Geologic Map of the
Wild Horse Butte Quadrangle,
Ada and Owyhee Counties, Idaho

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Bill Bonnichsen

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INTRODUCTION

The geologic map (scale 1:24,000) and this accompanying text describe the geology of the Wild Horse Butte quadrangle. We prepared this document from field work completed during the summer and fall of 1987. Our investigations build on the previous geologic studies of the area by Anderson (1965), Ekren and others (1981), Amini (1983), and Malde (1987).

The Wild Horse Butte quadrangle is located along the Snake River canyon south of Swan Falls Dam, about 30 miles south of Boise, Idaho. The Snake River, which flows from southeast to northwest through the south- west part of the quadrangle (see map), carved this canyon as deep as 600 feet. The walls of the canyon provide excellent exposures of the volcanic and sedimentary strata. The western and southern parts of the canyon are within the Snake River Birds of Prey Natural Area. This area has been set aside by the U.S. Bureau of Land Management as a nesting sanctuary for various raptor species.

Basalt flows, palagonitized basaltic tuff layers, lacustrine and fluvial sediments, and various unconsolidated surficial deposits, ranging from Miocene to Holocene in age, are exposed within the boundaries of the Wild Horse Butte quadrangle. For this project we have mapped each volcanic unit separately as a chronostratigraphic unit, locating the source of the flows or tuffs whenever possible. Earlier workers have taken a lithostratigraphic viewpoint and have included the volcanic units within larger sedimentary packages (Ekren and others, 1981; Anderson, 1965; Malde, 1987). We suggest that the lithostratigraphic approach, which is valid for the sedimentary units, has lim-
ited value in this region containing large amounts of volcanic material, because it does not recognize the chronostratigraphic importance of the basaltic lithologies.

The precipitous canyon walls make the portrayal of the geologic units exposed in the canyon cartographically difficult. Thus, we have slightly exaggerated the thicknesses of some units in steep areas where contour lines are extremely close. In the northwest part of the quadrangle, we have removed the canyon-wall contour lines to clarify the geologic contact lines.

The complex geologic history of the area and the lack of direct stratigraphic relations between many of the volcanic units precluded the formulation of a single, integrated stratigraphic column for the units of the quadrangle. To summarize the known stratigraphic relations, we developed separate columns for the northern, central, and southern parts of the Snake River canyon area and for the area northeast of the canyon (see map). In the unit descriptions that follow, we cite the K-Ar dates determined by Amini and others (1984) for six samples collected from the Wild Horse Butte quadrangle and for two samples from the adjoining Sinker Butte quadrangle. These dates are not precise or numerous enough, however, to be used to correlate the basalt units from place to place in the quadrangle.

The character of the deposits show that many of the basalt units flowed into, were erupted into, or were deposited entirely under water. This suggests that the area was inundated by a series of lakes, some permanent and some intermittent. The evidence for the inundation in this and adjacent quadrangles includes the following: (1) thick and areally extensive layers of palagonitized basaltic tuff; (2) pillowd flows at the bases of several of the basalt units; (3) phreatic volcanoes that appear to have erupted in standing water; and (4) considerable thicknesses of fine-grained sediments (Idaho Group) mainly deposited in lacustrine environments. Several erosional episodes formed unconformities within the stratigraphic sequence. Some of the basalt units appear to have flowed down paleoslopes and over erosional escarpments into basins that perhaps were similar to the present low area in the southwest part of the quadrangle.

We examined hand samples from all the units for general textural character and phenocryst content. The only phenocryst minerals in the samples are plagioclase and olivine. Table 1 defines the terms we use to characterize the sizes and abundances of phenocrysts in the unit descriptions.

<table>
<thead>
<tr>
<th>Plagioclase lath lengths (in millimeters)</th>
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<tr>
<td>aphanitic</td>
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<th>Olivine crystal diameters (in millimeters)</th>
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<th>Abundance (as percent of sample)</th>
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<td>aphyric</td>
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DESCRIPTION OF MAP UNITS

SEDIMENTARY AND TUFFACEOUS UNITS

Qal Alluvium (Holocene and Pleistocene)—Unconsolidated stream deposits, including clay, silt, sand, and gravel. Unit is along the bottom of the Snake River canyon, and deposits conform to the present topography.

Qls Landslide deposits (Holocene and Pleistocene)—Debris falls, flows, and slumps from the rim basalt units and the sediments that underlie them. This unit does not include talus slope deposits, which are mapped as parts of the underlying units. The landslides originated by natural canyon slope erosion as well as during the extraordinary canyon-wall undercutting accompanying the catastrophic Bonneville Flood.

