Text and references to accompany NBMG Field Studies Map 11

GEOLOGIC MAP OF THE BELL CANYON QUADRANGLE, WESTERN NEVADA

by
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Prepared in cooperation with the U.S. Geological Survey

INTRODUCTION

The Bell Canyon Quadrangle lies in southeastern Churchill County in western Nevada (fig. 1). It encompasses most of the range that includes Fairview Peak and the northern part of Slate Mountain. Detailed geologic mapping of the Bell Canyon Quadrangle and the Bell Mountain Quadrangle (Henry, 1996) to the east was undertaken for several purposes. (1) Significant mineralized areas, especially the Fairview mining district, lie within the quadrangles (Tingley, 1992), and initial reconnaissance suggested that mineralization was related to a Miocene ash-flow caldera. (2) The fault scarp resulting from the 1954 Fairview Peak earthquake runs through the eastern part of the Bell Canyon Quadrangle (fig. 2; Slemmons, 1957; Caskey and others, in press). The geologic map provides a framework for neotectonic studies and helps evaluate long-term motion on the fault. (3) The Bell Canyon and Bell Mountain Quadrangles lie along or near the transition between northwest-striking strike-slip faults of the Walker Lane to the southwest and north-northeast-striking normal faults characteristic of the Basin and Range province to the northeast (Stewart, 1988). The Bell Canyon-Bell Mountain area is one of the few places where bedrock crops out in this transition zone, so that the eastern extent of the Walker Lane and the nature of the transition can be examined.

Previous geologic maps of the area are small-scale (1:250,000) compilations of Churchill County (Willden and Speed, 1974) and the Reno 1° by 2° Quadrangle (Greene and others, 1991). Rock units within the Bell Canyon Quadrangle include Jurassic-Triassic(?) metamorphic rocks intruded by Cretaceous granodiorite, a wide range of Oligocene(?) to Miocene igneous and volcaniclastic rocks most of which are related to a 19-Ma caldera, and upper Tertiary to Quaternary sedimentary deposits (fig. 2).

ROCK UNITS

Pre-Tertiary Rocks

Pre-Tertiary rocks crop out at Slate Mountain, in the southern part of the quadrangle, and at the western edge of the Fairview district in the northwestern part (fig. 2). Rocks in both areas were included in the Triassic-Jurassic volcaniclastic rocks and limestone unit of Willden and Speed (1974) and within the Sand Springs terrane by Greene and others (1991) and Oldow and others (1993). However, rock types in the two locations are different. Amphibolite, biotite schist, and metarhyolite, all metamorphosed to amphibolite grade, occur at Slate Mountain. Marble and muscovite schist are present in the Slate Mountain Quadrangle just south of this map area. Both rocks and metamorphism are older than 82 Ma, the age of intruding granite (John, 1992a), but the rhyolites are sills that could be substantially younger than the other metamorphic rocks. Metamorphic rocks in the Fairview district are quartzite and relatively clean, phyllitic sandstone and shale; these lack an apparent volcanic component and have undergone only greenschist facies metamorphism. An area shown as metamorphic rock in the northern part of Bell Canyon by Willden and Speed (1974) actually consists of debris lenses (Tfpx) composed of clasts of metamorphic rock and Cretaceous granodiorite up to 1.5 m in diameter.

Granodiorite intrudes metamorphic rocks at Slate Mountain and in the Fairview district and is petrographically similar in both areas. The contact of granodiorite with metamorphic rocks at Slate Mountain is parallel to bedding and foliation, and sills are common in metamorphic rock near the contact. This geometry suggests a laccolith or other concordant intrusion; Willden and Speed (1974) found similar granodiorite and contact relations in the Sand

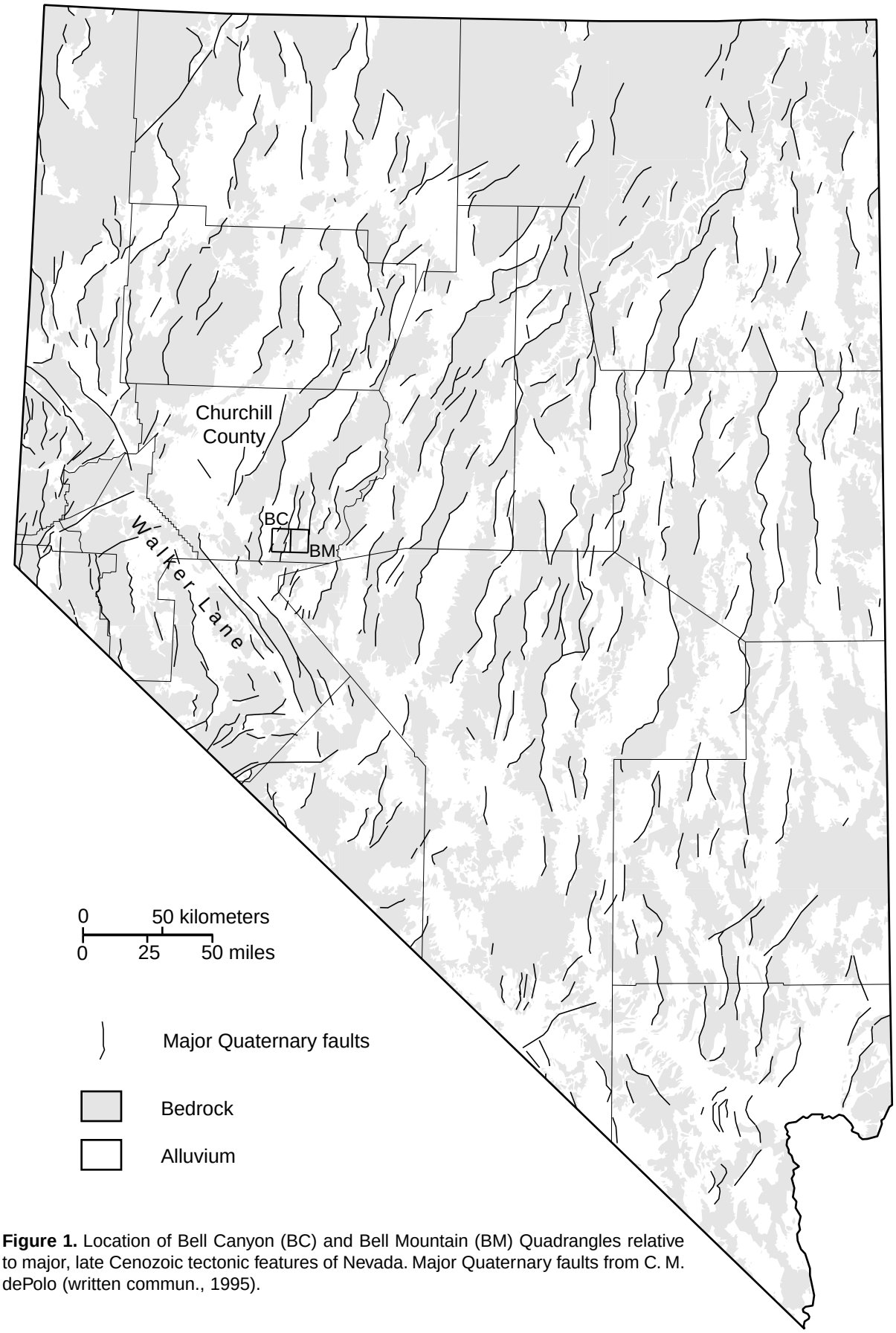


Figure 1. Location of Bell Canyon (BC) and Bell Mountain (BM) Quadrangles relative to major, late Cenozoic tectonic features of Nevada. Major Quaternary faults from C. M. dePolo (written commun., 1995).

