RADIOMETRIC DATING, VOLCANIC STRATIGRAPHY, AND SEDIMENTATION IN THE BOISE FOOTHILLS, NORTHEASTERN MARGIN OF THE WESTERN SNAKE RIVER PLAIN, ADA COUNTY, IDAHO

DREW M. CLEMENS *Department of Geology, Arizona State University, Tempe, AZ 85287-1404*
SPENCER H. WOOD *Department of Geosciences, Boise State University, Boise, ID 83725*

Correlating the geologic units of the southwestern and northeastern margins of the western Snake River Plain has proven difficult due to numerous faults, discontinuous volcanic units, and complex volcanic and sedimentary facies relationships. A new suite of K-Ar ages and chemical analyses of Neogene rhyolite and basalt exposed along the northeastern margin of the western Snake River Plain are presented in this paper. These ages provide a geochronology for sedimentation and volcanism in the western Snake River Plain near Boise over the last 11 million years. In addition, these data also constrain the timing of the earliest fluvio-lacustrine Idaho Group sedimentary deposits near Boise.

REGIONAL GEOLOGY

Although the Snake River Plain is a continuous physiographic lowland traversing southern Idaho, the western and eastern parts differ markedly in styles of volcanism and tectonic origin. Normal faults of the western plain are steeply dipping, trend N40°W, truncate north-south trending faults of the western Idaho Fault Belt (Hamilton, 1962), and down-drop the valley floor 320-3,400 m (Wood and Burnham, 1983, 1987; Wood, 1989). The boundaries of the eastern plain are defined not by prominent faults with large amounts of vertical displacement, but by late Cenozoic deposits dipping or down-warped into the eastern plain itself (Leeman, 1982, 1989; Allmendinger, 1982; Malde, 1991). Gravity and magnetic surveys (Mabey, 1982) and deep (>4,200 m) borehole data suggest that the Idaho Group sediments in the western Plain are underlain by over 2,000 m of interbedded basalts and tuffaceous sediments (Wood and others, 1980), whereas the late Tertiary and Neogene sequences of the eastern plain are thought to be underlain by a much thinner, and perhaps unrelated sequence of basalts and sediments (Leeman, 1982, 1989; Malde, 1991). Bonnichsen and others (1991) suggest that the two geomorphic regions also differ in their patterns of Neogene volcanism and products: western plain volcanism began with extrusion of rhyolitic lavas followed by the eruption of ash-flow tuffs. Rhyolite volcanism was followed within a few million years by the eruption of compositionally evolved basalts from phreatomagmatic shield volcanos typically erupting through the lake which covered the western plain region (Godchaux and Bonnichsen, 1991). According to Bonnichsen and others (1991), eastern Snake River Plain volcanism began with the eruption of aerially extensive ash flow tuffs from large caldera complexes, which were later filled in to varying degrees with rhyolite lavas and basaltic lavas from shield volcanos.

Malde and Powers (1962) and Armstrong and others (1975, 1980) divided the Neogene rhyolite stratigraphy of southwestern Idaho into two groups based on age and lithology: (1) the 15-16.4 Ma precious-metal mineralized, hydrous mineral-bearing tuffs and flows (2-3% biotite ± hornblende ± pyroxene), which include the Silver City, Wall Creek, and Jarbidge rhyolites; and (2) the 9-14 Ma non-mineralized, relatively anhydrous (sanidine, plagioclase ± pyroxene) Idavada Group volcanics. The silicic volcanics young from southwestern Idaho toward the Mount Bennett Hills and Twin Falls in the east (fig. 1a), and are related at least in time to the Miocene track of the Yellowstone Hotspot (Armstrong and others, 1975, 1980; Leeman, 1982).

Overlying the silicic volcanic rocks is a controversial sequence of basalt flows and basaltic tuffs with silicic ash interbeds called the Banbury Basalt (Malde and Powers, 1962; Armstrong and others, 1975). The somewhat erratic radiometric dates (weighted mean age of 9.4 ± 0.6 Ma (Armstrong and others, 1980) and lack of a dominant lacustrine facies in the overlying Banbury Basalt led Wood and Anderson (1981) to question the placement of the Banbury Basalt within the Idaho Group. The Idavada Group and Banbury Basalt Formation are overlain by the Neogene Idaho Group, consisting of 3 major units: 1) the Poison Creek Formation, which consists of silicic ash and tuffaceous material in massive beds with some beds of cemented arkosic sands, gravel, and basalt volcaniclastics; 2) the Chalk Hills Formation, which consists of a silt and sand unit with numerous thin layers of fine silicic ash; 3) the Glenns Ferry Formation, which consists of fluvio-lacustrine