Qm Melon Gravel (Pleistocene)—Sand- to boulder-sized sediments as gravel and boulder bar deposits. Several
occurrences are in the northwest part of the area in the Snake River canyon. Malde and Powers (1962) attribute deposition of the Melon Gravel to the Bonneville Flood. On top of the large bar in secs. 19, 20, 29, and 30, T. 2 S., R. 1 E., are tillled basalt blocks, as much as 20 feet (6 m) high, that were derived from the canyon rim during the flood. Jarrett and Malde (1987) place the time of the flood at about 15,000 years ago.

Qmr Tuff of Moore Road (Pleistocene)—Massive, dark brown tuffaceous materials; includes a thin, underly- ing, white clay and silt layer. The unit is in the northwest corner of the map in a small area of the upper canyon wall and the adjacent surface. The unit was previously unrec- ognized, but Anderson (1965) maps it as part of his Snake River Basalt undifferentiated unit. The source of the unit is unknown. The tuff of Moore Road is above both the upper basalt of Moore Road (Qmr) and the lower basalt of Moore Road (Qmrf); it is beneath the upper basalt of Promontory Point (Qppp).

Reference locality: Rim of Snake River canyon at top of Swan Falls Road grade, NE1/4 NW1/4 sec. 20, T. 2 S., R. 1 E. Thickness: 25-30 feet (7-9 m).

QTsf Tuff of Swan Falls Dam (Pleistocene or Pliocene)—Fresh and palagonitized basaltic tuff layers containing cut and fill, graded bedding, crossbedding, and loading deformation structures. One layer encloses cobble- to boulder-sized basalt pieces. The unit includes an underlying white sedimentary layer. The unit is in the northwest, on the east side of the Snake River canyon. It was previously mapped as Montini Formation, basalt member (Anderson, 1965) and lava and tuff in the third canyon of the Bruneau Formation (Malde, 1987). The tuffaceous materials in this unit are probably from several sources that may include the Sinker Butte volcano. The tuff of Swan Falls Dam is above the Idaho Group (QTsu) and the basalt of Swan Falls Reservoir (QTsf); it is beneath the basalt of Sinker Butte (Qsb) and the lower basalt of Moore Road (Qms). The unit pinches out over the thickest part of the basalt of Swan Falls Reservoir (QTsf) in NW1/4 sec. 17, T. 2 S., R. 1 E. Reference locality: Roadcut in Swan Falls Road grade, SW1/4 sec. 17, T. 2 S., R. 1 E. Thickness: Up to 100 feet (30 m).

QTtr Tuff of Red Trails (Pleistocene or Pliocene)— Stratified, gold-to black-colored, fresh and palagonitized basaltic tuff. Unit is in the southwest corner of the area and was previously mapped as Montini Formation, basalt and tuff member (Anderson, 1965), Bruneau Formation, basaltic lavas undivided and sediments (Ekren and others, 1981), water-laid basaltic tuff derived from the Montini volcano (Malde, 1987a), and tuff member at the top of older lake beds of the Bruneau Formation (Malde, 1987b). The tuffaceous sediments of this unit are from unknown sources that may include Sinker Creek Butte and an older volcano downstream from the Montini volcanic complex (Qmvc) in sec. 6, T. 3 S., R. 1 E. The upper surface of the unit appears to be striped of overlying fine-grained sediments in much of the exposure in the southwest part of the map. This stripping was apparently not caused by normal erosional processes and could have occurred during the Bonneville Flood. With several other units, the tuff of Red Trails partly fills a paleobasin eroded into Idaho Group (QTsu) sediments. These basin-filling units include the basalt of Otter Massacre Site (QToms), which underlies the tuff of Red Trails, and the lower basalt of Nahkis Ranch (QTur) and the Montini volcano complex (Qmvc), which are above it.

Reference locality: North end of alcove in east side of Snake River canyon, SE1/4 SW1/4 sec. 5, T. 3 S., R. 1 E. Thickness: Up to 150 feet (45 m).

QTbf Tuff of Big Foot Bar (Pleistocene or Pliocene)—Gray to green, stratified basaltic tuffs. The unit includes an underlying white clay, silt, and fine sand layer. The unit is in the southeast and was previously unrecognized as a separate unit. The source for this unit is unknown. The tuff of Big Foot Bar is above the lower basalt of Clarks Ferry (Tclf) and beneath the upper basalt of Clarks Ferry (QTcfu). Erosion occurred between the deposition of the tuff of Big Foot Bar and the emplacement of the upper basalt of Clarks Ferry (QTcfu).

