Text and references to accompany NBMG Field Studies Map 12

GEOLOGIC MAP OF THE BELL MOUNTAIN QUADRANGLE, WESTERN NEVADA

by
Christopher D. Henry

INTRODUCTION

The Bell Mountain Quadrangle lies in the southeastern part of Churchill County, in western Nevada (fig. 1). It covers a series of modest hills east of Fairview Peak, which lies in the Bell Canyon Quadrangle (Henry, 1996) to the west. Detailed geologic mapping of the Bell Mountain and Bell Canyon Quadrangles was undertaken for several purposes. (1) Significant mineralized areas 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 along the eastern edge of the Bell Canyon Quadrangle (fig. 2; Slemmons, 1957; Caskey and others, in press). Mapping was needed to provide a framework for neotectonic studies and to evaluate long-term motion on the fault. (3) The Bell Mountain and Bell Canyon 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, 1992a). The Bell Mountain-Bell Canyon 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 Mountain Quadrangle are predominantly Miocene igneous rocks, many related to a 19-Ma caldera, and upper Tertiary to Quaternary sedimentary deposits (fig. 2).

ROCK UNITS

Three major sequences of Tertiary volcanic, volcaniclastic, and intrusive rocks crop out in the Bell Mountain Quadrangle. From oldest to youngest, these are: (1) andesitic to rhyolitic lavas, tuffaceous sedimentary rocks, and minor ash-flow tuff (informally named lavas of West Gate) that crop out north of the Fairview Peak caldera and extend into the southern West Gate Quadrangle; (2) conglomerate, sandstone, basaltic andesite, and dacite that crop out south of the caldera and extend into the northern Broken Hills Quadrangle; and (3) a complex assemblage of ash-flow tuff, lava domes, debris deposits, and small intrusions that accumulated in and around the Fairview Peak caldera. Relative and absolute ages of all sequences are well established by field relations and $^{40}Ar/^{39}Ar$ ages.

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. All Tertiary igneous rocks are moderately alkalic (table 1; fig. 4).

Lavas of West Gate

The informally named lavas of West Gate and possibly related rhyolite dome (Tor) and bedded tuff (Tot) are the oldest rocks in the Bell Mountain Quadrangle. These rocks form a series of generally west-northwest-striking, southwest-dipping bands that are poorly exposed in the low hills north of the caldera. Dark-brown to dark-gray andesite is most abundant, followed by rhyolite and minor tuffaceous sedimentary rocks. Similar rocks, as well as abundant dacite lavas and nonwelded ash-flow tuff are extensive in the West Gate Quadrangle to the north (fig. 2). $^{40}Ar/^{39}Ar$ ages were determined on sanidine phenocrysts from a dacitic lava (22.53 ± 0.09 Ma; H93-85; table 2) and a rhyolitic ash-flow tuff (22.46 ± 0.06 Ma; H93-102) in the West Gate Quadrangle. These ages are consistent with the stratigraphic position of the sequence between the 19.2-Ma tuff of Fairview Peak and the 24.5-Ma tuff of Elevenmile Canyon (John, 1995), which underlies the lavas of West Gate to the north.

The total thickness of lavas of West Gate is uncertain but appears to be large. The outcrop belt,

