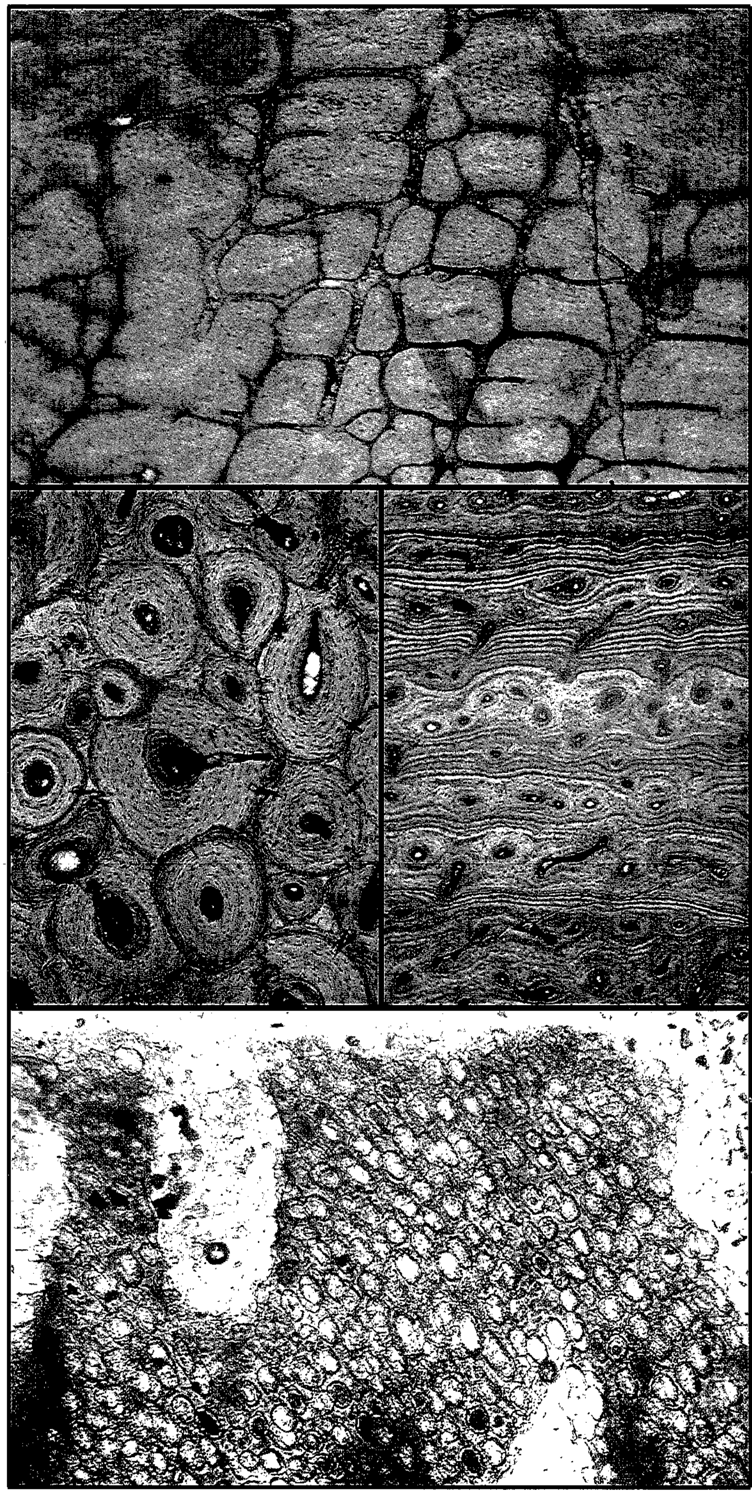
BRIGHAM YOUNG UNIVERSITY

GEOLOGY STUDIES



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Cover: Fossil tissues from Cleveland-Lloyd allosaurs.

Top: Uniform periosteal bone with reticulating primary vascular canals, some of which are aligned longitudinally (left to right) and radially. Caudal vertebra, centrum; longitudinal section; C-LQ 087.

Middle left: Vascular zonal bone with lamellated annuli and non-lamellated zones. Local development in a right radius; transverse section; C-LQ 109.

Middle right: Dense Haversian bone showing secondary osteons, secondary vascular canals at their centers, and the concentric arrangement of osteocyte lacunae (small dark bodies) around them. Dorsal rib; transverse section; C-LQ 106.

Bottom: Calcified cartilage showing the rounded form of the spaces (lacunae) once occupied by chondrocytes. Proximal end of a fibula; longitudinal section; C-LQ 014.

In all sections the direction of the external surface is upward.

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Early Miocene Bimodal Volcanism, Northern Wilson Creek Range, Lincoln County, Nevada

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ABSTRACT

Early Miocene volcanism in the northern Wilson Creek Range, Lincoln County, Nevada, produced an interfingered sequence of high-silica rhyolite (greater than 74% SiO_2) ash-flow tuffs, lava flows and dikes, and mafic lava flows. Three new potassium-argon ages range from 23.9 ± 1.0 Ma to 22.6 ± 1.2 Ma. The rocks are similar in composition, stratigraphic character, and age to the Blawn Formation, which is found in ranges to the east and southeast in Utah, and, therefore, are herein established as a western extension of the Blawn Formation.

Miocene volcanism in the northern Wilson Creek Range began with the eruption of two geochemically similar, weakly evolved ash-flow tuff cooling units. The lower unit consists of crystal-poor, loosely welded, lapilli ash-flow tuffs, herein called the tuff member of Atlanta Summit. The upper unit consists of homogeneous, crystal-rich, moderately to densely welded ash-flow tuffs, herein called the tuff member of Rosencrans Peak. This unit is as much as 300 m thick and has a minimum eruptive volume of 6.5 km^3, which is unusually voluminous for tuffs in the Blawn Formation. Thick, conspicuously flow-layered rhyolite lava flows were erupted penecontemporaneously with the tuffs. The rhyolite lava flows have a range of incompatible trace element concentrations, and some of them show an unusual mixing of aphyric and porphyritic magma. Small volumes of alkaline, vesicular, mafic flows containing 50 weight percent SiO_2 and 2.3 weight percent K_2O were extruded near the end of the rhyolite volcanic activity.

The Blawn Formation records a shift in eruptive style and magmatic composition in the northern Wilson Creek Range. The Blawn was preceded by voluminous Oligocene eruptions of dominantly calc-alkaline orogenic magmas. The Blawn and younger volcanic rocks in the area are low-volume, bimodal suites of high-silica rhyolite tuffs and lava flows and mafic lava flows.

INTRODUCTION

Lower Miocene, high-silica rhyolite ash-flow tuffs, lava flows, and dikes and related mafic lava flows are exposed in the northern part of the Wilson Creek Range and the northern part of the White Rock Mountains of eastern Nevada (Fig. 1). These ranges, hereafter collectively referred to as the northern Wilson Creek Range, are located near the Utah-Nevada border, south and southeast of the Atlanta mining district. The geologic map shows the distribution of the various tuffs, lava flows, and dikes (Fig. 2).

This paper discusses the time, space, and petrographic associations of the lower Miocene ash-flow tuffs and rhyolite and mafic lava flows of the northern Wilson Creek Range and considers the relationship of these rocks to earlier Oligocene and later Miocene and Pliocene volcanism. Such relationships are important in understanding the tectonic evolution of the area and the petrogenesis of the magmas.