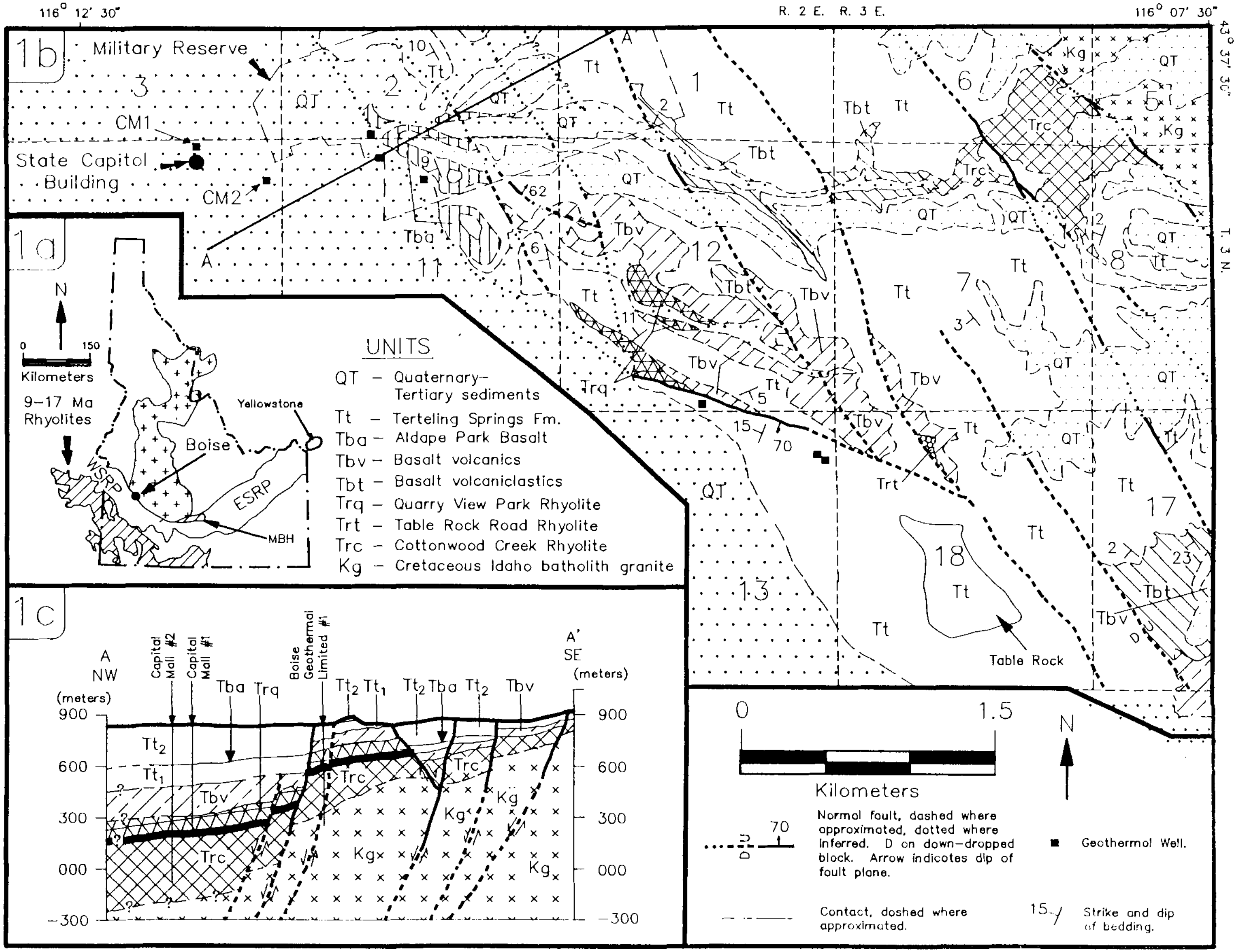

FIGURE 1. *a.* **Regional map of central and southwestern Idaho showing the western Snake River Plain (WSRP), eastern Snake River Plain (ESRP), Mount Bennett Hills (MBH) and Miocene rhyolites (Stewart and Carlson, 1978);** *b.* **geologic map of the Boise area after Burnham and Wood (in press), Boise Basalt Volcanic Assemblage composed of Tbv and Tbt;** *c.* **cross section of the Boise front after Burnham and Wood (in press), solid line between Trq and Trc is an arkosic sand separating the two units.**

sediments with minor basalt flows, respectively. The Neogene units are in turn overlain by the Quaternary basalt flows and lacustrine sediments of the Bruneau Formation and Snake River Group gravels (Kimmel, 1982; Malde, 1991; and Wood, in review).

GEOLOGIC SETTING

Idaho batholith (Kg)

The northeastern margin of the western plain and the mountains to the north are dominated by the Cretaceous Idaho batholith, which contains numerous Eocene mafic and felsic dikes, and forms the basement rock in the Boise foothills. This region was probably a topographic high even in the middle Neogene, and its dissected, southern flanks near the western plain's margin likely restricted the areal extent of the on-lapping volcanic sequences, which may account for the scattered outcrop pattern of the volcanic units.