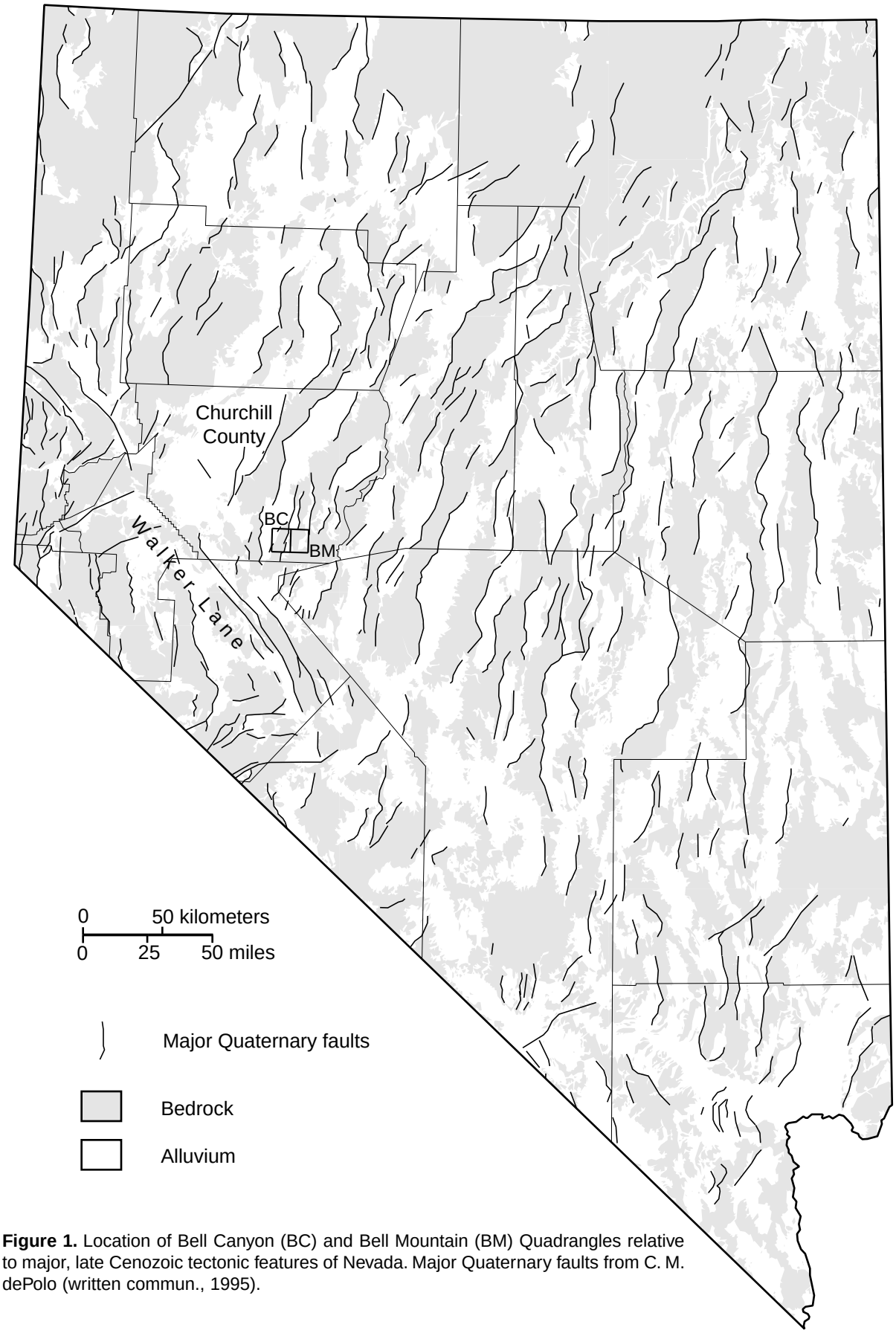


Figure 1. Location of Bell Canyon (BC) and Bell Mountain (BM) Quadrangles relative to major, late Cenozoic tectonic features of Nevada. Major Quaternary faults from C. M. dePolo (written commun., 1995).

including exposures in the West Gate Quadrangle, is 4 to 5 km wide perpendicular to the west-northwest strike. However, uncertainty in dip and in the extent of repetition by faulting makes determining an accurate thickness impossible. If the average dip is 20° and the sequence is not repeated by faulting, the outcrop width indicates an apparent thickness of 1,500 m.

SEDIMENTARY ROCKS, BASALTIC ANDESITE, AND DACITE SOUTH OF THE CALDERA

A thick sequence of coarse conglomerate, sandstone, basaltic andesite, and dacite crops out south of the Fairview Peak caldera. The rocks appear to form a northwest-plunging anticline with north-northwest- and west-northwest-striking limbs. The base of the sequence is not exposed in the mapped area, but the area southeast of the quadrangle, where a base could be exposed, is not mapped. Assuming that the sequence is not repeated by faulting, total thickness in the western limb is about 1,200 to 1,500 m.

Conglomerate (Tcg), which contains clasts of the interbedded basaltic andesite and dacite as well as sparse Cretaceous (?) granite, is the most abundant rock type. Conglomerate is markedly coarser in the western limb, where clasts are commonly up to 40 cm across, than in the eastern limb, where maximum clast size is about 20 cm. Sandstone, siltstone, and pebbly sandstone (Ts) occur in the upper part of the sequence in the western limb and in the lower part in the eastern limb. Basaltic andesite (Tb) forms several thin lava flows and flow breccias interbedded with conglomerate in the western belt. Several flows appear to consist entirely of breccia composed of scoriaceous to, rarely, massive blocks. Flows are absent in the eastern belt, but much of the conglomerate there consists entirely of basaltic andesite clasts. Abundantly porphyritic dacite (Tl) occupies the core of the anticline, forms several lenses in the western limb, and occurs only as pyroclastic breccia in the eastern limb.

$^{40}Ar/^{39}Ar$ ages on dacite are 20.04±0.10 and 19.88±0.07 Ma on hornblende and biotite, respectively (table 2; fig. 5). Sanidine from pumice in sandstone gives 19.36±0.12 Ma. These ages are consistent with the 19.2-Ma age of the overlying tuff of Fairview Peak. However, the ages require that deformation occurred between about 19.4 and 19.2 Ma, because the caldera truncates both the rocks and the anticline (see section on Structural Geology, below).

The thick sedimentary sequence dominated by coarse conglomerate suggests deposition in a graben or half graben generated by normal faulting. The distribution of lavas and the coarseness and clast-size distribution of conglomerate suggest a nearby, high-relief source to the west. Presence of Cretaceous (?) granitic clasts in the conglomerate suggests pre-Tertiary basement was exposed in the source area, presumably the footwall of a normal fault. During initial mapping, before recognition of the eastern limb, I interpreted the north-northwest-striking rocks of the western limb to have been deposited in a north-northwest-striking half graben, in which graben-bounding faults lay to the west. Recognition of the eastern limb requires a more complex evolution, although deposition in an initial north-northwest-striking half graben remains possible.