The Miocene bimodal volcanic association and older Oligocene volcanic units in the northern Wilson Creek Range were shown by Tschanz and Pampeyan (1970) and Ekren and others (1977) in their 1:250,000 scale geologic maps of Lincoln County, Nevada. More detailed, recent 1:50,000 scale geologic maps have delineated individual stratigraphic units (Best and others, 1990; Willis and others, 1987). The only other study completed in the area, an M.S. thesis by Cox (1981), details the mineralization of the Atlanta mining district.

K-Ar age determinations, mapping at 1:24,000 scale, modal analyses, and whole rock analyses for major and

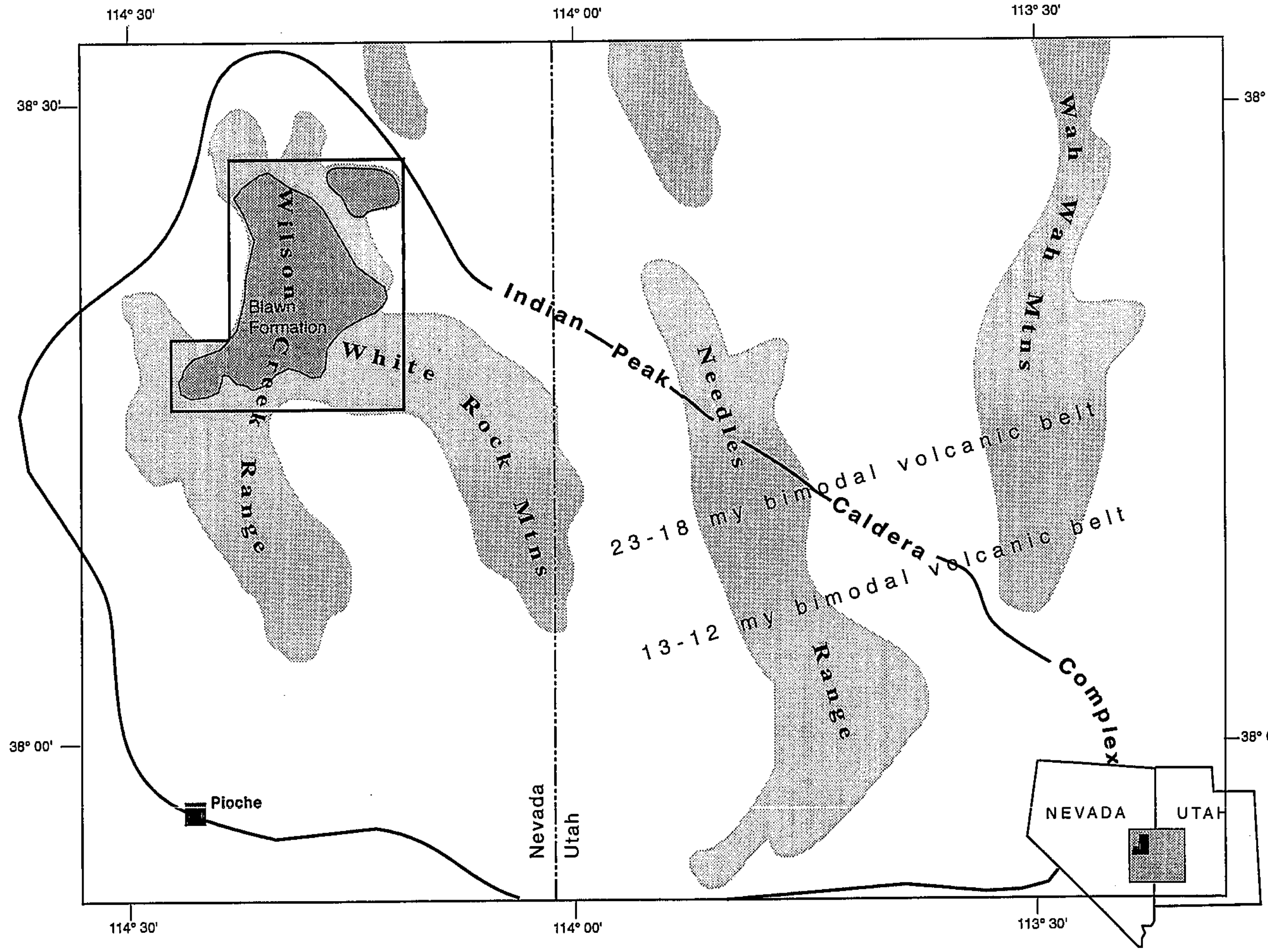

Figure 1. Index map showing location of the Wilson Creek Range and White Rock Mountains and area of fieldwork. The general distribution pattern of the early Miocene Blawn Formation in the Wilson Peak Range is shaded within the box. The approximate boundaries of the Oligocene Indian Peak caldera complex (Best and others, 1989) and the generalized location of early and middle Miocene bimodal volcanic belts are also shown.

trace elements by X-ray fluorescence spectrometry elucidated the stratigraphy, petrology, and chronology of the volcanic sequence. Locations of samples are given in Figure 2.

GEOLOGIC SETTING

During the middle to late Cenozoic, geologic activity in the northern Basin and Range Province was dominated by southward migrating magmatism associated with subduction along the western margin of North America (Cross and Pilger, 1978; Best and others, 1989). As subduction slowed during the Oligocene, a broad, east-west–trending belt of volcanism developed across Nevada and Utah. Volcanism within the belt produced voluminous, calc-alkaline, highly potassic, silicic to intermediate composition sheets of ash-flow tuff and minor lava flows. The Oligocene Indian Peak volcanic field (Best and others, 1989; Best and others, 1987a) straddles the Utah-Nevada border within the belt and formed a platform on which the lower Miocene rocks of this study rest (Fig. 1).

Beginning in the early Miocene, about 24 Ma, volcanic activity in the Indian Peak volcanic field changed from the voluminous, primarily dacitic ash-flow eruptions of the Oligocene to smaller, local eruptions of high-silica rhyolite and high-potassium mafic lavas that formed a bimodal association. This association is the earliest of three episodes of bimodal volcanism during the Miocene and Pliocene in which the mafic lavas show a declining content of K_2O and SiO_2 (Best and others, 1980). Only the latest episode contains true basalt; the earlier ones include as the mafic component trachyandesite or trachybasalt (Best and others, 1987b).