Springs Range to the west and suggested that a single, large, concordant intrusion underlies both ranges.

Tertiary Rocks

A wide variety of Oligocene(?) to early Miocene volcanic, volcaniclastic, and intrusive rocks crops out in the Bell Canyon quadrangle. Figures 3, 4, and 5 and tables 1 and 2 summarize petrographic, chemical, and $^{40}Ar/^{39}Ar$ age data on the volcanic rocks of the Fairview Peak area. Most of these rocks are probably related to the Fairview Peak caldera. Relative and absolute ages are well established by field relations and $^{40}Ar/^{39}Ar$ ages (table 2; fig. 5) for most of the rocks in the Fairview district. All Tertiary igneous rocks are moderately alkalic (table 1; fig. 4). Many intermediate rocks are strictly trachyandesite or trachyte (fig. 4) but are referred to here as andesite or dacite.

The oldest Tertiary rocks, which consist of dacitic to andesitic lavas and shallow intrusions and rhyolitic ash-flow tuff, occur in the Fairview mining district (fig. 2). The age and source of most of these rocks are uncertain. If correlation with the 25-Ma tuff of Elevenmile Canyon (John, 1995a, b) is correct, then it and the older andesite (Toa) are much older than the 19-Ma Fairview Peak caldera. However, the older andesite and other intermediate rocks in the district are lavas or shallow intrusions that must have had nearby sources. All intermediate rocks in the Fairview district preceded caldera-related magmatism by at least 0.7 Ma, given the age of the younger dacite (Tfdy; 20.02 ± 0.10 Ma; table 2). The younger dacite is similar in age and composition to the dacite lavas (Tl; 20.04 ± 0.10 Ma; table 2) in the southeastern part of the Bell Mountain Quadrangle and to dacitic dikes in the Stillwater Range 30 km to the north (D. A. John, written commun., 1995), which suggests that all are part of a regional magmatic event.

ROCKS OF THE FAIRVIEW PEAK CALDERA

A complex assemblage of ash-flow tuff, lavas, lava domes, debris deposits, and small intrusions accumulated in and around the Fairview Peak caldera during a brief period between 19.3 and 18.5 Ma (table 2; fig. 5). These rocks form four distinct sequences, only three of which are well represented in the Bell Canyon Quadrangle. These are (1) the tuff of Fairview Peak and related megabreccia and debris deposits, (2) the informally named lavas of Bell Canyon and related dikes and pyroclastic deposits, and (3) late intracaldera dikes. Rhyolitic lava domes are abundant in the Bell Mountain Quadrangle but form only a few small outcrops in the southeastern corner of the Bell Canyon Quadrangle.

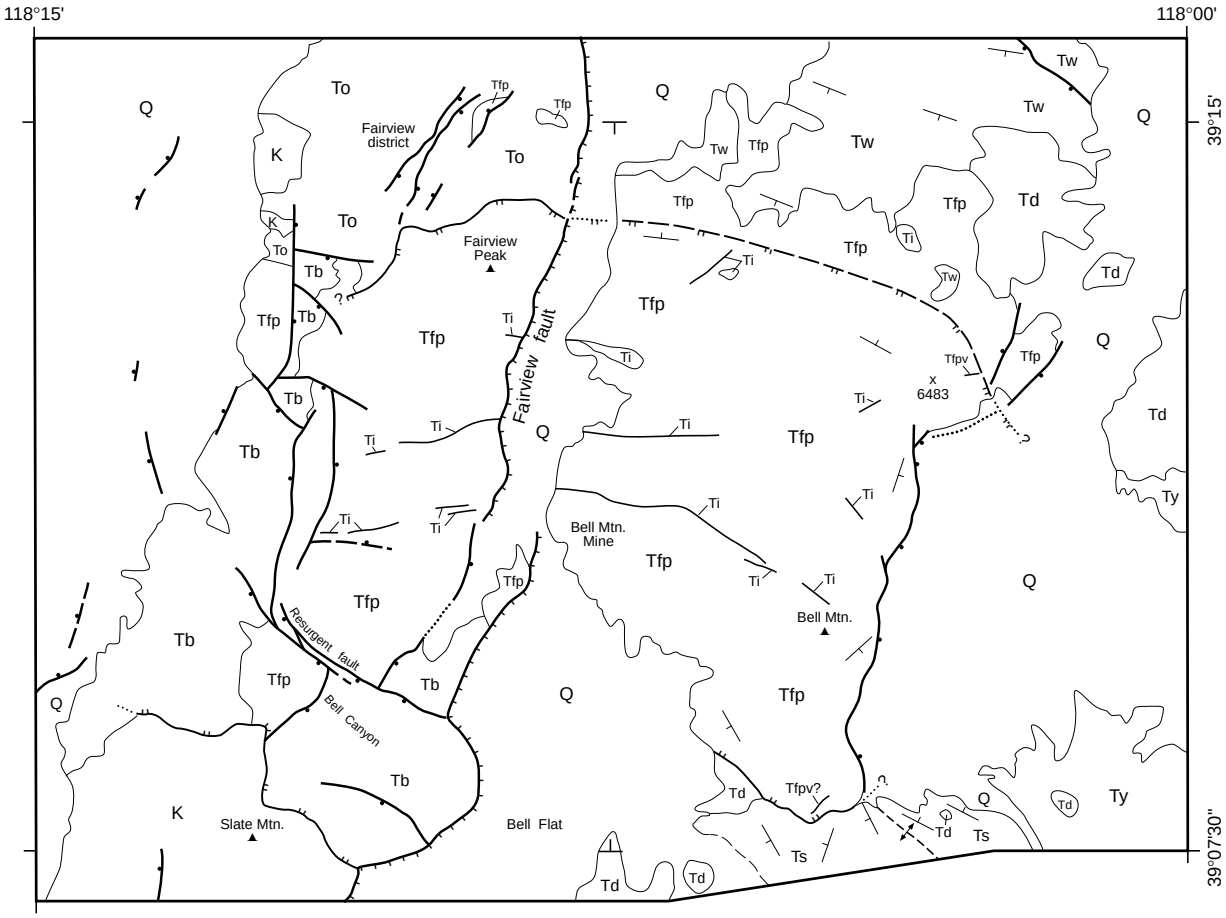
The earliest caldera-related igneous activity was emplacement of porphyritic rhyolite domes and dikes (Tir) in the Fairview district at 19.3 Ma. Rhyolitic pumice in sandstone south of the caldera in the Bell Mountain Quadrangle also gives an age of 19.3 Ma, which suggests that minor rhyolitic activity preceded major ash-flow eruption around much of the caldera.

Tuff of Fairview Peak and Related Megabreccia and Debris Deposits

Major caldera-related volcanism began with eruption of the rhyolitic tuff of Fairview Peak (Tfp) at 19.2 Ma. The tuff crops out extensively in the Bell Canyon and Bell Mountain Quadrangles and locally in the southwestern part of the West Gate Quadrangle. Throughout most of this area, the tuff accumulated within its own caldera. At least 700 m of tuff is exposed in the east face of Fairview Peak, the thickest intracaldera exposure, and the base is not exposed. Outflow deposits occur in the northern part of the Bell Mountain Quadrangle and southern part of the West Gate Quadrangle, north of the caldera, and in a small area in the southern Bell Mountain Quadrangle at the southern edge of the caldera. The tuff has not been recognized outside these areas.