Cottonwood Creek Rhyolite (Trc)

Field mapping and borehole data (Boise Geothermal Limited #1, Capital Mall #1 & 2) (Wood and Burnham, 1987, 1983) (fig. 1c) suggest that the oldest exposed unit in the Boise front is a rhyolite informally named the rhyolite of Cottonwood Creek (Trc) by Burnham and Wood (in press). It is formally named here the Cottonwood Creek Rhyolite (Trc) of the Idavada Group and interpreted to be a lava flow based on the presence of vertical and contorted flow banding, a basal crumble or flow breccia, and no remnant pyroclastic textures (Bonnichsen and Kauffman, 1987). Where exposed, the 120 m thick (W. L. Burnham, personal communication), sparsely phyric (5% sanidine, 1-2% plagioclase) lava flow overlies a 10 m thick sequence of Plinian air-fall pumice deposits 2-3 m thick inter-layered with arkosic sands. The pumice deposits consist of 1-5 cm pumice fragments and 10-60 cm clasts of fiamme-rich vitrophyre, granite, and basalt embedded in ash. Based on the Md_ϕ vs. distance plot of Fisher and Schmincke (1984, fig. 6-36, p. 155) the size of the predominant lithics and pumice clasts suggest that the vent which produced the Plinian deposit, and perhaps the overlying rhyolite lava flow, is within 8 km of the outcrop. The base of an identical rhyolite occurs in Capital Mall No. 2 at a depth of 1000 m and overlies a sandy conglomerate, the deepest unit yet drilled beneath the Boise area.

Table Rock Road Rhyolite (Trt)

A small exposure (<300 m^2) of glassy rhyolite occurs northwest of Table Rock (fig. 1b) and has been informally named by Burnham and Wood (in press) as the rhyolite of Table Rock Road (Trt) and is formally named here the Table Rock Road Rhyolite (Trt) of the Idavada Group. Trt is phyric (5-10% plagioclase, 10-15% sanidine), differentiating it from the sparsely phyric Trc. Only the upper portion of the unit is exposed and it is unconformably overlain by the lower basalts of the Boise Basalt Volcanic Assemblage. Owing to the limited exposure, it cannot be discerned whether Trt represents a lava flow, lava dome, or a densely welded ash flow tuff. To date, no petrographically similar unit has been found in the Boise front or in the cuttings of the deep geothermal wells, suggesting that Trt has a very small areal extent. Both the phenocryst assemblage and the geochemistry of Trt, as will be shown later, are very similar to those of Trc, which suggests that they had a common magma source. These similarities would suggest that Trc and Trt are correlative, though due to the large phenocryst population of Trt, we feel it is important to distinguish between the two units.

Quarry View Park Rhyodacite (Trq)

The lithology of the Capital Mall #2 geothermal well (fig. 1c) shows that a 30 m thick arkosic sand and conglomerate layer overlies Trc, and is in turn overlain by a 120 m thick, phyric rhyodacite (20-25% plagioclase, 2-3% ortho- and clinopyroxene ± hornblende). Wood and Burnham (1983, 1987) informally named this rhyodacite and correlated it with the plagioclase-rich rhyodacite of Quarry View Park (Trq) (fig. 1b). The unit is formally named here the Quarry View Park Rhyodacite (Trq) of the Idavada Group. Trq is a platy rhyodacite about 35 m thick, has normal remnant magnetic polarity, and displays various degrees of alteration and silicification, perhaps related to geothermal water which has percolated through the fault systems in the area. Drill core from this unit indicates the presence of a basal breccia, which suggests that Trq is not a densely welded ash flow tuff, but is either a dome or a lava flow. The exposure near Quarry View Park is crosscut by a glassy, phyric (20-25% plagioclase, 5% ortho- and clinopyroxene and primary hornblende, which occur as dark clots) rhyodacite dike trending N45°W;72°SW and consists of 0.2 m × 1.5 m nearly horizontal columns containing occasional inclusions from the surrounding rhyolite (Trq) unit.

Boise Basalt Volcanic Assemblage (Tbt and Tbv)

Unconformably overlying both rhyolite units is a 150 m sequence of basalt flows (Tbv), including the basalt of Pickett Pin Canyon (Tpb), and volcaniclastics (Tbt) collectively called the Boise Basalt Volcanic Assemblage (Burnham and Wood, in press) (fig. 1b). The lowermost portion of the volcanic assemblage is composed of tuffaceous sediments (Tbt), which contain batholith-derived arkosic sands and gravels, overlain by a sequence of palagonite tuff, with varying proportions of silicic and basaltic ash shards, and scoria layers. The lower part of the tuffaceous sequence also contains a discontinuous, 4 m thick rhyolite ash bed informally defined in one locality as the Barber Ash (Clemens, in press). The middle and upper portions of the volcanic assemblage (Tbv) contain phyric to aphyric basalt flows informally named by Burnham and Wood (in press) as the lower basalts and the basalt of Picket Pin Creek, respectively.

Aldape Park Basalts (Tba) and the Terteling Springs Formation (Tt)

The Boise Basalt Volcanic Assemblage is overlain by the Terteling Springs Formation (lower Idaho Group), which consists of poorly to well sorted sandstone-mudstone with minor gravel lenses (Burnham and Wood, in press). It is unclear if the Terteling Springs Formation is correlative with the older lacustrine Chalk Hills Formation, the younger lacustrine Glenns Ferry Formation, or an intervening fluvial transition, which is manifested as an unconformity in the southern part of the plain according to work done by Smith and others (1982) and Kimmel (1982).