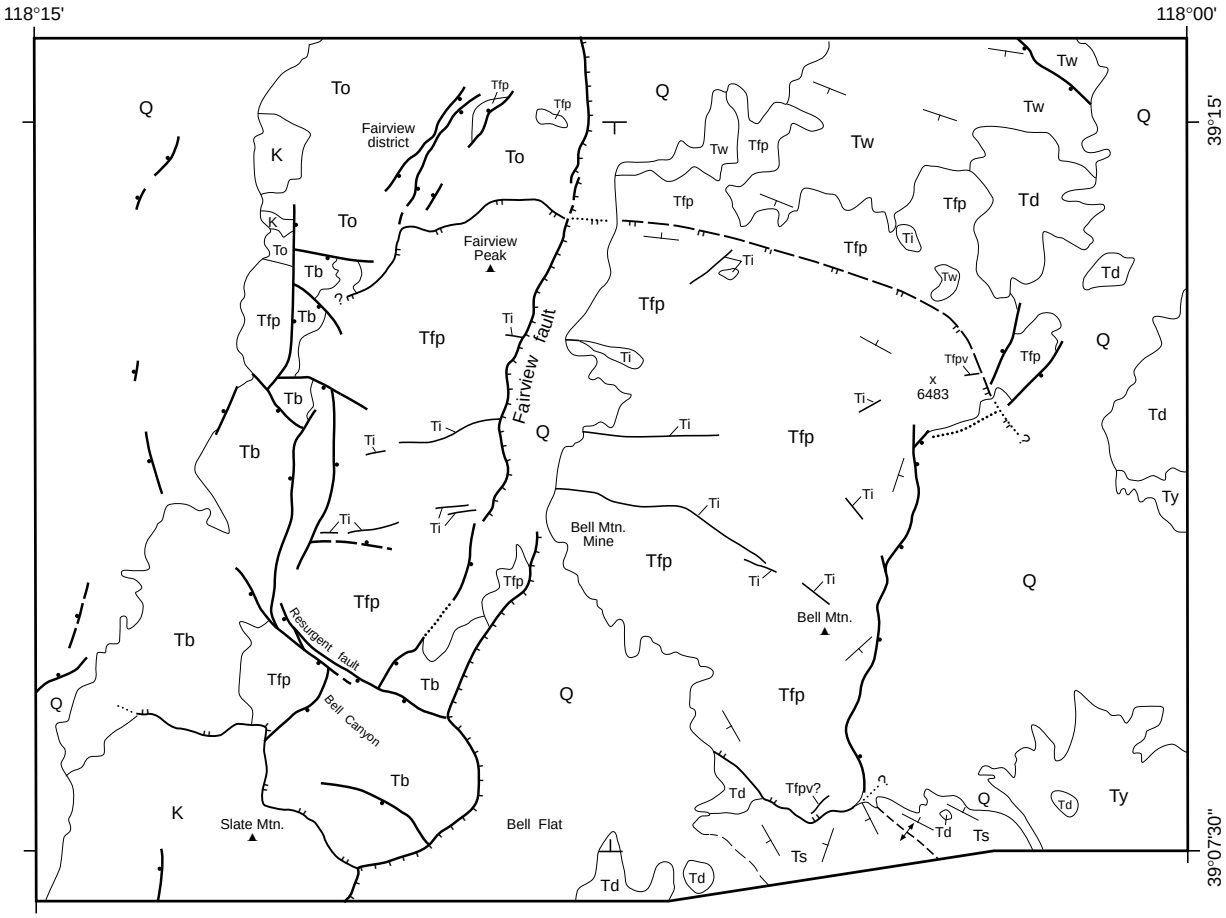
Rocks of the Fairview Peak Caldera

A complex assemblage of ash-flow tuff, basaltic andesite to rhyolite lava, rhyolite lava domes, and dacite to rhyolite dikes form a probably cogenetic suite erupted from the Fairview Peak caldera. These rocks erupted from sources in and around the caldera over a narrow time span between about 19.2 and 18.5 Ma (table 2; fig. 5). They form four distinct groups, only three of which are well represented in the Bell Mountain Quadrangle. The three are (1) the tuff of Fairview Peak and related megabreccia and debris deposits, (2) rhyolite lava domes and related tuffs and basaltic andesite lava, and (3) late intracaldera dikes. Basaltic andesite to rhyolite lavas (informal lavas of Bell Canyon) that are abundant in the Bell Canyon Quadrangle are sparsely present in the southwestern corner of the Bell Mountain Quadrangle.

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 Mountain and Bell Canyon Quadrangles and locally in the southwestern part of the West Gate Quadrangle. Throughout most of this area, the tuff accumulated within its own caldera, the Fairview Peak caldera. The thickest intracaldera exposure is 700 m of tuff in the east face of Fairview Peak in the Bell Canyon Quadrangle, and the base is not exposed. Outflow deposits extend into the southern part of the West Gate Quadrangle, north of the map area, and in a small area at the southern edge of the caldera. Outflow tuff north of the caldera partly covers irregular topography developed on top of the lavas of West Gate.

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 a single cooling unit in most outcrops. Moderately to poorly



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.

welded tuff and multiple cooling units occur within the caldera at Bell Mountain and in the northeastern part in the stratigraphically highest preserved deposits. Basal vitrophyre is present in probable outflow deposits near the northern and southern edge of the caldera.

One definite and one probable ash-flow vent (Tfpv), petrographically indistinguishable from the tuff of Fairview Peak, crop out in the quadrangle. The definite vent is an east-striking, dike-like body of vertically foliated rock that cuts through subhorizontal tuff near the approximate northeastern margin of the caldera (fig. 2). The dike is 200 m long, up to 20 m wide, and has a vitrophyric margin and a devitrified core. The probable vent consists of an irregularly northeast-striking, southeast-dipping, apparent dike of vitrophyre that cuts steeply through gently dipping, devitrified tuff.

Lenses of coarse, massive to poorly bedded debris-flow deposits, massive breccia, and minor bedded tuff (Tfpx) are interbedded with and overlie the uppermost parts of the tuff southwest of Bell Mountain. Large blocks, or megabreccia (Tfpb; Lipman, 1976), of precaldera rocks up to about 70 m in diameter lie within tuff or debris deposits, particularly in a north-striking belt east and northeast of Bell Mountain. The debris deposits and megabreccia represent large blocks that slumped from the caldera wall during eruption of the tuff of Fairview Peak and caldera collapse.