The tuff is sparsely porphyritic, moderately alkalic, high-silica rhyolite showing negligible compositional zoning (table 1; figs. 3 and 4). Both intracaldera and outflow deposits are densely welded and form a single cooling unit in most outcrops. Moderately to poorly welded tuff and multiple cooling units occur in Bell Canyon and in the western part of the caldera in the stratigraphically highest preserved deposits. All tuff in the Bell Canyon Quadrangle is devitrified, but basal vitrophyre is present at three locations in the Bell Mountain Quadrangle. Ash-flow tuff vents, consisting of dike-like bodies of vertically foliated rock that cuts through subhorizontal tuff, occur at two locations near the caldera margin in the Bell Mountain Quadrangle (fig. 2).

Lenses and irregular bodies of coarse, massive to crudely bedded debris-flow deposits, massive breccia, and minor bedded tuff (Tfpx) are interbedded with and overlie the uppermost parts of the tuff of Fairview Peak. They occur only near the caldera wall, notably in Bell Canyon. Megabreccia (Tfpb; Lipman, 1976) of precaldera rocks lie within tuff or debris deposits in many locations close to the caldera margin. Most megabreccia blocks are a few meters to about 70 m in diameter. One body, about 3 km south of Fairview Peak, is nearly 2 km long and consists of numerous individual blocks, each several hundred meters across, separated by thin lenses of tuff. The



Q	Quaternary deposits
Ty	Postcaldera sedimentary rocks
	Rocks of the Fairview Peak caldera
Ti	Late intracaldera dikes
Td	Felsic lava domes
Tb	Lavas of Bell Canyon
Tfpv / Tfp	Tuff of Fairview Peak; Tfpv = ash-flow vent
Ts	Southern sedimentary and lava sequence
Tw	Lavas of West Gate
To	Precaldera volcanic rocks of the Fairview mining district
K	Pre-Tertiary rocks undivided

Normal fault, with ball on downthrown side, dotted where concealed, queried where uncertain

1954 fault scarp, with hachures on downthrown side

Topographic or buried structural margin of Fairview Peak caldera, dashed where buried beneath beneath tuff of Fairview Peak, queried where uncertain

Anticline, dashed where approximately located

Generalized strike and dip of beds or compaction foliation in ash-flow tuff

Figure 2. Generalized geology of the Bell Canyon and Bell Mountain Quadrangles.

debris deposits and megabreccia represent material that slumped from the caldera wall during eruption of the tuff of Fairview Peak and caldera collapse.

Ponding of the tuff and interbedding of megabreccia and coarse debris deposits with tuff within the caldera demonstrate that ash-flow eruption and caldera collapse were contemporaneous. Minimum collapse was 700 m, the maximum observed thickness of tuff of Fairview Peak, but could be considerably greater.

Lavas of Bell Canyon

The next youngest igneous activity consists of rhyolitic to basaltic andesitic lavas, related coarse to fine pyroclastic and reworked deposits, dikes that were probably feeders to the lavas, and late caldera-collapse breccia that crop out extensively in Bell Canyon along the southwestern margin of the Fairview Peak caldera (fig. 2). Informally named the lavas of Bell Canyon, these rocks were emplaced between about 19.0 and 18.9 Ma (table 2; fig.5), within about 0.2 Ma after eruption of the tuff of Fairview Peak.

Lavas were divided into four petrographic-chemical types for mapping (table 1; fig. 3): rhyolite (Tbr), dacite (Tbd), andesite (Tba), and basaltic andesite (Tbb). The different types show no obvious stratigraphic progression, although the one basaltic andesite is late. Rhyolitic and dacitic lavas typically

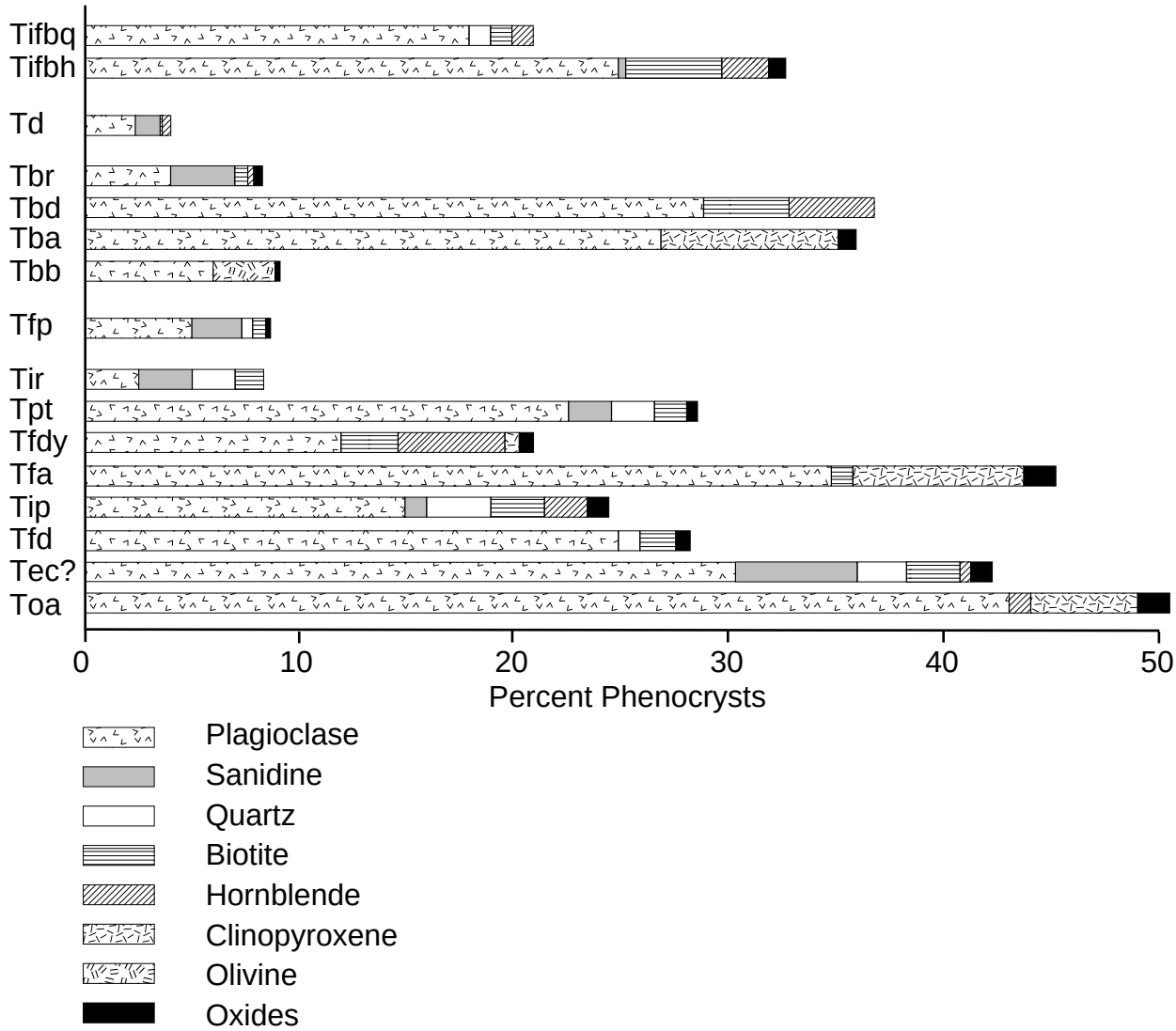


Figure 3. Phenocryst abundances in igneous rocks of the Bell Canyon Quadrangle.

