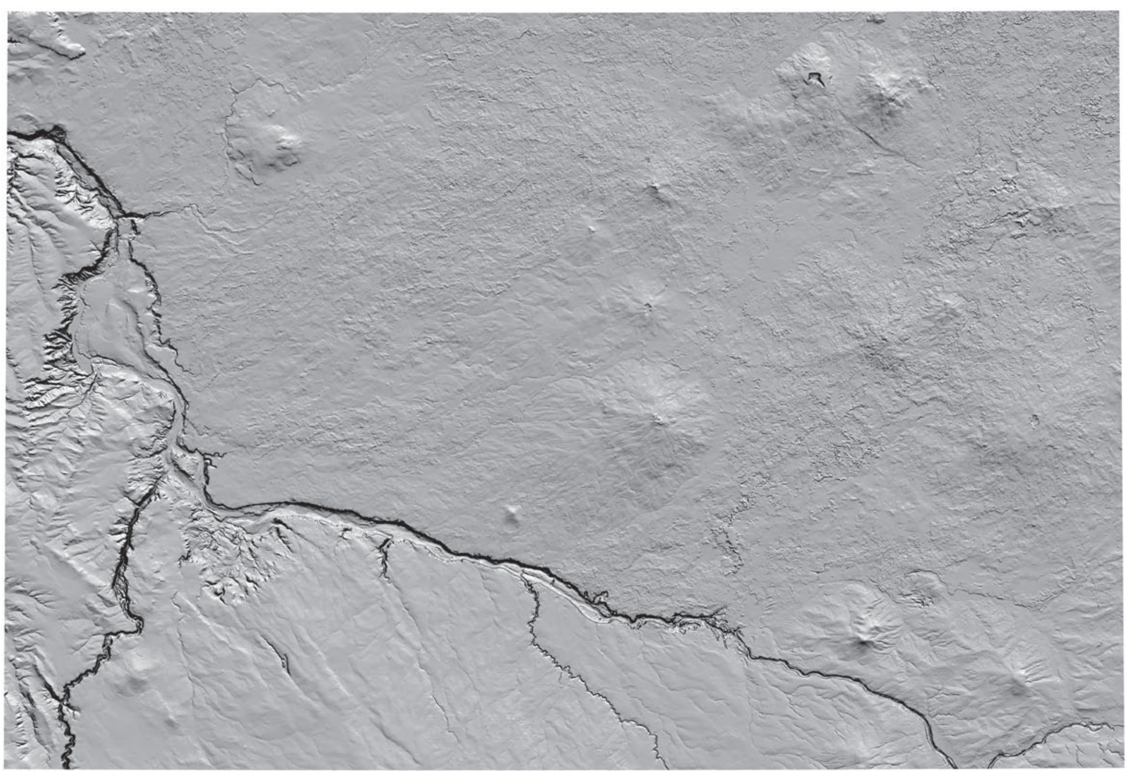
Geologic Map of the Twin Falls 30 x 60 Minute Quadrangle, Idaho

Compiled and Mapped by
Kurt L. Othberg, John D. Kauffman,
Virginia S. Gillerman, and Dean L. Garwood

2012



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Geologic Map 49
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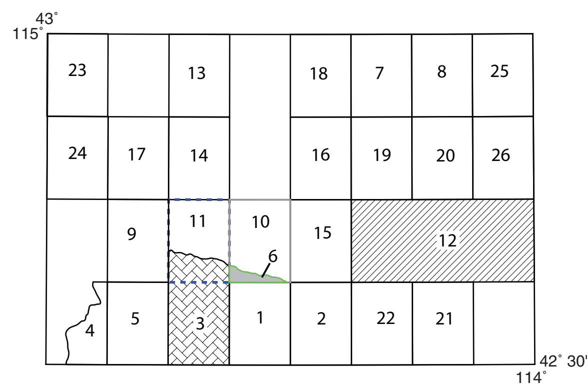
INTRODUCTION

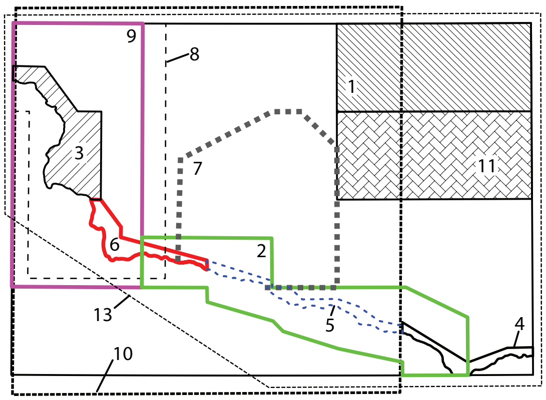
The geology in the 1:100,000-scale Twin Falls 30 x 60 minute quadrangle is based on field work conducted by the authors from 2002 through 2005, previous 1:24,000-scale maps published by the Idaho Geological Survey, mapping by other researchers, and compilation from previous work. Mapping sources are identified in Figures 1 and 2. The geologic mapping was funded in part by the STATEMAP and EDMAP components of the U.S. Geological Survey's National Cooperative Geologic Mapping Program (Figure 1). We recognize that small map units in the Snake River Canyon are difficult to identify at this map scale and we direct readers to the 1:24,000-scale geologic maps shown in Figure 1. The principal sources of previous mapping (Figure 2) are Stearns and others (1938), Malde and others (1963), Malde and Powers (1972), Covington (1976), Scott (1982), Covington and Weaver (1990a, 1990b, 1990c, and 1991),8 Cooke (1999), and Matthews (2000).

Chemistry, $^{40}Ar/^{39}Ar$ ages, and magnetic remanence of volcanic rocks sampled in the field provided supporting data for the geologic mapping. Whole-rock XRF analyses were done at the Washington State University GeoAnalytical Laboratory. Sample locations and results for XRF analyses are reported in Kauffman (2007, 2008). $^{40}Ar/^{39}Ar$ dating was done by the New Mexico



1. Bonnichsen and Godchaux, 1995a
2. Bonnichsen and Godchaux, 1995b; Othberg and others, 2005
3. Bonnichsen and Godchaux, 1996
4. Bonnichsen and Godchaux, 1997a
5. Bonnichsen and Godchaux, 1997b
6. Bonnichsen and Godchaux, 1997c
7. Cooke and Shervais, 2004a; Cooke and others, 2006a
8. Cooke and Shervais, 2004b; Cooke and others, 2006b
9. Gillerman and others, 2005a
10. Gillerman and others, 2005b
11. Gillerman and others, 2005c
12. Hobson and others, 2005
13. Kauffman and Othberg, 2004a
14. Kauffman and Othberg, 2004b
15. Kauffman and Othberg, 2005a
16. Kauffman and Othberg, 2005b
17. Kauffman and others, 2005a
18. Kauffman and others, 2005b
19. Matthews and Shervais, 2004a; Matthews and others, 2006a
20. Matthews and Shervais, 2004b; Matthews and others, 2006b
21. Othberg and Breckenridge, 2004a
22. Othberg and Breckenridge, 2004b
23. Othberg and Kauffman, 2005
24. Othberg and others, 2005a
25. Shervais and Cooke, 2004; Shervais and others, 2006a
26. Shervais and Matthews, 2004; Shervais and others, 2006b

Figure 1. *Sources of geologic mapping: STATEMAP and EDMAP.*



1. Cook, 1999
2. Covington, 1976
3. Covington and Weaver, 1990a
4. Covington and Weaver, 1990b
5. Covington and Weaver, 1990c
6. Covington and Weaver, 1991
7. Gillerman and Schiappa, 2001
8. Malde, 1971
9. Malde and Powers, 1972
10. Malde and others, 1963
11. Matthews, 2000
12. Scott, 1982
13. Stearns and others, 1938

Figure 2. *Sources of geologic mapping: previous geologic mapping.*

Geochronological Research Laboratory and the University of Alaska-Fairbanks Geochronology Laboratory. Magnetic polarity was measured by a fluxgate magnetometer in the field. Paleomagnetic directions of core samples drilled at selected sites were measured at either the Idaho Geological Survey Paleomagnetism Laboratory or the Western Washington University Pacific NW Paleomagnetism Laboratory (see Appendix).

The geologic map of the Twin Falls quadrangle identifies both bedrock and surficial geologic units. It shows the geographic distribution of rock types at the surface and in the shallow subsurface. Basalt is the principal rock type in the area. The quadrangle is in the central part of the Snake River Plain (SRP) where the northwesterly trending western SRP converges with the northeasterly trending eastern SRP. The land surface north of the Snake River is covered mostly by Pleistocene basalt flows from numerous shield volcanoes, although a few older Pliocene or possibly Miocene vents protrude through the younger flows. South of the Snake River, most of the shield volcanoes are Pliocene or Miocene in age. Basalt flows from these older sources are locally interbedded with, and in some instances likely interfinger with sediments. The course of the Snake River is controlled in large part by the contact of the Pleistocene basalt flows on the north with the older basalts on the south, although structure is also an important control of the river's position. In the western part of the quadrangle, thick sedimentary deposits of the Glenns Ferry Formation form bluffs west of the Snake River from Bliss to about Salmon Falls Creek south of Hagerman. These lacustrine and fluvial sediments, which probably extend but thin to the northeast beneath the Quaternary basalt flows, were deposited in Pliocene Lake Idaho. The sediments overlie older basalts erupted mostly from unidentified source vents. The oldest units exposed in the quadrangle are rhyolitic rocks in the Snake River canyon in the vicinity of Twin Falls and in the southwest part of the quadrangle along Salmon Falls Creek. Much of the basalt surface is mantled with wind-blown sand and silt which form the soils that are cultivated. Approximately 17,400 years ago, the Bonneville Flood filled and locally overtopped the Snake River canyon causing extensive erosion and depositing gravel in giant bars.

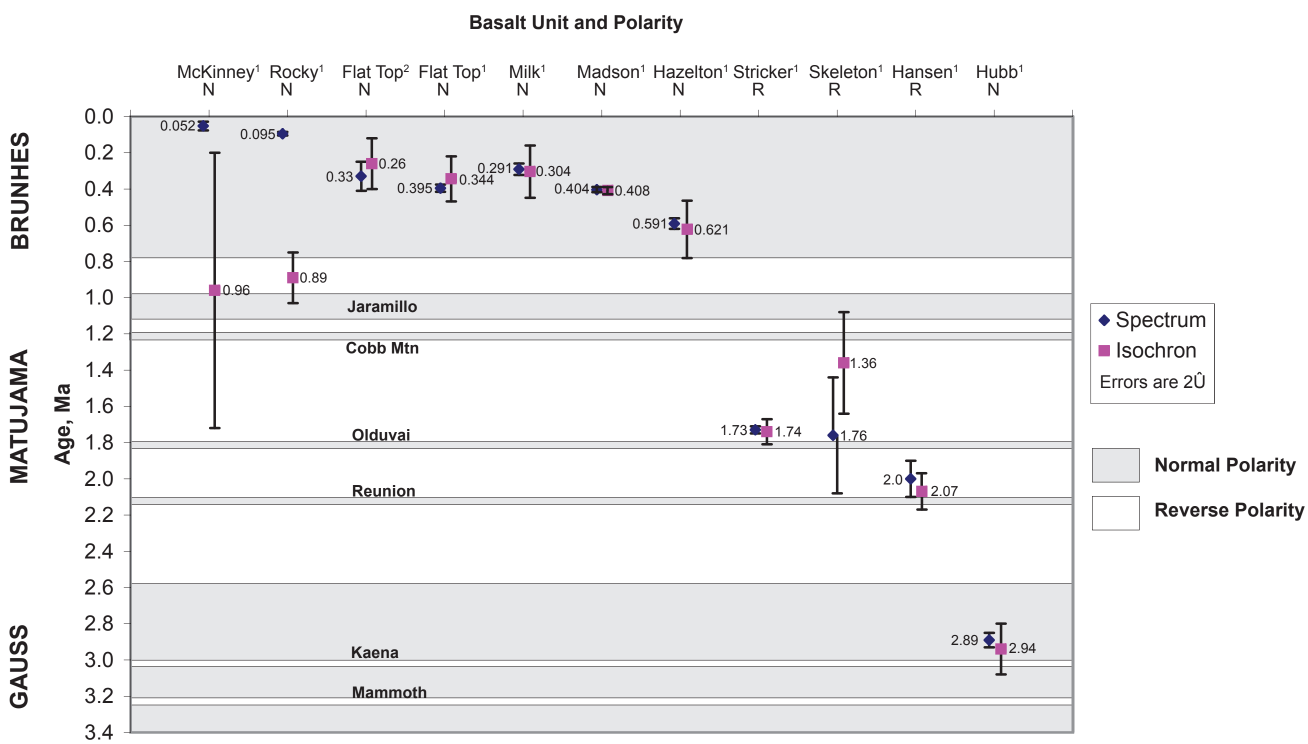
Most of the identifiable major structures occur in the southwest part of the map where older rocks are exposed. In general, these structures trend northwest-southeast and overall are stepped down to the northeast. Most faults displace the rhyolitic rocks but generally do not cut the overlying basalt units. Faults that do cut the basalts generally affect only the oldest units and are typically covered or poorly exposed. Surface expressions of these faults occur mainly in the Melon Valley area where deep-seated faults are further indicated by the presence of numerous hot springs and thermal wells. Faults mapped by Malde and Powers (1972) north of Bliss, cutting Glenns Ferry Formation sediments and a thin basalt flow within the sediments, also trend northwest-southeast but are stepped down to the southwest.

In general, lavas from vents north of the Snake River flowed westerly or southwesterly, whereas those from vents south of the river flowed northwesterly. These flow directions indicate that a regional westward tilt with a synclinal flexure at about the position of the present Snake River must have existed in the area from the Pliocene to the present.

The geologic units in the area control soil development, slope stability, groundwater movement and recharge, and geotechnical factors important in construction design and waste management. Land uses in the area include irrigated agriculture, rural and urban residential development, industrial and commercial enterprises, and dairy farms with confined animal feeding operations. The SRP aquifer underlies the area and discharges as springs in the Snake River canyon.

CHRONOLOGY

Ages for most volcanic and sedimentary units are relative and are determined by stratigraphic position, overlapping relations, and geomorphic characteristics. Some older shield volcanoes are surrounded by Quaternary flows but their ages are otherwise poorly constrained. A few units have been dated by K-Ar or $^{40}Ar/^{39}Ar$ methods which assist in bracketing the age of other units. Armstrong and others (1975) conducted K-Ar age dating on Quaternary and Neogene volcanic rocks in the SRP, a few of which were located in the quadrangle. Hart and Brueseke (1999) dated the Shoestring and Deer Gulch basalts within the upper part of the Glenns Ferry Formation in or near the quadrangle. Tauxe and others (2004) report fifteen $^{40}Ar/^{39}Ar$ dates for units within the map. The locations they selected for sampling were based on units identified on previous geologic maps. Several $^{40}Ar/^{39}Ar$ dates were also completed on basalt and rhyolite units in the quadrangle during this project. Units for which dates are available are described in the *Descriptions of Map Units* and noted in the *Correlation of Map Units*. Ages of some of the Pleistocene basalts and one Pliocene basalt are shown in Figure 3. Epoch divisions are based on the 2009 Geologic Time Scale (Walker and Geissman, 2009); several of the basalt units on this version of the Twin Falls 30' x 60' quadrangle reflect the new Quaternary-Tertiary boundary reported in that reference.