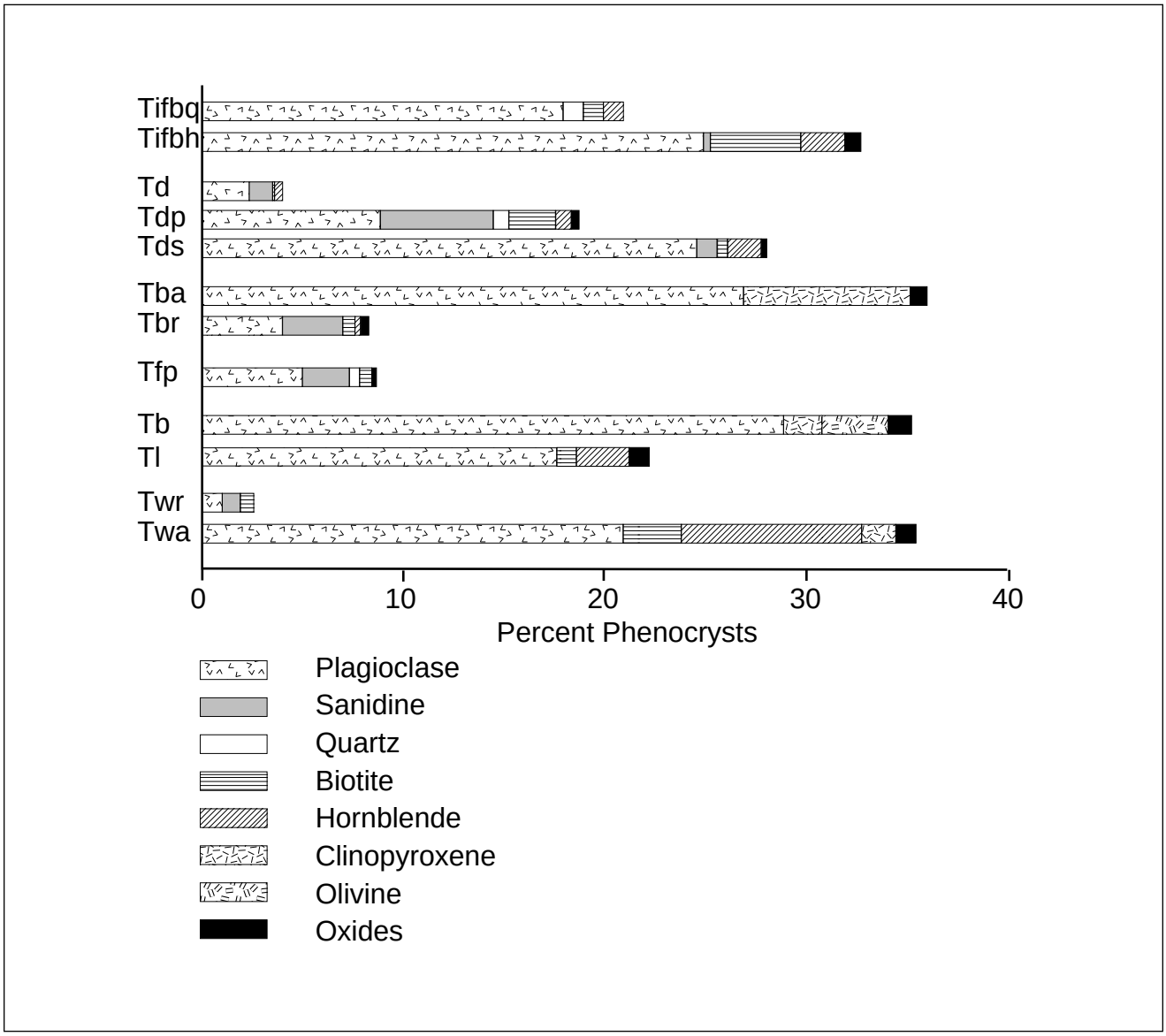


Figure 3. Phenocryst abundances in igneous rocks of the Bell Mountain Quadrangle.

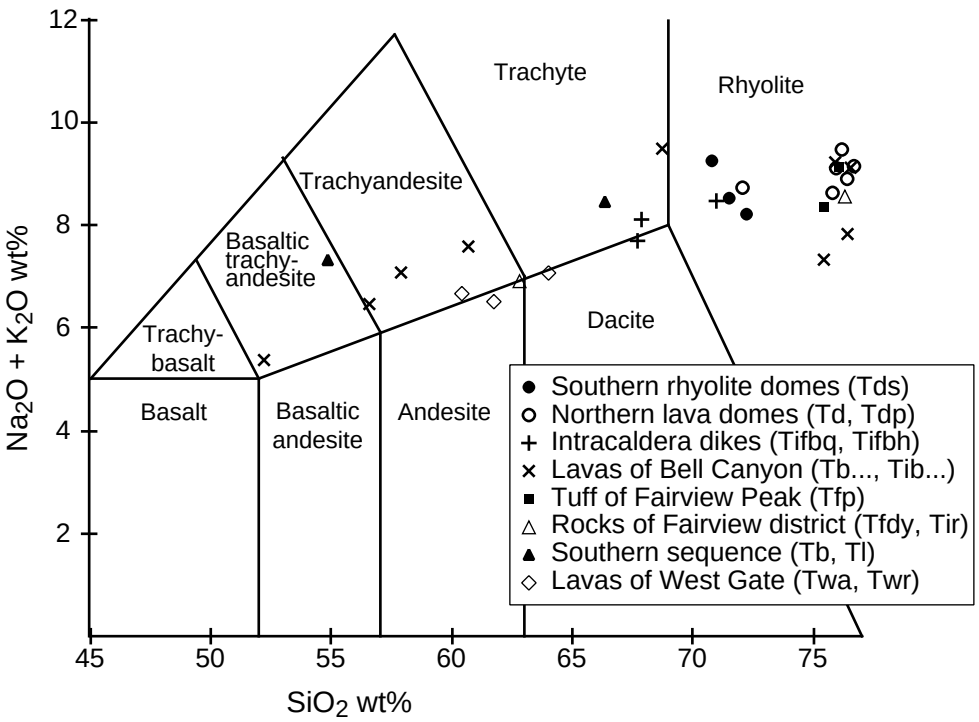


Figure 4. Total alkalies - silica plot of igneous rocks of the Fairview Peak caldera and vicinity, Nevada. Classification follows LeBas and others (1986). Major elements normalized to 100% volatile free.

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. The caldera underwent at least 700 m of collapse, the maximum observed thickness of tuff of Fairview Peak, and possibly much more than that.

LAVAS OF BELL CANYON

The lavas of Bell Canyon, which consist of basaltic andesite to rhyolite lava, related coarse to fine air-fall tuff, debris shed from the flanks of lava domes, and feeder dikes, were the next youngest igneous rocks of the caldera. These rocks crop out extensively in the Bell Canyon Quadrangle (fig. 2) but are present only as a small area of lava and one dike in the southwestern part of the Bell Mountain Quadrangle, where andesite lava (Tba) overlies flow-banded rhyolite lava (Tbr). A mostly vitrophyric dike of andesite (Tiba) cuts debris deposits 1 km east of the lava outcrop. $^{40}Ar/^{39}Ar$ ages from the Bell Canyon Quadrangle show that the lavas and dikes were emplaced between about 19.0 and 18.9 Ma (table 2; fig.4), 0.2 to 0.3 Ma after eruption of the tuff of Fairview Peak.