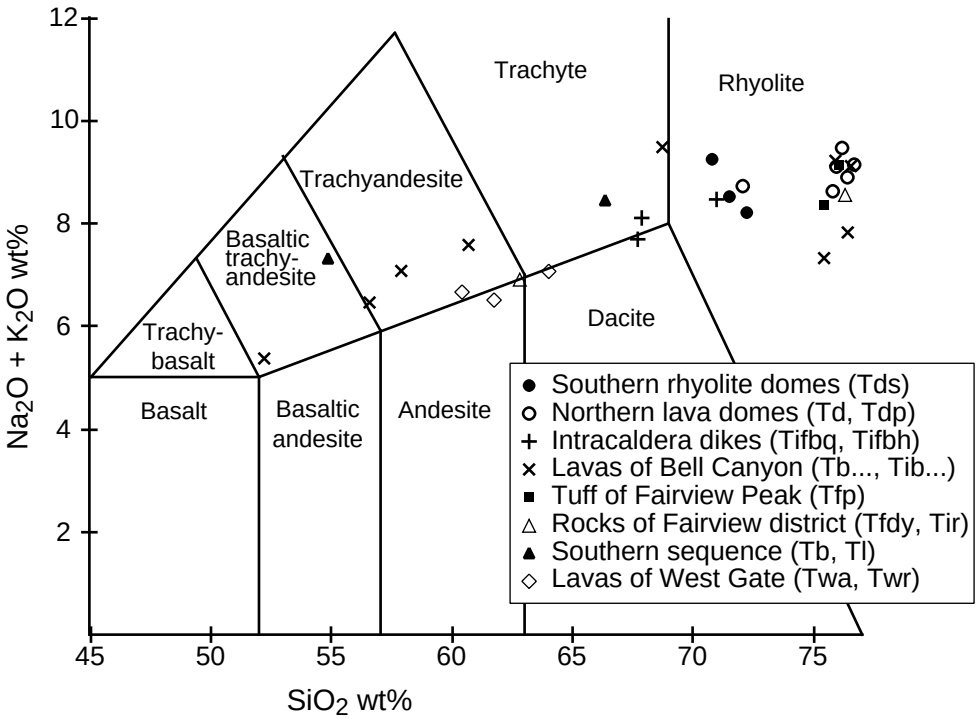


Figure 4. Total alkalies - silica plot of igneous rocks of the Fairview Peak caldera and vicinity, Nevada. Classification follows LeBas and others (1986). Major elements normalized to 100% volatile free.

form thick, short lava flows, locally with perlitic margins. Andesitic flows commonly consist entirely of vitrophyric breccia or have thick, vitrophyric breccia at the base that grades upward into massive vitrophyric lava. Dikes similar to the rhyolite (Tibr), dacite (Tibd), and andesite (Tiba) are common. Dikes invariably strike west-northwest, parallel to the caldera margin. Large, irregular intrusions of dacite are also abundant.

The lavas are interbedded with a heterogeneous mixture of primary and reworked tuff and volcaniclastic sedimentary rocks (Tbt). These rocks were mapped as a single unit because they are nonresistant, crop out only locally, and are difficult to distinguish.

Coarse, massive deposits containing angular, matrix-supported clasts up to 3 m in diameter in a soft tuffaceous matrix that is commonly altered to clay are abundant in Bell Canyon. These are probably coarse, proximal fall deposits (agglomerate) and debris shed from the flanks of lava domes. These coarse deposits range continuously to finer, bedded air-fall tuff consisting of beds about 3 to 20 cm thick that are defined by variations in size and abundance of lithic and pumice clasts. Clasts in all these deposits are mostly of nearby lavas, but fragments of other lavas and of amphibolite and granite are also present.

Sedimentary rocks include conglomerate, sandstone, and siltstone. Clasts in conglomerate are of lavas of Bell Canyon, mostly less than 10 cm in diameter, but coarser conglomerate with clasts up to 1 m in diameter is also present. Sandstone forms beds 1 to 10 cm thick that are commonly graded from coarse or medium sandstone to more finely laminated fine sandstone or siltstone.

Debris-flow and debris-avalanche deposits composed of amphibolite or granite from the caldera wall are interbedded with the volcaniclastic deposits and lavas. Most of these occur immediately adjacent to the caldera wall.

Rhyolitic Lava Domes, Related Tuffs, Dikes, and Basaltic Andesite

A group of rhyolitic lava domes (Td) and related air-fall tuffs and near-source pyroclastic deposits were emplaced contemporaneously with the lavas of Bell Canyon. The domes are extensive in the Bell Mountain Quadrangle but are represented by only three small areas of flow-banded rhyolite in the southeastern corner of the Bell Canyon Quadrangle. Ages on domes in the Bell Mountain Quadrangle are mostly between 19.0 and 18.9 Ma (table 2; fig. 5).

Late Intracaldera Dikes

The youngest recognized igneous activity related to the caldera is a series of east-striking dikes and small plugs that intrude the tuff of Fairview Peak and

continue eastward into the Bell Mountain Quadrangle (fig. 2). These are low-silica rhyolite or dacite, divided into two petrographic types (table 1; fig. 3): plagioclase-biotite-quartz phyric (Tifbq) and plagioclase-biotite-hornblende phyric (Tifbh). Sanidine is a minor component of some Tifbh dikes.

The plagioclase-biotite-quartz phyric dikes form two belts in the central and southern part of the caldera. Both belts continue as a single dike or two or three parallel dikes for 6 to 8 km across the major basin-and-range fault that forms the east face of Fairview Peak. Dikes are typically 10 to 20 m wide and near vertical. The plagioclase-biotite-hornblende phyric dike (Tifbh) can not be traced through talus on the east face of Fairview Peak. However, it widens eastward to about 300 m across at the eastern edge of the quadrangle.

$^{40}Ar/^{39}Ar$ ages on three samples of the plagioclase-biotite-hornblende phyric dikes are 18.82 ± 0.08 Ma (sanidine; H93-91), 18.83 ± 0.37 Ma (plagioclase; H93-12), and 18.37 ± 0.35 Ma (plagioclase; H93-104). The sanidine age probably most closely approximates the age of emplacement. Therefore, these dikes were intruded about 0.2 Ma after the lavas of Bell Canyon.

