak Dam and probably forced the Boise River to make the zigzag in its course. Slivers of rhyolite and granitic fault gouge occupy the zone of the fault, and rocks of the basalt volcanic assemblage form the

downthrown, southwest side of the fault. The large exposure just above the highway northwest of the dam reveals layers of basalt flows and pillow basalts. South of the top of the dam, toward the boat ramp, columnar basalt is visible and these rocks make up the southwest footings of the dam. In this area the basalt volcanic assemblage typically strikes north 50° west and dips 15° to the southwest.

The slope southwest of the dam approximates a dip slope on basalt. The clayey basaltic tuff layer which originally covered the basalt, was stripped away for construction of the dam's interior. South of this stripped surface there are exposures of the basaltic tuff, a thick bed of silicic ash, and thin beds of volcaniclastic sediments—the upper part of the basalt volcanic assemblage in this part of the Foothills. Immediately above those exposures is a large borrow pit, mostly revegetated now, from which sand and gravel were excavated for use in the dam construction. The deposit is part of the gravel of Bonneville Point, which will be described in more detail at Stop 4.

The drainageway southwest of Lucky Peak Dam is Lydle Gulch. It formed along another major fault, the trace of which can be seen on a bank of the Boise River when the water level behind Diversion Dam is lowered (Othberg and Burnham, 1990). The basalt volcanic assemblage makes up the northeast, upthrown side of the Lydle Gulch fault, whereas the gravel of Bonneville Point forms the southwest, downthrown side. Traced to the northwest, the fault is buried under alluvium of the Discovery Park, Idaho 21, and talus formed from the cliff of columnar basalt high above. This cliff exposes the basalt of Lucky Peak, which forms the bench seen west-northwest of the dam (Figure 5). This is a Pleistocene basalt flow estimated to be between 600,000 and 780,000 years old (Othberg and Burnham, 1990; Othberg, 1994; Othberg and others, in press). No evidence of offset by the Lydle Gulch fault has been seen in this basalt. Most of the basalt of Lucky Peak is covered by Pleistocene alluvial fan gravels. The source of the gravel was erosion of the gravel of Bonneville Point that caps the foothills northeast of Lucky Peak Dam .

Two other Pleistocene basalts form cliffs that can be seen from this location (Figure 5). Rockfall from the basalt cliffs has built the talus slopes on the southwest side of the Boise River. The highest of these lava flows is the basalt of Fivemile Creek, which erupted from a local vent about 5 km (3 miles) southwest of here. The other cliff-former, the basalt of Gowen terrace, consists of 4 thin flows that, like the Lucky Peak flow, are thought to have originated in Smith Prairie, about 60 km (37 miles) upstream. Magnetic polarity measurements and K-Ar dates suggest the basalt of Fivemile Creek is about 1 my old and the basalt of Gowen terrace is about 0.6 my old (Othberg and Burnham, 1990; Othberg, 1994). A third Pleistocene basalt (Figure 5), the basalt of Mores Creek, 12 the shores of Lucky Peak Lake east of here and forms canyon walls along Mores Creek. When the reservoirs are full, the basalt of Mores Creek is submerged (Othberg and Burnham, 1990; Othberg and Stanford, 1992). It has a K-Ar age of about 100,000 years (Othberg, 1994; Othberg and others, in press).

13.2 Return to Idaho 21, turn left and drive toward Boise continuing onto Warm Springs Avenue (no turns).

23.6 Intersection of Broadway and Warm Springs Avenues in Boise. **Reset odometer to 0.0 miles.** Drive northeast on Broadway past St. Lukes Hospital.

23.8 Turn right on Reserve street by Fort Boise Park.

24.2 Turn right on Shaw Mountain / Table Rock Road and continue uphill through houses.

24.8 Look at fault exposed at beginning and end of road cut on blind hairpin turn on left side of road. Do NOT stop; traffic is too dangerous. Fault cuts sandstone of Idaho Group.

25.3 Turn left on Shaw Mountain Road at sign to Rocky Canyon. Drive over ridge and down hill out of city, cross gulch and continue up paved Rocky Canyon road.

25.6 **STOP 2.** Stop and park at 4-lane wide turnaround at end of pavement.

**STOP 2A.** Walk 1/2 mile up dirt road, being careful of traffic and abundant, vicious poison ivy along creek. Do not stop to look at geology yet. Continue through steep, narrow canyon to tan outcrop