Reference locality: Southeast-facing slope, SE1/4 SE1/4 sec. 23, T. 3 S., R. 1 E. Thickness: Up to 50 feet (15 m).

QTsu Idaho Group, undivided (Pliocene or Miocene)—White to tan to gray, clay- to gravel-sized sediments deposited in fluvial and lacustrine environments. Contained within the sedimentary sections are minor amounts of basaltic tuff and unweathered sillicic ash. The unit is in the southwest part of the Snake River canyon. It is the oldest unit exposed in the area. The Idaho Formation was named by Cope (1883), further defined by Lindgren (1889), and more fully described by Russell (1902). These researchers included both volcanic and sedimentary sequences in the formation. Malde and Powers (1962) raised the formation to group status and subdivided it into a number of lithostatigraphic units containing both volcanic and sedimentary sequences. In the Wild Horse Butte quadrangle previous scientists have subdivided the Idaho Group sediments into a number of formations including the following: (1) Jackson Butte, Montini, and Oreana Formations and coelcivum (Anderson, 1965); (2) Glens Ferry Formation and sediments of the Bruneau Formation, lower part (Ekren and others, 1981); (3)
Glenns Ferry Formation and Bruneau sediments (Amini, 1983); and (4) Glenns Ferry and Bruneau Formations (Malde, 1987). Because of uncertainties and inconsistencies in the K-Ar ages of the volcanic units that we have defined in this mapping, we are unsure of correlations with the previously defined lithostratigraphic units. Therefore, for this mapping we have adopted the more general "Idaho Group" terminology and are restricting its usage to the sedimentary lithologies. We suspect that most of the Idaho Group undivided sediments in the quadrangle are equivalent to the Glenns Ferry Formation as defined elsewhere in the Snake River Plain (Malde and Powers, 1962). Erosional unconformities can be mapped within the Idaho Group sequences, and disconformities exist where sedimentary deposition was interrupted by the eruption and deposition of volcanioclastic materials.

**Thickness:** Up to 600 feet (180 m).

**Tcbu Upper tuff of Castle Butte area (Pliocene or Miocene)—Faintly bedded, subangular, glassy pyroclastic fragments ranging in size from 1 centimeter in diameter to very fine silt and ash (Amini, 1983). In addition, it is laminated and contains some volcanic and sedimentary structures. The unit is in the south-central part of the area and is noted by a railroad track symbol. It was previously mapped as Montini Formation, basalt tuff member (Anderson, 1965) and Montini Tuff (Amini, 1983) and described as erupted from the Montini volcano (Malde, 1987). The tuff is everywhere enclosed within the Idaho Group (Qtu) sediments. However, it is underlain in NW1/4 sec. 25, T. 3 S., R. 1 E., by the lower tuff of Castle Butte area (TcbI). On the southwest side of the small peninsula in NE1/4 sec. 26, T. 3 S., R. 1 E., the upper tuff of Castle Butte area pinches out against a paleoslope of talus shed from the lower basalt of Clarks Ferry (TcfI), which forms a resistor above the talus slope to the northeast. At this locality the upper tuff of Castle Butte area is overlain by a cobble gravel of unknown origin consisting mainly of rounded granitic cobbles. This tuff unit probably was erupted from Castle Butte, a phreato-volcanic complex about 1.5 miles south of the exposures of this unit and located on the west side of the Snake River in the Castle Butte quadrangle.

**Thickness:** Up to 6 feet (2 m).

**Tcbl Lower tuff of Castle Butte area (Pliocene or Miocene)—Proximal cinders and scoriaceous chilled bombs (up to 6 inches across). Color grades from black at the base to brown at the top, and the unit is capped by a layer of basaltic ash 2 feet (0.6 m) thick. The unit is in a small area in the southeast part of the map and was previously mapped as landslide deposits (Anderson, 1965). A small phreatic or cinder eruption probably created the unit. The exposures are on line with the multiple phreatic volcanoes to the south in the Castle Butte quadrangle that make up the Castle Butte volcano complex. The eruption appears to have caused a local hiatus in the deposition of the Idaho Group (Qtu) sediments that overlie it. The unit is below the upper tuff of Castle Butte area (Tcbu).

**Reference locality:** Exposures in SW1/4 NW1/4 sec. 25, T. 3 S., R. 1 E.

**Thicknes:** Up to 100 feet (30 m).

**BASALTIC UNITS**

**Qwe? Basalt of Wind Caves? (Pleistocene)—Massive basalt with some large plagioclase laths and abundant, very large olivine phenocrysts in cumolaphyric clumps. Only a small part of the entire unit is in the southeast part of the area, and it was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965). Lithologic similarities suggest that the source for the unit may be Hill 3456 (elevation), informally known as the Wind Caves volcano, in secs. 17 and 18, T. 2 S., R. 3 E., in the Christmas Mountain quadrangle. The basalt of Wind Caves? lies on the upper basalt of Old Powerline Road (Qqpru) and is not overlain by any other unit.