RHYOLITIC LAVA DOMES, RELATED TUFFS, DIKES, AND BASALTIC ANDESITE

Numerous rhyolite lava domes, accompanied by air-fall tuff, dikes, and basaltic andesite lava, were emplaced along or just outside the ring fracture of the caldera. Most domes formed between 19.0 and 18.9 Ma; one dome may be as young as 18.5 Ma (table 2; fig. 5). The domes are divided into three map units on the basis of their distribution and petrographic-chemical characteristics (table 1; fig. 3). A northeastern group of high-silica rhyolites are divided into sparsely and abundantly porphyritic types (Td and Tdp, respectively). Both types have the same phenocryst assemblage of plagioclase, sanidine, biotite, hornblende, and minor quartz. Abundantly porphyritic rocks contain 10 to 20% phenocrysts whereas sparsely porphyritic rocks contain no more than about 4% phenocrysts. A southern group consists of abundantly porphyritic, low-silica rhyolite (Tds). These contain about 30% phenocrysts, mostly plagioclase, hornblende, and biotite, with quartz and sanidine in some samples.

The northeastern group includes at least three abundantly porphyritic and four sparsely porphyritic domes. These domes form a northwest-striking belt that parallels but is probably 1 to 2 km outside the

caldera ring fracture. Both petrographic types form distinct topographic domes that probably mimic original extrusive morphology. Most have vitrophyric and/or vesicular margins that pass inward into devitrified, strongly flow-banded and flow-folded rock.

Several types of tuffs (Tdt) underlie or are intruded by the domes. These include poorly welded, lithic ash-flow tuff, well-bedded air-fall tuff, and minor tuffaceous sedimentary rock. Clasts in the tuffs are mostly perlitic, devitrified, or pumiceous blocks of rhyolite petrographically similar to that in the adjacent dome. These relations indicate that the tuffs are pyroclastic eruptions that immediately preceded lava extrusion.

$^{40}Ar/^{39}Ar$ ages of two abundantly and three sparsely porphyritic domes cluster tightly between 18.9 and 19.0 Ma (table 2). The 20.06 ± 1.00 Ma age on plagioclase from one dome could indicate an older body, but this age is indistinguishable from those of other domes within the very large uncertainty. Emplacement of the two petrographic types appears to have overlapped in time. The northernmost sparsely porphyritic dome overlies the adjacent abundantly porphyritic dome, whereas an abundantly porphyritic dome overlies a sparsely porphyritic dome near the east-central edge of the quadrangle.

The southern rhyolite domes (Tds) form an east-striking belt along and outward from the caldera margin. Individual domes vary from 200 m to 2 km across. Most of the smaller bodies are probably shallow intrusions, but all probably fed lava domes. Most are nonresistant and rise only slightly above the surrounding ground. All bodies have thick perlitic margins; interiors show thick, generally planar flow bands that parallel contacts and dip steeply inward. The largest dome, at the western end of the belt, appears to have intruded along the caldera ring fracture. It intrudes between intracaldera tuff of Fairview Peak on the northeast and precaldera conglomerate and basaltic andesite on the south. Coarse, massive to poorly bedded tuffaceous rocks (Tdst) occur around the easternmost dome.

$^{40}Ar/^{39}Ar$ ages determined on the westernmost and easternmost of the southern domes differ significantly (table 2; fig. 5). The hornblende age of 18.94 ± 0.06 Ma on sample H94-19 is probably the most reliable and is indistinguishable from ages on domes of the northeastern group. The age of 18.53 ± 0.08 Ma