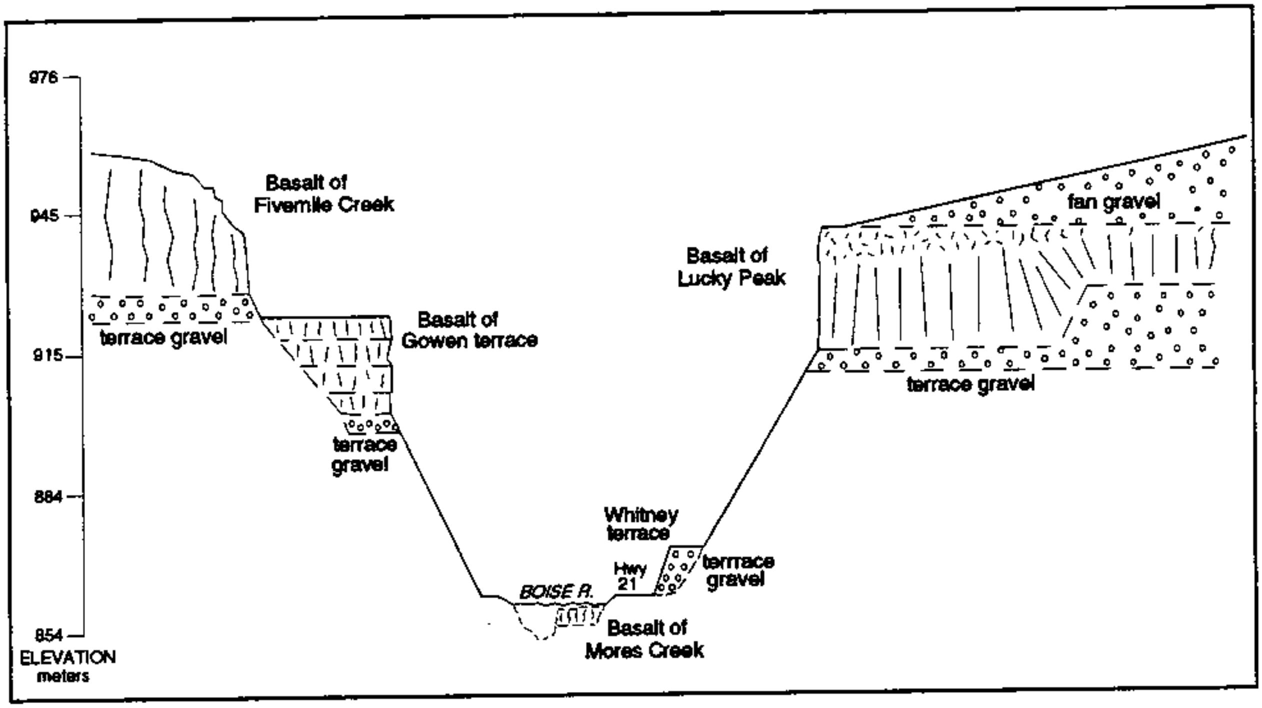


Figure 5. Profile and cross section of the Boise River canyon near Lucky Peak Dam showing stratigraphy of lava flows and buried terrace gravels. Stratigraphy of basalt units, oldest to youngest: basalt of Fivemile Creek, basalt of Lucky Peak, basalt of Gowen terrace, and basalt of Mores Creek.

by left side of road as canyon widens.

*Idaho Batholith.* Typical biotite granodiorite of Cretaceous-age Idaho Batholith. Note similar outcrops further up road. This same rock unit continues for many miles northward past McCall. Outcrop is medium-grained granodiorite composed of whitish feldspars, grey quartz, and black biotite. Look for pieces of coarser-grained pegmatite in stream cobbles. Light brown color of outcrop is due to oxidation of iron-bearing minerals like biotite and magnetite. Age of rock is 70-100 my.

Turnaround and walk back down road towards cars, this time looking at the geology. Approximately 25-30 m down road note the brown soil on hillside to right (north). This is the fault which places the granodiorite in contact with much younger volcanic rocks. Possible fault breccia outcrop, probably clays as well.

*Cottonwood Creek Rhyolite.* Tertiary rhyolite makes up the narrow, steep-walled portion of Rocky Canyon. These large, high outcrops are composed of Cottonwood Creek Rhyolite, a volcanic flow dated at 11.3 $\pm$ 0.3 my (Clemens and Wood, 1993). The stony rhyolite is pinkish grey in color and composed of a fine-grained matrix with 5-7 % phenocrysts of sanidine feldspar and lesser quartz. Small gas vugs and vertical to contorted flow-banding are common. Vitrophyre-bearing breccia and pumice-rich ash layers are present at the margins of the flow or dome, near the fault and parking area.

Walk through the rhyolite exposures back to the cars. As you leave the narrow part of the canyon, note the flat, planar erosion surface carved onto the rhyolite. Could this be a wave-cut platform? You may want to examine the grey outcrop on private property near the cars. It is a perlite breccia and ash deposit associated with the rhyolite.

**STOP 2B (New Road cut):** From the cars, walk 0.1 miles down the paved road to a newly blasted road cut on the turn with the concrete barriers. Be careful of traffic on the blind curve. Look at the large blocks of rhyolite placed by the side of the road. Black and red obsidian breccias, incipient thundereggs, yellow solfataric alteration stain and spherulites are some of the interesting features. Go all the way to the far side of the road cut. There is an excellent exposure of an Unconformity and Contact. Pink rhyolite is overlain by approximately 1 m of weathered rhyolite or soil, which is unconformably overlain by a brownish grey "basalt tuff" unit, belonging to the Boise Basalt Volcanic Assemblage as mapped by Burnham and Wood (1992, in press). Note that the unconformity represents a time interval needed for erosion of the rhyolite and a change in the volcanic and depositional setting. From this spot, turn and look back towards the entrance to Rocky Canyon. You can see the nearly horizontal, erosion surface on the rhyolite extending south to Picket Pen Canyon. Yellowish-tan sands of the overlying Idaho Group sediments are exposed in road cuts 30-40 m above the rhyolite.