**Reference locality:** Area around VABM 2973, E1/2 sec. 24, T. 3 S., R. 1 E.

**Thicknes:** Up to 30 feet (10 m).

**Qppu Upper basalt of Promontory Point (Pleistocene)—Diktytaxitic with abundant, large olivine phenocrysts in hand sample. The unit covers much of the central and northern parts of the quadrangle and was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965) and basalt of Big Foot Butte (Malde, 1987). This flow probably erupted from one of the volcanoes north and east of the quadrangle. The exposures of this unit consist of thin and irregular basalt flow margins and an underlying, but virtually unexposed, fine-grained white sediment of unknown thickness. The upper basalt of Promontory Point is stratigraphically above the tuff of Moore Road (Qqmr), the lower basalt of Promontory Point (Qqpl), the tuff of Red Trails (Qtr), and the lower basalt of Old Powerline Road (Qqpr), but it is not overlain by any other unit. It may be correlative with the upper basalt of Old Powerline Road (Qqpr).

**Reference locality:** Rim on east side of Red Trails draw, NW1/4 NE1/4 sec. 5, T. 3 S., R. 1 E.

**Thicknes:** Up to 20 feet (6 m) at edge of unit.

**Qqpru Upper basalt of Old Powerline Road (Pleistocene)—Aphanitic to diktytaxitic and nearly phryric, although in hand samples some sparse, small to tiny plagioclase laths and some large olivine phenocrysts. The unit covers much of the east side of the quadrangle and...**
was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965), basalt of Wild Horse Butte and basalt of Big Foot Butte (Amini, 1983), and basalt of Big Foot Butte (Malde, 1987). The source for the unit is unknown, but it was probably erupted from a volcano north and east of the quadrangle. In the southeast the upper basalt of Old Powerline Road is the highest resistor on the northeast rim of the Snake River canyon and is thick, filling a slight paleotopographic low. The unit is above the upper basalt of Clarkes Ferry (QTcfu), the lower basalt of Promontory Point (Qppl), and the lower basalt of Old Powerline Road (Qoprl). It is below the basalt of Wind Cavest (1) (Qwce1). The upper basalt of Old Powerline Road may be correlative with the upper basalt of Promontory Point (Qppu), but it is mapped separately on the basis of hand sample phenocryst content.

K-Ar dates: 8.94±0.84 (unreliable) and 1.57±0.16 million years (Amini and others, 1984).

Reference locality: Rim that Old Powerline Road crosses, NE1/4 NW1/4 sec. 24, T. 3 S., R. 1 E.

Thickness: Typically 25-50 feet (8-15 m), but 100 feet (30 m) in the southeast.

Qoprl Lower basalt of Old Powerline Road (Pleistocene)—Aphyric in hand sample. The unit is exposed in a small area near the center of the map and was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965). The flows of this unit erupted from an unknown volcano, probably north or east of the quadrangle. The lower basalt of Old Powerline Road is stratigraphically above the lower basalt of Promontory Point (Qppu) and below the upper basalt of Promontory Point (Qppu) and the upper basalt of Old Powerline Road (Qopru).

Reference locality: Exposures in S1/2 sec 11, T. 3 S., R. 1 E.

Thickness: Up to 40 feet (12 m).

Qppu Lower basalt of Promontory Point (Pleistocene)—Diktytactic with abundant, medium-sized plagioclase laths, and sparse olivine phenocrysts in hand sample. It includes an underlying sediment and at some localities a thin, basal tuffaceous layer. The unit is present throughout much of the western and central parts of the area and was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965), Promontory Basalt (Amini, 1983), and the basalt of Promontory Point (Malde, 1987). The source for these flows has not been identified, but they may have erupted from a volcano north and east of the quadrangle. The unit contains large flow lobes in the northern part of its exposure on the Snake River canyon rim. It fills a paleotopographic low at the eastern end of the large alcove south of Promontory Point and is overlain at the rim on Promontory Point by a thin gravel layer. The lower basalt of Promontory Point covers a broad area and is related stratigraphically to several other units. It is above the upper basalt of Moore Road (Qmu), the lower basalt of Moore Road (Qmfl), the tuff of Swan Falls Dam (QTsf), the basalt of Sink Butte (Qsb1), the Montini volcanic complex (Qmve), the upper basalt of Nahans Ranch (Qtnr), the tuff of Red Trails (QTtr), the upper basalt of Clarkes Ferry (QTcfu), and the Idaho Group (QTiu). It is below the upper basalt of Old Powerline Road (Qppu), the lower basalt of Old Powerline Road (Qoprl), the upper basalt of Promontory Point (Qppu), and the tuff of Moore Road (Qmr). Malde (1987) has tentatively assigned this basalt to the Jaramillo Normal Polarity Subchron (0.97-0.90 million years in age).