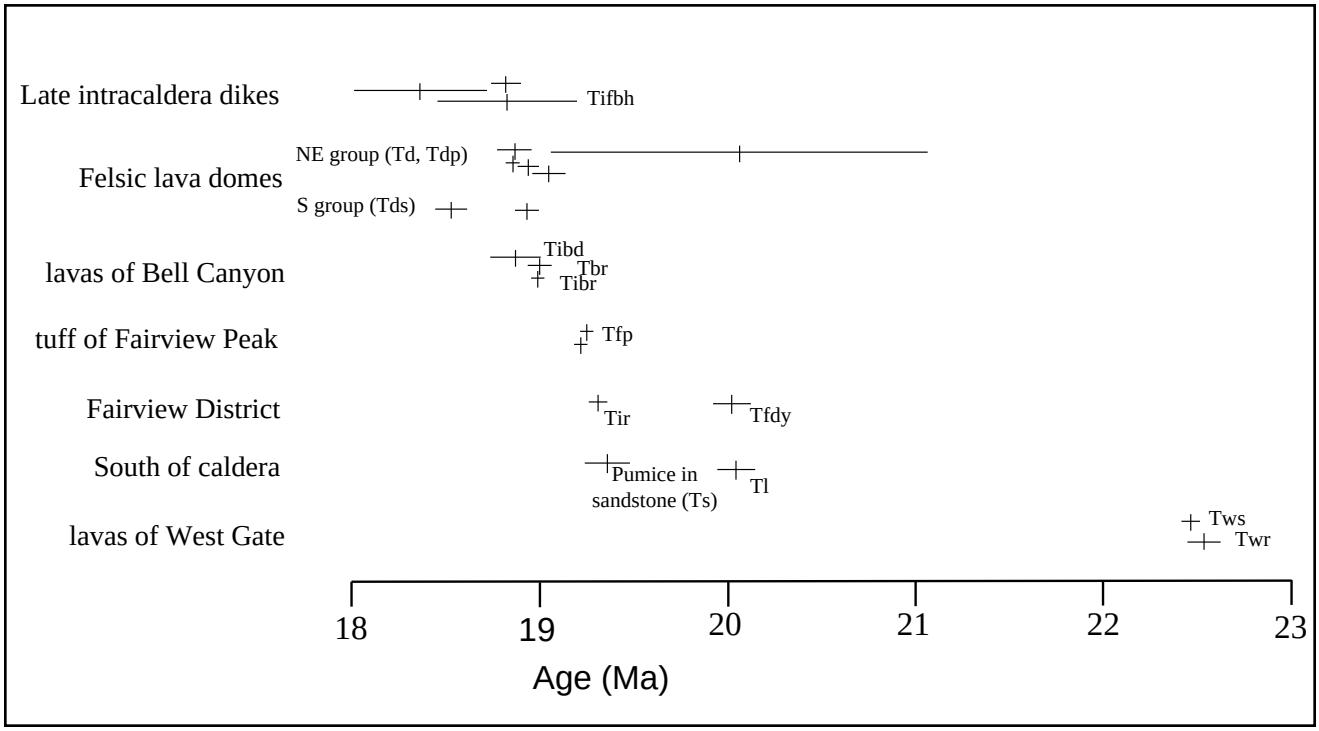


Figure 5. $^{40}Ar/^{39}Ar$ ages of volcanic rocks of the Fairview Peak caldera and vicinity, Nevada. Samples are plotted in stratigraphic order. Vertical line is mean age; horizontal line equals mean ± 1σ.

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.

on sample H93-118 is a weighted mean of one sanidine and five plagioclase analyses and is controlled almost entirely by the sanidine analysis. This age should be interpreted cautiously.

Basaltic andesite lavas occur at two stratigraphic levels near the east-central edge of the quadrangle. The older basaltic andesite (Tba1) overlies a sparsely porphyritic dome and underlies an abundantly porphyritic dome. Therefore, the older basaltic andesite was contemporaneous with the domes and could be a part of the caldera magmatic system. The younger lavas (Tba2) consist of several flows of sparsely and very finely porphyritic basaltic andesite that are more extensive to the east in the Quartz Mountain NW Quadrangle. These flows overlie the sedimentary rock sequence (Tsr) that overlies air-fall tuff (Tdt). Therefore, they could be significantly younger than the older basaltic andesite lavas or rhyolitic domes.

Unit Tsr consists of poorly cemented brown sandstone composed of volcanic rock and mineral fragments and white, tuffaceous sandstone. These overlie air-fall tuff (Tdt) along the eastern edge of the Bell Mountain Quadrangle. The brown sandstone contains rhyolitic fragments that are probably reworked from the domes and more mafic fragments that may be derived from the older basaltic andesite lavas. As with the younger basaltic andesite, these rocks could be significantly younger than the Fairview Peak caldera.

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

LATE INTRACALDERA DIKES

The youngest recognized igneous activity in the caldera is a series of generally east-striking dikes and small plugs that intrude the tuff of Fairview Peak and continue westward into the Bell Canyon Quadrangle (fig. 2). These are mostly 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 phenocrysts are a minor component of some Tifbh dikes. One andesite dike (Tia) is present.

The two largest plagioclase-biotite-quartz phyric dikes are 10 to 20 m wide and extend 6 to 8 km westward into the Bell Canyon Quadrangle. Several shorter dikes and a small (~50-m diameter) plug occur east along strike with the two larger dikes. The plagioclase-biotite-hornblende phyric type forms three stocks and a northeast-striking dike near the northern margin of the caldera. One stock, a 350-m wide body at the western edge of the quadrangle, narrows westward to a dike in the Bell Canyon Quadrangle.

$^{40}Ar/^{39}Ar$ ages on three samples of the plagioclase-biotite-hornblende phyric intrusions 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 best indicates the actual age of emplacement. Therefore, these dikes were intruded about 0.2 Ma after the lavas of Bell Canyon.

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.

STRUCTURAL GEOLOGY

Precaldera Structures

WEST-NORTHWEST-STRIKING LAVAS OF WEST GATE

The lavas of West Gate strike west-northwest and generally dip gently to the south (fig. 2). Detailed structural analysis is hampered by the paucity of good structural markers and poor exposure. Nevertheless, the west-northwest strike and gentle dip suggests an episode of low-magnitude north-northeast extension unless the beds have undergone subsequent vertical axis rotation. This episode of extension must have occurred between 22.5 and 19.2 Ma, the age of the tilted lavas of West Gate and the untilted tuff of Fairview Peak. John (1992) interpreted a similar episode of low-magnitude, north-northeast extension in the southern Stillwater Range at about 19 to 18 Ma on the basis of a swarm of west-northwest striking dikes. Steeper dips in lavas of West Gate and the older bedded tuff (Tot) near the buried caldera margin in the northwestern part of the quadrangle may indicate slumping into the caldera.

NORTHWEST-PLUNGING ANTICLINE SOUTH OF THE CALDERA

The sedimentary and lava sequence south of the caldera appears to form an open, northwest-plunging

anticline (fig. 2). The western limb strikes north-northwest and dips 20° to 50° westward. The eastern limb strikes west-northwest and dips 15° to 40° to the northeast. Details of the structure are poorly understood. Most of the hinge line is within massive, structureless dacite. Only a small part of the nose of the fold is exposed, but poor exposure precludes tracing individual beds around it. Farther northwest, the fold is buried beneath Quaternary deposits and cut off by the Fairview Peak caldera. The southeastern continuation of the structure in the Broken Hills Quadrangle has not been mapped.

The origin of this structure is uncertain. An initial interpretation was that the north-northwest-striking, west-dipping limb was deposited in a half graben resulting from east-northeast extension. East-northeast extension is characteristic of early extension in the Basin and Range province, including the Walker Lane and other nearby areas (Proffett, 1977; Zoback and others, 1981; John and others, 1989; John, 1992). Furthermore, east-northeast extension in the nearest well-documented example, in the Paradise Range 40 km to the south, occurred between 22 and 19 Ma (John and others, 1989), indistinguishable from the timing of activity here. However, east-northeast extension does not explain the west-northwest-striking limb, which is similar to the structural orientation in the lavas of West Gate. Continuation of structure between the two areas can not be demonstrated because they are at least 10 km apart, and the intervening area is covered by the caldera. Possibly the anticline developed along early strike-slip faults

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

similar to those of the Walker Lane. Although folds are common along strike-slip faults, they do not appear to be common in the Walker Lane (Ekren and Byers, 1984; Stewart, 1988; Hardyman and Oldow, 1991; Dilles, 1992). No clear evidence exists for strike-slip faults in the Bell Mountain area. Further work is required.