[1] Tauxe and others (2004).
[2] Esser (2005).
Geomagnetic Polarity Timescale:
Cande, S.C., and Kent, D.V., 1995, Revised calibration of the geomagnetic polarity timescale for the late Cretaceous and Cenozoic: Journal of Geophysical Research, v 100, p 6,093-6,095.
Nomage, S., Renne, P.R., Vogel, N., Deino, A.L., Sharp, W.D., Becker, T.A., Jaouni, A.R., and Mundil, R., 2005, Alder Creek sanidine (ACs-2): A Quaternary 40Ar/39Ar dating standard tied to the Cobb Mountain geomagnetic event: Chemical Geology, v 218, p 315-338.

Figure 3. *$^{40}Ar/^{39}Ar$ ages of selected Pleistocene and Pliocene basalt units, Twin Falls 30' x 60' quadrangle.*

DESCRIPTION OF MAP UNITS

ARTIFICIAL DEPOSITS

m—Made ground (Holocene)—Artificial fills composed of excavated, transported, and emplaced construction materials typically derived locally. Primarily highway fills, railroad beds, and areas modified for settling ponds and fish ponds.

ALLUVIAL DEPOSITS

Qam—Alluvium of mainstreams (Holocene)—Channel and flood-plain deposits of the Snake River, Big Wood and Little Wood rivers, and Salmon Falls Creek. Channel deposits are primarily stratified sand and pebble gravel; coarser gravel is present in thicker deposits. Flood-plain deposits are primarily stratified sand along the Big Wood River and silt in the Little Wood River. Basalt outcrop is common in channels during low water. Thickness of the alluvium is <1-6 m (1-20 feet).

Qoam—Older alluvium of mainstreams (Holocene)—Coarse sand and pebble to cobble gravel deposited by previous river regimes.

Qas—Alluvium of side streams (Holocene)—Silt and sand flood-plain and sheet-wash deposits in the drainage systems formed between older and younger basalt units.

Qoas—Older alluvium of side streams (Holocene)—Channel, flood-plain, and alluvial-fan deposits of ancestral Yahoo Creek and minor tributaries to the Snake River. Primarily stratified silt, sand, and minor pebble gravel. Gravel clast lithologies suggest reworking of eroded Tuana Gravel (*QTt*). Includes debris-flow deposits on steep, alluvial-fan slopes west of the Snake River.

Qoab—Older alluvium of Big Wood River (Holocene)—Cobble and boulder gravel deposited by high-energy floods of the Big Wood River (Malad River). Gravel forms four terraces that are 3 m, 8 m, 16 m, and 30 m (10 feet, 25 feet, 50 feet, and 100 feet), respectively, above the present Snake River level near the mouth of Malad Canyon.

Qaf—Alluvial-fan deposits (Holocene)—Stratified silt, sand, and gravel that form small fans. Merges and is interstratified with alluvium of side streams (*Qas*) or mainstreams (*Qam*). Thickness varies, but typically ranges ~1-10 m (5-30 feet).

Qass—Scoured flood pathways of side streams (Holocene)—Surface scoured by one or more floods of the Big Wood River (Malad River) that were primarily responsible for eroding Malad Gorge. Common small scour marks on basalt surfaces are aligned with the direction of water flow. Surface is mantled with thin and discontinuous sand and gravel deposits.

Qlp—Playa deposits (Holocene and Pleistocene)—Fine sand, silt, and clay sorted into thin beds and laminae. Sediments largely derived from erosion of loess or Glenns Ferry Formation (*Tsgf*) and washed into areas of internal drainage or nearly flat slopes primarily between basalt flows. Deposited during periodic floods, especially during periods of heavy rains and times of rapid snow melt which may have been more prevalent during the Pleistocene.

Qcg—Crowsnest Gravel (Pleistocene)—Stratified sand and pebble gravel. At exposures along Crowsnest Road, the unit overlies well-bedded clay, silt, and rippled sand deposits. Gravel clasts composed of felsic volcanic rocks, quartzite, and chert. Original thickness and extent unknown owing to streamlined erosion by Bonneville Flood. Location suggests possible ancestral Yahoo Creek channel deposits. Thickness about 2 m (6 feet).

Qy—Yahoo Clay (Pleistocene)—Laminated to thin-bedded clay and silty clay. Pinkish white to light yellowish brown and conchoidal fracture when dry. Common partings along bedding and vertical joints produces small blocks when exposed. Malde (1982) described the type locality near the mouth of Yahoo Creek, the lava-dam origin, and the distribution of the clay in the Snake River canyon from near Bliss to the Melon Valley. Stratigraphic evidence demonstrates the Yahoo Clay is younger than the basalt of Notch Butte (*Qnb*), but older than the Bonneville Flood. Malde (1982) attributes the clay to McKinney Lake, a temporary lake formed by damming of the Snake River by basalt of McKinney Butte (*Qmk* and *Qmkv* units). Malde's interpretation of the lake is compelling and his stratigraphic evidence was confirmed in field mapping. East and south of Hagerman, Malde and Powers (1972) and Covington and Weaver (1990a; 1991) show the Yahoo Clay buried by Crowsnest Gravel except where dissected. Our field mapping and the soil survey by Johnson (2002) suggest the Yahoo Clay is the primary mappable unit in those areas. Sandy soils on the nearly flat surfaces are similar to that described by Malde (1982) in the Yahoo Creek area, and the sands likely have their origin as wind-reworked Bonneville Flood sands. Yahoo Clay was scoured by the maximum stage of the Bonneville Flood.

QTag—Alluvial gravel, undifferentiated (Pleistocene or Pliocene)—Sand and gravel stream-channel deposits interbedded with basalt flows.

QTt—Tuana Gravel (Pleistocene or Pliocene)—Well-bedded and sorted gravel, sand, and subordinate silt. Gravel clasts of pebbles and cobbles are well rounded and commonly disc shaped. Imbrication of clasts is common. Tuana Gravel contains distinctive zircon assemblages derived from northern Nevada (Link and others, 2002). South of the Snake River, gravel-clast lithologies and imbrication directions suggest the gravel was deposited by north-flowing branches of the ancestral Salmon Falls Creek that prograded braided-stream deposits across a high, nearly flat plain formed on the Glenns Ferry Formation. Imbrication exposed in gravel-pits near Bliss suggest northwest stream flow. Original extent unknown owing to erosion. Highest erosion remnants are mantled by 3-8 m (10-25 feet) of loess with several buried soils. A thick duripan in the loess often forms an erosion-resistant cap. In addition, late Pleistocene loess with a weakly developed soil commonly mantles Tuana Gravel and forms gently sloping surfaces of irrigated farmland. Named by Malde and Powers (1962). Sadler and Link (1996) and Sadler and others (1997) describe lithofacies and interpret provenance, paleocurrents, and age of the Tuana Gravel, which largely corroborate the descriptions of Malde and Powers (1962). Tuana Gravel overlies upper Glenns Ferry Formation and is therefore younger than 3.11 Ma. The age of Tuana Gravel remains poorly constrained, but Malde (1991) and Othberg (1994) suggest the Tuana Gravel and the Tenmile Gravel near Boise, apparently graded to the same base level, are correlative. A minimum age for Tuana Gravel mapped to the northwest is 1.92 ± 0.16 Ma (Malde, 1991). A minimum age for the Tenmile Gravel is 1.58 ± 0.085 (Othberg, 1994). These gravels represent fluvial and glacial regimes driven by a cooler climate in the late Pliocene but before Pleistocene incision of the western SRP (Othberg, 1994).

Tsgf—Glenns Ferry Formation (Pliocene)—Poorly consolidated, bedded lake and stream deposits characterized by several facies and lithologies including silt, sand, clay, and subordinate gravel. See Malde and Powers (1962), Malde and Powers (1972), and Malde (1972; 1991) for detailed descriptions and mappable extent. To the west and northwest, the formation includes intercalated but laterally discontinuous basalt flows and beds of tephra. Repenning and others (1995) interpret the ages of various localities included in the Glenns Ferry Formation and present a paleogeographic history of Pliocene to early Pleistocene lake and stream deposits in the western SRP. The basin-filling contribution of the Glenns Ferry Formation to the western SRP's tectonic subsidence is described by Wood and Clemens (2002). Mammalian fossils in deposits at the Hagerman Fossil Beds National Monument are middle Blancan (Pliocene) in age (Repenning and others, 1995). Hart and Brueseke (1999) corroborate the Pliocene age with $^{40}Ar/^{39}Ar$ dates on basalt ranging from 3.4 to 3.8 Ma. Two magnetic polarity events recorded in the formation provide an estimate of the total age range: Near the base is the 4.18 to 4.29 Ma Cochiti, and near the top the beginning of the Kaena at 3.11 Ma (Neville and others, 1979; Hart and Brueseke, 1999). For most of the formation, detrital zircon populations indicate south-flowing drainage into the basin from the ancestral Big and Little Wood rivers. However, detrital zircons near the top of the formation indicate the drainage reversed to north-flowing (Link and others, 2002).

Tms—Sediment of Melon Valley (Pliocene or Miocene?)—Light tan to white, pale greenish, or pinkish, fine- to medium-grained, bedded lake and stream deposits with tephra beds and rare, glassy plagioclase-olivine phyric, valley-filling basalt flows. Typically very fine-grained, nondescript sediments, but greenish-gray and local conglomeratic beds with rounded quartzite cobbles were noted at several localities. At one locality, a buried soil horizon was exposed suggesting an intermittent erosional unconformity within the unit. Malde and Powers (1972) mapped the unit as Tbs (Sedimentary deposits of the middle part of the Banbury Basalt) and noted brownish channel sands and pebble gravels as well as the lake deposits with local diatomite and silicic ash beds. They ascribe a thickness of as much as 70 m (100 feet) to the unit, which seems reasonable for the exposed part of the section. However, driller's logs from water wells drilled in the Melon Valley area suggest there may be as much as 100 m (several hundred feet) of interbedded lava flows and sediments below the current exposure level.

Bonneville Flood Deposits

Qabs—Scabland of flood pathways (Pleistocene)—Flood-scoured basalt surface. Loess stripped, basin and butte topography is common. Unit adapted from Scott (1982) and O'Connor (1993). Original basalt morphology stripped of pre-flood loess and soils in contrast with area north of maximum flood extent but in same basalt unit. Includes patchy sheets and bars of thin sand and gravel that are not mapped, but have been locally used for gravel (see *Symbols*).

Qabf—Fine-grained deposits in slack-water basins (Pleistocene)—Sand and silt deposited in basins of basalt surface that were protected from high-energy water flow.

Qabg—Sand and gravel in giant flood bars (Pleistocene)—Stratified, giant cross-bedded deposits of boulders, cobbles, and pebbles of basalt in a coarse-sand matrix. Forms streamlined expansion bars in the Hagerman Valley. Deposited during highest-energy, maximum stage of flood. Similar to Melon Gravel (Malde and Powers, 1962; Malde and others, 1963; and Covington and Weaver, 1991), but restricted to Bonneville Flood constructional forms and deposits.

Qabgl—Sand and gravel in eddy deposits and lower-energy bars (Pleistocene)—Stratified coarse sand and pebble-cobble gravel deposited in side channel positions and in lower-energy, waning-stage flood channels. Mantled with thin loess and minor fine-grained alluvium and slope wash.

EOLIAN DEPOSITS

Qed—Dune sand (Holocene)—Thin, stratified fine sand of stabilized wind dunes. Shown only where identified on aerial photographs.

Qeld—Loess and dune sand, undifferentiated (Holocene)—Wind-blown silt and sand. Typical textures are fine sand, silty fine sand, and sandy silt. Generally less than 2 m (6 feet) thick and mostly buries original basalt flow surface. Rock outcrops are rarely exposed.

Qes—Eolian sand of the Snake River Canyon (Holocene)—Uncompacted fine sand deposited by wind along the base of canyon walls. Locally reworked by water, possibly irrigation-return water from the canyon rim.

MASS MOVEMENT DEPOSITS

Qt—Talus (Holocene)—Angular pebble-, cobble-, and boulder-size fragments of basalt that have broken off nearly vertical rock walls and accumulated below. Deposits are characterized by a steeply sloping surface that is at or near the angle of repose. Not mapped where thin talus partially covers units.

Qlsa—Deposits of active landslides (Holocene)—Primarily unsorted and unstratified silt and clay in slumps, slides, and debris flows that have been recently active. Aerial photographs flown in 1972, 1998, and 2004 were used to identify and map active landslides. There are three main areas of active landslides. In Snake River bluffs west of Hagerman, new landslides have activated or old landslides have reactivated since 1979 (Hagerman Fossil Beds National Monument, 2004). The recent failure of slopes on Glenns Ferry Formation correlates with irrigated farming on the adjacent upland west of bluffs of the Snake River valley. Near Bliss, a large, multi-aged landslide complex in both Glenns Ferry Formation and Yahoo Clay reactivated in 1993 (Gillerman, 1993). In Salmon Falls Creek canyon, the 1937 Sinking Canyon movements and the 1998-1999 Bluegill landslide (Ellis and others, 2004; Glenn and others, 2006) are shown as one polygon on the map. In addition to the landslide deposit, the map may also show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols).

Qls—Landslide deposits (Holocene and Pleistocene)—Unsorted and unstratified deposits composed of clasts of sediments and basalt. On the map, landslides are restricted to the canyons west of Melon Valley. In Salmon Falls Creek canyon, large slump complexes like the Bluegill landslide (see *Qlsa*) are associated with Tertiary sediments and basaltic tephra. From Thousand Springs to Bliss, canyon slopes of the Snake River, Billingsley Creek, and Malad Gorge have common slumps, slides, and debris flows that originated in the Glenns Ferry Formation and Yahoo Clay. In addition to the landslide deposit, the map may also show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols).

BASALT UNITS NAMES AND CORRELATION

Wherever possible, we have named the basalt units for their source vent, such as "basalt of Flat Top Butte." In instances where no butte name is identified on the topographic map, we have derived a name from a nearby survey point, feature, or local land ownership, such as "basalt of Rocky Butte ," "basalt of Wilson Lake Reservoir," and "basalt of Bowman Farm," respectively. In these instances, derivation of the name is noted in the description of the unit. Mapping older basalt units at a distance from the source is difficult because they are typically covered by loess, soil, or younger flows. Correlation for all units relied on remanent magnetic polarity and chemical composition in addition to stratigraphic and geomorphic considerations. In the process, we have abandoned some previous names from mapping by Malde and others (1963). In particular, we have abandoned their "Sand Springs basalt" because it includes basalt from different sources of different ages. Sand Springs basalt was named for basalt at Sand Springs Creek in the vicinity of Thousand Springs and the source was identified as a butte northeast of Twin Falls, which corresponds to the butte we identify as "Rocky Butte." However, we believe the basalt at Sand Springs Creek was erupted from Bacon Butte, a much older vent than Rocky Butte. Also, some of what was mapped as Sand Springs basalt is included in our Flat Top Butte basalt, again from a much older vent than Rocky Butte. In addition, basalt they mapped as Sand Springs on the flat west of Hagerman in the Snake River canyon we correlate with flows derived from Notch Butte, not Rocky Butte. "Thousand Springs basalt" was also abandoned because that unit includes flows from Flat Top Butte and Bacon Butte as well as from two older buttes, Sonnickson and Lincoln, which we map as separate units to indicate their source vents.

For similar reasons, we have abandoned their term "Banbury basalt." That term has been used for basalt flows that are likely from different sources and of different ages, which causes confusing stratigraphic relations on a regional scale. We were not able to determine specific sources for these older basalts, but we attempt to separate them by magnetic polarity and composition, in addition to stratigraphic and geomorphic considerations, and propose general source areas.

All analyzed samples of basaltic units are classified as "basalt" in the total alkali versus silica diagram (Le Maitre, 1984). As previously noted, major oxide and trace element analyzes of samples in the Twin Falls 30 x 60 minute quadrangle can be found in Kauffman (2007) and Kauffman (2008); all analyses were done at the Washington State University GeoAnalytical Laboratory.