***Basalt Tuff.*** This massive brownish-grey bed, approximately 1-3 meters thick, is an unsorted, unstratified breccia with ashy matrix and volcanic-derived clasts. 25 - 50 % small (less than 1 cm) clasts of pumice, black volcanic glass, altered vesicular rock fragments, and a few feldspar crystals comprise the clasts. The lack of sorting or bedding suggest deposition by a lahar (volcanic-derived mudflow) or debris flow.

***Siltstone.*** Overlying the basaltic tuff is a pinkish tan, 1-2 m thick siltstone. The siltstone is fine-grained and gritty with local, planar stratification and possible scouring into the underlying tuff. Small clasts of lithics, ash, and glass make up approximately 10 % of the siltstone, which appears to be a water-lain sediment with a large component of volcanic ash and detritus. An upper brownish unit of basaltic tuff overlies the siltstone on the uphill side of the road cut. Look for possible soft-sediment deformation.

29.1 Return to cars and drive back to Fort Boise, retracing your route out of Rocky Canyon and back down Shaw Mountain Road to the base of the Foothills.

29.6 Turn right on Mountain Cove Road, opposite the old Armory just before the park. Drive to the second right turn (there will be a large sign) onto Cottonwood Creek Road towards the Archery Range.

29.9 Park at a large pullout on left by very high bank cut into the hill.

**STOP 3: "Gilbert Delta" in Idaho Group sands.** The cut hillside exposes an approximately 20 meter section showing a lower unit of huge cross beds (10-15 m high), overlain by 3-m thick, planar stratified sands, which are unconformably overlain by Quaternary gravels.

This outcrop has been interpreted by Gallegos and others (1987) as a classic deltaic facies. The large cross beds are deltaic foresets, and they are overlain by parallel laminated, finer-grained sands which form the topset beds. Small cobbles form a horizontal lag gravel at the contact. The forset beds are composed of coarse to medium-grained sand with brown iron oxide stain marking the coarser, more permeable beds. Paleocurrent data indicate a W-SW transport direction (Gallegos and others, 1987). The delta formed where large rivers dropped their load of batholith-derived sand as they entered Lake Idaho several million years ago. Note that these rocks overlie those at Stop 2B further up the same drainage.

The upper part of the hill exposes younger terrace gravels deposited in braided stream channels locally incised into the topset beds.

32.6 Return to cars and continue back to intersection of Broadway and Warm Springs Avenues.

35.8 Drive south on Broadway to I-84 interchange. Take the ramp onto I-84 East toward Mountain Home and Twin Falls.

44.8 Follow I-84 East to Blacks Creek Road exit. Turn left and go through underpass following Blacks Creek Road northeast toward the mountains.

48.4 Turn left onto gravel road at sign for Oregon Trail historical site. Road climbs hill toward microwave facility.

48.7 Stop at side of road near the summit before the "Y" in the road.

48.7 Continue, turning left away from the microwave facility and toward the historical site. Park in the loop next to the fenced site.

**STOP 4a: Patterned ground.** The weathered surface of the gravel of Bonneville Point is characterized by round to oblate mounds 4-6 meters in diameter with nearly equal spacing between the mounds. The mounds consist of thicker horizons of silty surface soil with a clayey B horizon. The upper part of the gravel, which is exposed between the mounds, is highly oxidized and partly cemented. The patterned ground may have developed during periods of Pleistocene periglacial conditions (Malde, 1964).

**STOP 4b: Bonneville Point Historical Site.** This is the high point of a branch of the Oregon Trail, named after Lieutenant Bonneville who coined "Boise" from this spot when he could see the Cottonwoods in the floodplain of the river below. From this vantage one can see several features of the foothills, some of the terraces, and, when visibility is good, the volcanos of the central ridge of the graben.

The gravel of Bonneville Point originally was included in the Payette Formation by Lindgren (1898), who recognized that it represents facies of the ancestral Boise River. Unlike the near source, dominantly granodioritic composition Idaho Group sediments of the north foothills, the gravel of Bonneville Point is composed of granitic rocks and porphyritic felsites that came from the central Idaho mountains. Savage (1958) included the deposit in the Tenmile Gravel, but because of differences in stratigraphy, weathering, and depositional settings, a separate name was warranted (Othberg, 1986; Othberg and Burnham, 1990; Othberg and Stanford, 1992; Othberg, 1994). Exposures within a long washout gully on this side of Lydle Gulch show that the gravel of Bonneville Point is composed of interbeds of channel gravel and sand with common depositional breaks represented by buried soils. The color of this unit is characteristically yellow-orange, due to considerable weathering and release of iron oxide. In many locations as much as fifty percent of gravel clasts have been softened by weathering.