Within the Terteling Springs Formation lies a basalt flow named by Burnham and Wood (in press) the basalt of Aldape Park (Tba), an aphyric to sparsely phyric basalt which varies from vesicular to mostly nonvesicular, with the very vesicular (~30%) material containing amygdules and entrained blocks of underlying sediment up to 0.5 m in size. These blocks of sediment, the vesicular zones around them, and the lack of pillow structures suggest that the Tba was emplaced in a shallow subaqueous or subaerial environment. Tba has been correlated on the basis of petrography to a sequence of aphyric to slightly phyric basalt flows encountered in several geothermal wells (Burnham and Wood, in press). Information from the Capital Mall geothermal wells (petrography of well cuttings, drilling rate, acoustic velocity, and resistivity logs) indicates the presence of four thin basalt flows (Basalt #1-4, with #1 being the oldest), totalling less than 55 m in thickness. Each of these basalt flows has oxidized basal contacts and vesicular upper and lower crusts. In the subsurface, Basalt #1-4 are used to separate the lower portion of the Terteling Springs Formation (Tt_1), from the upper Terteling Springs Formation (Tt_2).

Pliocene and Quaternary Deposits (QT)

The Terteling Springs Formation is overlain in the western Boise front by a sequence of deltaic coarse sand informally called the Pierce Park sand (upper Idaho Group) by Burnham and Wood (in press). This unit crops out in the Boise North 7.5′ Quadrangle, and is thought to be present in the subsurface in the Boise River Valley, but parameters for distinguishing it from the underlying Terteling Springs Formation using borehole techniques have not yet been constrained (Burnham and Wood, in press). The Idaho Group is in turn overlain by Plio-Pleistocene alluvial fans, sand and gravel terraces related to the Boise River, and by Quaternary (<1.1 Ma) intracanyon basalt flows (Othberg and Burnham, 1989; Othberg, 1991).

ANALYTICAL AND RADIOMETRIC DATING PROCEDURES

All well cuttings used for x-ray fluorescence (XRF) geochemical analysis were hand-picked to insure only fresh chips were used. These chips were washed in a nalgene 1 mm sieve with distilled water to remove silt and clay. The chips were washed again in a 10% by volume solution of HCl so that those chips containing $CaCO_3$ could be identified and removed. Chemical analyses were conducted at the Analytical Lab in the Department of Geology at Washington State University. All chemical analyses are taken from Clemens (1993).

All samples used for K-Ar dating were taken from fresh-appearing rock and were selected from bedrock outcrops of the type sections. These samples were initially reduced using a hydraulic rock splitter to remove all weathered material. The resulting fresh samples were crushed, sieved, and analyzed at the Geochron Laboratories Division of Krueger Enterprises, Inc. Mineral separates were obtained using heavy liquid separation techniques, and treated with dilute HF and HNO_3. For the modified whole rock K-Ar age determination on basalt, all material having a density greater than 3.3 g/cm^3 (olivines and pyroxenes) was removed. The constants and formulas used for the age determination were those of Steiger and Jaeger (1977).

SAMPLE DESCRIPTIONS

1. *R-9341* K-Ar
Aldape Park Basalt (Tba) (43°37′36″N, 116°11′18″W; SW1/4, SE1/4, S2,T3N, R2E; Boise South 7.5′ quad.; aphyric basalt flow exposed in northern road cut on Military Reserve Road [nonvesicular sample was collected 1 m above road]). *Analytical data:* ave. K = 0.648 wt. %; average ^{40}Ar = 0.000428 ppm. *Collected by:* Drew Clemens.
(modified whole rock) 9.5 ± 0.6 Ma

2. *R-9419* K-Ar
Basalt of Pickett Pin Canyon (Tbv), Boise Basalt Volcanic Assemblage (43°36′41″N, 116°06′46″W; SW1/4, SE1/4, S2,T3N,R2E; Lucky Peak 7.5′ quad.; porphyritic basalt flow exposed about 2 mi NE of Table Rock). Collected from boulder reduced with a sledge hammer. *Analytical data:* ave. K = 0.316 wt. %; average ^{40}Ar= 0.000297 ppm. *Collected by:* Drew Clemens and Wil Burnham.
(modified whole rock) 13.5 ± 0.9 Ma

3. *F-9342* K-Ar
Cottonwood Creek Rhyolite (Trc) lava flow (43°37′19″N, 116°8′14″W; NE1/4, SE1/4, S6, T3N,R3E; Boise South 7.5′ quad.; phyric stony rhyolite flow crops out in Rocky Canyon 2 mi NNE of Table Rock). *Analytical data:* ave. K = 6.856 wt. %; ^{40}Ar = 0.005398. *Collected by:* Drew Clemens.
(sanidine) 11.3 ± 0.3 Ma

4. *F-9343* K-Ar
Quarry View Park Rhyodacite vitrophyre (Trq) (43°36′15″N, 116°10′00″W; SE1/4, SW1/4, S12,T3N,R3E; Boise South 7.5′ quad. fresh, coarsely phyric glassy rhyodacite vitrophyre from dump of caved adit just S of Castle Rock and E of Quarryview Park). *Analytical data:* ave. K = 0.913 wt. %; ^{40}Ar=0.402. *Collected by:* Drew Clemens.
(andesine plagioclase) 11.8 ± 0.6 Ma