QUATERNARY BASALT UNITS

Most of the mapped Quaternary basalt units consist of series of flows from shield volcanoes located within or peripheral to the Twin Falls 30 x 60 minute quadrangle and most occur north of the Snake River.

Qblb—Basalt of Black Butte Crater (Holocene or Pleistocene)—Dark gray, fine-grained, glassy basalt with common to abundant olivine as individual grains and clots as large as 1-2 mm, and abundant small plagioclase crystals 0.5-1 mm that give the basalt a sparkly character in sunlight; diktytaxitic and vesicular; vesicles circular to irregular and tubular. Minor carbonate lining some voids. Remanent magnetic polarity is normal, as determined in the field with a fluxgate magnetometer. Source is Black Butte Crater to the northeast near Magic Reservoir. Possibly several flow units or lobes. Youthful surface characterized by very irregular topography of pressure ridges and collapse features with little or no loess or other surficial deposits (see Symbols); vegetation restricted to sagebrush and some grass. Equivalent to Ql (Lava flows) of Malde and others (1963) and the Shoshone flow of Cooke (1999) and Kuntz and others (1986), who reported a radiocarbon age of 10,130 ± 350 years B.P. from charred sediment at base of the lava flow. Calibrated age is 11,744 ± 501 cal years B.P. (Stuiver and Reimer, 1993, version 5.0).

Qbrc$_1$—Basalt of Black Ridge Crater, unit 1 (Pleistocene)—Dark gray, fine-grained, basalt with scattered small olivine phenocrysts as much as 1 mm in diameter. Remanent magnetic polarity not determined. The vent is located approximately 16 km (10 miles) east-southeast of Richfield. Includes basalt of Notch Butte Basin of Matthews (2000) and equivalent to basalt of Black Ridge Crater of Cooke (1999). Although previously mapped as a separate flow (Cooke, 1999; Cooke and Shervais, 2004b; Cooke and others, 2006b), we also include basalt of Richfield in this unit because it appears the proposed vent near Richfield may be an elongated collapsed lava tube.

Qbrc$_2$—Basalt of Black Ridge Crater, unit 2 (Pleistocene)—Dark gray, fine- to medium-grained, plagioclase-physic basalt with plagioclase phenocrysts ranging from less than 1 mm to 2.5 mm. Olivine phenocrysts 1 mm or less are uncommon to common. Remanent magnetic polarity not determined. Occurs at higher stratigraphic levels and closer proximity to the vent than *Qbrc$_1$* flows and represents younger, late-stage eruptions (Cooke, 1999).

Qmk—Basalt of McKinney Butte (Pleistocene)—Dark gray, fine-grained basalt with very abundant plagioclase phenocrysts as crisscrossed interlocking crystals as large as 1 cm, or as glomerocrysts commonly with olivine grains and clots. Voids are common among the interlocking crystals. The abundance of phenocrysts and the voids gives the rock a coarse-textured appearance. Equivalent to McKinney Basalt of Malde and Powers (1972). Remanent magnetic polarity is normal (Malde, 1971). Forms a thin capping unit along the Snake River canyon north of Malad Gorge. Farther to the north, the McKinney basalt surface is characterized by youthful flow features such as lava channels and tubes, collapse pits, and pressure ridges. Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.052 Ma for this unit (their sample sr16, McKinney Basalt).

Qmkv—Volcaniclastic deposits of McKinney Butte (Pleistocene)—Black glassy spatter, phyric to glomerophyric pillows, and tephra deposited where flows from McKinney Butte entered and dammed the Snake River and flowed into the resulting lake. Forms thick tephra deposits in the Snake River canyon west of Bliss and pillow deltas south of Bliss to Malad Gorge. Crude layering and foreset bedding is common.

Qnb—Basalt of Notch Butte (Pleistocene)—Dark gray, fine-grained, basalt, similar in hand specimen to basalt of Black Butte Crater but not as glassy; contains a few scattered clusters of plagioclase and olivine 2-3 mm, and scattered plagioclase phenocrysts 1-2 mm in length. Moderately to very vesicular. More carbonate lining and filling in voids than *Qblb*. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Source is Notch Butte located about 5 km (3 miles) south of Shoshone. Surface not as youthful in appearance as *Qblb*, but fairly irregular with pressure ridges, locally with sand and loess deposits in depressions. Vegetation characterized by sagebrush and grasses, or rarely farmed on flatter, soil-covered areas. Equivalent to Qwg (Wendell Grade Basalt) of Malde and others (1963).

Qwb—Basalt of Wilson Butte (Pleistocene)—Dark gray to black, fine-grained basalt with common to abundant plagioclase phenocrysts 1-3 mm in length and common olivine grains to about 1 mm in diameter, and some plagioclase-olivine intergrowths. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Source is Wilson Butte. Similar to *Qnb* only typically more phyric. Surface also similar to *Qnb* with pressure ridges and little or no drainage development. Vegetation mostly sagebrush and grasses. Age relation with *Qnb* uncertain, but may be slightly older.

Qrb—Basalt of Rocky Butte (Pleistocene)—Dark gray to black, fine-grained, glassy basalt with common to abundant olivine grains 0.5-1 mm and clusters 1-3 mm in diameter. Common to abundant small plagioclase laths to about 1 mm in length. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Erupted from a shield volcano located 35 km (22 miles) northeast of the city of Twin Falls in the Eden NE topographic quadrangle, which shows a permanent horizontal-control mark labeled “Rocky” on the south rim of the vent (sec. 14, T. 8 S., R. 20 E., Eden NE 7.5-minute quadrangle, elevation 4,526). Equivalent in part to Sand Springs Basalt of Malde and Powers (1962), Malde and others (1963), Covington (1976), and Covington and Weaver (1990c). Covington and Weaver (1990c) identified the source as “Butte 4526.” In the Falls City 7.5-minute quadrangle, most of the unit is scoured by the Bonneville Flood (*Qabs*) and is mostly outcrop. North of maximum extent of Bonneville Flood (see *Symbols*), thin loess covers the surface of the unit except for pressure ridges, and soil caliche is present but generally thin and weakly developed (Baldwin, 1925; Poulson and Thompson, 1927; Ames, 2003). Some of the land is cultivatable. Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.095 Ma for “Sand Springs” basalt. The location of their sample, on the north rim of the Snake River canyon near Shoshone Falls, is from the unit we map as basalt of Rocky Butte.

Qmc—Basalt of Mammoth Cave (Pleistocene)—Dark gray, coarse-grained basalt with abundant plagioclase laths 5-7 mm long and common to abundant olivine grains and clots. Remanent magnetic polarity is normal, as determined in the field. Source is unnamed butte with survey elevation 4,975 located to the north in the southeast corner of the Summit Reservoir 7.5-minute quadrangle. Flows of this basalt host the former tourist attraction of Mammoth Cave as well as several other lava-formed caves. Occurs along the north-central edge of the quadrangle where it is mostly covered by loess and much of the land is farmed.

Qcib—Basalt of Cinder Butte (Pleistocene)—Dark gray, fine-grained basalt with olivine as grains about 1 mm and clots 5-7 mm in diameter. Excavations on the small cone expose cinders, spatter, and pahoehoe basalt. Remanent magentic polarity not determined. Erupted from Cinder Butte, located on the Eden NE 7.5-minute quadrangle. May be a satellite vent to Rocky Butte located about 8 km (5 miles) to the north, or may be a separate, older volcano. Flows from Rocky Butte appear to surround this small butte and its associated flow.

Qob—Basalt of Owinza Butte (Pleistocene)—Black, medium-grained, plagioclase- and olivine-phyric basalt. Plagioclase phenocrysts are lath shaped and range from 0.8 to 4.0 mm in length. Olivine phenocrysts are 0.3-1.3 mm in diameter. Erupted from Owinza Butte, located about 5 km (3 miles) south of Owinza, a former railroad siding along State Highway 24. Much of the basalt surface is covered with soil and thin eolian deposits, but some pressure ridges and collapsed lava tubes are still visible.

Qcb—Basalt of Crater Butte (Pleistocene)—Medium to dark gray, fine- to medium-grained, abundantly plagioclase-phyric basalt with common to abundant olivine, some as inclusions or intergrowths in plagioclase. Plagioclase laths typically 2-5 mm in length and randomly oriented, forming a coarse open texture of voids and intersecting crystals. Remanent magnetic polarity is normal, as determined in the field. Source is Crater Butte about 11 km (7 miles) east of Shoshone. Loess covers most of the surface. Loess thickness ranges 1 to 3 m (3 to10 feet) and soil caliche (duripan) is commonly well developed within the soil profile and at the soil-basalt contact (Johnson, 2002), but the thickness of caliche is highly variable. Most of the land is cultivatable.

Qdb—Basalt of Dietrich Butte (Pleistocene)—Dark gray, fine-grained, plagioclase- and olivine-phyric basalt. Plagioclase pheoncrysts 1-3 mm in length and olivine phenocrysts ≤1 mm in diameter. Some olivine has been oxidized to iddingsite (Cooke, 1999). Erupted from Dietrich Butte shield volcano, located about 16 km (10 miles) east of Shoshone. Surface topography is subdued by soil and eolian cover, but some outcrops occur on radial ridges and pavement outcrops are present on the flanks of the volcano (Cooke, 1999).

Qkim—Basalt of Kimama Butte (Pleistocene)—Dark gray, fine-grained, abundantly plagioclase- and olivine-phyric basalt. Plagioclase phenocrysts 5-10 mm in length. Common to abundant olivine grains 1-2 mm in diameter. Erupted from Kimama Butte about 1.4 km (0.9 mile) east of the quadrangle. Remanent magnetic polarity uncertain; both normal and reverse polarities were obtained in the field. Duane Champion (written comm., 2004) reports normal polarity based on laboratory analysis of a sample collected from a flow several kilometers northeast of Kimama Butte.

Qmlk—Basalt of Milk Butte (Pleistocene)—Dark gray, fine- to medium-grained, plagioclase-phyric to glomerophyric basalt. Glomerocrysts are commonly about 1 cm in diameter, although one large clot measured more than 2 cm. Olivine is common as small phenocrysts and inclusions in glomerocrysts. Remanent magnetic polarity is normal as determined in the field. Named for shield volcano with survey marker labeled "Milk" on the Burley SW 7.5-minute quadranlge, located just east of the map boundary. A quarry on the butte exposes thick deposits of cinders, spatter, and pahoehoe basalt. Equivalent to unit Qi1 of Covington and Weaver (1990b). Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.291 Ma for this unit (their sample sr23).

Qbb—Basalt of Bacon Butte, undivided (Pleistocene)—Dark gray, fine-grained basalt with common to abundant plagioclase laths as much as 5 mm in length and common olivine grains and clots, commonly as intergrowths with plagioclase. Locally diktytaxitic. Locally contains abundant carbonate accumulation in vesicles and fractures. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Flows erupted from a shield volcano northeast of Jerome. The name "Bacon Butte" is derived from nearby Bacon Ranch, located on the east side of the unnamed butte. The name was also used by Covington and Weaver (1991). Included in Thousand Springs Basalt (Qtt) by Malde and others (1963). West of Jerome, the unit is divided into younger and older units as noted below.

Qbby—Basalt of Bacon Butte, younger unit (Pleistocene)—Dark gray, fine- to medium-grained basalt with common to abundant olivine as grains and clots as large as 3 mm and scattered small plagioclase laths. Similar in texture and appearance to basalt of Notch Butte, although slightly coarser grained overall. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Forms a raised, hilly surface of partly exposed pressure ridges where it overlies *Qbbo* in the vicinity of Wendell and extends southwestward to the Snake River canyon in the Sand Springs Creek area, where Malde and others (1963) mapped it as Sand Springs Basalt, which they correlated with Rocky Butte basalt. However, we interpret the unit at Sand Springs Creek, on the basis of paleomagnetic direction and chemical composition, as a younger flow or series of flows erupted from Bacon Butte, which is considerably older than Rocky Butte. Stream drainage is poorly developed. Discontinuous loess and eolian sand deposits cover less than 50 percent of the surface and are <1-3 m (1-10 feet) thick. Soil caliche (duripan) is commonly well developed within the soil profile (Johnson, 2002) and at the soil-basalt contact, but the thickness of caliche varies considerably. Some of the land is cultivatable and some is used as pasture.

Qbbo—Basalt of Bacon Butte, older unit (Pleistocene)—Dark gray, fine-grained basalt with common to abundant plagioclase laths as much as 5 mm in length and common olivine grains and clots; olivine commonly forms intergrowths with plagioclase. Locally diktytaxitic. Locally contains abundant carbonate accumulation in vesicles and fractures. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Also erupted from Bacon Butte shield volcano northeast of Jerome. Age not determined, but geomorphology is similar to that of Flat Top Butte. Included in Thousand Springs Basalt (Qtt) by Malde and others (1963) and mapped as West Basalt by Gillerman and Schiappa (1994; 2001). Topography contrasts with area of basalt of Notch Butte (*Qnb*) to the northeast and the basalt of Bacon Butte, younger unit (*Qbby*). Almost no basalt pressure ridges rise above a nearly complete mantle of loess and dune sand. Surface drainage is moderately developed. Thickness of mantle ranges from 1 to 8 m (3 to 25 feet); commonly 1-4 m (3 -12 feet) thick. Soil caliche (duripan) is typically well developed within the soil profile (Johnson, 2002) and at the soil-basalt contact, but the thickness of caliche varies considerably. Most of the land is cultivatable.

Qftb—Basalt of Flat Top Butte (Pleistocene)—Medium gray, fine-grained basalt with scattered to very abundant plagioclase-olivine intergrowths 4-7 mm across and olivine grains and clots 1-4 mm in diameter. Flows typically vesicular near the top and more dense in the center, but diktytaxitic throughout with abundant fine-grained plagioclase laths. Carbonate coatings and fillings common in voids. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Erupted from the Flat Top Butte shield volcano east of Jerome. Equivalent to part of Thousand Springs Basalt of Malde and Powers (1962), Malde and others (1963), and Gillerman and Schiappa (1994, 2001). Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.395 Ma for this unit (their sample sr09, Thousand Springs Basalt). A sample we dated produced an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.33 ± 0.08 Ma (R.P. Esser, written commun., 2003). Topography contrasts with surface of younger basalt flows to the east. Almost no basalt pressure ridges rise above a nearly complete mantle of loess. Surface drainage is moderately developed. Thickness of mantle ranges 1 to 8 m (3 to 25 feet); commonly 1-4 m (3-12 feet) thick. Soil caliche (duripan) is typically well developed within the soil profile (Ames, 2003) and at the soil-basalt contact, but the thickness of caliche varies considerably. Most of the land is cultivatable.

Qcp—Basalt of Jerome Cinder Pits (Pleistocene)—Basalt flow or flows associated with cinder pits located 10 km (6 miles) south of Jerome in sec. 13, T. 9 S., R. 16 E. Lithologically similar to and possibly a secondary vent for early basalts erupted from Flat Top Butte; mapped as Thousand Springs Basalt by Gillerman and Schiappa (2001). The vents are characterized by glassy cinders and welded spatter of dark red to black scoriaceous lavas. Strongly to spectacularly glomerophyric with clusters of plagioclase and olivine intergrowths as large as 10 mm in diameter. Remanent magnetic polarity is normal as determined in the field. Surface drainage on the flow is moderately developed. Prior to agriculture, about 10-30 percent of the surface was basalt outcrop (Poulson and Thompson, 1927). Farming has reduced outcrops to about 10 percent of the surface.