The gravel of Bonneville Point forms the Bonneville Point upland, an east-west ridge stepped downward along faults to the west and southwest (Othberg and Stanford, 1992; Othberg, 1994). Its high point lies at an elevation of about 1,256 meters (4,120 feet), some 98 meters (321 feet) above the historical site. Looking toward the high remnant of gravel to the east, one can see the irregular topography of weathered Idaho batholith that lies beyond. The gravel once formed a river lowland that lay below the surrounding hills of the granodiorite. Rocks of the batholith have suffered more erosion than the gravel, and this ridge of gravel is, therefore, an example of reversed topography caused by the gravel's greater resistance to erosion. The gravel of Bonneville Point is at least 500 feet thick and may thicken to over 800 feet under the Oregon Trail site, which is on the downthrown side of the Lydle Gulch fault. As noted at Stop 1, the gravel also caps hills on the north side of Lucky Peak Dam, and its highest known elevation is about 4,120 feet. The thickness of the gravel on the other side of the fault zone is about 300 feet, tapering rapidly to the east where it makes a cap of only about 80 feet thick under the 4,120 foot ridge top. This suggests the ancestral Boise River was filling the edge of the plain as it was dropping along the range-front fault.

Looking northwest, Table Rock may be seen rising above the city. Just beyond it are the locations of Stops 2 and 3. Table Rock is composed of near-shore sands that have been cemented by silica-rich geothermal water. Table Rock was formed because the cemented rock resisted erosion more than the surrounding less cemented sediments. On the west side of Table Rock lies Warm Springs Mesa, a bench area that was formed by movement of an ancient landslide—probably the largest example of many landslides known to exist in the foothills (Beck, 1989; Othberg and Burnham, 1990; Burnham and Wood, in review).

The view toward the west side of Boise shows the broad bench areas across which the city is growing. The benches consist of two main terraces of the Pleistocene Boise River—the Whitney and Sunrise terraces (Figures 3 and 4) (Othberg and Stanford, 1992; Othberg, 1994), which are described in Stops 9 and 10.

Aircraft may be seen from here on final approach into Boise International Airport. The airport rests on the Gowen terrace (Figures 3 and 4), which will be described in more detail at Stop 8. Between here and the airport lies the Micron microchip manufacturing plant and the large south Boise water tower. They rest on the surface of the basalt of Fivemile Creek (Figures 3 and 4), which erupted from a fault-line gully in the Bonneville Point upland just south of Micron and east of I-84.

Looking west the Bonneville Point upland can be seen to flatten and grade into the Tenmile terrace (Figures 3 and 4) (Othberg and Stanford, 1992). Remnants of this early terrace, composed of the Tenmile Gravel, extend west to the Snake River. Stops 5, 6, and 7 describe the Tenmile terrace and the Tenmile Gravel.

Farther to the west and southwest several volcanos of the central ridge zone of volcanic vents of the graben can be seen on a clear day. These include Kuna Butte, Powers Butte, Initial Point, and Christmas Mountain. The more recent volcanos, as young as about 400,000 years (Othberg, 1994; Othberg and others, in press), represent some of the last tectonic and volcanic activity that created the rifted basin. On a very clear day, the Owyhee Mountains can be seen rising above the southwest-bounding fault zone of the graben (Figure 1), completing the picture from the Boise range-front fault across the plain.

## The Terrace Sequence

54.3 Retrace the route down to Blacks Creek Road and back to I-84, crossing under the freeway overpass. Continue west on Blacks Creek Road to a railroad crossing.

54.6 Turn right onto primitive four-wheel drive road and drive 0.3 mile northwest parallel to the railroad tracks, crossing Blacks Creek (usually dry in the summer and autumn). Park at the base of the escarpment. **Beware of rifle target practicing in this area! Let the shooters know you are present!** Continue up the primitive road on foot for about 400 meters, then cross the barbed-wire fence to enter the railroad grade.

**STOP 5: Tenmile terrace soil--Blacks Creek railroad cut.** The surface of the Tenmile terrace, although originally as flat as a floodplain, has been modified by faulting, erosion, and periglacial processes to form many northwest-southeast ravines and pervasive patterned ground. In the areas that escaped erosion, soils on relatively stable surfaces have formed thick caliches, or duripans, for over 1.6 my since the Tenmile Gravel was deposited (Othberg, 1994). This site shows the accumulation of calcium carbonate and silica that have been cemented into interconnected hard plates in the B horizon (Figure 6). In addition to the more than 1-meter thick duripan, the great age of this soil is indicated by calcium carbonate in concentrations of 60% or more, and B horizon clay accumulation of about 50%. This is the Chilcott Series soil, the oldest of the defined sequence of soils based on age (Othberg, 1994).

60.6 Return to Blacks Creek Road, turn right and drive west to the intersection with Pleasant Valley Road (the Idaho State Penitentiary will be visible on the right). The road travels across the surface of the basalt of Slaters Flat, which is about 1 million years old (Othberg, 1994; Othberg and others, in press).