K-Ar dates: 0.78±0.04 million years (Amini and others, 1984). Sample from east edge of Sink Butte quadrangle.

Reference locality: Canyon rim at west end of Promontory Point, sec. 30, T. 2 S., R. 1 E., Sink Butte quadrangle.

Thickness: Up to 150 feet (45 m).

Qmr Upper basalt of Moore Road (Pleistocene)—Generally aphyric with some small plagioclase and olivine phenocrysts. The unit consists of (1) a basal layer of cinders which may or may not be genetically related to the eruption of the overlying flows, (2) a lower, thick sequence of water-affected basalt which is pervasively altered, and (3) an upper sequence of several, unaltered, scoriaceous thin flows. The upper basalt of Moore Road is exposed in a small area in the east wall of the Snake River canyon in the northwest part of the map. It was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965) and Swan Falls Rim Basalt (Amini, 1983). A source for the flows of this unit is not definitely known, but they probably erupted from one of the volcanoes north and east of the quadrangle. The upper basalt of Moore Road is above the lower basalt of Moore Road (Qmur); it pinches out over the thickest exposures of the basalt of Swan Falls Reservoir (QTsf) and is beneath the tuff of Moore Road (Qmr), the upper basalt of Promontory Point (Qppu), and the lower basalt of Promontory Point (Qppl).

K-Ar date: 7.34±0.39 million years (Amini and others, 1984). This date is unreliable.

Reference locality: Upper part of roadcut on Swan Falls Road grade, NE1/4 NW1/4 sec. 20, T. 2 S., R. 1 E.

Thickness: Up to 50 feet (15 m).

Qmu Lower basalt of Moore Road (Pleistocene)—Essentially aphyric, although in hand samples some widely scattered, altered olivine phenocrysts. The internal character of this unit is similar to the overlying upper basalt of Moore Road (Qmut) in that its flows overlie a layer of red cinders and the lower flows are water-affected, altered, and spheroidally weathered. The upper part of the unit consists of numerous thin flows of scoriaceous basalt. The lower basalt of Moore Road is exposed in a small area of the east wall of the Snake River canyon in the northwest.
corner of the quadrangle. It was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965) and Swan Falls Rim Basalt (Amini, 1983). The volcano that eroded this unit is unknown, but it is probably one of the volcanoes north and east of the quadrangle. The lower basalt of Moore Road is above the tuff of Swan Falls Dam (QTsf6); it pinches out above the thickest exposures of the basalt of Swan Falls Reservoir (QTsf3) and is below the upper basalt of Moore Road (Qmtr) and the lower basalt of Promontory Point (Qppl).

**K-Ar date:** 2.67±0.1 million years (Amini and others, 1984).

**Reference locality:** Upper part of roadcut on Swan Falls Road grade, NE1/4 NW1/4 sec. 20, T. 2 S., R. 1 E.

**Thickness:** Up to 30 feet (10 m).

**Qsib Basalt of Singer Butte (Pleistocene)—** Cumulophyric rosettes and clumps of abundant, large to very large (as much as 1.5 cm) plagioclase phenocrysts and small to medium-sized olivine crystals. Within the area, the unit contains several massive basalt flows. In the Singer Butte quadrangle, the unit contains a basin pillowcd section and appears to have flowed down paleoclines. The unit has a large areal exposure in the adjacent Singer Butte quadrangle, but within this area it is only exposed along 1/2 mile of the east wall of the Snake River canyon, south of Swan Falls Dam. It was previously mapped as Montini Formation, basalt member (Anderson, 1965), Emigrant Basalt (Amini, 1983), and rosette-spar basalt (Male, 1987). The unit erupted from the Singer Butte volcano. Within the area the basalt of Singer Butte is above the tuff of Swan Falls Dam (QTsf6) and below the lower basalt of Promontory Point (Qppl).