Qgb—Basalt of Gooding Butte (Pleistocene)—Medium to dark gray, fine-grained basalt with scattered to abundant plagioclase phenocrysts as large as 1 cm in length, and plagioclase-olivine intergrowths as much as 1 cm in diameter; olivine olive-greenish-brown in color; olivine mostly as clusters; diktytaxitic and vesicular; vesicles small and circular to large and irregular. Common carbonate filling and coating in voids. Remanent magnetic polarity normal as determined in the field.

Source is Gooding Butte, 3 km (2 miles) southwest of Gooding. Surface subdued, soil covered, and generally farmed. Outcrops uncommon. Equivalent to Qtm (Thousand Springs Basalt, Malad Member) of Malde and others (1963). Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.373 Ma for this unit (their sample sr11, Malad Basalt).

Qma—Basalt of Madson Spring (Pleistocene)—Dark gray, fine- to medium-grained basalt with very abundant olivine grains and clots as much as 4 mm in diameter. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Exposed on U.S. Highway 30 grade north of Hagerman. Equivalent to the Madson Basalt of Malde and Powers (1972). Source undetermined, but Malde (1971) suggests the source was likely to the east. It may represent early eruptions from Gooding Butte. Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.404 Ma for this unit (their sample sr12, Madson Basalt).

Qhz—Basalt of Hazelton Butte (Pleistocene)—Gray to dark gray, medium- to coarse-grained, plagioclase- and olivine-phyric basalt. Erupted from Hazelton Butte shield volcano. Williams and others (1990) report plagioclase phenocrysts 1-4 mm long and honey to amber olivine phenocrysts 0.15-5.0 mm in diameter that are slightly altered to iddingsite. Remanent magnetic polarity is normal as determined in the laboratory (Tauxe and others, 2004, sample sr22). We also determined normal polarity for this unit in the field. Tauxe and others (2004) report an $^{40}Ar/^{39}Ar$ weighted mean plateau age of 0.591 Ma for Hazelton Butte.

Qsid—Basalt of Sid Butte (Pleistocene)—Basalt flows originating from Sid Butte, located about 8-10 km (5-6 miles) southeast of Owinza Butte and east of the map. Not examined in detail. Cinder pit near the summit contains gabbroic xenoliths (Matthews, 2000). Remanent magnetic polarity is reverse as determined in the laboratory (Duane Champion, written commun., 2004) and in the field.

Qmil—Basalt of Milner Butte (Pleistocene)—Gray, dense, plagioclase-olivine-pyroxene phyric basalt from vent at Milner Butte, located 8 km (5 miles) south of Milner Dam (Covington and Weaver, 1990b). Remanent magnetic polarity not determined. Poorly exposed except where flood-scoured in the Snake River canyon downstream from Milner Dam, where it was mapped by Covington and Weaver (1990b) as unit Qi2. Age uncertain, but older than Hazelton Butte basalt which Taux and others (2004) dated at 0.591 Ma.

Qbur—Basalt of Burley Butte (Pleistocene)—Gray, vesicular, olivine-rich basalt erupted from Burley Butte shield volcano, located 8 km (5 miles) southeast of Milner Dam (Covington and Weaver, 1990b). Remanent magnetic polarity reverse as determined in the field. Map of Covington and Weaver (1990b) shows this unit as older than basalt of Milner Butte. Probably early Pleistocene.

Qskb—Basalt of Skeleton Butte (Peistocene)—Medium to dark gray, medium- to coarse-grained basalt with large, interlocking plagioclase crystals as large as 1 cm where exposed along Interstate 84 and Frontage Road just south of the butte. Remanent magnetic polarity is reverse as determined in the field. Tauxe and others (2004) also report reverse polarity from laboratory analysis and an age determination of 1.76 Ma, but their sample location just west of Hansen Bridge on Highway 50 is in an area we map as *QTbu* that may not be Skeleton Butte basalt. Basalt at that location is more likely from another source, possibly from Hansen Butte. The age of Skeleton Butte is therefore uncertain, although on the basis of geomorphic evidence, it may be older than Hansen Butte.

Qstr—Basalt of Stricker Butte (Peistocene)—Described by Williams and others (1991) as light gray to gray, medium- to coarse-grained, dense basalt with small plagioclase laths 1-2 mm long and olivine grains 0.4-0.5 mm in diameter; olivine is amber to reddish brown and probably altered to iddingsite. Erupted from Stricker Butte located south of Hansen beyond the map boundary. Remanent magnetic polarity is reverse as determined in the field. Tauxe and others (2004) also report reverse polarity from laboratory analysis and an age determination of 1.73 Ma from a site on Rock Creek just south of Stricker Butte.

Qhan—Basalt of Hansen Butte (Pleistocene)—Described by Williams and others (1991) as gray, fine- to coarse-grained basalt with a few small phenocrysts of plagioclase 0.5-3 mm long and honey to amber olivine, rimmed by iddingsite 0.3-1 mm in diameter. Bill Bonnichsen (verbal commun., 2004) reports reverse polarity for a sample that was collected from Auger Falls grade and analyzed in the laboratory; this basalt was mapped as Hansen Butte basalt (unit Qi7) by Covington and Weaver (1990c). Tauxe and others (2004) report reverse magnetic polarity and an age of 2.0 Ma for a sample collected from the canyon wall north of Shoshone Falls in what was mapped as Hansen Butte basalt by Covington and Weaver (1990c, unit Qi7). Williams and others (1991), however, report normal polarity for Hansen Butte but give no site location for their polarity determination. Erupted from Hansen Butte, located about 5.5 km (3.5) miles southeast of the town of Hansen near the southern boundary of the map.

Qbu—Basalt flows, undivided (Pleistocene)—Medium to dark gray, fine- to medium-grained basalt. Some units have common plagioclase phenocrysts 1-3 mm and olivine mostly as individual grains in the groundmass or as small scattered clusters. Commonly diktytaxitic and vesicular. Source(s) undetermined. Mapped along part of the northern edge of the map. The source or sources were probably from the Mount Bennett Hills area to the north and may include flows from several unnamed buttes. Both normal and reverse polarity readings were noted in the field, also indicating several sources. Equivalent to Qbb (Bruneau Formation, basaltic lava flows) of Malde and others (1963). Surface topography is subdued and outcrops are uncommon. A mantle of loess nearly completely covers original basalt surface. Stream drainage is moderately developed. Loess ranges 1 to 3 m (3 to 10 feet) thick. Soil caliche (duripan) is commonly well developed within the soil profile (Johnson, 2002) and at the soil-basalt contact, but the thickness of caliche is highly variable. Most of the land is cultivatable.

QUATERNARY OR TERTIARY BASALT UNITS

Units in this section include old shield volcanoes that are surrounded and isolated by Quaternary flows but have no other relative or absolute age data available. Most have very subdued topography indicating they are relatively old and probably Tertiary.

QTtbu—Basalt flows, undivided (Pleistocene or Pliocene)—Undivided poorly exposed basalt flows in the southeastern part of the map and in the Snake River canyon walls from just north of Twin Falls to the east boundary of the map. Typically obscured by thin to thick loess and soil cover. Source(s) undetermined. Several outcrops examined in the northern part of the Milner quadrangle consisted of fine grained basalt with common to abundant 2-3 mm plagioclase phenocrysts, olivine grains <1 mm, and reverse magnetic polarity.

QTwlr—Basalt of Wilson Lake Reservoir (Pleistocene or Pliocene)—Fine-grained basalt with small plagioclase phenocrysts 2-3 mm in length and olivine grains <1 mm in diameter. Erupted from unnamed butte at west end of Wilson Lake Reservoir. Remanent magnetic polarity from one outcrop was normal. Age is poorly constrained, but the small butte is flanked on the east, north, and west by younger flows from Rocky Butte, and on the south by flows from Hazelton Butte, which was dated by Tauxe and others (2004) at 0.591 Ma. Mapped as "Quaternary basalt, undivided" (Qbu) by Othberg and Breckenridge (2004a).

QTslb—Basalt of Star Lake Butte (Pleistocene or Pliocene)—Equivalent to Star Lake Butte basalt of Matthews (2000) and Matthews and Shervais (2004b). Matthews (2000, p. 26) does not describe hand sample characteristics, but notes "The mode of the basalt is 35-40% plagioclase, 10-15% olivine, 10-20% pyroxene, 5-8% oxides, and 15-20% glass." Remanent magnetic polarity not determined. The unit is surrounded by basalts of Rocky Butte and Wilson Butte, but otherwise the age is poorly constrained.

QTkn—Basalt of Knoll 4610 (Pleistocene or Pliocene)—Dark gray, fine-grained, basalt with common plagioclase phenocrysts. Remanent magnetic polarity is reverse, as determined in the field. Equivalent to Baby Butte basalt of Matthews (2000) and Shervais and Matthews (2004). Exposures are poor and limited to pavement outcrops on top of knoll 4610 (elevation survey point, east of the map) and scattered small outcrops on the flanks. Surface mostly soil covered. The unit is flanked on the north, east, and south by flows from Kimama Butte, and on the west by flows from Rocky Butte.

QTlb—Basalt of Lincoln Butte (Pleistocene or Pliocene)—Dark gray, abundantly plagioclase-phyric to plagioclase-olivine glomerophyric basalt. Plagioclase laths typically 2-5 mm long; glomerocrysts 4-7 mm in diameter. Remanent magnetic polarity uncertain. Fluxgate magnetometer gave conflicting normal and reverse polarity readings in the field and laboratory paleomagnetic analysis produced unreliable results, possibly the result of lightning strikes. Source is unnamed butte with survey point "Lincoln" in northwest part of the Shoshone SW 7.5-minute quadrangle. Included in Thousand Springs Basalt by Malde and others (1963), but we interpret it to be an older shield volcano surrounded by younger flows from Notch Butte and Bacon Butte. Topography contrasts sharply with surface of Notch Butte basalt flows. No pressure ridges rise above a complete mantle of loess; basalt crops out only at crest of butte and a few isolated exposures on the flanks. Relief of butte has been subdued both by erosion and accumulation of loess. Loess thickness is greater than 2 m (6 feet). Soil caliche (duripan) is typically well developed within the soil profile (Ames, 2003; Johnson, 2002) and at the soil-basalt contact, but the thickness of caliche varies considerably. Nearly all the land is cultivatable.

QTmh—Basalt of Milner Hill (Pleistocene or Pliocene)—Basalt flows from hill 4338 with survey marker "Milner" located about 1.6 km (1 mile) east of the southeast edge of the map. No outcrops were found on or surrounding the hill. Covered with loess deposits as much as 7-10 m (20-30 feet) thick at the base of the hill. Topography very subdued. Interpreted from geomorphic appearance to be older than Burley Butte and Milner Butte.

QTson—Basalt of Sonnickson Butte (Pleistocene or Pliocene)—Very poorly exposed basalt flows erupted from Sonnickson Butte located 5 km (3 miles) south of Jerome. A few small outcrops and float samples of basalt, possibly from the butte, are medium to dark gray, fine to medium grained and diktytaxitic with common plagioclase phenocrysts and small olivine phenocrysts. Remanent magnetic polarity not determined. Very subdued topography with no relict volcanic features. The butte is surrounded by flows from Flat Top Butte.

QTbrb—Basalt of Brown Butte (Pleistocene or Pliocene)—Black, fine-grained, vesicular to massive plagioclase- and olivine-phyric basalt (Cooke, 1999). Remanent magnetic polarity not determined. Very poorly exposed. A few exposures occur as pavement outcrops along the flanks of the volcano.

QTbf—Basalt of Bowman Farm (Pleistocene or Pliocene)—Black, fine-grained aphyric basalt (Cooke, 1999). Remanent magnetic polarity not determined. Equivalent to Farm Butte basalt of Cook (1999) and Cooke and Shervais (2004a; 2004b). Name derived from land ownership map of farm located near summit of the volcano. Topography is very subdued, retaining no relict volcanic features.

TERTIARY BASALT UNITS

Thub—Basalt of Hub Butte (Pliocene)—Described by Williams and others (1991) as gray to dark gray, aphanitic or fine- to medium-grained plagioclase- and olivine-phyric basalt. Plagioclase phenocrysts range from 1-4 mm in length; olivine is amber and 0.5-1 mm in diameter and rimmed by or altered to iddingsite. Our unit includes flows from a small butte (Qo unit of Williams and others, 1991) located south of the quadrangle on the northeast flank of Hub Butte near the confluence of Rock and Cottonwood creeks. Tauxe and others (2004) report normal magnetic polarity for Hub Butte, although Williams and others (1991) report reverse polarity. Tauxe and others (2004) also report an age of 2.89 Ma for Hub Butte and 2.94 Ma for older Hub Butte (the associated small butte Qo noted above).

Tbrg—Basalt of Berger Butte (Pliocene)—Medium to dark gray, fine- to medium-grained basalt generally with abundant plagioclase phenocrysts as large as 5 mm and olivine phenocrysts about 1 mm in diameter. Remanent magnetic polarity is reverse as determined in the field and through laboratory analysis. Source is Berger Butte and associated satellite vents. Most of the unit is equivalent to the "basalt of Sucker Flat" unit of Bonnichsen and Godchaux (1995a, 1996, and 1997b), although we include their Lucerne School basalt (Lucerne Basalt of Malde and Powers, 1972), which Bonnichsen and Godchaux considered to be from Sunset Butte. We include it in *Tbrg* rather than in the Sunset Butte unit (*Tsb*) because paleomagnetic directions for Lucerne School basalt more closely match those from Berger Butte than those from Sunset Butte. Two samples were submitted for $^{40}Ar/^{39}Ar$ dating, one from Bonnichsen and Godchaux's Lucerne School basalt (sample 03P015) and one from the east flank of Berger Butte (sample 04P008). Average weighted mean plateau ages for two runs of each sample were 3.14 ± 0.17 Ma and 2.91 ± 0.37 Ma, respectively (Paul Layer and Jeff Drake, written commun., 2006).

Tsh—Basalt of Shoestring Road (Pliocene)—Gray to gray-brown, medium-grained basalt with common to abundant plagioclase laths as long as 1 cm and weathered olivine crystals. Remanent magnetic polarity is reverse, as determined in the field and as reported by Neville and others (1979). Forms a thin layer 10-15 m (30-50) feet thick within the Glenns Ferry sediments on the west side of the Snake River from the Hagerman Horse Quarry (fossil-collection site within the Hagerman Fossil Beds National Monument) northward and thins and pinches out locally or is replaced by layered volcaniclastic deposits. A thicker sequence of basalt is exposed in the northwest part of the quadrangle. Source may be vent of *Tshv* unit, or may be unidentified source to the north. Equivalent to the Shoestring Basalt of Malde and Powers (1972). May include the Deer Gulch basalt of Hart and Brueseke (1999) who dated the Shoestring basalt at 3.68 Ma and the Deer Gulch basalt at 3.40 Ma, although they report that both units occupy the same stratigraphic horizon in the Glenns Ferry Formation, and chemical compositions of the two units are very similar (Hart and Brueseke, 1999). Their Deer Gulch basalt sample 94HA-5 was collected from the Hagerman Fossil Beds National Monument. Similar in stratigraphic position and chemical composition to *Tbp* unit below.

Tshv—Basalt and vent material, basalt of Shoestring Road? (Pliocene)—Basalt and vent-derived scoriaceous and ropy rubble, spatter, and basalt fragments. Basalt is fine grained and glassy in places with abundant plagioclase laths and glomerocrysts as large as 1 cm, and common to abundant olivine grains and clots 0.5-3 mm in diameter. Some olivine and plagioclase intergrowths. Invasive into Glenns Ferry Formation sediments, which are baked for several centimeters at the basalt-sediment contact. Malde and Powers (1972) considered this a vent for the Shoestring Basalt, but we did not confirm that correlation in the field and therefore have mapped it as a separate unit. Its position within the Glenns Ferry sediments, however, gives credence to their interpretation.