62.6 Drive north on Pleasant Valley Road past the entrance to the Penitentiary. Ahead the road drops into the valley of Tenmile Creek and then rises onto the high ridge of gravel. Just before the descent into the valley, the basalt of Slaters Flat can be seen in road cuts where it overlies gravel. Continue across Tenmile Creek and as you start up the grade park at the side of the road next to the gravel military tank track.

**STOP 6: Faulting in Tenmile Gravel—Pleasant Valley Road tank track road cut.** The Tenmile Gravel exposed in this cut shows the gray color, coarse texture, and crude bedding that is characteristic not only of the this terrace gravel deposit, but of all the terrace gravels in the eastern Boise Valley. Active faces in nearby gravel pits reveal the crude bedding, the poor sorting, and the lenses of sand that are typical of braided-stream deposits found in glacial outwash. The main feature at this site, however, is an exposure of several meters of offset on one of the northwest-southeast faults that are common in this gravel ridge. Many of the faults show movement down on the southwest side, but some, like this fault, are antithetic to the main graben boundary fault and show movement down on the northeast side. Here, the northeast side of the fault was filled with wind-blown silt (loess), presumably as a fault scarp was episodically formed. Thin caliche layers in the loess represent relatively long periods of stability between fault movements and loess deposition. There appears to be no scarp at the surface today, suggesting that movement on the fault ceased long ago.

64.7 Continue driving north on the Pleasant Valley Road. As the road begins its descent into a ravine, be prepared to stop at the gravel

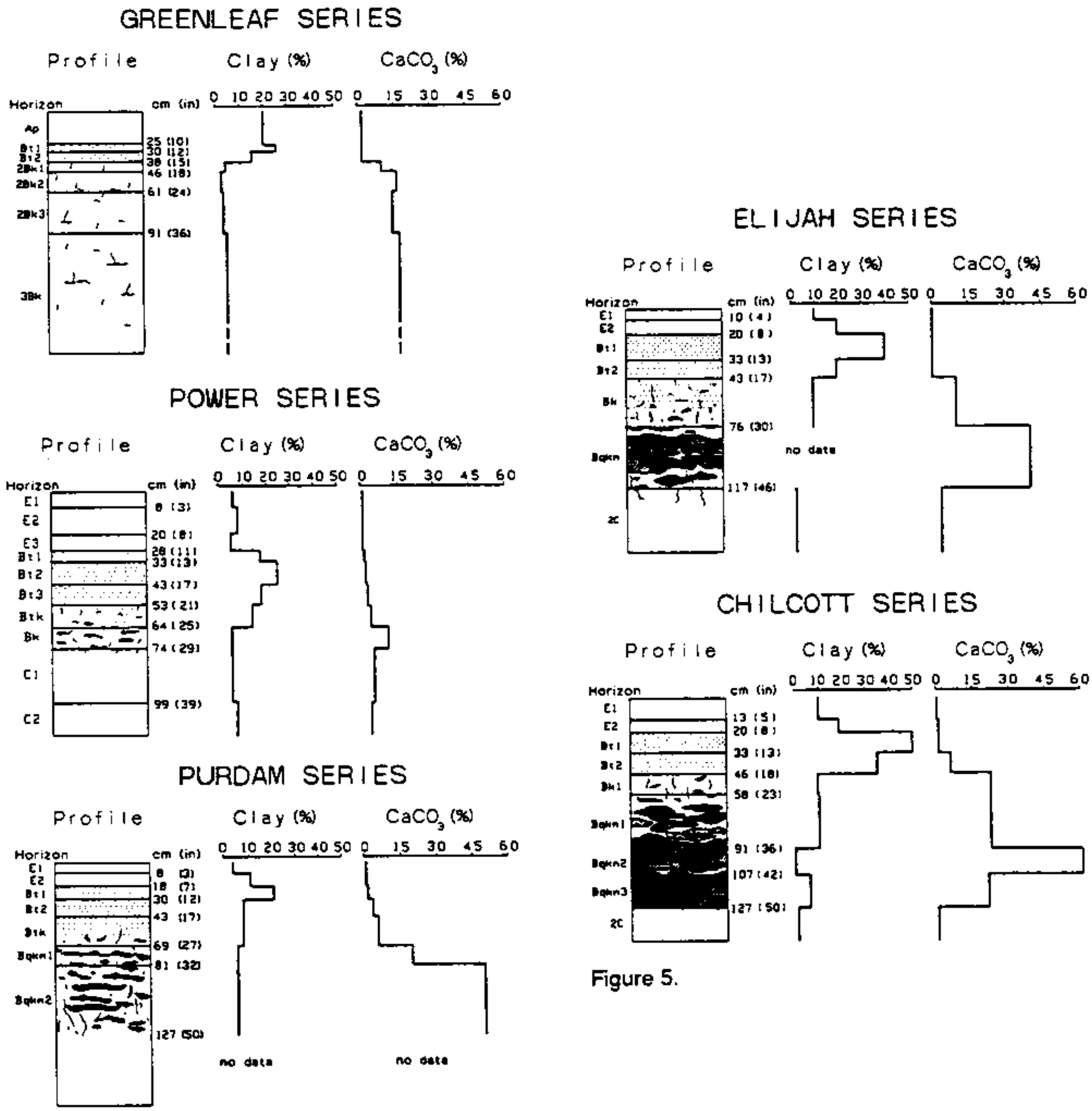


Figure 5.