Caldera-Related Structures

CALDERA COLLAPSE

The Fairview Peak caldera is the major volcanic structure of the Bell Mountain and Bell Canyon Quadrangles. Caldera collapse occurred at approximately 19.2 Ma at the same time as eruption of the tuff of Fairview Peak. The caldera margin in the southern part of the Bell Mountain Quadrangle is marked by the truncation of the precaldera sedimentary rock sequence by the tuff of Fairview Peak (fig. 2). Near hill 6126, this tuff appears to form a thin, outflow veneer on precaldera rocks, with basal vitrophyre in several locations. Therefore, the ring fracture of the caldera must be slightly to the north. The linear, northwest-striking contact between tuff of Fairview Peak and the southern dome may follow the ring fracture. Continuation of the caldera margin to the east is uncertain. If outcrops of conglomerate (Tcg) east of the basin-and-range fault east of Bell Mountain are precaldera, then the caldera margin must turn abruptly northward and nearly follow the basin-and-range fault. Alternatively, the conglomerate is younger, and the caldera margin is buried beneath Quaternary fan deposits farther east.

The northern and northeastern margins of the caldera are buried by tuff of Fairview Peak. The ring fracture must lie south of the southernmost outcrops of lavas of West Gate. Postcollapse rhyolitic domes in the northeastern and eastern part of the quadrangle may lie along fractures parallel and related to, but outside, the caldera ring fracture.

CALDERA RESURGENCE

Resurgence of the Fairview Peak caldera is best shown by fault relations in Bell Canyon west of the quadrangle. There, the tuff of Fairview Peak was uplifted as much as 1 km along a near vertical, west-northwest-striking fault (fig. 2). Evidence for resurgence is more equivocal in the Bell Mountain Quadrangle, but attitudes of the intracaldera 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, in that 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. These attitudes do not seem to reflect tilting related to basin and range faulting.

The tuff of Fairview Peak forms gentle folds in two locations, near and southwest of Bell Mountain and north of hill 6483 in the northeastern part of the caldera. These folds could have formed by caldera resurgence or by protracted or episodic collapse.

Caldera 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

North-northeast-striking, late Tertiary to Holocene, basin-and-range faults are the major post-caldera structures. The most prominent is the Fairview fault, which bounds the eastern side of Fairview Peak in the Bell Canyon Quadrangle (fig. 2) and has at least 1800 m of normal slip. A basin-and-range fault bounds the eastern side of Bell Mountain and turns to a more northeastern strike in the northern part of the quadrangle before dying out still farther northeast. The topographic scarp and distribution of tuff of Fairview Peak indicate minimum displacement of 250 m along this fault. Bell (1984) showed the latest break as Pleistocene, but probably most displacement is older.

HYDROTHERMAL ALTERATION AND MINERALIZATION

The Bell Mountain Quadrangle includes the eastern parts of the Gold Basin and Bell Mountain mining districts (Tingley, 1990, 1992). Total production from these districts has been minor. Several mines in the Gold Basin district produced a small, but unknown amount of gold and silver during sporadic activity in the 1920s and 1930s (Tingley, 1990). The Bell Mountain Mine produced 39 tons of ore with a grade of 0.5 oz/ ton gold and 16.4 oz/ton silver in 1927 (A. L. Payne, cited in Tingley, 1990).

Mineralization at the Gold Bug Mine in the Gold Basin district at the western edge of the quadrangle occurred along the contact between the thick part of

one of the intracaldera dikes (Tifbh) and tuff of Fairview Peak. Rock there is moderately kaolinized and silicified. Several adits and shafts in the canyon to the northeast follow minor north-northeast-striking faults and fractures in the tuff of Fairview Peak. The tuff has undergone minor silicification and weak propylitic alteration, which is also developed in tuff throughout most of the caldera. Intensely silicified tuff forms two prominent knobs at the eastern end of the canyon. Quaternary alluvium in the canyon has been mined for placer gold.

Mineralization at the Bell Mountain Mine occurs along a N70°E-striking, 50-60°S-dipping calcite vein that is partly replaced by quartz. The vein is as much as 15 m wide and at least 1.5 km long, extending westward into the Bell Canyon Quadrangle. A similar east-striking vein that occurs approximately 800 m east of the eastern end of the Bell Mountain vein has also been explored. In the Bell Canyon Quadrangle, the vein contains native silver, cerargyrite, and possibly acanthite, which are interpreted to have resulted 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 veins. Tingley (1995) reported grades between 0.02 and 0.14 oz/ton gold and 0.08 and 3.5 oz oz/ton silver over widths of 10 to 155 feet (3 to 47 m). Most of this material is probably in the Bell Canyon Quadrangle. Globex Mining of Montreal recently optioned the property and plans additional drilling (Tingley, 1995).

The Cye Cox prospect in the eastern part of the Bell Mountain district at peak 6483 is in highly fractured and intensely silicified tuff of Fairview Peak. Attempts to leach ore at the property were probably unsuccessful (Tingley, 1990). A small outcrop surrounded by gravel southeast of peak 6483 consists of intensely brecciated, silicified bedded tuff (Tfph). The tuff contains angular clasts of flow-banded rhyolite, pumice, and other volcanic rocks and contains minor pyrite. This deposit appears to be hydrothermal breccia formed in the uppermost part of a hydrothermal system, probably related to the Fairview Peak caldera.