Tbp—Basalt of Bliss Point (Pliocene)—Gray to gray-brown, fine-grained, aphyric to slightly plagioclase-phyric basalt within Glenns Ferry Formation sediments in the northwest corner of the map. Consists of one flow 15 m (50 feet) or less thick that thins and pinches out locally. Field magnetometer gave conflicting normal and reverse polarity readings from the same outcrop, but polarity is probably reverse. Mapped as Shoestring Basalt (our *Tsh* unit) by Malde and Powers (1972). Chemical composition indistinguishable from *Tsh* and may be same unit. Unit has slight dip to the south, indicating the source area may be to the north, or it may be structurally tilted.

Tsb—Basalt of Sunset Butte (Pliocene)—Medium to dark gray, fine-grained basalt with common to abundant plagioclase phenocrysts 4-8 mm in length. Remanent magnetic polarity is reverse as determined in the field and through laboratory analysis. Source is Sunset Butte shield volcano. Vesicular pahoehoe basalt exposed on the rim of Salmon Falls Creek canyon northwest of the butte abruptly changes to massive columnar basalt. Malde and Powers (1972) and Bonnichsen and Godchaux (1997a, 1997b) identify the source for the Lucerne basalt (or Lucerne School basalt) as Sunset Butte. However, as noted above in the basalt of Berger Butte description, we believe the source for the Lucerne basalt may have been Berger Butte. *Tmbr* flows beneath the basalt of Sunset Butte in Salmon Falls Creek canyon and the western part of Melon Valley may also have originated from Sunset Butte. A sample submitted for $^{40}Ar/^{39}Ar$ dating resulted in a weighted mean plateau age of 3.68 ± 0.17 Ma (Paul Layer and Jeff Drake, written commun., 2006).

Tos—Basalt of Oster Lakes (early Pliocene)—Grainy, fine- to medium-grained but coarse-textured vesicular basalt. Dark gray to brownish gray or brick colored with a light purplish hue in places. Abundant plagioclase phenocrysts as long as 5 mm; groundmass is glassy in places. Unit is subaerial and quite fresh where exposed near the fish hatcheries at Oster Lakes. Includes some sedimentary interbeds in the Thousand Springs quadrangle. Remanent magnetic polarity is normal, as determined in the field and through laboratory analysis. Field relations suggest it stratigraphically and probably unconformably overlies the *Tvd* vent tephras and the altered or water-affected basalt flows, assigned here to *Tmbr*, which have reverse polarity where analyzed. Source or sources undetermined, but may be to the west or southwest. Previously mapped as "Banbury Basalt, basalt of upper part" by Malde and Powers (1972) and Covington and Weaver (1991). A K-Ar date by Armstrong and others (1975) on this unit resulted in an age of 4.4 ± 0.6 Ma. An $^{40}Ar/^{39}Ar$ date on a sample collected during this mapping project resulted in a similar age of 4.46 ± 0.39 Ma.

Melon Valley Basalts

The Melon Valley area is a complicated mixture of basalt flows and sediments. The basalt flows are interbedded with the sedimentary deposits and may interfinger with the sediments and with each other and appear to have several source areas. North of Buhl, near the east edge of Melon Valley, flows were probably derived from sources to the southeast, whereas near the west edge of Melon Valley, in the vicinity of Salmon Falls Creek, flows appear to have originated from the south or southwest. Flows from these two source areas probably thin and interfinger near the center of Melon Valley. Structural displacement may further complicate the stratigraphy, although only minor offset of about 15 m (50 feet) of a few units was documented in the field. Faults interpreted by Malde and Powers (1972) to offset some of these units could not be confirmed with certainty, although faulting is likely in the older units as indicated by strong northwest-trending topographic linears. Alternative explanations, such as erosional, interfingering, or buttress contact relations could also account for some of their observations. Where possible, we have separated the basalts into packages based on remanent magnetic polarity and stratigraphic position (*Tmbr and Tmbn*). Flows within these packages are not necessarily from the same source(s) or of the same age. In areas where polarity was not determined or where only a few polarities were obtained, the flows are mapped as basalt of Melon Valley, undivided (*Tmb*). All of these basalt units may include thin interlayered sediments in places.

Tmb—Basalt of Melon Valley, undivided (Pliocene or Miocene?)—Brownish-weathering, fresh to altered aphyric to phyric, olivine-plagioclase and olivine basalt. Probably contains normal and reverse polarity flows. Within Melon Valley, may be equivalent in part to either *Tmbr* or *Tmbn*, or may be unrelated sequence of basalt flows. Equivalent in part to undivided basalt flows (*Tb)* east of Melon Valley.

Tmbr—Basalt of Melon Valley, reverse polarity flows (Pliocene or Miocene?)—Brownish-weathering, fresh to altered aphyric to phyric, olivine-plagioclase and olivine basalt. Remanent magnetic polarity is reverse based on field and laboratory analysis. In the field, a few flows have weak normal or conflicting polarity. Columnar flows are as thick as 15 m (50 feet) and thinner vesicular flows are about 5 m (15 feet) thick. Normally overlies *Tms* unit but may locally lie directly on *Tmb* or *Tmbn* flows. At least four flows are present beneath a basalt of Sunset Butte flow in Salmon Falls Creek canyon and may be a series of early flows erupted from Sunset Butte. Other flows may be from shield volcanoes south of the quadrangle. Includes some water-affected basalt (Sucker Flat basalt, altered facies) of Bonnichsen and Godchaux (1996) in the Melon Valley area. Malde and Powers (1972) mapped much of this basalt as Tbu, “Banbury Basalt, basalt of upper part.”

Tmbn—Basalt of Melon Valley, normal polarity flows (Pliocene or Miocene?)—Brownish-weathering, weakly altered aphyric to very phyric, olivine-plagioclase and olivine basalt. Remanent magnetic polarity is normal based on field and laboratory analysis. Forms subdued, columnar lava flows as thick as 15 m (50 feet) and thinner vesicular flows 5 m (15 feet) thick. Alteration includes trace chlorite and clay and may be due to combinations of saprolitic spheroidal weathering, to effects of water (water-affected basalt, or WAB, of Godchaux and Bonnichsen, 2002) where flow may have been emplaced underwater or into wet sediments, or to very weak hydrothermal effects of geothermal system. Minor sedimentary interbeds include light-colored clay, silt, sand, and pebble gravel. Reed casts in lacustrine clay beds immediately under the basalt were noted in two localities. An $^{40}Ar/^{39}Ar$ date on a sample collected during this mapping project resulted in a weighted mean plateau age of 6.90 ± 0.46 Ma (Esser, 2005). Chemical similarities to basalts in upper Salmon Falls Creek canyon south of the Twin Falls 30 x 60 minute quadrangle indicate the source(s) for the *Tmbn* flows may be from that area. Malde and Powers (1972) mapped these as Tbl, “Banbury Basalt, basalt of lower part.”

Tsfb—Basalt flows of upper Salmon Falls Creek, undivided (Pliocene to late Miocene)—undivided basalt flows in Salmon Falls Creek canyon near the southwest edge of the map from undetermined sources, probably located to the south. Both normal and reverse magnetic polarity units were identified in the field. Textures vary from grainy with common to abundant plagioclase phenocrysts as long as 5 mm and olivine grains about 1 mm in diameter to fine grained and aphyric.

Teh—Basalt of Elmas Hill (Pliocene to late Miocene)—Medium to dark gray, medium-grained, abundantly plagioclase-phyric to dense, fine-grained aphyric basalt. Plagioclase-phyric basalt is very vesicular with a significant amount of caliche coating or filling in the vesicles. Some outcrops appear fresh while others are altered or degraded. Remanent magnetic polarity is reverse as determined in the field and from laboratory analysis. Named for butte just west of the map with a survey point “Elmas” noted on the Crows Nest NE 7.5-minute topographic map. In upper Yahoo Creek, where *Teh* rests directly on Salmon Falls Creek rhyolite unit (*Tsfr*), the basalt is abundantly plagioclase-phyric and vesicular. In the lower part of Yahoo Creek, *Teh* forms a gentle dip slope to about Crows Nest Road, where the unit steepens to about 15 degrees and dips beneath Glenns Ferry Formation sediments (*Tsgf*). Two flows are present in the gully where the dip steepens. The upper flow is dense, fine-grained and aphyric, but the older flow is degraded with gray-brown weathering and a grainy texture. The chemical compositions of the two flows are dissimilar, indicating either chemical changes in the erupting magma or possibly different sources. Textural differences between plagioclase-phyric and aphyric exposures may be due to distance from the source or to separate eruptive events from one or more sources.

Tdct—Basalt of Devil Creek Butte or Tuanna Butte (Pliocene to late Miocene)—Medium to dark gray, medium-grained aphyric basalt with fairly abundant olivine grains about 1 mm in diameter, some of which are altered to amber iddingsite. Remanent magnetic polarity is normal as determined in the field and from laboratory analysis, although some polarity readings in the field were weak or conflicting. Probably erupted from Devil Creek Butte or Tuanna Butte, located just south of the map. Directly overlies Castleford Crossing rhyolite (*Tcc*) south of Balanced Rock County Park, and farther south, near the south edge of the map, overlies basalt flows of upper Salmon Falls Creek (*Tsfb*).

Tcb—Basalt of Castleford Butte (Pliocene to late Miocene)—Medium gray, fine-grained, sugary-textured aphyric basalt. Remanent magnetic polarity is reverse as determined in the field. Erupted from Castleford Butte shield volcano, located just beyond the southwest corner of the map. Typically poorly exposed. In the southwest part of the Balanced Rock 7.5-minute quadrangle, the basalt directly overlies porphyritic rhyolite vitrophyre of Castleford Crossing (*Tcc*).

Tcan—Basalt of Canyon Hill (Pliocene to late Miocene)—Not examined in the field but projected into the southwestern edge of the map by Bonnichsen and Godchaux (1997b). Named for a shield volcano with the survey point name "Canyon," located about 8 km (5 miles) south of the map boundary.

Tvp—Vent deposits, proximal facies (Pliocene to late Miocene?)—Coarse tuff breccias (blocks to 1-meter diameter), thick air fall tuffs, probable base surge deposits, cinders, and spatter-laden deposits in local phreatomagmatic vent complexes that include the prominent Riverside cone of Stearns and others (1939) and the "Thousand" vent, located in sec. 29 and secs.18 and 19 respectively, T. 8 S., R. 14 E. Includes sequences of explosively erupted layers of ash- to block-sized juvenile tephra and accidental fragments, locally tilted in the vent complex. Proximal facies were mapped by Malde and Powers (1972) who assigned them to the lower Banbury Basalt. Proximal facies are called "tuff of Blue Heart Springs" by Bonnichsen and Godchaux (2002), named for a spring near the Riverside cone. Small stream pebbles and blocks of coherent bedded clay, as well as spatter and blocks of older coarse-grained basalt, are present in the vent deposits. Small exposure of basalt flow over the Riverside cone is included in *Tvp* but may be equivalent to *Tmbr* unit. Age poorly constrained. Both vents appear to be unconformably overlain by *Tos*, *Tmbr*, or *Tb*, but the exact nature of the contact with *Tbo* (lower Banbury Basalt unit of Malde and Powers, 1972) is problematic.

Tvd—Vent deposits, distal facies (Pliocene to late Miocene?)—Variably colored, tan to orangish brown, crudely layered, pyroclastic and volcaniclastic deposits poorly exposed along the eastern Snake River canyon wall near Thousand Springs and Banbury Springs. Correlative to parts of the Banbury volcanics of Stearns and others (1938) and the Tbls and Tbu units mapped by Malde and Powers (1972). Distal facies tuffaceous and volcaniclastic deposits appear to grade laterally into more proximal facies (*Tvp*) where several vents occur along the Snake River. Unit includes cyclically repeated air fall tuff, local spatter, pebbly gravel deposits suggestive of reworking, and locally palagonitized tuff. Locally unconformably overlain by baked sediments under *Tos*.

Tb—Basalt flows, undivided (Pliocene-late Miocene?)—Fine- to coarse-grained, unaltered to altered undivided basalt flows exposed in the Snake River canyon. Stratigraphically above *Tbo* unit and commonly separated from it by a thin orange baked soil or sediment horizon <1 m (1-2 feet) thick. Source(s) unknown, but probably consists of flows from different sources of different ages. Includes some basalt mapped as "Sucker Flat basalt, altered" by Bonnichsen and Godchaux (1995a, 1997b). Near Melon Valley, may be equivalent in part to *Tmbr* or to *Tmb*.

Tub—Older basalt flows, undivided, downstream from Thousand Springs (early Pliocene to late Miocene?)—Gray to gray-brown, medium- to coarse-grained, dense to altered or weathered basalt flows exposed in the lower part of the Snake River canyon from just north of Thousand Springs to west of Bliss. Includes fine-grained sediments either intercalated with or underlying the basalt near the mouth of Big Wood River (Malad River). Source(s) unknown but may be from the south and southwest. Age is poorly constrained, but underlies sediment of the Glenns Ferry Formation (*Tsgf*). May be equivalent in part to *Tbo* or *Tmbr*. All flows in this unit that were analyzed for remanent magnetism have reverse polarity, although all may not be age-equivalent and not all flows were analyzed. Malde and Powers (1972) included most of these flows in their "Banbury Basalt, basalt of upper part." Stearns and others (1938) included them in the Banbury volcanics.

Tbo—Older basalt flows, undivided, upstream from Thousand Springs (early Pliocene to Miocene)—Gray to gray-brown, medium- to coarse-grained, mostly altered or weathered basalt flows exposed in the lower part Snake River canyon from south of Thousand Springs to just west of Twin Falls. Source(s) unknown but probably erupted from the south and southeast. Age poorly constrained but probably includes flows from different sources of different ages. One K-Ar date on this unit by Armstrong and others (1975), from an outcrop at the base of Clear Lakes grade, resulted in an age of 4.9 ± 0.6 Ma, indicating it is younger than our *Tmbn* unit at that location. May be equivalent in part to *Tub* or *Tmbr*. All flows included in this unit that were analyzed for remanent magnetism have reverse polarity, although all may not be age-equivalent and not all flows were analyzed. Malde and Powers (1972) included most of these flows in their "Banbury Basalt, basalt of lower part."

RHYOLITIC UNITS

The oldest units exposed in the Twin Falls 30 x 60 minute quadrangle are rocks that have been referred to in the literature as "rhyolite." Chemical analyses of a few samples are at the dacite-rhyolite boundary in the total alkali versus silica diagram (Le Maitre, 1984), but we retain the term "rhyolite" to be consistent with the literature and avoid confusion. Chemical compositions of the Castleford Crossing (*Tcc*) and Balanced Rock (*Tbr*) rhyolites are indistinguishable from one another, even though a significant amount of time between their emplacement is indicated by different magnetic polarities and by a soil horizon developed in places between the two units. The undivided rhyolite of Salmon Falls Creek (*Tsfr*) also has a chemical composition indistinguishable from Casltlford Crossing and Balanced Rock rhyolites and is probably equivalent to those units (see Kauffman, 2007, 2008). The rhyolite of Shoshone Falls is also physically and chemically similar to the other units but has very slight compositional differences in a few elements. Northwest-trending faults displace the rhyolites with an overall down-to-the-northeast offset, although local horst and graben displacement is evident, as occurs in Salmon Falls Creek near Balanced Rock. Few of the faults displace the overlying basalt units which cap or surround the rhyolites. Where not faulted, the irregular surface of the rhyolites appears to be the original emplacement surface, but in places the irregularity could also be caused by folding or erosion.