East-west to northeast-southwest extension and related normal faulting accompanied early Miocene volcanic activity in parts of the Indian Peak volcanic field (Best and

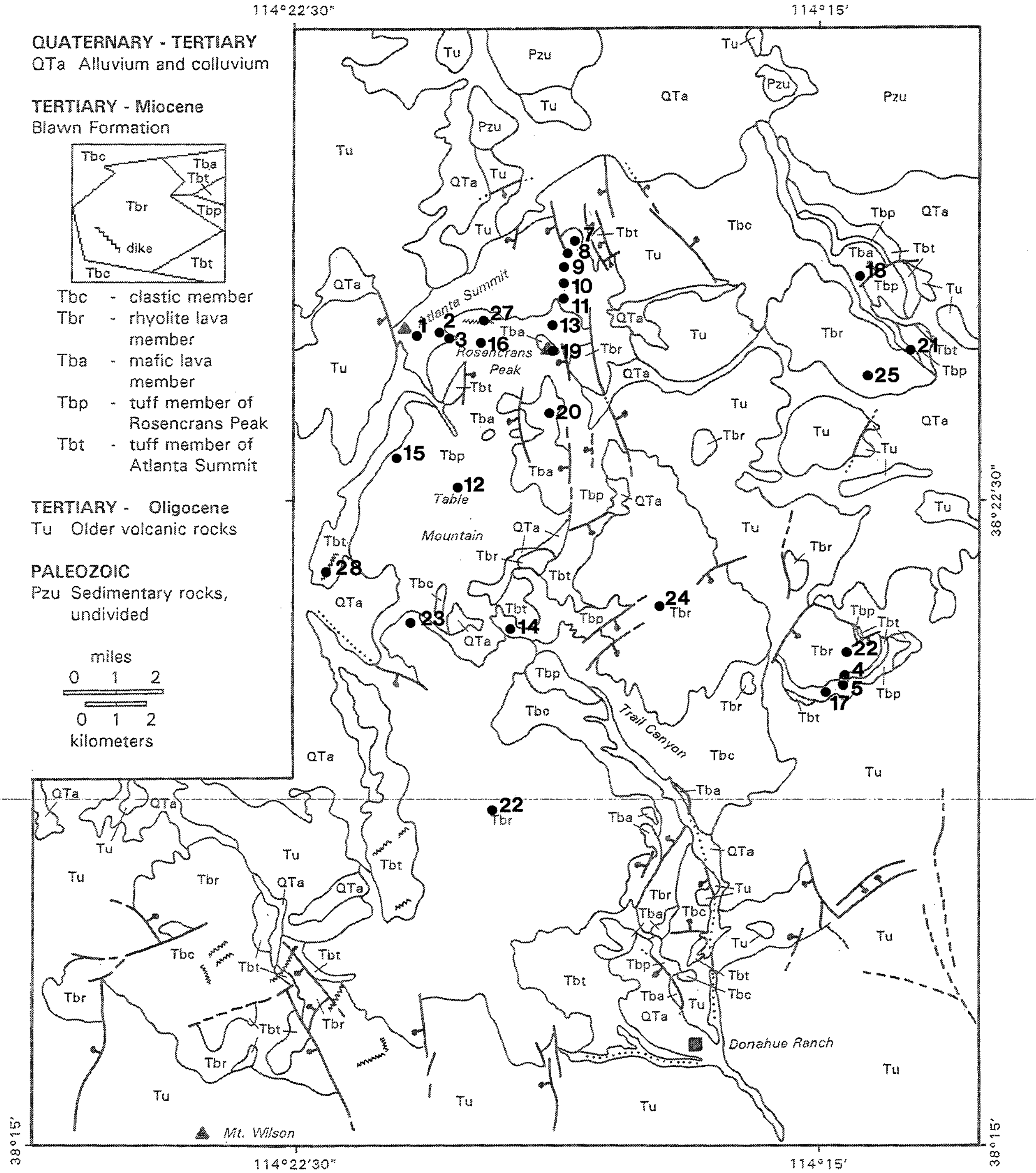

Figure 2. Generalized geologic map of the northern Wilson Creek Range and locations of samples referred to in Tables 3 and 4. Boundaries of the map area are the same as those of the box shown on Figure 1. Stratigraphic correlation of the members of the Blawn Formation is also shown.

others, 1987b; Best and Grant, 1987). A later episode of more northerly striking basin-and-range normal faulting postdates the volcanism. The later faulting is responsible for uplift of the Wilson Creek Range and the inversion of topography of the Oligocene calderas.

REGIONAL CORRELATION

The lower Miocene volcanic rocks in the northern Wilson Creek Range were emplaced about 23 Ma ago. They resemble the Blawn Formation, a lower Miocene volcanic unit that is widely exposed in ranges in southwestern Utah within the confines of the Indian Peak volcanic field (Fig. 1; Best and others 1987b). A comparison of the lower Miocene rocks of the northern Wilson Creek Range with the Blawn Formation shows similarities in composition, age, and stratigraphic character (Table 1). Because of these similarities, and because both groups of rocks lie within the Indian Peak volcanic field and therefore might share a genetic relationship, we propose that the lower Miocene volcanic rocks in the northern Wilson Creek Range are part of the Blawn Formation.

DESCRIPTION OF STRATIGRAPHIC UNITS

The Blawn Formation in the northern Wilson Creek Range is divided herein into five units: clastic member, tuff member of Atlanta Summit, tuff member of Rosencrans Peak, rhyolite lava member, and mafic lava member (Willis and others, 1987). Emplacement of the rhyolite lava member was nearly contemporaneous with emplacement of the other members. The tuff units are overlain and underlain by tongues of the clastic member, and dikes of the rhyolite lava member cut through all units except the mafic lava member. Extrusion of mafic lava flows appears to have concluded early Miocene volcanism in this area. Figure 3 shows typical field relationships and topographic expression of the members.

CLASTIC MEMBER

The clastic member of the Blawn Formation consists mostly of poorly sorted and crudely bedded, conglomeratic fluvial deposits. Tongues of the clastic member are found at the base of the Blawn Formation and are interfingered

Table 1. Comparison of the Blawn Formation in Utah with the lower Miocene volcanic rocks in the Northern Wilson Creek Range.

	LOWER MIOCENE VOLCANIC ROCKS IN NORTHERN WILSON CREEK RANGE	BLAWN FORMATION IN UTAH (Best and others, 1987b)
Mafic Member Composition	potassic trachybasalt 51–52% SiO_2 2.0–3.0% K_2O	trachyandesite 54–62% SiO_2 2.2–4.7% K_2O
Phenocrysts	plagioclase, augite hypersthene, olivine	plagioclase, augite, hypersthene, olivine
Silicic Member Composition	high-silica rhyolite 74–78.2% SiO_2	high-silica rhyolite 71–77% SiO_2
Phenocrysts	sanidine, quartz, plagioclase, minor biotite, (rare vapor-phase topaz)	sanidine, quartz, plagioclase, minor biotite, (only 18-Ma-old rhyolites have vapor-phase topaz)
Ash-Flow Units	one of cooling units is locally thick and densely welded	locally thick, but nowhere densely welded
Age of Eruptions	24–23 Ma (based on three K-Ar ages)	23–18 Ma (based on nineteen ages)