Figure 6. Soil profile characteristics and percentages of clay and calcium carbonate for the Greenleaf, Power, Purdam, Elija, and Chilcott Series. Profile symbols: stipple pattern – pedogenic clay; other symbols – stringers, nodules, and plates of calcium carbonate and silica.

pits near the north escarpment of the high ridge. Exposures in these pits are undependable and in the autumn, rifle target practicing is common. If conditions are favorable, park on the side of the road near the entrances to the pits.

**STOP 7: Tenmile Gravel—Pleasant Valley Road gravel pits.** The terraces of the eastern Boise Valley have several features in common. First, the gravel deposits of all the terraces are very similar in texture, sorting, and bedding. Second, prior to aggrading the valley bottom with coarse gravel, the river cut down into the older, Tertiary basin-fill deposits. In this area south and southeast of Boise, the basin fill consists of the gravel of Bonneville Point, representing the facies of the ancestral Boise River. These pits show the Tenmile Gravel to overlie the gravel of Bonneville Point. The Tenmile Gravel is less-weathered and generally coarser-grained than the underlying more-weathered, generally finer-grained and finer-bedded gravel of Bonneville Point. A fault exposed in a wall of the west pit strikes northwest-southeast and shows movement down to the southwest. The suite of gravel clasts, representing the plutonic and volcanic rocks in the headwaters of the Boise River, is the same in the gravel of Bonneville Point and the Tenmile Gravel. This is distinctive compared with the younger terrace gravels that additionally contain a 10% component of basalt clasts derived from Pleistocene lavas erupted in the Boise River drainage. This provides a limiting age which helps confirm that the Tenmile Gravel probably is latest Pliocene, or about 1.7 my (Othberg, 1994).

67.3 Continue north on Pleasant Valley Road to East Gowen Road along the south side of the airport descending from the high ridge of gravel onto the surface of the basalt of Fivemile Creek (Figure 3). This lava flowed into the floodplain of the ancestral Boise River (at this time still flowing west) and followed the valley bottom downstream to the vicinity of Tenmile Creek. The river was forced to shift its channel to the northern edge of the lava flow. The gravel of the buried floodplain is exposed only in a few excavations. One notable site is the Federal Way road cut near a new Simplot Building.

71.3 Turn right onto East Gowen Road and drive east continuing under I-84 to the traffic light.

71.6 Turn left onto Federal Way. The Simplot Building is ahead on the right and the road begins a descent to the next (Gowen) terrace. Drive slowly past the road cut, which exposes a single basalt flow about 3-4 meters thick. Just before reaching the escarpment of this bench, gravel can be seen underlying the basalt. The top of the gravel, which has been baked reddish orange, lies near a bench mark with an elevation of 2989 feet. This is the lava-buried surface of the sixth terrace above the Boise River (Othberg, 1994). The basalt of Fivemile Creek has a K-Ar date of about 974,000 years (Othberg and others, in press), and based on its normal paleomagnetic polarity, probably erupted during the Jaramillo Normal Polarity Subchron approximately 1 million years ago. The terrace gravel buried by the basalt has clasts of Pleistocene basalt, which probably were derived from basalt in the Smith Prairie area, perhaps the Steamboat Rock Basalt which probably is older than the basalt of Fivemile Creek (Othberg and others, in press).

72.1 Continue north down onto the Gowen terrace. Just after crossing the railroad tracks, park along the broad shoulder or in one of the parking lots of the industrial area to the right.

**STOP 8: Gowen terrace—railroad cut parallel to Federal Way [?].** Walk west across Federal Way [?] at Yamhill Road and follow the railroad tracks as they curve northward toward a long cut that exposes the gravel of Gowen terrace. Gowen terrace is the fourth terrace above the Boise River, and when it was the ancestral Boise River's floodplain, the river was still flowing approximately westward after going around the basalt of Fivemile Creek. The next highest (seventh) terrace, buried by the basalt of Lucky Peak, is only known to exist in the canyon area between here and Lucky Peak Dam. Gravel pits in the Gowen terrace near this site have shown that the gravel of Gowen terrace was deposited on a surface cut into the gravel of Bonneville Point. However, further northwest these gravels and those of younger terraces were deposited on finer-grained facies of the basin fill (Squires and others, 1993; Othberg, 1994). The age of the Gowen terrace is best estimated by the thick caliche or duripan formed on its surface (Figure 6), and dating of the basalt of Gowen terrace. This basalt probably erupted in Smith Prairie (see description in Stop 4) and flowed downstream onto the floodplain of the ancestral Boise River to a point about one-half mile east of this railroad cut. A K-Ar date of about 575,000 years is consistent with its normal paleomagnetic polarity and the Elija Series soil (Figure 6), the second oldest of the defined sequence of soils based on age (Othberg, 1994).