Tshr—Rhyolite of Shoshone Falls (Miocene)—Light gray to pinkish gray porphyritic rhyolite with a black porphyritic vitrophyre 3-5 m (10-15 feet) thick at the top. Remanent magnetic polarity is normal as determined in the field and through laboratory analysis. Chemical composition similar to that of Castleford Crossing and Balanced Rock rhyolites, but has slightly lower TiO_2 and MgO values; a few trace elements are also slightly different. Distribution is restricted to the bottom of the Snake River canyon in the Twin Falls area where falls at both Shoshone Falls and Twin Falls are developed on the rhyolite. Includes breccia unit of Covington and Weaver (1990c), which they describe as "mud-flow breccia composed of subangular rhyolite gravel in a vitric sand and clay matrix." Breccia unit is exposed in the cliff face below Perrine Bridge and on the road to Shoshone Falls; locally exceeds 15 m (50 feet) in thickness (Shawn Willsey, written commun., 2011). An age of about 6.25 Ma is reported for the rhyolite at Shoshone Falls (B. Bonnichsen, written commun., 2005). We obtained a whole rock $^{40}Ar/^{39}Ar$ plateau age of 6.53 ± 0.04 and a plagioclase age of 5.98 ± 0.34 from the same sample at a location near the falls (Paul Layer and Jeff Drake, written commun., 2006).

Tsfr—Rhyolite of Salmon Falls Creek, undivided (Miocene)—Physical characteristics and chemical composition indistinguishable from Castleford Crossing (*Tcc*) and Balanced Rock (*Tbr*) rhyolites. Most is probably equivalent to the normal polarity *Tcc* unit but a few locations which gave reverse polarity readings in the field may be equivalent to *Tbr* unit or perhaps to a younger reverse polarity rhyolite. An $^{40}Ar/^{39}Ar$ date on a normal polarity unit sampled during this mapping project near the mouth of Salmon Falls Creek canyon resulted in a poorly constrained age of younger than approximately 10 Ma (Esser, 2005).

Tcc—Rhyolite of Castleford Crossing (Miocene)—Gray to pinkish gray porphyritic rhyolite. Black porphyritic vitrophyre occurs at both the top and base of the unit. Brecciated vitrophyre is present at the base in places. Remanent magnetic polarity is normal as determined in the field and through laboratory analysis. Name taken from Bonnichsen and Godchaux (1997a). Exposed in the southwest part of the map where it overlies the irregular surface of rhyolite of Balanced Rock (*Tbr*). A thickness of about 70 m (200 feet) is exposed in Salmon Falls Creek canyon several kilometers south of Balanced Rock.

Tbr—Rhyolite of Balanced Rock (Miocene)—Gray to pinkish gray porphyritic rhyolite. Black porphyritic vitrophyre occurs at the top of the unit. Remanent magnetic polarity is reverse as determined in the field and through laboratory analysis. Name taken from Bonnichsen and Godchaux (1997a). Exposed in the southwest part of the map in Salmon Falls Creek canyon and at Balanced Rock. The base of the unit is at or below the canyon bottom and was not exposed at any sites examined. A maximum thickness of 80 m (250 feet) is exposed in Salmon Falls Creek canyon south of Balanced Rock. A whole rock $^{40}Ar/^{39}Ar$ date on sample 04P018 resulted in a plateau age of 8.24 ± 0.04 Ma, and a weighted average of two feldspar dates was 8.14 ± 0.53 Ma (Paul Layer and Jeff Drake, written commun., 2006).

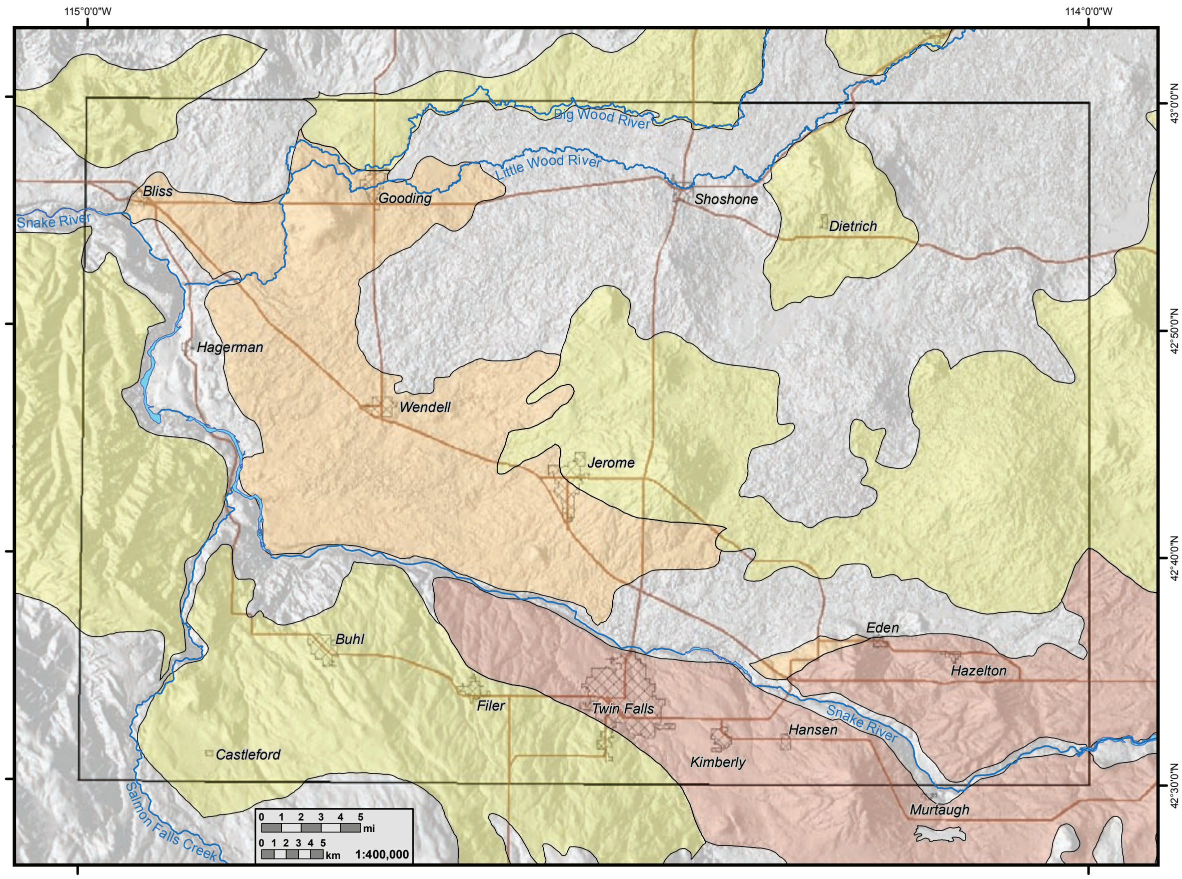
WINDBLOWN DEPOSITS AND SOILS

In this geologic map, loess is not shown as a map unit. Rather, the relative amount of loess cover on a rock unit, principally basalt, is described with the unit's description (see *Description of Map Units*), and the overall pattern, thickness, as well as principal loess soils are described in this section, as is eolian sand, which grades into areas of loess.

Silt- and sandy silt-textured loess is widespread and is the parent material for the productive agricultural soils in the SRP. Soils formed in loess and dune sand in the project area were first described and mapped in soil surveys as early as the 1920s (Poulson and Thompson, 1927; Youngs and others, 1929) and most recently in the 2000s (Johnson, 2002; Ames, 2003). Loess deposits of south-central and southeast Idaho were studied by the University of Idaho and the USDA Soil Conservation Service in the 1960s. One of the results of these studies is the distribution and character of loess reported by Lewis and Fosberg (1982). Their Figure 1 shows an areal distribution of four categories of loess thickness: 25 cm or absent, 25-50 cm, 50-175 cm, and greater than 175 cm. The scale of their figure does not justify enlargement for the Twin Falls 30' x 60' quadrangle. However, newer data from 1:24,000-scale soil maps provide detail for showing the distribution and thickness of loess in the project area. The soil maps also provide data on soils formed in eolian sand. Figure 4 shows the general distribution of thicker blankets of loess and eolian sand as derived from the Natural Resources Conservation Service soil surveys. Figure 4 was created from the Digital General Soil Map, Idaho data set (U.S. Department of Agriculture, Natural Resources Conservation Service, 2006). Using the GIS data and soil descriptions from the detailed soil maps, general soil units were grouped according to (1) loess soils and their thickness using Lewis and Fosberg's categories, and (2) eolian-sand soils.

Judging from thickness patterns and dune landforms, the prevailing wind direction has been from the west in this part of the SRP throughout the Pleistocene, as it is today. The thickest loess deposits occur in the eastern part of the quadrangle, on the oldest basalt units, and in the eastern, "lee" sides of shield volcanos. The source of windblown silt and sand is primarily deflation in the river valleys (Lewis and Fosberg, 1982), which were major contributors of sediment, especially during times of glacial climates in the Pleistocene. The Bonneville Flood, in its later, lower energy phases, probably contributed sandy deposits prone to later wind deflation. Some of the major sand sheets are downwind of Bonneville Flood expansion areas where fine-grained sediment accumulated. Another probable source of windblown silt and sand is erosion of the Glenns Ferry Formation and the Yahoo Clay; both form badland topography in the upwind, western part of the quadrangle near the Snake River.

Characteristically, the SRP surface is a mosaic of Pliocene, Pleistocene, and Holocene basalt flows that are differentially mantled by wind-blown sediments, predominantly loess (Lewis and Fosberg, 1982; Scott, 1982). Typically, the thickness and degree of continuous extent of loess cover is proportional to the age of the ba-



LOESS SOILS

Thickness >152 cm (>60 in)
Predominant soil series:
Portneuf (deep silt loam with calcic horizons within 5ft).
Description:
Surface soil primarily Portneuf series, which is at least 152 cm (60 in) thick at its typical pedon location near Hazelton (Ames, 2003). Near Twin Falls loess is as much as 5 m thick, and east of Twin Falls near the eastern border of the quadrangle loess has been measured as much as 36 m thick in lee positions (Lewis and Fosberg, 1982).

Thickness 50 - 152 cm (20 - 60 in)
Predominant Soil series:
Sluka and Purdam (approximately 50 cm [20 in] silt loam over a duripan)
Power (approximately 152 cm [60 in] silt loam, but intermingled with areas of thin loess)
Description:
Areas of variable loess thickness in soils, including small areas of less than 50 cm (20 in) or no loess at all, such as where basalt pressure ridges are near or at the land surface. Includes small areas of thicker loess soils such as the Gooding, Kinzie, and Portneuf series. In many areas loess buries a duripan (cemented, silica-lime hardpan).

EOLIAN-SAND SOILS

Primarily areas of dune sand that have been mostly re-graded by agriculture. Typical thicknesses range from 50 cm (20 in) to more than 152 cm (60 in). Locally, the sand is thin over basalt pressure ridges that are close to the land surface. Sand gradually thins in transition to areas of predominantly loess soils.
Thick sandy soil series (≥ 152 cm [60 in])
Ackelton, Chijer, Kecko, and Fathom
Moderately thick sandy soil series: (50 cm - 152 cm [20 - 60 in])
Wendell
Thin-sand soil series (≤ 50 cm (20 in)
Jestrick, Taunton, and Ticeska

Figure 4. *Hillshade showing areas of loess and eolian-sand soils and their approximate thicknesses. Inner rectangle is the border of the Twin Falls 30' x 60' quadrangle.*

salt surface, i.e., the oldest basalt surfaces are mantled by the thickest and oldest loess deposits and have fewer remaining lava-flow constructional features like pressure ridges. However, remnants of old shield volcanos, such as Hansen Butte, have a morphology that results from much more than an increase in loess thickness. They exhibit a complex history of loess deposition, soil development, erosion, and radial-drainage development (see Wells and others (1985) for similar trends in the Cima volcanic field of California). Variations in geomorphic features and soils are important criteria for distinguishing boundaries and relative ages of basalt units.

Exposures of thick loess show buried soils that indicate a long and complex history of Pleistocene loess deposition. All of the loess soils observed at the surface or buried are aridisols, and many have a duripan, a calcium carbonate- and silica-cemented hardpan (caliche). Thick, platy duripan paleosols that formed on the surface of reverse-polarity basalt flows and on the Tuana Gravel indicate aridisol-forming dry climate in the early Pleistocene. Buried paleosols capping Pliocene and Miocene units lack aridisol characteristics, and suggest a more moist climate (see Geologic History). Areas with thick loess may have several buried soils (Lewis and Fosberg, 1982), especially in the southeast part of the map near Hansen Butte and near Hazelton. At Jerome, an excavation revealed four buried soils within 3.6 meters (12 feet) of loess covering basalt of Flat Top Butte, which is late Pleistocene (dated at approximately 330 ka).

Mappable units of eolian sand deposits are common across the central and eastern SRP (Scott, 1982). These range from major accumulations with well-defined dune landforms to elongate streaks of thin sand that only slightly modify the basalt surface across which they have moved. The shape of many of the deposits reflects the prevailing westerly winds in the Twin Falls quadrangle (see Symbols). Evidence of dunes, almost all of which are stabilized, is best preserved in the absence of agriculture, such as areas of rugged lava-flow topography and wildlife-refuge land preserved from cultivation. Many sand deposits are best mapped from aerial photographs (1972 NASA false-color infrared and 1990s NAPP black and white). Sand sheets are common near the Snake River canyon and near Gooding, probably owing to sand contributed by the Snake, Big Wood, and Little Wood rivers. Stablilized dunes were previously more extensive based on descriptions of Poulson and Thompson (1927) and Youngs and others (1929). Fine-sand soils with little or no pedogenic horizonation were present in the early 20th century and were associated with dune morphology (Poulson and Thompson, 1927; Youngs and others, 1929). Poulson and Thompson (1927) describe “hummocky or dune-like” landforms and areas of actively blowing sand after field plowing in the early 20th century. Continued agricultural modifications to the land have tended to smooth topography and homogenize soils. The result has been an obliteration of the original topography, which probably included extensive areas of stabilized dunes.

BONNEVILLE FLOOD

By the middle of the 20th century, geologists recognized that giant gravel bars and stark erosional features common along the Snake River were caused by cataclysmic lowering of Pleistocene Lake Bonneville in Utah. Half a century earlier, G.K. Gilbert, in his pioneering study of Lake Bonneville, discovered evidence of water flowing from the ancient lake below Red Rock Pass, which he called the Bonneville River (Gilbert, 1878, 1890). In the Snake River basin, Russell (1902) explained gigantic boulders in the Snake River canyon as basalt blocks worn by water. Stearns and others (1938) explained the boulders as debris eroded from nearby lava dams. Malde (1968) recalls that “wide-reaching effects of the immense discharge downstream along the Snake River were not recognized until 1954, when they were explained to me by Howard A. Powers, of the U.S. Geological Survey.” Malde (1960) notes “impressive signs of havoc caused by water discharged from Lake Bonneville.”

The term “Bonneville Flood”

Malde (1968) defined the term when he wrote, “***to emphasize the catastrophic results of peak discharge, which lasted only a short time, I refer to the sudden outflow as the ‘Bonneville Flood’.” He reports that the many observations in support of his hypothesis were made in regional geologic studies beginning in 1954 and described in Malde and Powers (1962). In the Pocatello area, observations were reported by Trimble and Carr (1961a, 1961b) and in the Twin Falls quadrangle by Malde and others (1963). Malde (1968) notes that “Bonneville Flood” was first used in the guidebook for the 7th INQUA Congress (Richmond and others, 1965, p. 98).