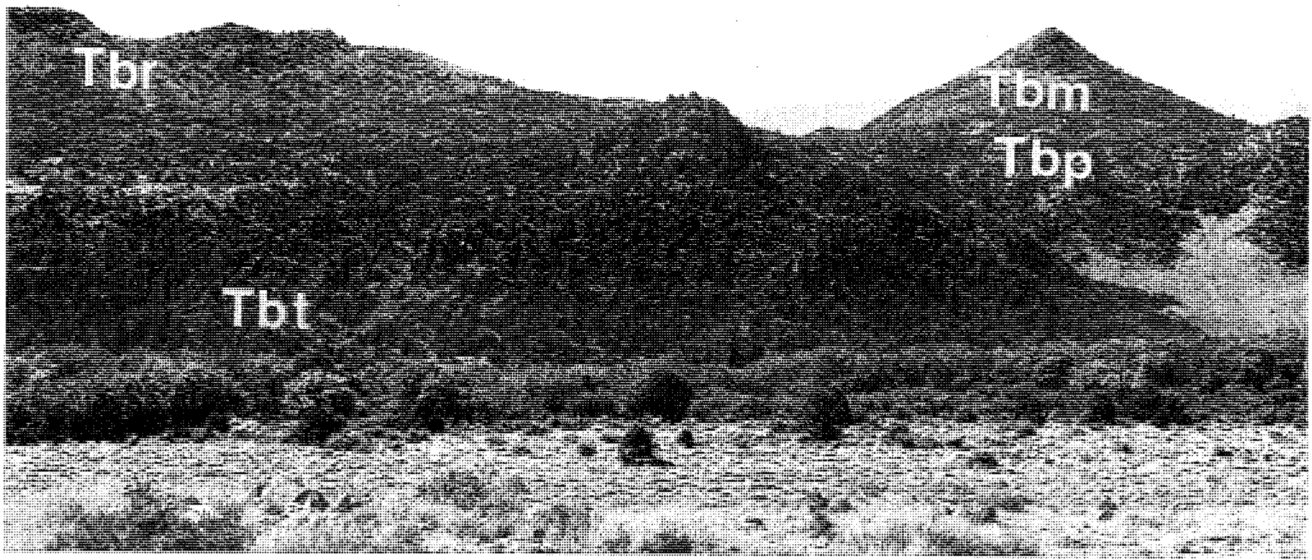

Figure 3. Photograph, looking north from the top of Table Mountain, showing typical topographic expression of the members of the Blawn Formation in the northern Wilson Creek Range. Tbr = rhyolite lava member; Tbt = tuff member of Atlanta Summit; Tbm = mafic lava member; Tbp = tuff member of Rosencrans Peak. The prominent peak on the right side of the photograph is Rosencrans Peak.

with the tuffs and lava flows (Fig. 2). The member consists of loosely consolidated, tan to yellow-brown coarse sandstone and coarse conglomerate. Subangular volcanic clasts 1 to 10 cm wide are locally abundant and make up from 5% to 50% of the rock volume. Clasts are mostly derived from formations included in the Needles Range Group (Best and Grant, 1987); clasts of the rhyolitic Greens Canyon Tuff Member of the Ryan Spring Formation and the dacitic, intracaldera tuff member of the Wah Wah Springs Formation are most abundant. Locally, especially north of the head of Trail Canyon, purplish-colored rhyolite lava flow clasts of the Blawn Formation predominate. The unit ranges up to 250 m in thickness.

TUFF MEMBER OF ATLANTA SUMMIT

The tuff member of Atlanta Summit is a heterogeneous unit that consists primarily of loosely welded, lithic-rich ash-flow tuffs. Also included in this unit are pyroclastic surge deposits, lenses of pyroclastic air-fall and water-laid tuff, reworked deposits of ash and older volcanic rocks, and debris flows associated with the emplacement of the rhyolite lava flows. The tuff member of Atlanta Summit is the oldest tuff of the Blawn Formation in the northern Wilson Creek Range. It is generally overlain by the tuff member of Rosencrans Peak or by the rhyolite lava member. Thin, scattered deposits of a lithic-rich, crystal-poor tuff overlie the tuff member of Rosencrans Peak on and near Table Mountain; we have included these younger but lithologically similar deposits in the tuff member of Atlanta Summit.

Crystal-poor, lapilli-rich ash-flow tuffs are the primary constituents of the tuff member of Atlanta Summit. They are loosely welded, tan, yellow, or light gray in color, and are generally poorly exposed, forming ledgy slopes. Prominent cliffs of the tuff are exposed near the western base of Table Mountain (Willis and others, 1987). The tuffs contain less than 10% phenocrysts, mostly quartz, sanidine, and plagioclase with traces of biotite (Table 2). Light-colored, rounded pumice fragments (1–5 cm in diameter) are abundant, commonly making up as much as 30% of the rock. Dark-colored, angular xenoliths of flow-layered rhyolites of the Blawn Formation and older volcanic rocks of the Needles Range Group are also abundant in the tuffs. The xenoliths are usually less than 5 cm in diameter and make up 25% or less of the rock. A sequence of pyroclastic surge and fall deposits of the tuff member is well exposed in the southeast portion of the mapped area northwest of Donahue Ranch (Willis and others, 1987). Locally, ash-flow deposits of the tuff member vary distinctly from bottom to top—the lower portions are light colored with dark pumice fragments and the upper portions are dark with light-colored pumice fragments. In general, however, the pumice is lighter than the rock matrix and the xenoliths are darker. The unit is locally as much as 200 m thick, and its preserved eruptive volume is about 2.7 km^3.

The ash-flow tuffs of the tuff member of Atlanta Summit range from 74.8% to 78.2% SiO_2 (Table 3) and are classified as high-silica rhyolites. In general, the tuff is depleted in incompatible trace elements and appears to be chemically less evolved than younger rhyolite lava flows (Fig. 4). The magma source for the tuffs became more fractionated over time, and the youngest tuff units are comparatively enriched in incompatible trace elements (Rb, Y, Nb). The youngest tuffs are scattered ash deposits, which overlie the tuff member of Rosencrans Peak. They are included in the tuff member of Atlanta Summit because of lithologic similarities. Their age and chemistry, however, indicate a closer relationship to younger rhyolite lava flows.

Debris flows associated with the tuff member of Atlanta Summit consist of angular clasts as much as 0.5 m across supported in a sandy, tuffaceous matrix. The clasts are chiefly flow-layered rhyolite with lesser amounts of older volcanic rocks. Locally, the clasts make up as much as 50% of the rock, but average 25%.

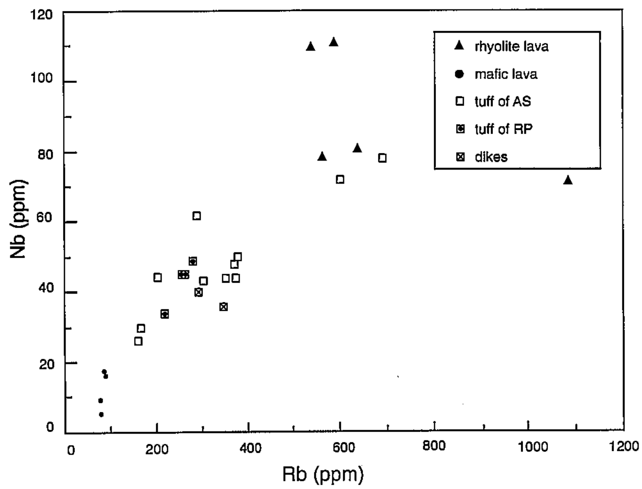

Figure 4. Nb and Rb concentrations in the Blawn Formation.

TUFF MEMBER OF ROSENCRANS PEAK

The tuff member of Rosencrans Peak consists of a moderately to densely welded, crystal-rich ash-flow sheet and related dikes. A single cooling unit of the tuff forms Table Mountain, a conspicuous, flat bench in the northern Wilson Creek Range surrounded by prominent cliffs. A potassium-argon age on sanidine for the tuff is 23.4 ± 0.9 years (Table 4). The tuff appears homogeneous in outcrop and has a uniformly high percentage of phenocrysts (25–30%). The phenocrysts are mostly slightly iridescent sanidine (1–2 mm) and bipyramidal smoky quartz (2–3 mm), with lesser plagioclase, minor biotite, and traces of ilmenite and magnetite (Table 2). Intrusions located around the perimeter of Table Mountain contain sanidine phenocrysts as much as 2 cm long. The unit is virtually pumice free and contains less than 5% lithic fragments that are derived primarily from older dacitic volcanic rocks of the Oligocene Needles Range Group. The rock appears tan, gray, purple, or orange in outcrop.