75.0 Return to the vehicles and drive north on Federal Way to the Broadway and I-84 signs. Follow Broadway south to the freeway interchange and take the I-84 West on-ramp toward Nampa.

79.2 Drive west on I-84 about four miles to the Overland Road and Cole Road exit. The freeway lies on the Sunrise terrace, one level below the airport which is on the Gowen terrace.

80.2 Turn left onto Overland and cross the freeway. Immediately turn left to go south on Cole Road. Follow Cole Road about one-half mile and turn left. Drive east one-quarter mile to the entrance of a large gravel pit. The gate at the entrance may be locked, and the exposures in the pit may be altered at any time. If the conditions are favorable, enter the pit and ask permission to observe features at the office in the center of the pit.

**STOP 9: Cole Road and I-84 gravel pit:** This gravel pit was dug into the Sunrise terrace, which is the third terrace above the Boise River floodplain. The terrace gravel can be seen in the pit walls, and the unconformable, river-cut surface of the Tertiary basin-fill sand can be seen in the base of the pit. In some locations, faults can be seen cutting the Tertiary sands, and one fault was documented to cut the lower part of the terrace gravel (Othberg and Burnham, 1990). The rim of the pit exposes caliche, a soil duripan in the Purdam Series, that is less developed than on the Gowen terrace (Figure 6). No radiometric dates are available for this terrace, but Othberg (1994) suggested it was about 300,000 years old, based on glacial correlations.

82.2 Return to Cole Road, turn right and drive north to Overland Road. Turn right and drive east across I-84 to Orchard Street. The road descends onto the Whitney terrace, which is the broadest terrace and the main bench in the Boise-Meridian area.

84.3 Turn left onto Orchard Street and drive north. Continue north to the escarpment overlooking Garden City and the Boise River floodplain.

86.8 Turn left onto Mountain View Drive and follow it to Glenwood, the main road descending from the Whitney terrace.

88.5 Turn right onto Glenwood and drive north to State Street (Idaho Highways 44 and 55). Glenwood crosses the Boise River floodplain and rises gently onto the low, Boise terrace, on which State Street sits..

90.5 Turn left and follow the four-lane highway, paralleling the Boise River, to where Idaho 55 turns north. The highway lies on the nearly flat surface of the Boise terrace.

91.2 Turn right following Idaho 55 north. Ahead the escarpment of the Whitney terrace can be seen rising above the Boise terrace. At the very top of the escarpment, turn left into the entrance of the Highway 55 gravel pit. Permission to enter must be obtained at the office. This pit has had many good exposures, but is so active that it changes all the time. The far west wall of the pit probably will remain intact for some time.

**STOP 10: Whitney terrace—Hill Road and Highway 55 gravel pit.** The Whitney terrace is present on both sides of the Boise River. This exposure shows the gravel deposit and the floor of the pit is close to the contact with Tertiary Idaho Group basin-fill silt and sand. Toward the foothills the surface of the gravel is covered with sandy alluvial fan deposits, and the mainstream gravel exposed here probably interfingers with sandy sidestream deposits eroded from the local hills. Two soil series of the age sequence are represented in the soil development exposed in this pit—the Power and the Purdam Series (Figure 6). These two stages form a complex pattern of soil development on the surface of the Whitney terrace. The younger Power soils have an argillic horizon and strong calcic development; the older Purdam soils have greater clay accumulation and a plugged silica/calcium carbonate horizon, i.e., a duripan. This suggests a history of early soil development, then erosion, then later development. In the Boise River canyon near Lucky Peak Dam the basalt of Mores Creek lies at a level somewhat lower than the Whitney terrace, but above the Boise terrace. A K/Ar date of about 107,000 years for this basalt provides a minimum age for the Whitney terrace. Based on glacial correlations (Othberg, 1994), the Whitney terrace may have formed during an early phase of the Bull

Lake Glaciation.

91.9 Return to Idaho Highway 55, turn right and drive south to the traffic light at Idaho Highway 44.

111.4 Turn right onto Idaho Highway 44 and drive northwest, passing through the towns of Eagle, Star, and Middleton. Do not cross over I-84.

112.8 Turn left onto Merreton Boulevard, which is the old US 30 highway. At about one mile south the road begins to descend and blocks of basalt will be seen along the escarpment. Continue to the bridge across the Boise River and park.