The most complete descriptions and analyses of the Bonneville Flood were written by Malde (1968) and O'Connor (1993). O'Connor (1993, p.1) writes, "Approximately 14,500 yr ago[1], Pleistocene Lake Bonneville discharged 4,750 km^3 of water over the divide between the closed Bonneville basin and the watershed of the Snake River. The resulting flood, released near Red Rock Pass, Idaho, followed the present courses of Marsh Creek, the Portneuf River, and the Snake and Columbia River before reaching the Pacific Ocean. For 1,100 km between Red Rock Pass and Lewiston, Idaho, the Bonneville Flood left a spectacular array of flood features . . ." O'Connor (1993) goes on to describe the hydrology, hydraulics, and geomorphology of the flood, and provides a picture of the history and character of the flood and its many landforms and deposits. A major characteristic of the flood is a stepwise drop in the water surface caused by the diverse geologic and geomorphic environments along the flood route. A repeated phenomenon is a narrow canyon with constricted but high-discharge flow that opens up into a wider valley with less restricted, lower-discharge flow. In many locations, a constriction back-watered the flood causing inundation and overland flow. East of Twin Falls, from Eden to the area of Twin Falls city, flood water diverted north of the Snake River canyon scoured a long stretch of basalt surfaces and rejoined flood waters along the canyon rim for about 18 km (11 miles). Several systems of cataracts and plunge pools were formed, including Shoshone Falls and Twin Falls. Flood features from Twin Falls city to Hagerman show the stepwise nature of the flood's energy. West of Twin Falls city, 23 km (14 miles) of flood-scoured narrow canyon opens into the broad Melon Valley where a giant bar of flood gravel is mined for aggregate. Here, the river turns northward and the flood waters overfilled the narrowing canyon at Thousand Springs. The overland flow scoured and plucked basalt at the Sand Springs Nature Preserve, Box Canyon, and Blind Canyon.[2] Downstream of Thousand Springs, the canyon opens into the Hagerman Valley. Again, flood-water energy dropped and deposited a large expansion bar 5 km (3 miles) long with 5 m (10 foot) boulders at its upstream end. At maximum discharge, the flood waters would have been approximately 65 m (200 feet) deep at the location of downtown Hagerman. In the bottom of the Hagerman Valley, thick deposits of Yahoo clay that had buried basalt of Notch Butte were stripped away by the flood and the surface of the basalt was scoured.

The erosional and depositional features of the Bonneville Flood formed in a time period of only a few months. Unlike Glacial Lake Missoula floods that are thought to have emptied and produced catastrophic floods with durations of only several days to a week, the catastrophic flood from Pleistocene Lake Bonneville was more complex (O'Connor, 1993). The early phases were in low discharge when the lake overtopped Red Rock Pass and the divide began to erode. As erosion accelerated, the discharge grew to catastrophic proportions and was sustained for many weeks. The flood's discharge lowered gradually as the level of Lake Bonneville dropped. Ultimately, an equilibrium was achieved between the lake level and the outlet (Provo level of Lake Bonneville), and the lake continued to drain episodically into the Snake River drainage for approximately 2,000 years (Godsey and others, 2005). Scour and deposits from overland flood waters on uplands above the Snake River canyon represent flow at the greatest discharge, and would have ceased when the canyon could accommodate all the water. Features in the canyon range from high-discharge scouring of rock and deposition of giant, bouldery gravel bars, to lower-discharge thin sand and gravel deposits in the bottom of the canyon.

STRUCTURE

Detailed information on the structural and geologic setting of the eastern, central, and western SRP is available in two recent publications (Bonnichsen et al., 2002; Shervais and others, 2005). Also, Malde (1991) provides a thorough overview covering physiography, geophysical evidence, structural interpretations, and geologic history.

The geologic map of the Twin Falls quadrangle is approximately centered in distance and elevation within the SRP, a contiguous lowland that extends from eastern Oregon to Yellowstone National Park (Figure 5). The eastern and western portions of the SRP are dis-

[1]The accepted radiocarbon age at the time, more recently confirmed as happening just after 14,400 ± 400 14C yr B.P. (Godsey and others, 2005), which can now be calibrated at approximately 17,400 calendar years ago. A raw radiocarbon date cannot be used directly as a calendar date, because the level of atmospheric 14C has not been strictly constant during the span of time that can be radiocarbon dated. See http://calib.qub.ac.uk/calib/.

[2]Lamb and others (2008) attribute Box Canyon and Blind Canyon to possible flood events from Big Wood, Little Wood, and Big Lost river systems, and based on new age dates suggest these small canyons formed about 45 ka (Lamb, M.P., W.E. Dietrich, S.M. Aciego, D.J. DePaolo, and M. Manga, 2008, Formation of Box Canyon, Idaho, by Megaflood: Implications for Seepage Erosion on Earth and Mars: Science, v. 320, p. 1067-1070).

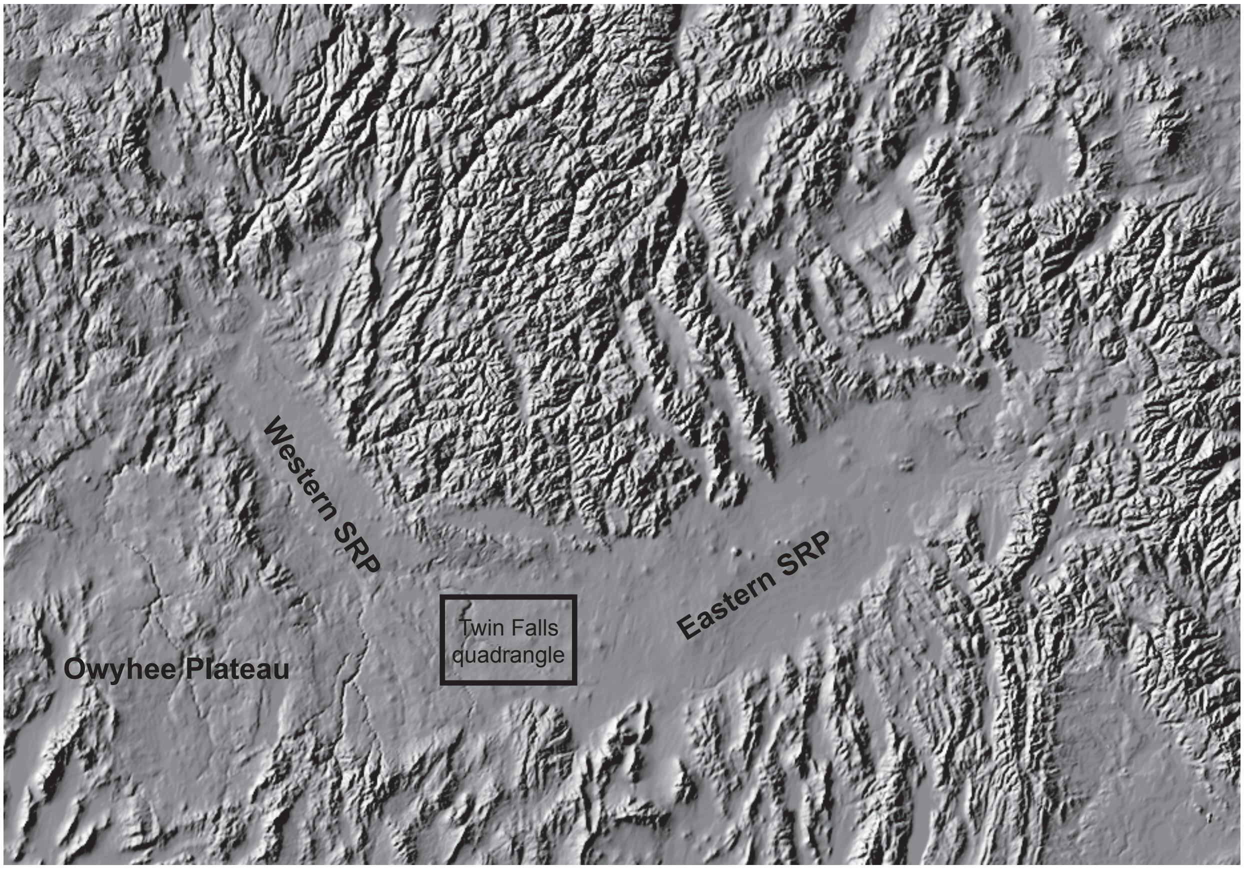


Figure 5. *Hillshade physiographic map showing the eastern and western Snake River Plain, the Owyhee Plateau, and the outline of the Twin Falls quadrangle.*

tinct geologically with different structural, geophysical, sedimentary, and volcanic features, and require different origins (Malde, 1991). The Twin Falls quadrangle is in the central SRP which lies at the junction of the physiographic western and eastern SRP and represents a critical link between the two provinces.

The east-northeast-trending central and eastern SRP begins as a gentle structural depression on the Owyhee Plateau that deepens to the northeast and merges with the physiographic SRP near Twin Falls. Origin of the eastern SRP has been associated with the passage of North America over a mantle hotspot that formed a volcanic province that youngs from west-southwest to east-northeast (Pierce and Morgan, 1992; Malde, 1991; Shervais and others, 2002; Shervais and others, 2005). Hotspot-related volcanism formed rhyolitic rocks of caldera complexes that were later overlain by basalt flows from shield volcanoes (Malde, 1991). The hotspot or plume model for the eastern SRP is supported by studies of tectonic uplift and collapse along the plume track (Rodgers et al., 2002).

The increase in elevation of the central and eastern SRP from southwest to northeast is thought to result from thermal buoyancy in the upper mantle that increases and decreases with passage of the plume. The elevation difference between the Owyhee Plateau and the central SRP (Figure 5) probably results from differences in the underlying crust: the Owyhee Plateau is underlain by the southern extension of the Idaho batholith, whereas the eastern SRP transects older crust of the Basin and Range province (Malde, 1991). Initial volcanic activity forming caldera complexes and ignimbrites at any given location is thought to mark the arrival of the hotspot. Ages of ignimbrites north and south of the Twin Falls quadrangle suggest a proposed Twin Falls volcanic center was active 10.0 to 8.6 Ma (Pierce and Morgan, 1992).

In contrast to the northeast-trending eastern SRP, the western SRP is a northwest-trending structural graben bounded by en echelon normal faults. The basin is filled with as much as 2.3 km of late Miocene through

Pliocene sediment and intercalated basalt from two major eruptive episodes in the late Miocene and early Pleistocene (Wood and Clemens, 2002; Shervais et al., 2002; Shervais and others, 2005).

The western SRP is characterized by a positive gravity anomaly that trends parallel to the axis of the plain, and magnetic anomalies that parallel its southern margin, whereas gravity and magnetic anomalies in the eastern SRP are normal to the trend of the eastern plain, paralleling structural trends in the adjacent Basin and Range province (Malde, 1991). The western SRP is a true graben, whereas the eastern SRP is structurally downwarped with little or no faulting along its margins (Wood and Clemens, 2002; Rodgers et al., 2002).

Normal faults in the western part of the Twin Falls quadrangle show evidence of extension in the same northeast-southwest direction characteristic of the western SRP. Boundary faults of the western SRP graben extend into the southwest part of the Twin Falls quadrangle before dying out near Berger Butte a few kilometers south of Filer. In general, these structures trend northwest-southeast and overall are stepped down to the northeast. Most faults displace the rhyolitic rocks but generally do not cut the overlying basalt units. Faults that do cut the basalts generally affect only the oldest units and are typically covered or poorly exposed. Surface expressions of these faults occur mainly in the Melon Valley area where deep-seated faults are further indicated by the presence of numerous hot springs and thermal wells. Faults mapped by Malde and Powers (1972) north of Bliss, cutting Glenns Ferry Formation sediments and a thin basalt flow within the sediments, also trend northwest-southeast but are stepped down to the southwest.

The axial Bouguer gravity high of the western SRP extends into and terminates within the west part of the Twin Falls quadrangle (Wood and Clemens, 2002; Malde, 1991), but the northwest-trending gravity and magnetic anomalies, which characterize the eastern SRP, are not clearly present in the quadrangle, but begin at approximately its eastern border (Malde, 1991; Shervais and others, 2005). Similarly, extension in the form of basalt rifts, like those in the eastern SRP, is not apparent in the Twin Falls quadrangle, but may begin just to the east (Richfield-Burley Butte zone of Wood and Clemens, 2002).

No pattern of structural control of shield vents is obvious in the Twin Falls quadrangle. Late Miocene and Pliocene basalts are mostly restricted to the southwest part of the quadrangle and were erupted from shield volcanoes in that area or farther south and west. A few Pliocene to early Pleistocene shield remnants protrude above younger surrounding Pleistocene flows, which cover most of the quadrangle. These remnants suggest that these older lava flows underlie most of the quadrangle. In general, the oldest shield volcanoes are in the southwest and the youngest are in the northeast part of the quadrangle. Although structural controls or patterns are not evident for the location of most volcanoes, Miocene vents south of Thousand Springs (*Tmv* unit) may be aligned along one of the northwest-trending late Tertiary faults. Structural controls for other shield volcanoes may occur at depth.

The present day Snake River flows westward through the quadrangle, with northward-flowing tributaries south of the river, and south- or southwestward-flowing tributaries north of the river. Recent data suggest that the main drainage was southward during the Miocene, which implies higher elevations to the north and west and south-flowing streams with provenance in the Wood River drainage of central Idaho (Link and others, 2002). Paleontological evidence similarly suggests southward drainage in the late Miocene (Repenning et al., 1995). Crustal inflation followed by deflation with the passage of the hotspot, first restricting and then allowing westward flow, may explain the change in drainage direction (Rodgers and others, 2002; Link and others, 2002; Wood and Clemens, 2002).

GEOLOGIC HISTORY

The geologic history within the Twin Falls quadrangle is restricted to Late Miocene and younger events, although Paleozoic, Cretaceous, and early Tertiary rocks occur to the north and south. At about 11 Ma, crust in the Twin Falls quadrangle was extended (Rogers and others, 2002), possibly by the passage of North America over a mantle plume that caused as much as 1 km of uplift (Pierce and others, 2002; Shervais and Hanan, 2008). As the continent moved southwest, the plume location effectively migrated northeast and the central SRP began subsiding. Late Miocene climatic interpretations from fossils suggest an upland with mixed hardwood-conifer forests in a summer-wet climate with annual precipitation of about 86 cm (>35 inches; Leopold and Wright, 1985). Paleosols associated with Miocene rhyolites and basalts also support a warm-wet climate interpretation.

The oldest rocks in the quadrangle are rhyolitic units exposed in the canyons of the Snake River and Salmon Falls Creek. These rocks, erupted between about 8 to 6.5 Ma, may be ignimbrites and flows associated with a large caldera inferred to have been centered in what is now the central SRP (Bonnichsen and Godchaux, 2002), or they may represent younger, postcaldera silicic eruptions. Evidence for the large caldera or eruptive center lies to the north and south of the quadrangle where high-temperature ignimbrites are exposed. Eruption of these rhyolitic rocks, as well as some of the oldest basaltic units, was probably related to the extensional structural setting and subsequent subsidence caused by the passing mantle plume. As faulting and subsidence of the rhyolites and older basalts continued, a basin formed. Late Miocene and early Pliocene basalt flows from shield volcanoes to the south and southwest, as well as sediments eroded from the northern highlands, were deposited in the developing basin. To the west, Lake Idaho had formed and extended into the western part of the quadrangle (Wood and Clemens, 2002).

At about 4.5 Ma, a thick sequence of sediments, the Glenns Ferry Formation, and intermittent basalt flows began to be deposited as basin subsidence continued. Provenance for these lacustrine and fluvial sediments was from the Big and Little Wood rivers to the north (Link and others, 2002). The diverse Hagerman fauna of browsing and grazing animals were extant at this time, as were predators and waterfowl that lived in the common swamps and sloughs associated with this Pliocene phase of Lake Idaho. Sedimentation equaled or exceeded subsidence, as evidenced by coarser grained stream deposits intermixed with lake sediments. The sediments buried much of the older basalt and rhyolite in the west part of the quadrangle (and probably extended into the central part) and formed a broad, flat plain (Sadler and others, 1996, 1997; Link and others, 2002).