**K-Ar date:** 1.08±0.14 million years (Amini and others, 1984). Sample from east edge of Singer Butte quadrangle.

**Reference locality:** Singer Butte volcano, secs. 24 and 19, T. 2 S., R. 1 W., and 1 E., Singer Butte quadrangle.

**Thickness:** Up to 60 feet (18 m).

**Qmve Montini volcanic complex (Pleistocene)—** Aphric. The unit forms a maficr depression and is characterized by near-vent appearing basaltic tuffs and lava flows. It contains one area of basaltic welded tuff or agglomerate as well as an intracratonic lava flow. The Montini volcanic complex is at the western edge of the quadrangle, in both the east and west walls of the Snake River canyon. The unit was previously mapped as (1) Montini Formation, basalt and tuff member (Anderson, 1965), (2) Bruneau Formation, basaltic lavas undivided (Eiken and others, 1981), (3) Montini Basalt (Amini, 1983), and (4) the central plug of the Montini volcano (Malde, 1987). The Montini volcanic complex basalts were erupted through, and thus crossover, the basalt of Otter Massacre Site (QToms), the tuff of Red Trails (QTrt), and the Idaho Group (QTiu). In addition, the unit is above the upper and lower basalts of Nahas Ranch (QTuru and QTTrl) and stratigraphically below the lower basalt of Promontory Point (Qppl). A small area of Melon Gravel (Qm) is in the depression in sec. 6, T. 3 S., R. 1 E.

**Reference locality:** East of the confluence of Sinker Creek and the Snake River (Sinker Butte quadrangle); NE1/4 NE1/4 sec. 7, SE1/4 SE1/4 sec. 6, T. 3 S., R. 1 E.

**Thickness:** Up to 500 feet (150 m) at the center of the complex.

**QTcfu Upper basalt of Clarks Ferry (Pleistocene or Pliocene)—** Predominantly abundant, large olivine crystals with some sparse, tiny to small plagioclase needles. The upper basalt of Clarks Ferry was emplaced after a period of fairly extensive erosion. Flows from the unit are pillowd in some areas and are massive and closely jointed where the flows were ponded after cascading over erosional escarpments. The unit is present on the northeast side of the Snake River canyon in the southeast part of the area and was previously mapped as Snake River Basalt, undifferentiated (Anderson, 1965), Big Foot Butte pillow lava (Amini, 1983), and basalt of Big Foot Butte (Male, 1987). A source for the flows of this unit is unknown, but they were probably erupted from volcanoes north and east of the quadrangle. The upper basalt of Clarks Ferry is above the tuff of Big Foot bar (QTbf6), the upper basalt of Nahas Ranch (QTuru), the lower basalt of Clarks Ferry (Tcf6), and the Idaho Group (QTiu). It is beneath the lower basalt of Promontory Point (Qppl).

**K-Ar dates:** 0.95±0.04, 2.14±0.15, and 2.55±0.21 million years (Amini and others, 1984). All three dates were obtained from samples from a single locality.

**Reference locality:** Beginning of unimproved road grade into Snake River canyon, NE1/4 SE1/4 sec. 26, T. 3 S., R. 1 E.

**Thickness:** Up to 175 feet (53 m).

**QTbf6 Basalt of Big Foot Butte (Pleistocene or Pliocene)—** Some large plagioclase phenocrysts in hand sample. The unit is at the east edge of the area. Its source volcano, Big Foot Butte, is a large flat-topped shield surrounded by flows of several younger units, including the upper basalt of Old Powerline Road (Qspu), that were erupted by volcanoes farther to the north and east. Only the west side of the volcano is within the mapped area.

**Reference locality:** Big Foot Butte, secs. 28, 29, 32, 33, and 34, T. 2 S., R. 2 E. and secs. 4 and 5, T. 3 S., R. 2 E., Big Foot Butte quadrangle.

**Thickness:** Up to 150 feet (45 m) in this quadrangle, but the entire volcano is 360 feet (108 m) tall.

**QTuru Upper basalt of Nahas Ranch (Pleistocene or Pliocene)—** Some to abundant, small to large phenocrysts
of olivine and sparse, small plagioclase laths. The unit is composed of near-vent appearing layers of basaltic tuff and closely jointed, bubbly lava masses. Within the unit a layer of agglomerate or basaltic welded tuff, located east of elevation point 2829 in S1 T4 sec. 10, T. 3 S., R. 1 E., forms a resistant rim. The upper basalt of Nahas Ranch is exposed east of the Snake River canyon in the central part of the area and was previously mapped as Jackass Butte Formation, basalt member (Anderson, 1965). A possible venting area for this basalt is at the eastern end of the alcove, in sec. 10, T. 3 S., R. 1 E., where the unit is thickest. The unit is above the lower basalt of Nahas Ranch (QTtrf), the basalt of Thomas Flats (Tf), the lower basalt of Clarks Ferry (Tcf), and the Idaho Group (QTsi); it is below the lower basalt of Promontory Point (Qopp), the Montini volcanic complex (Qmvnc), and the upper basalt of Clarks Ferry (QTcfu).