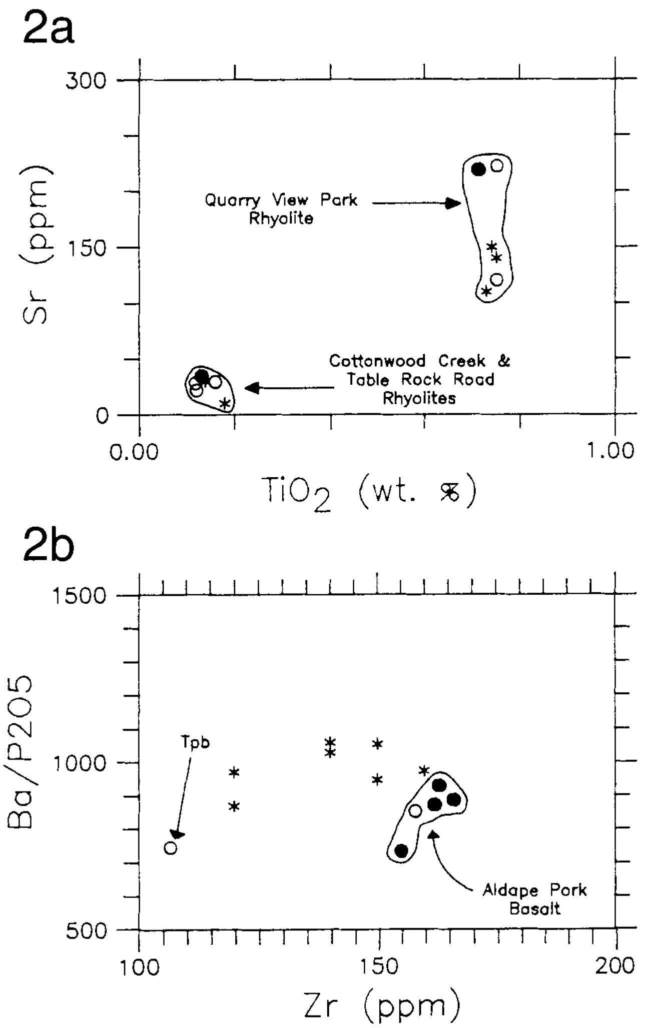

FIGURE 2. ***a.*** **Plot of TiO_2 vs. Sr for silicic volcanic rocks in the Boise front showing the distinct grouping of the Cottonwood Creek/Table Rock Road Rhyolites and the Quarry View Park Rhyodacite. ○ (outcrop) and ● (cuttings) are data from this study, * are data from Burnham and Wood (in press), oxide values are not normalized;** ***b.*** **plot of Zr vs Ba/P_2O_5 for mafic rocks after Hooper (1988), Aldape Park Basalt analysis fall into a distinct grouping whereas the other basalts from the Boise front are widely scattered, ○ (outcrop) and ● (cuttings) are data from this study, * and Tpb are basalt flows within the Boise Basalt Volcanic Assemblage from Burnham and Wood (in press), values are not normalized.**

DISCUSSION

Geochemistry

The geochemistry of well cuttings taken from the deepest well penetrating the least structurally complicated area (Capital Mall #2) were compared to the geochemistry of their suggested counterpart in outcrop to confirm previous stratigraphic interpretations. Because all of the volcanic units in the Boise front were submerged under Lake Idaho and/or were in close proximity to geothermal waters for various lengths of time (Wood and Burnham, 1983, 1987), only medium- to high-field strength elements such as Ti and Sr were used for correlation.

Wood and Burnham (1987) recognized two units with different petrographic and geochemical characteristics: the Cottonwood Creek Rhyolite (Trc) and Quarry View Park (Trq) rhyolites of the Idavada Group Volcanics (fig. 2a). Major- and trace-element analysis of drill cuttings from the Capital Mall #2 well confirms that these units occur in the subsurface beneath Boise, and that the Quarry View Park Rhyolite overlies the Cottonwood Creek Rhyolite. Note that the Table Rock Road Rhyodacite is chemically very similar to the Cottonwood Creek Member (fig. 2a).

The four basalt flows in the Capital Mall #2 well (Basalt #1-4) used to subdivide the lower portion of the Terteling Springs Formation (Tt_1) from the upper Terteling Springs Formation (Tt_2), share several compositional similarities, such as P_2O_5, TiO_2, Sc, V, and Y concentrations. These similarities were compared to other analyzed basalt flows within the Boise Basalt Volcanic Assemblage, as shown in figure 2b. Basalt #1-4 correlated very well with Tba in a plot of Zr vs. Ba/P_2O_5, but they do not match the flows within Boise Basalt Volcanic Assemblage. Based on the chemical similarities of Basalts #1-4 and the basalt of Aldape Park, which are markedly different from the basalts within the Boise Basalt Volcanic Assemblage (fig. 2b), Basalts #1-4 and the basalt of Aldape Park are here named the Aldape Park Basalt.

Geochronology and Field Magnetic Polarity Determinations

The 11.3 ± 0.3 Ma (K-Ar) Trc 11.8 ± 0.6 Ma (K-Ar) rhyodacite vitrophyre Trq geochronologically correlate to the 9-14 Ma range of ages for the Idavada Group Volcanics in southwestern Idaho as shown by Armstrong and others (1980) and Leeman (1989). Field relationships and correlation to wells where superposition relationships are certain show that the Cottonwood Creek member is the oldest volcanic unit in the Boise area, a result consistent with the K-Ar ages. Magnetic polarity of oriented samples was determined with a fluxgate magnetometer and indicated that the silicic volcanics within the Boise front have a consistent normal polarity. This normal polarity further constrains the K-Ar ages to the 11.2-11.8 Ma #5A normai polarity episode of the global geomagnetic time scale (La Brecque and others, 1977) (fig. 3). This constraint is possible because the 5A episode is the only known normal episode in the interval 10.2-12.6 Ma, as shown in figure 3. Because the K-Ar dates are on sanidine and andesine plagioclase separates, and they are consistent with relative and paleomagnetic chronology, we have confidence in the ages and conclude that all three flow units were emplaced between 11.6 and 11.2 Ma (see fig. 3).