STRUCTURAL GEOLOGY

Caldera-Related Structures

CALDERA COLLAPSE

The Fairview Peak caldera is the major volcanic structure of the Bell Canyon and Bell Mountain Quadrangles. Caldera collapse occurred at about 19.2 Ma at the same time as eruption of the tuff of Fairview Peak. Collapse seems mostly to have been by piston-like subsidence of a coherent block. The caldera wall is best displayed in Bell Canyon, along the southwestern edge of the caldera (fig. 2). Here, lavas of Bell Canyon, late debris deposits or breccia, and, in a few areas, tuff of Fairview Peak rest against Cretaceous granodiorite or Jurassic-Triassic(?) metamorphic rock in the caldera wall. Juxtaposition of postcollapse rocks against the older rocks indicates that this is the eroded wall, not the caldera ring fracture, which must be buried beneath postcollapse rocks inward from the wall. The ring fracture may

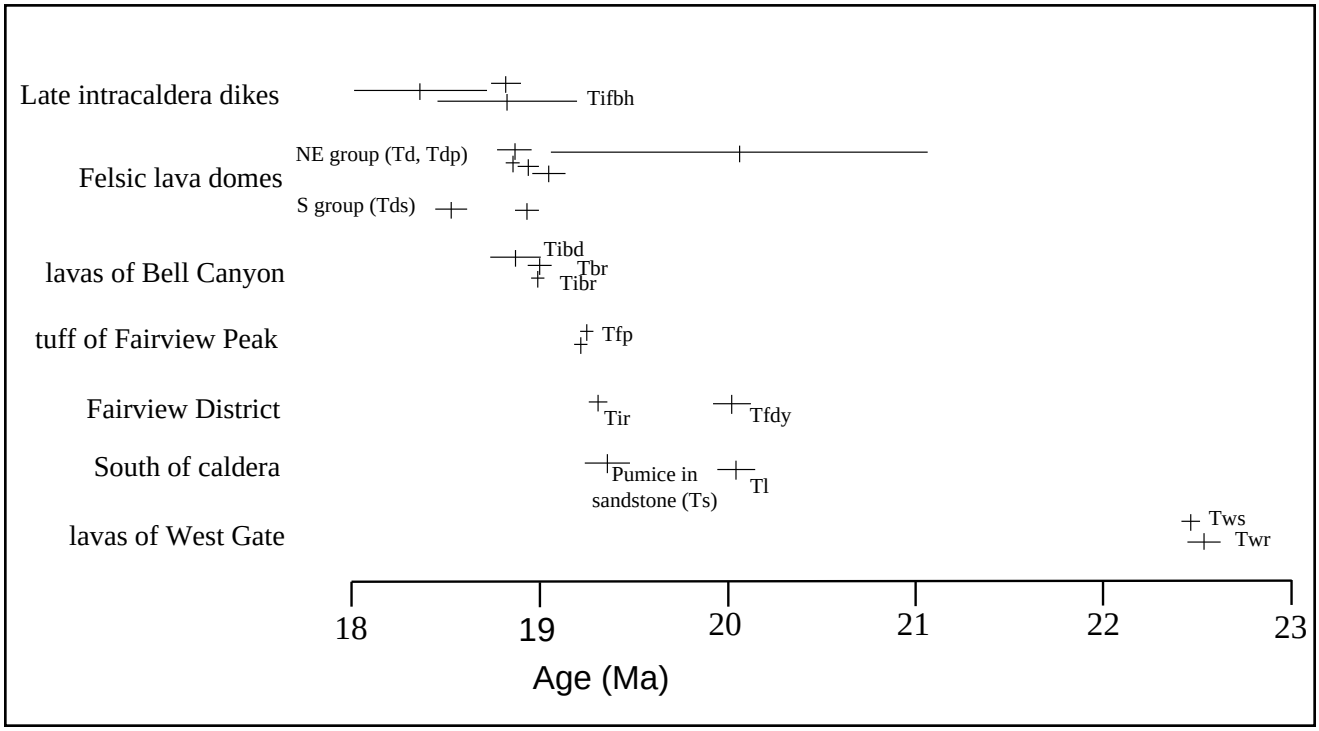


Figure 5. $^{40}Ar/^{39}Ar$ ages of volcanic rocks of the Fairview Peak caldera and vicinity, Nevada. Samples are plotted in stratigraphic order. Vertical line is mean age; horizontal line equals mean ± 1σ.

Table 1. Chemical analyses of Tertiary igneous rocks, Fairview Peak area.

	Lavas of West Gate			Southern sequence		Fairview district		Tuff of Fairview Peak		
Sample	**H93-7**	**H93-106**	**H93-85**	**H93-120**	**H94-19**	**H95-16**	**H95-5**	**H93-58**	**H93-135**	**H93-126**
Map unit	**Twa**	**Twa**	**Twr**	**Tb**	**Tl in Tcg**	**Tfdy**	**Tir**	**Tfp**	**Tfp**	**Tfp**
W. Long	**118°04.5′**	**118°02.9′**	**118°02.4′**	**118°04.9′**	**118°02.4′**	**118°09.5′**	**118°09.9′**	**118°05.4′**	**118°09.1′**	**118°09.1′**
N. Lat	**39°15.8′**	**39°14.7′**	**39°15.8′**	**39°07.0′**	**39°07.8′**	**39°14.8′**	**39°14.4′**	**39°08.1′**	**39°11.9′**	**39°13.5′**
Quadrangle	**WG**	**BM**	**WG**	**BH**	**BM**	**BC**	**BC**	**BM**	**BC**	**BC**
Major oxides (weight %):										
SiO_2	60.41	61.74	64.01	54.82	66.31	62.79	76.27	75.41	76.02	76.00
TiO_2	0.86	0.77	0.64	1.45	0.50	0.64	0.15	0.13	0.12	0.12
Al_2O_3	16.92	16.98	16.83	18.31	16.98	17.20	13.06	13.52	13.21	13.15
FeO*	6.12	5.21	4.30	7.68	2.99	4.61	0.93	1.06	1.02	0.97
MnO	0.06	0.09	0.14	0.12	0.08	0.10	0.02	0.06	0.06	0.06
MgO	2.81	3.13	1.08	2.48	0.92	2.47	0.16	0.04	0.02	0.11
CaO	5.83	5.28	5.70	6.88	3.58	5.02	0.82	1.40	0.51	0.51
Na_2O	4.17	3.57	4.16	4.63	4.61	4.35	3.78	3.67	4.25	4.74
K_2O	2.48	2.94	2.90	2.74	3.84	2.53	4.76	4.69	4.77	4.32
P_2O_5	0.35	0.30	0.24	0.89	0.20	0.28	0.05	0.03	0.03	0.03
Total	100.59	99.44	100.36	100.33	99.25	99.98	99.79	98.73	100.68	100.65
Trace elements (ppm):										
Sc	15	12	17	19	8	16	0	4	4	3
V	124	117	102	142	57	99	8	0	13	8
Cr	39	28	27	25	6	12	0	5	7	2
Ni	13	10	10	9	7	6	11	10	11	10
Cu	23	17	10	135	0	10	5	4	5	8
Zn	87	80	68	108	65	78	32	46	30	34
Ga	20	18	19	25	22	21	18	15	14	14
Rb	57	74	82	73	83	56	159	204	151	130
Sr	980	680	750	658	495	885	94	179	79	85
Y	14	16	14	39	15	14	18	19	18	17
Zr	162	180	138	340	249	158	131	130	121	118
Nb	7	11	8	20	12	9	18	20	20	18
Ba	1437	1359	1118	1054	1621	1169	401	647	562	552
La	44	36	34	32	23	18	35	35	54	41
Ce	57	51	56	100	59	40	69	59	72	60
Pb	18	16	19	22	16	14	26	24	17	14
Th	8	9	14	7	7	6	19	14	15	15

All analyses by X-ray fluorescence at the Geoanalytical Laboratory, Washington State University. WG=West Gate; BC=Bell Canyon; BM=Bell Mountain; SM=Slate Mountain; BH=Broken Hills. Major elements are normalized to 100% on a volatile-free basis; total is before normalization. *Total Fe expressed as FeO.

coincide with the broad zone of west-northwest-striking dikes. The anomalous north-striking segment of the caldera wall in Bell Canyon closely follows the contact between Cretaceous granodiorite and metamorphic rocks. The contact appears to have been a weak zone that guided collapse.