Reference locality: Along an unimproved road at the rim of alcove in Snake River canyon, NW¼ sec. 10, T. 3 S., R. 1 E.

Thickness: Up to 200 feet (60 m).

QTtrf Lower basalt of Nahas Ranch (Pleistocene or Pliocene)—Aphyric in some hand samples. Other samples contain abundant, tiny to small olivine phenocrysts, which typically are altered and in glomerophyric clumps. The unit consists of a thick, lower, pillowed and rubbly section and a thin, upper, subaerial and massive rim. It is on both sides of the Snake River canyon in the middle of the west side of the quadrangle. The unit was previously mapped as Montini Formation, basalt and tuff member (Anderson, 1965), Bruneau Formation, basaltic lavas undivided (Ekren and others, 1981), and as lava from the Montini volcano (Malde, 1987). The source for this unit is presumed to be volcanoes north and east of the quadrangle. The unit thins against the thickest exposures of the tuff of Red Trails (QTtr) and appears to be the uppermost unit in a series of basin filling units. It is above the tuff of Red Trails (QTtr), the basalt of Otter Massacre Site (QToms), the lower basalt of Clarks Ferry (Tcf), and the basalt of Thomas Flats (Tf); it lies beneath the Montini volcanic complex (Qmvnc) and the upper basalt of Nahas Ranch (QTnr).

Reference locality: Rim on east side of Snake River canyon, E½ sec. 8, T. 3 S., R. 1 E.

Thickness: Up to 200 feet (60 m).

QTsf—Basalt of Swan Falls Reservoir (Pleistocene or Pliocene)—Diktytaxitic upper sequence with small plagioclase laths and fairly massive flows. The lower sequence contains distinctive cumulusphyric clumps and rosettes of large plagioclase and medium-sized olivine phenocrysts and is scoriaceous and near-vent appearing. The lower flows are thickest at the small alcove in the Snake River canyon in the northeast corner of the quadrangle. This thickness and the near-vent appearance of the flows suggest that the source vent for this unit may be in secs. 17 and 18, T. 2 S.R. 1 E. The unit is present in the lower story of the Snake River canyon in the northwest part of the area and was previously mapped as Otter Basalt (Anderson, 1965), basalt of Swan Falls Reservoir (Amini, 1983), and the basalt of Swan Falls (Malde, 1987). In a roadcut in the Swan Falls Road grade, the lower flows are cut by several thin (up to 2 feet thick) sills and dikes. At Promontory Point, the unit has a thick, lower pillowed section. The base of the unit is not exposed within the area, but in areas outside the quadrangle it is above the Idaho Group (QTsi). The basalt of Swan Falls Reservoir is below the tuff of Swan Falls Dam (Qtsfd) everywhere it is exposed except in the alcove in the extreme northeast corner of the area, where it is overlain by the upper basalt of Promontory Point (Qopp). At this alcove four units—the tuff of Swan Falls Dam (Qtsfd), the upper basalt of Moore Road (Qmr), the lower basalt of Moore Road (Qmr), and the tuff of Moore Road (Qmr)—pinch out against the basalt of Swan Falls Reservoir.

K-Ar date: 1.58±0.13 million years (Amini and others, 1984).

Thickness: 100-400 feet (30-120 m).

QToms Basalt of Otter Massacre Site (Pleistocene or Pliocene)—Nearly aphyric; small to large olivine phenocrysts in some hand samples. The unit is exposed in the lower story of the Snake River canyon in the southwest part of the area and in the draw west of Thomas Flats. It was previously mapped as Otter Basalt (Anderson, 1965), Bruneau Formation, basaltic lavas undivided (Ekren and others, 1981), and basalt of the Otter Massacre Site and basalt of Swan Falls (Malde, 1987). The basalt of Otter Massacre Site was erupted from Sink Creek Butte, its source volcano, and flowed down an erosional paleoslope to form a lower thick sequence of pillowed and water-affected basalt flows overlain by massive, subaerial-appearing upper flows. The unit is above, and ends within, Idaho Group (QTsi) sediments; it is beneath the tuff of Red Trails (QTtr) and the lower basalt of Nahas Ranch (QTnr) and is crosscut by the central volcanic area of the Montini volcanic complex (Qmvnc). As it is mapped, the unit may include some of the underlying Idaho Group (Tiu) sediments.

Reference locality: Sink Creek Butte volcano, secs. 1 and 2, T. 3 S., R. 1 W., Sink Creek quadrangle.

Thickness: Up to 100 feet (30 m).