The K-Ar age on the Aldape Park Basalt (9.5 ± 0.6 Ma K-Ar) and its normal magnetic polarity are consistent with the 8.8-10.1 Ma normal magnetic polarity #5 episode (La Brecque and others, 1977) as shown in figure 3. Although the age date is from whole-rock basalt separate, the material was unweathered and nonvesicular with a relatively high K_2O content (0.76%), and therefore should be reliable.

The ages reported here bracket that of the Boise Basalt Volcanic Assemblage between the youngest rhyolite age of 11.3 ± 0.3 Ma and the Aldape Park Basalt (9.5 ± 0.6 Ma) because these dated units lie

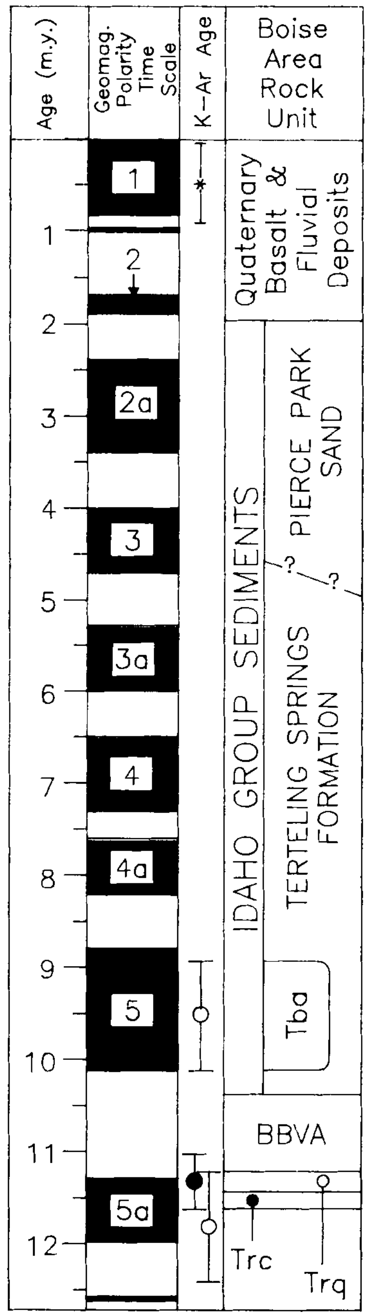

FIGURE 3. Geochronologic column showing the geomagnetic polarity time scale (dark bands represent normal polarity) after La Brecque and others (1977), and major Tertiary rock units in the Boise front. Abbreviations the same as for figure 1 and BBVA = Boise Basalt Volcanic Assemblage. ○ are data from this study, ✱ are data from Othberg and Burnham (1989). Field paleomagnetic readings were taken from fresh-appearing samples. All samples are of normal magnetic polarity.

below and above the volcanic assemblage respectively. The 13.5 ± 0.9 Ma age obtained from the Basalt of Pickett Pin Canyon within the Boise Basalt Volcanic Assemblage is inconsistent with the dates of units above and below it, which suggests that the Basalt of Pickett Pin Basalt may contain either *excess* ^{40}Ar incorporated in the mineral assemblage or *inherited* ^{40}Ar from older crustal rocks or incomplete degassing of the magma (Geyh and Schleicher, 1990). The 9.5-11.3 Ma age on the tuffaceous sediments and basalt flows over the rhyolite is consistent and correlative with the Armstrong and others (1980) revised ages on the Banbury Basalt (average mean age of 9.4 ± 0.6 Ma) mapped in the Twin Falls area, where basalt flows and tuffaceous sediments overly Idavada Group rhyolites and underlie the fluvio-lacustrine rocks of the Idaho Group. Past confusion regarding the Banbury Basalt resulted from calling any basalt within the lacustrine sequence the Banbury Basalt (Wood and others, 1981). The date on the Aldape Park Basalt also indicates that the sedimentation which filled the western plain basin spanned a time interval from 9.5 to 2 Ma.

The 9.5 ± 0.6 Ma age on the Aldape Park Basalt is significant because it shows that at least 150 m of fine-grained sand and silt, fluvio-lacustrine sediment, had accumulated on the eroded surface of the Boise Basalt Volcanic Assemblage in the Boise area (based on well logs from the Capital Mall wells) before the emplacement of the Aldape Park Basalt flows. The chemistry of these flows shows that they are geochemically distinct from the basalt flows within the volcanic assemblage. Therefore the lower part of the Idaho Group sediment exposed in the Boise front and encountered in the geothermal wells in the Boise area is older than previously reported by Wood and Burnham (1987) and Burnham and Wood (in press), and could be correlative with the oldest representation of the Poison Creek or Chalk Hills Formation on the south side of the western plain. A problem not addressed here is the determination of correlation criteria for these later formations within the Idaho Group and the location of a physically identifiable break in sedimentation (i.e., a mappable contact between the Chalk Hills and Glenns Ferry formations) in the Idaho Group sediments along the northeastern margin of the western plain.