The tuff member of Rosencrans Peak is as much as 300 m thick and has a minimum eruptive volume of 6.5 km^3. It is the thickest and most voluminous early Miocene ash-flow tuff cooling unit in the northern Wilson Creek Range. Table Mountain accounts for approximately 90% of the volume of the tuff; the rest of it is found in scattered outcrops east of the mountain. No outcrops occur to the west.

The large volume and densely welded fabric of the tuff member of Rosencrans Peak are unique when compared with cooling units of the Blawn Formation outside of the northern Wilson Creek Range. In Utah, the cooling units are much smaller in volume and are weakly welded, similar to the tuff member of Atlanta Summit (J. D. Keith, pers. comm., 1985). Because of the unique characteristics of the tuff member of Rosencrans Peak, it is possible that it is unrelated to the Blawn Formation and may have been derived from outside the area. It is included in the Blawn Formation because it is chemically similar to the underlying tuff member of Atlanta Summit, its distribution is confined to the northern Wilson Creek Range, and it is mineralogically and chemically similar to three probable feeder dikes located near the margin of Table Mountain (Table 3). The largest of the dikes, located on the northeastern edge of Table Mountain, was intruded along a north-south, down-to-the-west fault that juxtaposes the tuff member of Rosencrans Peak against older volcanic rocks to the east. The two smaller dikes are located along the western margin of Table Mountain. Eruptions from these conduits probably accumulated in a depression,

Table 2. Comparison of the members of the Blawn Formation in the Northern Wilson Creek Range.

	Tuff Member of Atlanta Summit	Tuff Member of Rosencrans Peak	Mafic Lava Member	Rhyolite Lava Member
% phenocrysts				
quartz	2–5	10–15	—	0–10
plagioclase	3–8	5	2–20	0–5
sanidine	1–3	15–20	—	0–10
biotite	tr	tr	in matrix	tr
olivine	—	—	1–5	tr
zircon	tr	—	—	—
pumice (volume %)	20–30	2–10	—	—
lithic fragments (volume %)	15–20	0–10	—	—
age (mya)	—	23.4 ± 0.9	23.9 ± 1.0	22.6 ± 1.2
thickness (m)	0–200	0–300	0–135	10–700
volume (km^3)	2.7	6.5	0.7	10
topographic expression	broken cliffs to slopes	prominent cliff	scattered lava flows	domes, flows, dikes

forming a thick, densely welded, localized cooling unit that is now Table Mountain.

The tuff member of Rosencrans Peak is high in silica, ranging from 74.0% to 77.9% SiO_2 (Table 3). Its major and trace element compositions are similar to the weakly evolved, loosely welded tuffs in the tuff member of Atlanta Summit.

RHYOLITE LAVA MEMBER

Numerous topaz-bearing, rhyolite lava domes and flows were emplaced throughout the early Miocene episode of volcanic activity in the northern Wilson Creek Range. A potassium-argon age on sanidine from one of the flows is 22.6 ± 0.9 Ma (Table 4). These flows, domes, and associated small dikes make up the rhyolite lava member of the Blawn Formation. The rhyolite lavas are lilac to gray pink and locally have well-developed flow-layers. All the sampled flows are high-silica rhyolites with 74.9%–75.8% SiO_2 (Table 3). Phenocrysts in the rhyolite lava flows (Table 2) consist of a combination of sanidine (locally iridescent), clear to smoky quartz, lesser amounts of plagioclase, and minor biotite (usually altered). Flows on the western and southern edges of the northern Wilson Creek Range are spherulitic and lithophysal, and a few contain vapor-phase topaz in vugs. Some of the flows have marginal vitrophyres. The lava flows range in thickness from 10 to 700 m and have a minimum eruptive volume of 10 km^3.

Samples of the rhyolite lava member are nearly identical in major element composition (Table 3); however, trace element concentrations and phenocryst proportions vary between flows. Some flows are crystal rich with as much as 25% phenocrysts, other flows are virtually aphyric, and still other flows contain a mixture of aphyric and porphyritic material on both an outcrop and microscopic scale. All the sampled flows are slightly peraluminous and are enriched in the incompatible trace elements Rb, Y, and Nb (Fig. 4) and are depleted in the feldspar-compatible trace elements Sr and Ba as well as in Zr, Fe, and Ti. These characteristics are most pronounced in the aphyric lavas, which are therefore the most highly evolved of the rhyolite lavas. The heterogeneous mixture of phenocrysts within the flows and complementary changes in trace element composition indicate either (1) significant zonation of a single-source magma, (2) evolution of the magma with time, or (3) extrusion of the magma from several sources that varied with respect to trace element and phenocryst concentrations, but not to major element concentrations.

Table 3. Chemical composition of members of the Blawn Formation.

	Tuff Member of Atlanta Summit											Tuff Member of Rosencrans Peak							
Sample #: (Field #)	1 (Ttw-35)	2 (Ttw-36)	3 (Ttw-37)	4 (Ttm-46w)	5 (Ttm-50)	6 (Ttw-37a)	7 (Ttw-83a)	8 (Ttw-83b)	9 (Ttw-83c)	10 (Ttw-83d)	11 (Ttw-83e)	12 (Tth-6a)	13 (Tth-1b)	14 (Tth-9)	15 (Tth-5)	16 (Tth-2)	17 (Tth-7)	27 (Tthi-3)	28 (Tthi-4)
SiO_2	77.0	78.2	75.0	77.8	76.8	77.0	74.8	77.6	76.2	76.3	76.3	76.7	76.9	77.3	76.4	74.0	74.4	74.2	77.6
TiO_2	0.07	0.17	0.24	0.05	0.07	0.18	0.22	0.10	0.11	0.11	0.11	0.06	0.06	0.10	0.07	0.38	0.39	0.44	0.11
Al_2O_3	13.8	12.1	13.3	11.7	13.0	12.3	12.9	11.5	12.7	12.4	12.4	12.9	12.8	12.4	12.5	13.6	12.9	14.0	12.4
Fe_2O_3	1.52	1.71	2.4	1.36	1.47	1.5	1.3	1.3	1.3	1.6	1.4	1.0	1.27	1.29	1.13	2.7	2.7	2.5	1.4
MnO	0.04	0.06	0.05	0.05	0.04	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.04	0.01	0.02	0.03
MgO	0.05	0.05	0.07	0.04	0.12	0.08	0.05	0.09	0.03	0.06	0.06	0.07	0.05	0.11	0.06	0.08	0.03	0.08	0.06
CaO	1.22	1.54	1.4	0.32	0.86	2.05	0.92	0.85	1.29	0.85	0.75	1.29	0.51	1.06	1.3	1.16	1.52	0.47	0.71
Na_2O	1.94	1.4	2.5	3.2	1.7	2.3	2.8	2.0	2.2	2.3	1.9	1.4	2.4	2.2	2.5	3.3	2.5	2.01	2.4
K_2O	3.72	4.3	5.1	4.7	5.5	4.5	6.3	5.65	5.27	5.77	6.2	6.0	6.1	5.4	5.6	5.3	5.6	6.7	5.1
Total	(94.36)	(92.8)	(97.9)	(95.92)	(94.51)	(91.03)	(96.7)	(96.25)	(95.41)	(95.94)	(94.07)	(96.7)	(95.4)	(95.79)	(96.57)	(97.0)	(97.81)	(99.98)	(99.71)
(ppm)																			
Rb	284	202	301	688	596	160	166	369	373	370	349	276	216	—	258	252	—	344	290
Sr	192	537	311	64	102	205	196	128	128	106	101	34	42	—	59	144	—	109	38
Y	106	84	79	133	100	60	61	86	90	85	81	46	67	—	82	89	—	56	67
Zr	159	88	134	159	149	195	170	135	144	136	137	139	165	—	134	275	—	291	171
Nb	62	44	43	78	72	26	30	48	50	44	44	49	34	—	45	45	—	36	40
Ba	46	163	269	103	234	565	585	100	107	116	144	84	86	—	83	524	—	517	47