Elsewhere, the caldera margin is mostly buried beneath younger rocks. It strikes eastward across Bell Flat in the southern part of the quadrangle. It is mostly buried beneath tuff of Fairview Peak or lavas of Bell Canyon west and southwest of Fairview Peak. However, the topographic wall appears to pass just south of the Fairview district, and the northeast-striking, down-to-the-southeast faults in the Fairview district could be minor, outer parts of the ring fracture system. The caldera margin crosses to the east just north of Fairview Peak but is obscured by extensive talus.

CALDERA RESURGENCE

The Fairview Peak caldera is resurgent. The most prominent evidence for resurgence is the west-northwest-striking fault on the north side of Bell Canyon (fig. 2). This fault uplifts tuff of Fairview Peak at least 1 km on the northeast against lavas of Bell Canyon on the southwest. The fault turns to strike north past the Gold Coin Mine and then dies out still farther north.

Similar faults are not observed elsewhere around

Table 1. Chemical analyses of Tertiary igneous rocks, Fairview Peak area (continued).

	Lavas of Bell Canyon									Late intracaldera dikes		
Sample	**H93-144**	**H93-140**	**H93-139**	**H93-155**	**H93-137**	**H94-46**	**H93-20**	**H93-52**	**H93-141**	**H93-12**	**H93-90**	**H93-104**
Map unit	**Tbb**	**Tba**	**Tba**	**Tba**	**Tbd**	**Tibd**	**Tbr**	**Tbr**	**Tibr**	**Tifbh**	**Tifbq**	**Tifbh**
W. Long	**118°13.4′**	**118°12.9′**	**118°13.0′**	**118°10.2′**	**118°12.8′**	**118°10.0′**	**118°11.5′**	**118°11.9′**	**118°13.4′**	**118°06.1′**	**118°06.4′**	**118°03.7′**
N. Lat	**39°10.2’**	**39°09.3’**	**39°09.3’**	**39°08.7′**	**39°08.9′**	**39°08.9′**	**39°08.6′**	**39°08.3′**	**39°08.4′**	**39°13.6′**	**39°11.7′**	**39°13.7′**
Quadrangle	**BC**	**BC**	**BC**	**BC**	**BC**	**BC**	**BC**	**BC**	**BC**	**BM**	**BM**	**BM**
Major oxides (weight %):												
SiO_2	52.21	56.50	57.81	60.62	68.68	75.38	75.87	76.41	76.52	67.87	67.68	70.94
TiO_2	1.54	1.12	1.18	0.92	0.49	0.26	0.14	0.14	0.11	0.45	0.41	0.34
Al_2O_3	17.83	17.86	19.17	18.08	15.76	13.03	13.27	13.20	12.91	16.00	15.90	15.39
FeO*	9.38	6.97	5.00	4.95	2.58	1.56	0.78	0.92	0.66	3.33	3.11	2.24
MnO	0.15	0.13	0.08	0.10	0.04	0.05	0.03	0.03	0.07	0.09	0.09	0.05
MgO	4.32	3.17	2.41	1.99	0.68	0.44	0.00	0.66	0.00	1.38	1.25	0.46
CaO	8.62	7.53	6.98	5.52	2.11	1.84	0.69	0.79	0.62	2.60	3.69	1.99
Na_2O	3.91	4.50	4.72	4.77	5.03	3.71	4.41	2.20	4.14	4.51	3.88	4.57
K_2O	1.42	1.89	2.27	2.74	4.46	3.59	4.80	5.62	4.96	3.58	3.80	3.90
P_2O_5	0.62	0.35	0.37	0.30	0.17	0.13	0.02	0.03	0.01	0.20	0.18	0.13
Total	100.90	100.72	100.82	100.82	100.83	100.35	101.62	99.33	98.27	100.73	99.95	100.72
Trace elements (ppm):												
Sc	30	25	24	19	9	9	6	5	3	6	10	10
V	214	160	171	114	32	19	0	9	0	52	53	30
Cr	73	61	52	27	2	0	1	0	2	5	11	5
Ni	20	16	15	4	5	9	10	9	8	6	6	6
Cu	37	22	27	15	5	4	8	5	10	8	11	4
Zn	114	82	86	79	56	40	27	46	35	63	55	55
Ga	20	19	21	20	19	15	17	14	14	19	19	20
Rb	20	52	53	68	131	169	162	175	218	103	131	121
Sr	803	695	740	607	321	291	75	70	43	414	550	307
Y	31	21	22	23	21	12	16	15	17	16	16	13
Zr	188	178	191	208	285	150	114	120	100	194	158	182
Nb	12	13	13	13	19	12	18	18	20	15	13	15
Ba	784	932	980	1216	1922	846	1058	1276	341	1235	860	1199
La	22	25	34	31	34	31	50	32	43	35	31	36
Ce	49	45	62	64	55	29	62	42	74	55	72	69
Pb	4	13	12	13	16	19	22	25	28	19	13	17
Th	2	4	3	7	14	8	17	19	20	11	9	11

All analyses by X-ray fluorescence at the Geoanalytical Laboratory, Washington State University. WG=West Gate; BC=Bell Canyon; BM=Bell Mountain; SM=Slate Mountain; BH=Broken Hills. Major elements are normalized to 100% on a volatile-free basis; total is before normalization. *Total Fe expressed as FeO.

continued

the caldera, but attitudes in the tuff of Fairview Peak suggest broad doming. The tuff in interior parts of the caldera is mostly flat lying, whereas tuff and debris deposits near the caldera margin dip toward the margin as much as 60° (fig. 2). This pattern is irregular. Tuff in the interior is locally moderately dipping, and tuff across the buried northern margin of the caldera appears to be mostly flat lying. Nevertheless, the overall pattern suggests the interior of the caldera has been uplifted relative to the margins. The attitudes show no relation to basin-and-range faults.

Resurgence occurred at about 18.9 Ma. The resurgent fault in Bell Canyon cuts rocks dated at 18.98 ± 0.06 and 18.97 ± 0.03 Ma. The fault is intruded by a 18.85±0.13 Ma dacite dike, which is itself faulted. This indicates that resurgence is related to the renewed pulse of magmatism manifest by the Bell Canyon rocks.

Basin-and-Range Faults

Present-day topography mostly reflects north-northeast-striking, late Tertiary to Holocene, basin-and-range faulting. The most prominent fault is the Fairview fault, which forms the eastern boundary of Fairview Peak and Slate Mountain (fig. 2). Total normal slip along the fault is at least 1,800 m, which is estimated from apparent offset of the tuff of Fairview Peak. Surface rupturing occurred along this fault during the 1954 Fairview Peak earthquake

Table 1. Chemical analyses of Tertiary igneous rocks, Fairview Peak area (continued).