**STOP 11: Basalt of Caldwell—early Boise River channel?** The basalt of Caldwell forms a bench of reversed topography that extends along the side of the Indian Creek drainage. Caldwell and Nampa lie in the valley of Indian Creek, which flows northwest to join the Boise River near here. The Boise Valley follows this northwest-southeast trend from Caldwell to its confluence with the Snake River. Interpretation of the basin structure suggests this is a subbasin within the western Snake River Plain graben (Wood and Anderson, 1981). Tilting of the older terraces changes across this zone, suggesting faulting and warping downward toward the Nampa-Caldwell basin during the Pleistocene (Othberg, 1994). The basalt of Caldwell was earlier thought to have a source upstream along the drainage of Indian Creek, in the central volcanic ridge. Evidence from rock chemistry, paleomagnetism, and radiometric dating of basalts in the region, however, suggests that the basalt of Caldwell correlates with the Steamboat Rock Basalt in Smith Prairie. It may have flowed down the ancestral Boise River to this location. All the younger upstream terraces of the Boise River formed to the north and northeast of this basalt.

The surface of the Caldwell bench was just awash with slackwater of the Bonneville Flood (Othberg and Stanford, 1992). Downstream, the Boise and Snake valleys were inundated to the elevation of the constriction at Farewell Bend—about 750 meters (O'Connor, 1993).

113.1 Retrace route to the I-84 interchange where US Highway 20/26 crosses the freeway.

125.8 Go west on US Highway 20/26 driving through Notus enroute to the interchange with US Highway 95. The highway mostly follows the edge of the low, Boise terrace and the floodplain of the Boise River is generally in view on the left. The Boise terrace is narrow; typically one-quarter mile or less wide. On the right (north) a diffuse break in slope is the escarpment of the Whitney terrace that has been mantled by Bonneville Flood sediments. The surface of the Whitney terrace slopes upward toward the foothills in the near distance that are composed of Tertiary basin fill sediments. The gradient on the Whitney terrace is due to sandy alluvial fan sediments, which also were mantled by the Bonneville Flood slackwater sediments. At the base of the foothills remnants of older terraces are locally exposed, but erosion on this side of the valley has removed most of the older terraces.

130.2 Turn right to follow US Highway 95 south toward Wilder. About one-half mile after crossing the Boise River the highway rises onto the Whitney terrace for a short distance before entering Mammen Gulch. Road cuts and natural exposures lower in the gulch show the thin-bedded, pale greenish gray Glenns Ferry Formation. A gravel pit near the rim of the gulch on the left exposes terrace gravel. Other exposures in the area show the terrace gravel resting on a surface cut into the Glenns Ferry Formation. Continue south 4.4 miles to an intersection with a farm road.

131.6 Turn right onto the farm road and drive west one-half mile; turn right again and drive north one-half mile; turn right again and drive east nearly one-half mile, thereby making a loop back to US Highway 95 to find safe parking. Park along the right side of the road near the intersection with US Highway 95. Walk across the highway and at the beginning of a hill, turn left into an unimproved road and enter an old silage pit.

**STOP 12: Wilder terrace—silage pit.** Gravel exposed here forms the Wilder terrace. Lithologies of gravel clasts show the influence of the Snake River by volcanic clasts carried into the Snake system from the Owyhee Mountains. A buried duripan formed in the top of the gravel is preserved. The thickness of the duripan is somewhat less than typical for the Elija Series, and may be more similar to the Purdam Series (Figure 6). The Wilder terrace may correlate with the Sunrise terrace in the eastern Boise Valley, or with an unidentified terrace intermediate in age between the Gowen and Sunrise terraces. The duripan is buried by a massive silt deposit that shows virtually no effects of pedeogenesis. It is probably a loess. The top of loess is buried by thin bedded tan silt interpreted to be 14,500 year-old Bonneville Flood slackwater sediments. Fine sand seems to cause parting along the bedding surfaces. Stringers of calcium carbonate extend vertically along fractures and horizontally along bedding. This exposure lies along the escarpment between a nearly flat terrace surface and the headward-eroding gulch. As a result, the Bonneville Flood sediments are thinner here than away from the gulch where well logs show the thickness to be 10-14 feet. The weak calcic soil of the Greenleaf Series that developed on this 14,500 year old surface is the youngest in the sequence of soils defined by age (Figure 6). The freshness and lack of pedogenic effects in the loess underlying the Bonneville Flood sediments suggests that the loess was actively accumulating at the time that the flood inundation occurred. The loess, therefore, was forming during the latest stages of the last glaciation.

135.6 Return to the vehicles and turn left onto US Highway 95 and drive north to the intersection of US Highways 20/26 and 95. Park in the triangular area between lanes in the interchange area. Cross the west- and northbound lane to view the road cut. Some cutting of vegetation in the drainage ditch may be necessary to see the lower part of the section.

**STOP 13: Bonneville Flood slackwater sediments—current directions.** The upper part of this exposure shows thin-bedded silts similar to those seen mantling the Wilder terrace at Stop 12. Near the base of the exposure, however, the deposits are coarser and ripple-drift laminated sand can be seen grading upward to thin-bedded silt with fine sand partings. Where they are found, the ripple-drift directions indicate a current to the east, opposite that of the present Boise River. This indicates the rising waters of the Bonneville Flood caused a reversal of stream flow in this part of the Boise Valley.

## END OF TRIP

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