1. Loosely welded tuff: 8% phenocrysts, 25% pumice; lat. 38°25′23″, long. 114°19′56″.
2. Loosely welded tuff: 10% phenocrysts, 25% pumice; lat. 38°25′26″, long. 114°19′40″.
3. Pumicious matrix: 5% phenocrysts, 2% lithics, 10% pumice; lat. 38°25′22″, long. 114°19′34″.
4. Moderately welded tuff: 5% phenocrysts, 10% lithics, 10% pumice, overlies tuff of Rosencrans Peak; lat. 38°19′39″, long. 114°14′23″.
5. Moderately welded tuff: 5% phenocrysts, 10% lithics, 10% pumice, overlies tuff of Rosencrans Peak; lat. 38°19′29″, long. 114°14′50″.
6. Loosely welded tuff: 8% phenocrysts, 15% pumice; lat. 38°34′03″, long. 114°17′31″.
7. Firmly welded tuff: 15% phenocrysts, 15% slightly altered pumice, up to 20% lithics; lat. 38°25′29″, long. 114°17′59″.
8. Firmly welded tuff: 10% phenocrysts, 20% slightly altered pumice, up to 20% lithics; lat. 38°26′23″, long. 114°18′06″.
9. Firmly welded tuff: 10% phenocrysts, 20% slightly altered pumice, up to 20% lithics; lat. 38°26′17″, long. 114°18′08″.
10. Firmly welded tuff: 10% phenocrysts, 20% slightly altered pumice, up to 20% lithics; lat. 38°26′11″, long. 114°18′06″.
11. Firmly welded tuff: 10% phenocrysts, 20% slightly altered pumice, up to 20% lithics; lat. 38°24′03″, long. 114°18′06″.

Oxide values have been recalculated to 100% on a volatile-free basis.
Analytical total for nine oxides in parentheses.

12. Densely welded, glassy matrix: 40% phenocrysts, minor pumice; lat. 38°23′34″, long. 114°17′36″.
13. Moderately welded: 25% phenocrysts, minor pumice; lat. 38°25′30″, long. 114°18′13″.
14. Densely welded, glassy matrix: 50% phenocrysts, 5% pumice; minor lithics; lat. 38°20′15″, long. 114°18′13″.
15. Moderately welded: 25% phenocrysts, minor pumice; lat. 38°23′59″, long. 114°20′07″.
16. Firmly welded: 30% phenocrysts, minor, slightly devitrified pumice, sanidine up to 1 cm long; lat. 38°25′26″, long. 114°18′59″.
17. Porous matrix: 35% phenocrysts, minor pumice; lat. 38°19′20″, long. 114°14′39″.
27. Porphyritic rhyolite dike: 40% phenocrysts, sanidine up to 2 cm; lat. 38°25′34″, long. 114°18′59″.
28. Porphyritic rhyolite dike: 40% phenocrysts, sanidine up to 2 cm; lat. 38°20′43″, long. 114°20′58″.

Sample #: (Field #)	Mafic Lava Member 18 (Ttmf-83a)	19 (Ttmf-14a)	20 (Ttmf-3)	21 (Ttmf-36)	Rhyolite Lava Member 22 (Ttr-19)	23 (Ttr-20)	24 (Ttr-21)	25 (Ttr-22)	26 (Ttr-23)
SiO_2	52.0	51.4	51.1	51.0	75.6	75.3	75.8	74.5	74.9
TiO_2	1.9	2.0	2.0	2.0	0.02	0.03	0.06	0.06	0.05
Al_2O_3	16.8	16.9	16.7	16.6	13.1	13.2	13.0	13.5	13.0
Fe_2O_3	10.5	11.7	11.5	11.5	1.0	1.28	1.2	1.41	1.5
MnO	0.12	0.14	0.12	0.14	0.05	0.04	0.03	0.03	0.04
MgO	4.5	4.3	4.3	4.2	0.06	0.04	0.02	0.05	0.05
CaO	6.7	7.2	8.0	7.8	0.52	0.50	0.19	0.51	0.39
Na_2O	4.2	4.2	4.1	4.2	4.7	4.8	4.7	4.6	4.9
K_2O	2.4	2.3	2.4	2.3	3.8	4.5	4.9	4.6	4.6
Total	(99.80)	(99.10)	(99.20)	(99.44)	(99.50)	(99.80)	(98.80)	(99.80)	(100.2)
(ppm)									
Rb	89	78	88	77	1082	582	636	524	533
Sr	564	580	553	581	15	17	14	7	15
Y	40	31	38	30	157	89	123	147	156
Zr	167	156	168	158	139	177	162	196	185
Nb	16	5	17	9	73	111	81	78	110
Ba	524	575	530	578	19	26	15	9	24

18. Aphanitic matrix: 20% phenocrysts, plagioclase up to 1.25 cm; lat. 38°24′27″, long. 114°14′55″.
19. Aphanitic matrix: less than 5% phenocrysts, plagioclase less than 1 mm; lat. 38°25′13″, long. 114°18′13″.
20. Aphanitic matrix: 20% phenocrysts, plagioclase up to 1.25 cm; lat. 38°24′36″, long. 114°18′13″.
21. Aphanitic matrix: 5% phenocrysts; lat. 38°24′10″, long. 114°14′02″.
22. Aphyric rhyolite lava: less than 5% phenocrysts; lat. 38°20′13″, long. 114°13′50″.
23. Porphyritic rhyolite lava: 25% phenocrysts; lat. 38°20′04″, long. 114°19′49″.
24. Porphyritic rhyolite lava: 20% phenocrysts; lat. 38°20′22″, long. 114°16′50″.
25. Porphyritic rhyolite lava: 25% phenocrysts; lat. 38°24′04″, long. 114°14′34″.
26. Porphyritic rhyolite lava: 25% phenocrysts; lat. 38°18′31″, long. 114°18′45″.

Oxide values have been recalculated to 100% on a volatile-free basis.
Analytical total for nine oxides in parentheses.

Table 4. K-Ar ages of samples of the Blawn Formation in the Northern Wilson Creek Range. Argon analyses by Stanley Evans at the University of Utah; potassium analyses by X-ray fluorescence at Brigham Young University. Decay constants: 40 Kλ_ε = 0.581 x 10^{-10}/yr; λ_β = 4.962 x 10^{-10}/yr; 40 K/K (total) = 1.67 x 10^{-4}.