	Northern rhyolite lava domes						Southern rhyolite domes		
Sample	**H93-107**	**H94-21**	**H94-22**	**H93-101**	**H93-114**	**H94-23**	**H93-118**	**H94-16**	**H94-20b**
Map unit	**Td**	**Td**	**Td**	**Tdp**	**Tdp**	**Tdp**	**Tds**	**Tds**	**Tds**
W. Long	**118°01.4′**	**118°00.8′**	**118°01.5′**	**118°02.1′**	**118°00.2′**	**118°01.4′**	**118°06.1′**	**118°30.1′**	**118°01.6′**
N. Lat	**39°13.5′**	**39°11.3′**	**39°14.3′**	**39°16.3′**	**39°12.4′**	**39°14.2′**	**39°08.3′**	**39°07.9′**	**39°08.0′**
Quadrangle	**BM**	**BM**	**BM**	**WG**	**BM**	**BM**	**BM**	**BM**	**BM**
Major oxides (weight %):									
SiO_2	75.86	76.43	75.78	72.07	76.16	76.70	70.75	71.50	72.20
TiO_2	0.10	0.11	0.09	0.32	0.11	0.10	0.28	0.31	0.30
Al_2O_3	12.65	12.98	12.62	14.95	12.87	12.82	15.13	15.26	14.76
FeO*	0.67	0.62	0.50	1.85	0.73	0.70	1.96	1.79	1.61
MnO	0.05	0.05	0.02	0.03	0.07	0.07	0.07	0.08	0.05
MgO	0.00	0.00	0.00	0.37	0.00	0.00	0.37	0.45	0.70
CaO	1.59	0.90	2.35	1.60	0.57	0.47	2.09	1.97	2.05
Na_2O	4.27	4.09	4.04	4.79	3.65	3.97	5.07	4.41	3.87
K_2O	4.81	4.80	4.57	3.92	5.82	5.17	4.17	4.11	4.36
P_2O_5	0.02	0.01	0.03	0.10	0.01	0.01	0.11	0.12	0.10
Total	100.72	100.62	99.95	101.16	99.41	99.09	100.00	99.53	99.35
Trace elements (ppm):									
Sc	7	2	4	5	2	6	5	4	4
V	1	0	8	25	7	11	21	28	37
Cr	2	0	0	1	2	0	8	0	0
Ni	7	9	8	6	9	8	6	10	12
Cu	9	3	0	4	6	4	9	4	5
Zn	32	38	29	49	39	42	45	45	47
Ga	18	17	18	19	15	16	16	20	18
Rb	165	162	138	111	170	164	119	117	116
Sr	44	48	109	268	20	14	339	311	354
Y	16	17	13	14	17	18	14	15	11
Zr	94	95	81	162	108	108	171	173	142
Nb	20	20	17	16	22	20	15	15	12
Ba	164	461	776	1221	312	209	1110	1197	1237
La	31	54	28	30	35	35	25	32	40
Ce	66	57	45	53	67	63	48	59	44
Pb	25	49	21	16	28	27	18	20	21
Th	19	19	17	12	17	17	13	13	15

All analyses by X-ray fluorescence at the Geoanalytical Laboratory, Washington State University. WG=West Gate; BC=Bell Canyon; BM=Bell Mountain; SM=Slate Mountain; BH=Broken Hills. Major elements are normalized to 100% on a volatile-free basis; total is before normalization. *Total Fe expressed as FeO.

(Slemmons, 1957; Slemmons and others, 1979; Caskey and others, in press). Movement on the fault has uplifted the range and tilted it to the west as indicated by westward dips of the tuff of Fairview Peak and lavas of Bell Canyon. Dips on these rocks range from 15° to as much as 72°. However, basin-and-range tilting is probably no more than about 20°. The steeper dips probably reflect a combination of tilting during resurgence and primary dips from draping of tuff over megabreccia. The steepest dips are concentrated above the nearly 2-km-long megabreccia block that is exposed south of Fairview Peak. Tuff deposited around this block would acquire a primary dip as it welded around the already solid block. Although this primary dip should be symmetrical, i.e., there should be a similar eastward dip east of the block, that area is buried beneath alluvial fan deposits on the downthrown, eastern side of the Fairview fault. The Fairview Peak caldera is younger than the approximately 24 Ma episode of high-magnitude extension and steep tilting that affected the nearby Stillwater Range (John, 1992b, 1995a), so did not undergo that episode of extension.

Basin-and-range faults also bound the western side of the range, but displacement along these faults is apparently much less than along the Fairview fault. The range is tilted to the west, and the western contact between bedrock and basin fill is much more irregular than along the east side. Nevertheless, Quaternary displacement has occurred along several fault segments on the western side.

Caldera-related structures greatly influenced the

location and geometry of the Fairview fault. The most noticeable influence is at the eastern end of Bell Canyon, where the fault makes two abrupt lateral steps (fig. 2). The fault steps eastward more than 1 km where it intersects the west-northwest “resurgent” fault. The Fairview fault then steps back a similar distance westward as it reaches the caldera wall where lavas of Bell Canyon abut metamorphic rocks. The area between these two steps forms a prominent eastward bulge in the otherwise broadly linear fault system.

The major, en-echelon step in the Fairview fault west of the Bell Mountain Mine may reflect a more subtle caldera-related structure. Here, the Fairview fault steps eastward about 1 km. Although considerable displacement has occurred along the western segment south of this step, surface displacement in 1954 died out along the western segment at this point and picked up on the eastern segment. This step aligns approximately with the east-striking vein system at the Bell Mountain Mine, one of the intracaldera dike systems, and an unusual, possibly fault-controlled, west-striking canyon in the Fairview Peak range.

A topographic profile along the surface trace of the Fairview fault is symmetrical through the caldera. The highest elevation along the fault, approximately 2,070 m (6,800 ft), is in the middle of the caldera. The surface trace of the fault drops progressively to the north and south from there, to approximately 1,370 m (4,500 ft) near US 50 to the north and 1,710 m (5,600 ft) east of Slate Mountain to the south. Calderas and

Table 2. $^{40}Ar/^{39}Ar$ Ages of Tertiary igneous rocks, Fairview Peak caldera and vicinity, Nevada.