CONCLUSIONS

Between 11.6 and 11.2 Ma, silicic lava flows and pyroclastic material were erupted along the northeastern margin of the western Snake River Plain near Boise, Idaho. The Cottonwood Creek Rhyolite (Trc) of the Idavada Group consists of a 10 m thick sequence of Plinian air-fall pumice with 2-60 cm clasts of granite, basalt, and vitrophyre interbedded with ashy arkosic sands. The pumice is overlain by a 100 m-thick 11.3 ± 0.3 Ma, normal polarity rhyolite lava flow. The lava flow at Cottonwood Creek correlates with the deepest silicic unit encountered in the Capital Mall #2 well, based on similarity of petrography and geochemistry, making Trc the oldest known Miocene volcanic unit in the Boise front. Since the Table Rock Road Rhyolite (Trt) of the Idavada Group has the same geochemistry as the Trc sequence of volcanics, Trt is considered to be chemically and geochronologically related to Trc. The ages of these two flows and associated pyroclastic units also make them correlative to the Idavada Group as defined by Armstrong and others (1975, 1980) and Malde (1991).

The upper silicic volcanic rock unit encountered in numerous geothermal wells is a rhyodacite and geochemically correlates with the rhyodacite flow and cross-cutting rhyodacite dike at Quarry View Park and is here called the Quarryview Park Rhyodacite (Trq) of the Idavada Group. Since outcrop and subsurface units are chemically similar, it is proposed here that the definition of Trq be broadened to recognize and include the glassy dacite dike at Quarry View Park, its host, and all the upper rhyodacite in the geothermal wells. The orientation of this dike follows the N45°W trend of the graben faults (fig. 1b), and suggests that at least the rhyodacite units in the Boise front may have erupted from dikes intruding along the graben faults in the same fashion as the dikes which produced many of the domes in the Mono Basin and Medicine Lake in California (Fink and Pollard, 1983; Bursik and Seih, 1989), and not from calderas or eruptive centers. The age of the Quarry View Park member makes it correlative with the Idavada Group as defined by Armstrong and others (1975, 1980) and Malde (1991).

Unconformably overlying the silicic volcanic units is the Boise Basalt Volcanic Assemblage, tuffaceous sediment and scoria deposits interbedded with basalt flows, silicic ash layers, and arkosic sands. Based on age and lithology, the Boise Basalt Volcanic Assemblage is tentatively correlated with the Banbury Basalt, a sequence of basalt flows and tuffaceous sediments originally defined by Malde and Powers (1962), but corrected and redefined by Armstrong and others (1980). Further mapping north and west of Boise will be necessary to better define the nature of the Boise Basalt Volcanic Assemblage and its relationship to other units in the western plain.

The Boise Basalt Volcanic Assemblage is overlain by the Terteling Springs Formation of the lower Idaho Group fluvio-lacustrine sediments (Burnham and Wood, in press). Within the Terteling Springs Formation is the basalt of Aldape Park, a high-K, high-Ti olivine tholeiite basalt dated at 9.5 ± 0.6 Ma. The lack of basaltic glass and well-defined pillow structures indicates that Tba was not emplaced in deep water, but flowed over sediments which were either dry or in shallow water according to the criteria of Fisher and Schmincke (1984). This outcropping of basalt is chemically correlative with all of the basalt flows (most likely Basalt #2) within the Terteling Springs Formation encountered in the deep geothermal wells. This sequence of four basalt flows is used to subdivide the Terteling Springs Formation into Tt_1 (lower) and Tt_2 (upper) portions, respectively, and is combined with the basalt of Aldape Park into the unit we call the Aldape Park Basalt. The 9.5 ± 0.6 Ma date on the Aldape Park Basalts within the Terteling Springs Formation suggests that sedimentation from the lake systems began before 9.5 ± 0.6 Ma in the late Miocene and continued into the latest Pliocene, the time when Malde (1991) suggests the large lake system of the western plain disappeared.

ACKNOWLEDGMENTS

Funding for this study was provided by Idaho State Board of Education Grant 92-126, Boise Front Project and by the Geological Society of America Grants in Aid Program (Grant #4655-91). Computer and laboratory facilities were provided by the Boise State University Department of Geosciences and Arizona State University. Editing and comments from Craig White and Walter Snyder are greatly appreciated. We would like to thank Todd Morgan and Troy Young for their assistance in the field, and the site operators at Arizona State University's remote computer sites for all the special plot jobs they handled for the authors.

REFERENCES

Allmendinger, R. W. (1982) Sequence of late Cenozoic deformation in the Blackfoot Mountains, Southeastern Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 505.

Armstrong, R. L., Harakal, J. E., and Neill, W. M. (1980) K-Ar dating of Snake River Plain rocks—new results: Isochron/West, no. 27, p. 5.

Armstrong, R. L., Leeman, W. P., and Malde, H. E. (1975) K/Ar dating of Quaternary and Neogene volcanic rocks of the Snake River Plain, Idaho: American Journal of Science, v. 275, p. 225.