	Tuff Member of Rosencrans Peak	Mafic Lava Member	Rhyolite Member
MATERIAL DATED	sanidine	whole rock	sanidine
WEIGHT (gms)	0.20136	0.28205	0.25182
K_2O (wt.%)	8.77, 8.71	2.03, 2.11	7.24, 7.32
RADIOGENIC Ar			
Moles/gx10^{-10}	35.807	8.48	28.523
% Atm	45	82	53
AGE ± 2σ	23.4 ± 0.9	23.9 ± 1.0	22.6 ± 0.9
SAMPLE NUMBER	13	18	25
LOCATION			
latitude	38°25′30″	38°24′27″	38°24′04″
longitude	114°18′13″	114°14′55″	114°14′34″

Table 5 compares the geochemistry of rhyolite lava flows from the northern Wilson Creek Range with typical rhyolites (LeMaitre, 1976) and topaz-bearing rhyolites found in the western United States (Christiansen and others, 1986). Both major and trace element concentrations indicate that the rhyolite lava member can be classified as a highly evolved topaz rhyolite (Fig. 5). The rhyolite lava member is slightly more enriched in incompatible elements and depleted in compatible elements than the typical topaz-bearing rhyolite, and it has a slightly higher Na/K ratio, another monitor of evolution in high-SiO_2 rhyolites. These tendencies indicate that the rhyolite lava member is even more evolved than the typical topaz-bearing rhyolite. Fluorine analyses were not completed on the lava; however, it is assumed that the rhyolite lavas in the northern Wilson Creek Range are fluorine enriched because many of the flows are topaz bearing and all sampled flows have relatively high Na/K ratios.

MAFIC LAVA MEMBER

The mafic lava member of the Blawn Formation consists of a sequence of vesicular mafic lava flows that are sparsely distributed around the margins and across the top of Table Mountain. The flows are gray, black, or red brown and generally form low ledges. They were erupted 23.9 ± 1.0 Ma ago (Table 4). The mafic lava flows vary from aphyric to porphyritic, and some contain up to 20% plagioclase phenocrysts that are as long as 3 cm (Table 2). Smaller phenocrysts of augite, hypersthene, and olivine altered to "iddingsite" are present in lesser amounts. Most plagioclase phenocrysts are zoned, and many show signs of corrosion. The matrix in the flows contains plagioclase, pyroxene, iron-titanium oxides, and local glass.

Although the unit is as much as 135 m thick, the calculated volume of mafic magma (0.7 km^3) is only about 5% of the cumulative volume of erupted rhyolite magma. This low mafic to silicic ratio may reflect the blocking effect that low-density rhyolite magma in the crust has on ascending mafic magma.

The mafic lava flows are potassic trachybasalt and shoshonite, with 2.3 weight percent K_2O and 51 weight percent SiO_2 (Fig. 6). These flows have lower SiO_2 concentrations than the mafic flows in the Blawn Formation in Utah (Best and others, 1987b). All of the samples are mildly silica-undersaturated with 0.4 to 3.3 weight percent normative nepheline and high normative orthoclase

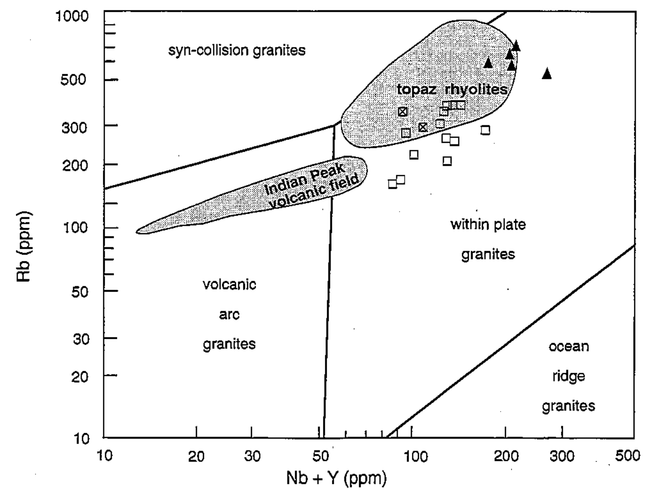

Figure 5. Trace element discrimination diagram (Pearce and others, 1984) comparing the rhyolite lavas and tuffs of the Blawn Formation in the northern Wilson Creek Range with other topaz rhyolites in western North America (Christiansen and others, 1986) and with dacites and rhyolites of the Indian Peak volcanic field (Best and others, 1987b). See Figure 4 for key to symbols.

Table 5. Comparison of an average rhyolite from the Blawn Formation with an average rhyolite (LeMaitre, 1976) and a typical topaz-bearing rhyolite (Christiansen and others, 1986).

	Blawn* Rhyolite	Average Rhyolite	Topaz-Bearing Rhyolite
SiO_2	75.2	72.8	76.0
TiO_2	0.04	0.28	0.04
Al_2O_3	13.2	13.27	12.8
Fe_2O_3	1.28	1.48	1.07
MnO	0.04	0.06	0.06
MgO	0.04	0.39	0.04
CaO	0.04	1.14	0.74
Na_2O	4.7	3.55	3.73
K_2O	4.54	4.3	5.00
(ppm)			
Rb	617		423
Sr	14		28
Y	172		58
Zr	172		129
Nb	91		53
Ba	19		41

*Average of values given in Table 3 for the rhyolite member.

(about 14 weight percent). Thus, these lavas do not fit Gill's (1981) definition of orogenic lavas. Moreover, the lavas have high $FeO^*/(FeO^* + MgO)$ ratios and TiO_2 concentrations that make them similar to other alkaline mafic rocks and that distinguish them from the older calc-alkaline lavas erupted in the Indian Peak volcanic field (32 to 27 Ma) (Fig. 7). Compared to late Cenozoic mafic lavas erupted in the Basin and Range Province as a whole, the lavas have high concentrations of Rb as well as K_2O and similar concentrations of Ba, Sr, Zr, Nb, and Y (Fitton and others, 1991). They are most similar to mafic lavas erupted before 5 Ma in the Basin and Range Province, but they differ from these lavas in their higher than average concentrations of alkalies and lower CaO and MgO. Like the other basin and range lavas, those from the northern Wilson Creek Range have Nb depletions as indicated by Ba/Nb ratios that exceed those found in mid-ocean ridge basalt and ocean island basalt (Fig. 8).

CONCLUSIONS AND DISCUSSION

A bimodal sequence of volcanic rocks was emplaced in the northern Wilson Creek Range of Nevada 23.4 to 22.6 Ma ago. This sequence, which has local sources, is a western extension of the Blawn Formation in southwestern Utah.

XRF whole-rock analyses indicate that the Blawn Formation in the northern Wilson Creek Range is bimodal with potassic trachybasalt (2.3 weight percent K_2O, 51 weight percent SiO_2) as the mafic end member and high silica rhyolite (4–6 weight percent K_2O, 74–78 weight percent SiO_2) as the silicic end member. In the northern Wilson Creek Range, the Blawn Formation is herein divided into five members: clastic member, tuff member of Atlanta Summit, tuff member of Rosencrans Peak, rhyolite lava member, and mafic lava member. Emplacement of the lava members followed emplacement of the ash-flow tuffs.