By late Pliocene to early Pleistocene, the divides had shifted and drainage was directed northward toward the central SRP (Link and others, 2002). Pollen studies show the climate also shifted toward cool-temperate with increasing grassland and increasingly drier summers (Leopold and Wright, 1985). Shield volcanoes continued to erupt lavas throughout much of the quadrangle. Great Basin mountain building and further climatic cooling led to increased stream discharges and progradation of coarse-grained sediment of the Tuana Gravel onto the broad plain of Glenns Ferry sediments. Stream incision in the western SRP had also begun and the process of canyon cutting worked its way into the quadrangle. Ensuing Pleistocene basalt eruptions altered stream courses as a mosaic of overlapping shield volcanoes formed the surface north of the Snake River. The Snake River now is mostly adjusted to the southern and western edges of the youngest basalt flows. Remnants of the earlier Pliocene to early Pleistocene shield volcanoes (Sonnickson Butte, Lincoln Butte, Star Lake Butte, etc.) protrude through the Pleistocene lava surface.

By late Pleistocene, the Snake River had cut a channel to the depth of its present level. Basalt from Notch Butte flowed west and reached the Snake River at Hagerman, cascaded over the canyon rim, and now forms the flat west of town. Later, McKinney Butte lava eruptions flowed south and poured into the Snake River canyon north of Hagerman. Near Bliss, the lava dammed the river, forming a lake. Pillow basalt and tephra deposits occur in the canyon from just upstream of Bliss to about 5 km (3 miles) downstream. Fine grained sediment, the Yahoo Clay, accumulated in the lake to an elevation of about 980 m (~3200 feet). When the dam was breached, much of the dam-forming tephra, pillows, and lava was eroded, although localized remnants remain along the canyon walls.

Pollen evidence shows that by the early to middle Pleistocene the climate had become like today's, with summer-dry conditions, precipitation below 37 cm (15 inches) annually, and evaporation exceeding precipitation. This is corroborated by aridisol soil development on Pleistocene basalt surfaces. The change to dry climate coincides with increased deposition of loess and eolian sand. To various degrees, loess and dune sand cover part or all of Pleistocene basalt surfaces (see *Windblown Deposits and Soils* section). Approximately 17,400 years ago, the Bonneville Flood filled and locally overtopped the Snake River canyon causing extensive erosion and depositing gravel in giant flood bars (see *Bonneville Flood* section).

Quaternary landslides, including older mostly stabilized and recent active ones, are typically associated with steep slopes along canyon walls. Most of the active landslides are in Glenns Ferry sediments west of the Snake River or in Yahoo Clay sediments, such as the large landslide in the canyon at Bliss.

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APPENDIX: PALEOMAGNETISM

Characteristic paleomagnetic directions and polarities of selected volcanic units provided supporting evidence for stratigraphy, chronology, and geologic mapping. Cores were drilled and field orientations measured using standard protocols and sampling equipment. Prior to 2004, all samples were analyzed and site statistics determined at the Idaho Geological Survey's Paleomagnetism Laboratory in Moscow, Idaho. Samples collected in 2004 were analyzed and site statistics determined at Western Washington University's Pacific NW Paleomagnetism Laboratory in Bellingham, Washington.

Table 1. Sampling sites and results of laboratory measurement of paleomagnetic directions on the Twin Falls 30' x 60' quadrangle.

Site number	Latitude	Longitude	Quadrangle	Map name	Unit name	n	DL (mT)	D	I	α_{95}	κ	Polarity
02P001	42.63895	-114.56141	Jerome	Qftb	basalt of Flat Top Butte	8	20	343.20	71.08	3.00	341.33	N
02P002A	42.68096	-114.75124	Thousand Springs	Qftb	basalt of Flat Top Butte	8	15	358.12	81.08	2.42	523.83	N
02P002B	42.68096	-114.75124	Thousand Springs	Qftb	basalt of Flat Top Butte	8	20	348.33	82.35	1.55	1276.87	N
02P003	42.71251	-114.7029	Niagara Springs	Qbby	basalt of Bacon Butte, younger unit	8	15	16.70	59.17	2.97	348.42	N
02P004	42.70152	-114.6163	Jerome	Qftb	basalt of Flat Top Butte	6	20	9.41	49.19	3.98	283.89	N
02P005	42.77252	-114.7146	Wendell	Qbby	basalt of Bacon Butte, younger unit	6	20	6.40	71.36	4.31	242.54	N
02P006	42.9247	-114.65414	Gooding	Qnb	basalt of Notch Butte	8	25	354.50	72.63	1.38	1614.83	N
02P007	42.88472	-114.41731	Shoshone	Qnb	basalt of Notch Butte	8	20	322.12	69.61	2.81	390.25	N
02P009A	42.73288	-114.41818	Falls City	Qftb	basalt of Flat Top Butte	4	20	11.14	66.93	3.19	830.43	N
02P010	42.64917	-114.3846	Falls City	Qrb	basalt of Rocky Butte	6	15	17.00	46.22	1.91	1232.65	N
02P011	42.85087	-114.44228	Shoshone SW	Qnb	basalt of Notch Butte	8	20	348.88	64.67	1.47	1428.50	N
02P012	42.78192	-114.44732	Shoshone SW	Qbb	basalt of Bacon Butte, undivided	8	25	17.60	59.54	3.87	206.13	N
02P013	42.75321	-114.47288	Shoshone SW	Qftb	basalt of Flat Top Butte	8	20	356.93	64.82	2.28	590.69	N
02P014	42.80274	-114.59668	Gooding SE	Qbby	basalt of Bacon Butte, younger unit	8	20	21.63	56.93	2.71	419.95	N
02P015	42.7386	-114.59092	Jerome	Qbb	basalt of Bacon Butte, undivided	4	15	39.34	53.84	2.06	1981.53	N
02P016	42.67095	-114.69983	Niagara Springs	Tb	younger Tertiary basalt, undivided	8	25	204.00	-77.94	1.36	1666.12	R
03P001	42.6687	-114.34128	Twin Falls NE	Qrb	basalt of Rocky Butte	9	15	12.15	54.93	2.92	311.79	N
03P002	42.64397	-114.26549	Twin Falls NE	Qrb	basalt of Rocky Butte	10	15	11.42	51.93	3.32	212.76	N
03P003	42.74446	-114.3628	Twin Falls NE	Qwb	basalt of Wilson Butte	8	10	353.8	64.07	1.96	797.49	N
03P005	42.78294	-114.84819	Tuttle	Qnb	basalt of Notch Butte	9	10	332.14	74.54	2.06	623.73	N
03P006	42.81162	-114.91711	Hagerman	Qnb	basalt of Notch Butte	10	10	349.94	68.78	3.79	163.36	N
03P007	42.84022	-114.89889	Hagerman	Qnb	basalt of Notch Butte	8	15	346.32	69.06	1.82	928.39	N
03P008	42.88395	-114.91193	Bliss	Qma	basalt of Madson Spring	8	10	25.47	46.2	2.03	742.80	N
03P009	42.86672	-114.84663	Tuttle	Qgb	basalt of Gooding Butte	8	15	351.04	77.48	2.14	674.12	N
03P010	42.99653	-114.43188	Shoshone	Qmc	basalt of Mammoth Cave	8	20	344.17	65.79	1.52	1325.82	N
03P011	42.93902	-114.4541	Shoshone	Qnb	basalt of Notch Butte	8	20	329.62	72.54	2.38	543.59	N
03P012	42.80971	-114.70396	Wendell	Qnb	basalt of Notch Butte	8	20	338.33	74.13	1.82	925.98	N
03P013	42.7224	-114.83913	Thousand Springs	Qbby	basalt of Bacon Butte, younger unit	8	15	22.10	55.01	4.21	174.47	N
03P014	42.71655	-114.84615	Thousand Springs	Qbby	basalt of Bacon Butte, younger unit	8	15	16.29	54.17	2.21	628.25	N
03P015	42.66572	-114.85054	Thousand Springs	Tbrg	basalt of Berger Butte	8	15	169.85	-67.95	2.69	424.12	R
03P016	42.68869	-114.86535	Thousand Springs	Tsfr	rhyolite of Salmon Falls Creek	8	10	2.65	62.36	2.33	566.48	N
03P017	42.68903	-114.84599	Thousand Springs	Tmbn	basalt of Melon Valley, normal polarity	8	5	20.66	56.93	2.63	444.48	N
03P018	42.6767	-114.75224	Thousand Springs	Tb	younger Tertiary basalt, undivided	8	10	187.06	-71.87	3.40	265.70	R
03P019	42.66544	-114.75703	Thousand Springs	Tb	younger Tertiary basalt, undivided	8	20	190.96	-77.33	2.37	547.87	R
03P020	42.75854	-114.86276	Tuttle	Tos	basalt of Oster Lakes	8	15	15.71	51.45	1.88	870.64	N
03P021	42.95855	-114.41457	Shoshone	Qbu	Quaternary basalt, undivided	8	15	338.48	68.28	2.78	398.62	N

n = number of oriented cores .
DL (mT) = alternating field demagnetization level in milliTesla.
D = site mean declination of remanent magnetization in degrees east of north.
I = site mean inclination of remanent magnetization in degrees with respect to horizontal.
α_{95} = confidence limit for the mean direction at the 95% level.
κ = precision parameter.
Polarity: N = normal; R = reverse.

Table 1. continued.

Site number	Latitude	Longitude	Quadrangle	Map name	Unit name	n	DL (mT)	D	I	α_{95}	κ	Polarity
03P022	42.96334	-114.41249	Shoshone	Qcb	basalt of Crater Butte?	8	15	309.29	52.18	4.98	124.81	N
03P023	42.96591	-114.41398	Shoshone	Qblb	basalt of Black Butte Crater	8	15	358.96	59.31	2.38	543.12	N
03P024	42.72405	-114.48082	Falls City	Qftb	basalt of Flat Top Butte	8	15	13.73	71.14	2.56	470.61	N
03P025	42.666	-114.41634	Falls City	Qrb	basalt of Rocky Butte	7	15	20.29	67.68	5.37	127.11	N
03P026	42.76661	-114.48188	Shoshone SW	Qbb	basalt of Bacon Butte, undivided	8	20	12.18	53.67	2.55	471.88	N
03P027	42.76064	-114.57664	Gooding SE	Qbb	basalt of Bacon Butte, undivided	8	15	26.49	56.6	4.29	167.36	N
03P028	42.75403	-114.73252	Wendell	Qftb	basalt of Flat Top Butte	4	25	355.61	59.96	2.03	2049.36	N
03P030	42.8212	-114.26964	Shoshone SE	Qwb	basalt of Wilson Butte	8	15	2.95	57.06	3.52	248.81	N
04P001	42.74948	-114.92539	Yahoo Creek	Teh	basalt of Elmas Hill ?	8	30	193.2	-68.0	3.2	300	R
04P002	42.7028	-114.89047	Yahoo Creek	Tmbr	basalt of Melon Valley, reverse polarity	8	30	199.6	-55.0	3.4	262	R
04P003	42.69783	-114.86633	Thousand Springs	Tos	basalt of Oster Lakes	8	30	31.7	61.1	4.2	171	N
04P004	42.91348	-114.98121	Bliss	Tub	older Tertiary basalt, undivided	8	20	193.0	-75.0	3.5	250	R
04P005	42.69994	-114.84901	Thousand Springs	Tmbn	basalt of Melon Valley, normal polarity	8	20	59.8	57.6	6.1	99	N
04P006	42.69839	-114.84297	Thousand Springs	Tmbr	basalt of Melon Valley, reverse polarity	8	25	217.7	-74.6	2.2	621	R
04P007	42.67155	-114.76028	Thousand Springs	Tbo	older Tertiary basalt, undivided	8	30	189.4	-59.0	1.7	1095	R
04P009	42.65002	-114.64896	Niagara Springs	Qftb	basalt of Flat Top Butte	8	100	346.0	71.7	7.3	58	N
04P010	42.59358	-114.52589	Filer	Qhan	basalt of Hansen Butte ?	8	35	164.3	-61.0	3.1	329	R
04P011	42.59359	-114.52648	Filer	Thub	basalt of Hub Butte ?	8	25	17.8	60.0	1.6	1198	N
04P013	42.61439	-114.78835	Buhl	Tmbr	basalt of Melon Valley, reverse polarity	8	30	212.3	-72.5	2.2	638	R
04P015	42.65086	-114.64485	Niagara Springs	Tb	younger Tertiary basalt, undivided	8	25	221.2	-75.7	2.5	475	R
04P016	42.59589	-114.398	Twin Falls	Tshr	rhyolite of Shoshone Falls	8	20	341.4	72.6	2.7	431	N
04P018	42.53928	-114.95115	Balanced Rock	Tbr	rhyolite of Balanced Rock	8	20	191.5	-59.8	3.4	316	R
04P019	42.54518	-114.95322	Balanced Rock	Tsb	basalt of Sunset Butte	8	90	40.9	57.0	9.4	36	N
04P020	42.67813	-114.8962	Yahoo Creek	Tsb	basalt of Sunset Butte	8	30	216.2	-62.7	2.8	387	R
04P021	42.65475	-114.75572	Thousand Springs	Tmb	basalt of Melon Valley, undivided	8	20	49.3	54.4	4.1	182	N
04P022	42.66866	-114.81795	Thousand Springs	Tmbn	basalt of Melon Valley, normal polarity	8	20	27.4	57.8	3.2	298	N
04P023	42.84347	-114.90142	Hagerman	Tub	older Tertiary basalt, undivided	8	20	197.7	-70.9	2.4	518	R
04P024	42.76745	-114.89749	Hagerman	Tub	older Tertiary basalt, undivided	8	20	186.5	-63.2	3.5	247	R
04P025	42.6454	-114.88554	Yahoo Creek	Tsb	basalt of Sunset Butte ?	8	30	200.2	-57.7	8.8	40	R
04P026	42.64559	-114.88539	Yahoo Creek	Tsb	basalt of Sunset Butte ?	8	20	194.4	-59.9	3.3	338	R
04P027	42.64569	-114.88549	Yahoo Creek	Tsb	basalt of Sunset Butte ?	8	20	199.6	-63.6	1.7	1110	R
04P028	42.64643	-114.88493	Yahoo Creek	Tsb	basalt of Sunset Butte ?	8	20	217.3	-61.9	2.6	456	R
04P030	42.67236	-114.97726	Yahoo Creek	Teh	basalt of Elmas Hill	8	20	198.7	-55.8	2.9	359	R
BB2272	42.67161	-114.70324	Niagara Springs	Qftb	basalt of Flat Top Butte	16	15	5.29	77.21	1.24	877.25	N
BB2278	42.63353	-114.51965	Jerome	Qhan	basalt of Hansen Butte	14	20	172.65	-38.34	9.93	17.00	R
BB2307-U	42.59365	-114.52764	Filer	Qhan	basalt of Hansen Butte	14	20	152.56	-58.87	1.41	798.856	R
BB2322	42.61488	-114.45797	Twin Falls	Qrb	basalt of Rocky Butte	9	20	12.93	63.73	1.56	1095.21	N

n = number of oriented cores .
DL (mT) = alternating field demagnetization level in milliTesla.
D = site mean declination of remanent magnetization in degrees east of north.
I = site mean inclination of remanent magnetization in degrees with respect to horizontal.
α_{95} = confidence limit for the mean direction at the 95% level.
κ = precision parameter.
Polarity: N = normal; R = reverse.