Bonnichsen, B., Godchaux, M. M., and Jenks, M. D. (1991) Volcanism in the Snake River Plain: 38th Pacific Northwest AGU Meeting Abstracts with Programs, p. 10.

Bonnichsen, B., and Kauffman, D. F. (1987) Physical features of rhyolite lava flows in the Snake River Plain volcanic province, southwestern Idaho: Geological Society of America Special Paper 212, p.119.

Burnham, W. L., and Wood, S. H. (in press) Geologic map of the Boise South Quadrangle, Ada County, Idaho: Idaho Geological Survey Technical Report Series.

Bursik, M., and Seih, K. (1989) Range front faulting and volcanism in the Mono Basin, eastern California: Journal of Geophysical Research, v. 94, n. B11, 15587.

Clemens, D. M. (1993) Tectonics and volcanic stratigraphy of the western Snake River Plain, Idaho: MS thesis, Arizona State University, 209 p.

______ (in press) The Barber ash, a tephrochronology case study in southwestern Idaho, USA, submitted to the Sigma Gamma Epsilon Compass.

Fink, J. H., and Pollard, D. D. (1983) Structural evidence for dikes beneath silicic domes, Medicine Lake Highland, California: Geology, v. 11, p. 458.

Fisher, R. V., and Schmincke, H.-U. (1984) Pyroclastic rocks: Springer Verlag, Berlin.

Geyh, M. A., and Schleicher, H. (1990) Absolute Age Determinations—Physical and chemical dating methods and their applications: Springer Verlag, Berlin.

Godchaux, M. M., and Bonnichsen, B. (1991) The three types of phreatomagmatic volcanos in the western Snake River Plain, Idaho: 38th Pacific Northwest AGU Meeting Abstracts with Programs, p. 16.

Hamilton, W. (1962) Late Cenozoic structures of west-central Idaho: Geological Society of America Bulletin, v. 73, p. 511.

Hooper, P. R. (1988) The Columbia River Basalt: Kluwer Academic Publishers, p. 1.

Kimmel, P. G. (1982) Stratigraphy, age, and tectonic setting of the Miocene-Pliocene lacustrine sediments of the western Snake River Plain, Oregon and Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 559.

La Brecque, J. L., Kent, D. V., and Jones, D. L. (1977) Revised magnetic polarity time scale for Late Cretaceous and Cenozoic time: Geology, v. 5, p. 330.

Leeman, W. P. (1982) Development of the Snake River Plain-Yellowstone Plateau Province, Idaho and Wyoming, an overview and petrologic model: Idaho Bureau of Mines and Geology 26, p. 155.

_____ (1989) Origin and development of the Snake River Plain (SRP)—an overview: International Geophysical Union Field Trip Guide T305, American Geophysical Union, Washington D.C., p. 4.

Mabey, D. R. (1982) Geophysics and tectonics of the Snake River Plain, Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 139.

Malde, H. E. (1991) Quaternary geology and structural history of the Snake River Plain, Idaho and Oregon: Geological Society of America, The Geology of North America, v. K-2, p. 251.

Malde, H. E., and Powers, H. A. (1962) Upper Cenozoic stratigraphy of the western Snake River Plain, Idaho: Geological Society of America Bulletin 73, p. 1197.

Othberg, K. (1991) Quaternary tectonics and terrace surface gradients, Boise Valley, Idaho: 38th Pacific Northwest AGU Meeting Abstracts with Programs, p. 25.

Othberg, K., and Burnham, W. L. (1989) Geologic map of the Lucky Peak Quadrangle, Ada County, Idaho, Idaho Geological Survey Technical Report 90-4.

Smith, G. R., Swirydczuk, K., Kimmel, P. G., and Wilkinson, B. H. (1982) Fish biostratigraphy of late Miocene to Pleistocene sediments of the western Snake River Plain, Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 519.

Steiger, R. H., and Jaeger, E. (1977) Subcommission on geochronology, convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359.

Stewart, J. H., and Carlson, J. E. (1978) Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 263.

Wood, S. H. (in review) Seismic expression and significance of a lacustrine delta in Neogene deposits of the western Snake River Plain: American Association of Petroleum Geologists Bulletin, 28 p.

______ (1989) Silicic volcanic rocks and structure of the western Mount Bennett Hills and adjacent Snake River Plain, Idaho: 28th International Geological Congress Field Trip Guide T305, American Geophysical Union, p. 69.

Wood, S. H., Applegate, J. K., and Donaldson, P. R. (1981) Geological, hydrological, geochemical, and geophysical investigations of the Nampa-Caldwell and adjacent area, southeastern Idaho: Water Information Bulletin No. 30, Idaho Department of Water Resources, p. 115.

Wood, S. H., and Burnham, W. L. (1983) Boise, Idaho geothermal system: Geothermal Resources Council Transactions, v. 7, p. 215.

______ (1987) Geological framework of the Boise Warm Springs geothermal area, Idaho: Geological Society of America Centennial Field Guide, v. 2, Rocky Mountain Section, p. 117.

Wood, S. H., Mitchell, J. C., and Anderson, J. (1980) Subsurface geology and geothermal prospects in the Nampa-Caldwell area of the western Snake River Plain, Idaho: Geothermal Resources Council Transactions, v. 4, p. 265.