Table Mountain, a prominent geographic feature in the northern Wilson Creek Range, is capped by a thick cooling unit of rhyolite ash-flow tuff named the tuff member of Rosencrans Peak and is underlain by the older tuff member of Atlanta Summit. Chemically and mineralogically similar dikes located around Table Mountain were the probable sources for the tuff member of Rosencrans Peak. Undisputed sources for the tuff member of Atlanta Summit are not found in the northern Wilson Creek Range; however, similarity in both major and trace elements suggest that it was erupted from the same magma that produced the tuff member of Rosencrans Peak. Neither tuff is strongly enriched in incompatible trace elements, and both appear to have been derived from a weakly evolved and undifferentiated magma.

The rhyolite lavas are chemically highly evolved and show an affinity to topaz-bearing rhyolites found elsewhere

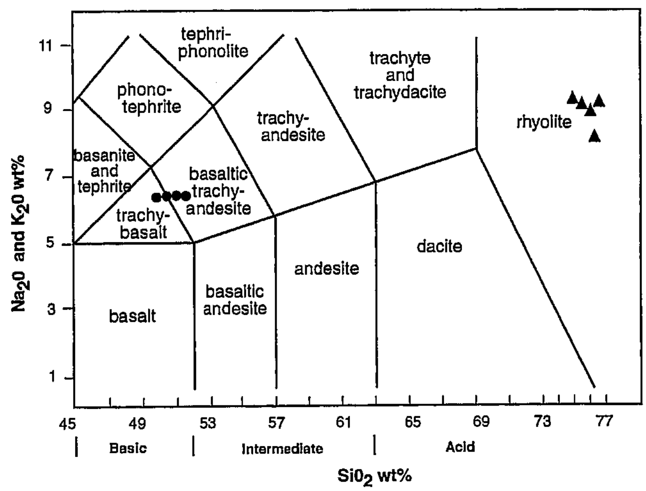

Figure 6. IUGS classification (LeMaitre, 1989) of the mafic and rhyolite lavas of the Blawn Formation in the northern Wilson Creek Range. See Figure 4 for key to symbols.

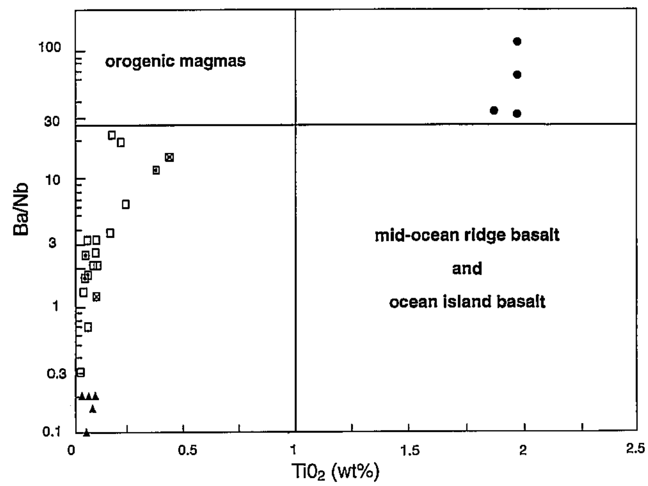

FIGURE 8.FINAL

Figure 8. Comparison of trachybasalts of the Blawn Formation in the northern Wilson Creek Range with the range of mid-ocean ridge basalt and ocean island basalt. See Figure 4 for key to symbols.

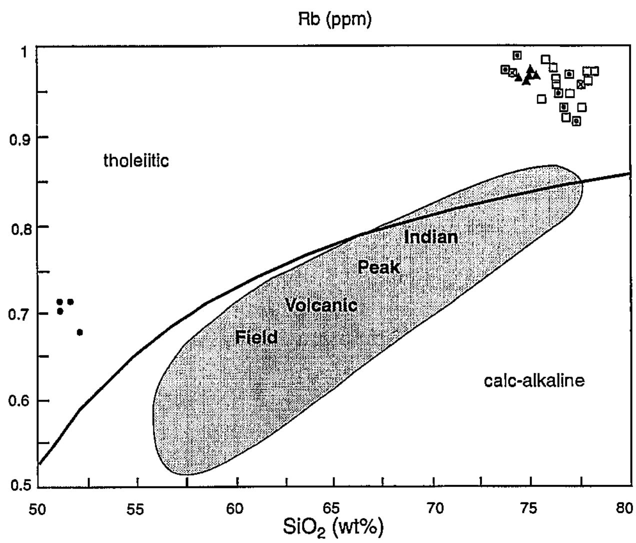

Figure 7. Comparison of trachybasalts of the Blawn Formation in the northern Wilson Creek Range with the calc-alkaline rocks of the Indian Peak volcanic field (Best and others, 1987b). Note the distinct bimodal nature of the Blawn Formation. See Figure 4 for key to symbols.

in the western United States. Some of the lavas in the rhyolite lava member of the Blawn Formation contain topaz and are extremely enriched in incompatible elements (e.g., Rb, Nb, and Y).

Trace element and stratigraphic considerations suggest that the ash-flow tuffs and the rhyolite lava flows were likely derived from a multi-chambered magma system that was enriched in SiO_2 and variably enriched in incompatible elements. The earliest eruptions of rhyolite tuffs were tapped from a less evolved magma; later eruptions involved highly evolved and differentiated melts that were enriched in incompatible elements.

The derivation of silica-enriched rhyolite magmas and potassium-enriched mafic magmas may involve moderately differentiated Oligocene batholiths. The batholiths formed as residual magma associated with Oligocene calc-alkaline eruptions in the Indian Peak volcanic field cooled (Fig. 9). After the transition from Oligocene subduction to Miocene extension, an influx of Miocene mantle-derived magma could have generated sufficient thermal energy to partially melt a previously fractionated Oligocene batholith. Partial melting of rock near the top of the batholith, coupled with subsequent fractional crystallization of the resulting melt, could have produced the enrichment trends seen in the rhyolite tuffs and lavas. Extensional mantle-derived material could have produced the high K_2O and TiO_2 concentrations and the high $FeO^*/(FeO^* + MgO)$ ratios seen in the mafic lava flows.

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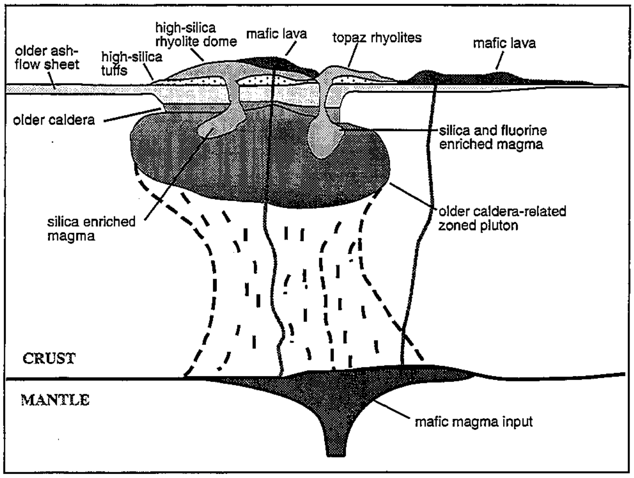

Figure 9. Hypothetical model for the derivation of the magmas associated with the Blawn Formation in the Wilson Creek Range. Vertical scale above surface exaggerated.

Modified in part from Christiansen and others, 1986.

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