ACKNOWLEDGMENTS

$^{40}Ar/^{39}Ar$ ages were determined by the author in the Geochronology Laboratory of the New Mexico Bureau of Mines and Mineral Resources, under the guidance of Bill McIntosh and Matt Heizler. All chemical analyses were by X-ray fluorescence by Diane Johnson at the Geoanalytical Laboratory, Washington State University. Geologic mapping was supported by Kennecott Exploration Company.

REFERENCES

Bell, J. W., 1984, Quaternary fault map of Nevada-Reno sheet: Nevada Bureau of Mines and Geology Map 79, scale 1:250,000.

Caskey, S. J., Wensousky, S. G., Zhang, P., and Slemmons, D. B., in press, Surface faulting of the 1954 Fairview Peak (Ms=7.2) and Dixie Valley (Ms=6.9) earthquakes, central Nevada: Bulletin of the Seismological Society of America.

Dilles, J. H., 1992, Cenozoic normal and strike-slip faults in the northern Wassuk Range, western Nevada: *in* Craig, S. D., ed., Structure, tectonics, and mineralization of the Walker Lane, Geological Society of Nevada, p. 114-136.

Ekren, E. B., and Byers, F. M., Jr., 1984, The Gabbs Valley Range - A well exposed segment of the Walker Lane in west-central Nevada, *in* Lintz, Joseph, Jr., ed., Western geological excursions, volume 4, Annual Meeting of the Geological Society of America: Boulder, Geological Society of America, p. 203-215.

Ekren, E. B., and Byers, F. M., Jr., 1986, Geologic map of the Mount Annie NE, Mount Annie, Ramsey Springs, and Mount Annie SE Quadrangles, Mineral and Nye Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-1579, scale 1:48,000.

Garside, L. J., and Bonham, H. F., Jr., 1984, Precious metal districts in west-central Nevada, *in* Johnson, J. L., and Steininger, R. C., eds., Exploration for ore deposits of the North American cordillera: Association of Exploration Geochemists, p. FT4-1 FT4-30.

Greene, R. C., Stewart, J. H., John, D. A., Hardyman, R. F., Silberling, N. J., and Sorensen, M. L., 1991, Geologic map of the Reno 1° by 2° Quadrangle, Nevada and California: U. S. Geological Survey Miscellaneous Field Studies Map MF-2154-A, scale 1:250,000.

Hardyman, R. F., and Oldow, J. S., 1991, Tertiary tectonic framework and Cenozoic history of the central Walker Lane, Nevada, *in* Raines, G. L., Lisle, R. E., Schafer, R. W., and Wilkinson, W. H., eds., Geology and ore deposits of the Great Basin: Geological Society of Nevada Symposium Proceedings, v. 1, p. 279-301.

Henry, C. D., 1996, Geologic map of the Bell Canyon Quadrangle, western Nevada: Nevada Bureau of Mines and Geology Field Studies Map.

John, D. A., 1992, Late Cenozoic volcanotectonic evolution of the southern Stillwater Range, west-central Nevada: *in* Craig, S. D., ed., Structure, tectonics, and mineralization of the Walker Lane, Geological Society of Nevada, p. 64-92.

John, D. A., 1995, Tilted middle Tertiary ash-flow calderas and subjacent granitic plutons, southern Stillwater Range, Nevada: Cross sections of an Oligocene igneous center: Geological Society of America Bulletin, v. 107, p. 180-200.

John, D. A., Thomason, R. E., and McKee, E. H., 1989, Geology and K-Ar geochronology of the Paradise Peak Mine and the relationship of pre-Basin and Range extension to early Miocene precious metal mineralization in west-central Nevada: Economic Geology, v. 84, p. 631-649.

Le Bas, M. J., Le Maitre, R. W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750.

Lipman, P. W., 1976, Caldera-collapse breccias in the western San Juan Mountains, Colorado: Geological Society of America Bulletin, v. 87, p. 1397-1410.

Proffett, J. M., Jr., 1977, Cenozoic geology of the Yerington district, Nevada, and implications for the nature and origin of basin and range faulting: Geological Society of America Bulletin, v. 88, p. 247-266.

Slemmons, D. B., 1957, Geologic effects of the Dixie Valley-Fairview Peak, Nevada, earthquakes of December 16, 1954: Bulletin of the Seismological Society of America, v. 47, p. 353-375.

Stewart, J. H., 1988, Tectonics of the Walker Lane belt, western Great Basin: Mesozoic and Cenozoic deformation in a zone of shear, *in* Ernst, W. G., Metamorphism and crustal evolution of the western United States, Rubey volume VII: Englewood Cliffs, New Jersey, Prentice Hall, p. 683-713.

Stewart, J. H., 1992a, Walker Lane belt, Nevada and California, *in* Craig, S. D., ed., Structure, tectonics, and mineralization of the Walker Lane: Geological Society of Nevada, p. 1-16.

Stewart, J. H., 1992b, Paleogeography and tectonic setting of Miocene continental strata in the northern part of the Walker Lane belt, *in* Craig, S. D., ed., Structure, tectonics, and mineralization of the Walker Lane: Geological Society of Nevada, p. 53-61.

Tingley, J. V., 1990, Mineral resource inventory, Bureau of Land Management, Carson City District, Nevada: Nevada Bureau of Mines and Geology Open-File Report 90-1, 257 p.

Tingley, J. V., 1992, Mining districts of Nevada: Nevada Bureau of Mines and Geology Report 47, 124 p.

Tingley, J. V., 1995, Metals, *in* The Nevada Mineral Industry - 1994: Nevada Bureau of Mines and Geology Special Publication MI-1994, p. 11-22.

Willden, R., and Speed, R. C., 1974, Geology and mineral deposits of Churchill County, Nevada: Nevada Bureau of Mines and Geology Bulletin 83, 95 p.

Zoback, M., Anderson, R. E., and Thompson, G. A., 1981, Cainozoic evolution of the state of stress and style of tectonism of the Basin and Range province of the western United States: Philosophical Transactions of the Royal Society of London, Series A, v. 300, p. 407-434.