Sample No.	Rock type	Quadrangle	Mineral	Age Method	Mean	std. dev.
Rhyolite domes						
Northeast domes (Td and Tdp)						
H93-114	Porphyritic rhyolite (Tdp)	Bell Mtn	sanidine	single crystal	18.94	0.06
H94-23	Porphyritic rhyolite (Tdp)	Bell Mtn	sanidine	single crystal	18.87	0.09
H94-21	Sparsely porphyritic rhyolite (Td)	Bell Mtn	sanidine	single crystal	19.05	0.09
H94-22	Sparsely porphyritic rhyolite (Td)	Bell Mtn	plagioclase	single crystal	20.06	1.00
H93-107	Sparsely porphyritic rhyolite (Td)	Bell Mtn	sanidine/plag	single crystal	18.86	0.04
Southern domes (Tds)						
H93-118	Rhyolite	Bell Mtn	plagioclase	single crystal	18.53	0.08
H94-20	Rhyolite	Bell Mtn	hornblende	plateau	18.94	0.06
			biotite	plateau	19.10	0.10
Late intracaldera dikes (Tifbh)						
H93-91	Dacite dike	Bell Mtn	sanidine	single crystal	18.82	0.08
H93-12	Dacite dike	Bell Mtn	plagioclase	single crystal	18.83	0.37
H93-104	Rhyolite dike	Bell Mtn	plagioclase	single crystal	18.37	0.35
Lavas of Bell Canyon						
H94-46	Dacite dike (Tibd)	Bell Canyon		plateau	18.85	0.13
H93-20	Rhyolite lava (Tbr)	Bell Canyon	sanidine	single crystal	18.98	0.06
H93-52	Rhyolite dike (Tibr)	Bell Canyon	sanidine	single crystal	18.97	0.03
Tuff of Fairview Peak (Tfp)						
H93-58	Vitrophyre	Bell Mtn	sanidine	single crystal	19.25	0.03
H93-108	Devitrified	Bell Mtn	sanidine	single crystal	19.22	0.03
Southern sequence						
H94-17	Pumice in Sandstone (Ts)	Bell Mtn	sanidine	single crystal	19.36	0.12
H94-19	Dacite (Tl) in Tcg	Bell Mtn	hornblende	plateau	20.04	0.10
			biotite	plateau	19.88	0.07
Fairview district						
H95-5	Rhyolite dome (Tir)	Bell Canyon	sanidine	single crystal	19.31	0.06
H95-16	Younger dacite (Tfdy)	Bell Canyon	hornblende	plateau	20.02	0.10
Lavas of Westgate						
H93-102	Tuff (Tws)	West Gate	sanidine	single crystal	22.46	0.06
H93-85	Dacite (Twr)	West Gate	sanidine	single crystal	22.53	0.09

their underlying magma bodies commonly resist extension elsewhere in the Basin and Range province (Hudson and others, 1994; Henry, in press). The Fairview Peak caldera apparently resisted but did not prevent extension here (see, for example, John, 1995a).

Alignment of the three late intracaldera dike swarms across the Fairview fault shows that net strike-slip displacement along the fault is negligible (fig. 2). Uncertainty in alignment allows a maximum of a few hundred meters of lateral slip but does not require any. This suggests that mullions that indicate a significant component of right-lateral strike-slip during the 1954 earthquake (Slemmons, 1957; Caskey and others, in press) can not be representative of long-term motion. Additionally, this indicates the Fairview Peak area is east of the Walker Lane, where northwest-striking, right-lateral strike-slip faults are prominent (Ekren and Byers, 1984; Hardyman and Oldow, 1991; Dilles and others, 1993).

HYDROTHERMAL ALTERATION AND MINERALIZATION

The Bell Canyon Quadrangle includes most of the Fairview and the western parts of the Gold Basin and Bell Mountain mining districts (Tingley, 1992). Gold-silver mineralization was discovered in the Fairview district near what was to become the Nevada Hills Mine in 1905, and major mining began in 1906 (Vanderburg, 1940; Schrader, 1947). Most other mines and prospects in the quadrangle were located within the next few years. Almost all production was from the northern part of the Fairview district, particularly from the Nevada Hills vein. Production totaled 52,799 troy ounces of gold and 5,124,369 ounces of silver, which, however, includes a small amount of production from Chalk Mountain (Willden and Speed, 1974). Most mining occurred between 1906 and 1917, after which time ore was largely depleted (Vanderburg, 1940). Minor, but unknown, amounts of gold and silver were produced from mines in the central and southern parts of the Fairview district, including workings in Gold Coin and Bell Canyons, and from Gold Basin. Bell Mountain has had extensive exploration and development, including as recently as 1994 (Tingley, 1995), but little production.

Volcanic rocks in the Fairview district have undergone propylitic alteration, which is most intense around the Nevada Hills Mine and, to a slightly lesser extent, around Gold Coin Canyon. Weak propylitic alteration is developed in the tuff of Fairview Peak and other igneous rocks throughout most of the western part of the caldera.

Most ore occurs in west-northwest-striking, steeply dipping quartz veins; quartz commonly replaced bladed calcite. Ore minerals were argentite, stephanite, cerargyrite, bromyryte, and gold; gangue minerals include quartz, calcite, rhodochrosite, and pyrite (Schrader, 1947; Tingley, 1990). The largest production was from the Nevada Hills vein, which is as much as 5 m wide. Similar veins are abundant throughout the northern part of the district. West-northwest- to east-striking veins occur at and near the Mizpah, Big Ledge, and Nevada Crown Mines. (Big Ledge is mislabeled Mizpah Mine on the Bell Canyon Quadrangle; Mizpah is about 500 m north of Big Ledge). Veins at the Gold Coin Mines (Nevada Fairview or Snyder Mines of Schrader, 1947) strike north along the resurgent fault or splay northeast from it. The Nevada Crown Mine is on the west-northwest-striking part of the resurgent fault in the northern part of Bell Canyon. Thick masses of calcite occur along the western part of the fault. Eastward, into formerly deeper parts of the fault, calcite is replaced by quartz, and a zone as much as 10 m wide along the fault is intensely silicified.

Most mineralization of the Fairview district probably formed at about 18.9 Ma or shortly thereafter. This conclusion is based on the similarity of veins and alteration along the resurgent fault in Bell Canyon to veins throughout the Fairview district. Veins in the main part of the district, around Nevada Hills, are in older and largely undated rock. However, similar veins to the south are in tuff of Fairview Peak, and, in Bell Canyon, in lavas and intrusions of the lavas of Bell Canyon. Previous workers inferred that the younger dacite (Tfdy) and rhyolite intrusions (Tir) near the Nevada Hills Mine were postmineralization (Schrader, 1947; Willden and Speed, 1974) because they are relatively little altered. This would make mineralization there older than about 20 Ma, the age of the younger dacite (table 2). However, both units have undergone weak propylitic alteration, with local conversion of biotite to chlorite and epidote, and rhyolite dikes similar to the main plug are locally intensely altered. The less intense alteration of these rocks probably reflects their former position much higher in the hydrothermal system before they were dropped down along the northeast-striking faults.

Mineralization in the western part of the Gold Basin district, in the Bell Canyon Quadrangle, occurred along or near the contact between the thick part of one of the intracaldera dikes (Tifbh) and tuff of Fairview Peak. Alteration of these rocks is minor, although the tuff is intensely silicified farther east.

Mineralization at the Bell Mountain Mine occurred along a N70°E-striking, 50-60° S-dipping

calcite vein. The vein is as much as 15 m wide and at least 1.5 km long, extending eastward into the Bell Mountain Quadrangle. It is cut off on the west by a north-northwest-striking normal fault. Quartz partly replaces calcite but less completely than in the veins in the Fairview district. The vein contains native silver, cerargyrite, and possibly acanthite, which are interpreted to have formed from supergene oxidation of hypogene electrum, argentite, and possibly base metal sulfides and silver sulfosalts (A.L. Payne *in* Garside and Bonham, 1984). Gangue minerals are manganiferous calcite, quartz, and minor adularia, barite, fluorite, rhodochrosite, and montmorillonite. The tuff of Fairview Peak is locally intensely silicified around the vein. Tingley (1995) reported grades between 0.02 and 0.14 oz/ton gold and 0.08 and 3.5 oz/ton silver over widths of 10 to 155 feet. The only known production was 39 tons of ore with a grade of 0.5 oz/ton gold and 16.4 oz/ ton silver in 1927 (A.L. Payne in Garside and Bonham, 1984). Globex Mining of Montreal recently optioned the property and plans additional drilling (Tingley, 1995).

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