Twbh U. Upper basalt of Wild Horse Butte (Pliocene or Miocene)—Variable, predominantly plagioclase phenocrysts. Generally, the unit consists of numerous (up to 10) subaerial flows. However, in some areas it contains a
lower pillowed sequence. It forms the rims of two buttes on the west side of the Snake River and was mapped previously as (1) Jackass Butte Formation, basalt member (Anderson, 1965), (2) Bruneau Formation, older basaltic lavas (Ekren and others, 1981), (3) Wild Horse Butte basalt (Amini, 1983), and (4) basalt of Wild Horse Butte (Malde, 1987). We suspect that the unit was erupted from volcanoes north and east of the quadrangle, but an exact source is unknown. The lithologic variability of the unit suggests it may have more than one source. The stratigraphic position of the upper basalt of Wild Horse Butte is above the lower basalt of Wild Horse Butte (Twbh) and the Idaho Group (QTu). The positions of the buttes suggest that the units which cap them are outliers of the basaltic units exposed in the east wall of the Snake River canyon, but exact correlations are not yet possible.

K-Ar dates: 1.92±0.16 and 3.87±0.28 million years (Amini and others, 1984). Both dates are from samples collected at one locality.

Reference locality: Upper rim of Wild Horse Butte, sec. 27, T. 3 S., R. 1 E.

Thickness: Up to 50 feet (15 m).

Tff Basalt of Thomas Flats (Pliocene or Miocene)—Subophitic and aphric. The unit is characterized by a thick lower section of water-affected basalt, which in some areas is weathered to a brown-colored slope, overlain by a thin upper sequence of one or two subaerial-appearing flows. The unit includes a thin overlying layer of palagonitized tuff. The basalt of Thomas Flats is present in the southwest part of the area in the walls of an alcove on the east side of the Snake River canyon. It was mapped previously as Jackass Butte Formation, basalt member (Anderson, 1965). The source of this unit is unknown, but it was probably erupted from one of the volcanoes north and east of the quadrangle. The unit is above the lower basalt of Clarks Ferry (Tff) and below the lower basalt of Nahas Ranch (QTnr) and the upper basalt of Nahas Ranch (QTtr).

Reference locality: Northwest rim of alcove to Snake River canyon, sec. 15, T. 3 S., R. 1 E.

Thickness: Up to 75 feet (23 m).

Twbh Lower basalt of Wild Horse Butte (Pliocene or Miocene)—Aphanitic and nearly aphric in hand specimen; some sparse, small plagioclase and olivine phenocrysts. In secs. 16 and 21, T. 3 S., R. 1 E., it is overlain by 4 to 5 feet of gravel and other sediments that are included within the unit. The unit, along with the upper basalt of Wild Horse Butte (Twbb), caps two buttes on the west side of the Snake River in the southwest part of the area. It was previously mapped as (1) Jackass Butte Formation, basalt member (Anderson, 1965), (2) Bruneau Formation, basaltic lavas-older lavas (Ekren and others, 1981), (3) Wild Horse Butte Basalt (Amini, 1983), and (4) basalt of Wild Horse Butte (Malde, 1987). Generally, the unit appears to be the distal edge of one or two flows. This characteristic and the position of the unit suggest that it is an outlier of, and may be correlative with, one or more of the units which are exposed on the east side of the Snake River. The lower basalt of Wild Horse Butte is above the Idaho Group (QTiu) and beneath the upper basalt of Wild Horse Butte (Twbu).

Reference locality: Lower rim on east side of Wild Horse Butte, sec. 27, T. 3 S., R. 1 E.

Thickness: Up to 60 feet (20 m).

Tf Clarks Ferry basalt (Pliocene or Miocene)—Compound unit. It consists of flows erupted from two or more volcanoes north and east of the quadrangle; in some areas it has a lower pillowed section and may include interbedded sediments. The unit is exposed along a long stretch of the rim on the east side of the Snake River canyon in the southern part of the area. It was previously mapped as Jackass Butte Formation, basalt member (Anderson, 1965) and basalt of Wild Horse Butte (Malde, 1987). The lower basalt of Clarks Ferry may be correlative with one or both of the upper and lower basalt of Wild Horse Butte (Twbh and Twbb), which cap the buttes west of the Snake River. It is above the Idaho Group (QTiu) and beneath the upper basalt of Clarks Ferry (QTcfu), the lower basalt of Nahas Ranch (QTnr), the tuff of Big Foot bar (QTbf), the upper basalt of Nahas Ranch (QTtr), and the basalt of Thomas Flats (Tff).

Thickness: Up to 100 feet (30 m).

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