Text and references to accompany Nevada Bureau of Mines and Geology Map 109

GEOLOGY OF THE WONDER MOUNTAIN QUADRANGLE

CHURCHILL COUNTY, NEVADA

by

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INTRODUCTION

The Wonder Mountain Quadrangle covers about 150 km^2 spanning the Louderback Mountains and the southwest edge of the Clan Alpine Mountains in southeastern Churchill County, Nevada (fig. 1). These ranges are separated by Badger Flat, an alluviated upland surface in the south-central part of the quadrangle. Rocks and deposits exposed in the quadrangle are Mesozoic to Holocene in age. The oldest rocks are Mesozoic metamorphic rocks that crop out in a small area near the southwest corner of the quadrangle. These rocks are exposed in a small fault block in the footwall of a fault scarp formed during the 1954 Fairview Peak earthquake. Oligocene to earliest Miocene volcanic and hypabyssal intrusive rocks form most of the exposed bedrock and consist of several ash-flow tuffs from both proximal and distal sources, less abundant silicic to intermediate composition lava flows, minor volcaniclastic sedimentary rocks, and numerous silicic dikes and small intrusions. Most rocks were tilted moderately to steeply (20°-80°) by early Miocene extensional faulting. The early Miocene and older rocks are unconformably overlain by middle(?) Miocene intermediate composition lava flows at the northeast edge of the quadrangle and by latest Tertiary(?) and Quaternary surficial deposits that cover much of the central and southern parts of the quadrangle. Basin-and-range faulting, which began after approximately 13 Ma, formed the present topography and has continued into Holocene time as indicated by historic (1903 and 1954) faulting in several parts of the quadrangle (Slemmons, 1957; Slemmons and others, 1959; Bell, 1984; Caskey and others, 1996).

Geologic mapping of the Wonder Mountain Quadrangle was started in 1992 as part of the Reno 1° by 2° project of the Conterminous United States Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey and was completed in 1996 under the auspices of the Nevada Bureau of Mines and Geology Geologic Quadrangle Mapping Program. Published geologic maps of the area include reconnaissance maps of Schrader (1917, *in* Willden and Speed, 1974), Willden and Speed (1974), and Greene and others (1991). A geologic map of the adjacent Pirouette Mountain Quadrangle was published recently by John (1995a), and geologic maps of the Table Mountain (John, 1992), Job Peak (John, 1993a), and La Plata Canyon (John and Silberling, 1994) Quadrangles in the southern Stillwater Range, which contain many of the volcanic units present in the Wonder Mountain Quadrangle, also were published recently (fig. 1). Henry (1996a,b) also recently published geologic maps of the Bell Mountain and Bell Canyon Quadrangles to the south (fig. 1). John (1993b, 1994, 1995b), John and others (1993), and Dilles and others (1993) summarized the Cenozoic igneous and tectonic histories of the southern Stillwater Range. Numerous studies of Dixie Valley and the Dixie Valley fault were published following the 1954 earthquakes, including those of Byerly (1956), Slemmons (1957), Slemmons and others (1959), Thompson and others (1967), Thompson and Burke (1973), Anderson and others (1983), Okaya and Thompson (1985), Bell and Katzer (1987, 1990), Schaefer (1988), Parry and others (1991), and Caskey and others (1996). Mineral deposits in the Wonder Mountain Quadrangle have been described by Burgess (1917), Vanderburg (1940), Schrader (1947), Willden and Speed (1974), and Quade and Tingley (1987).

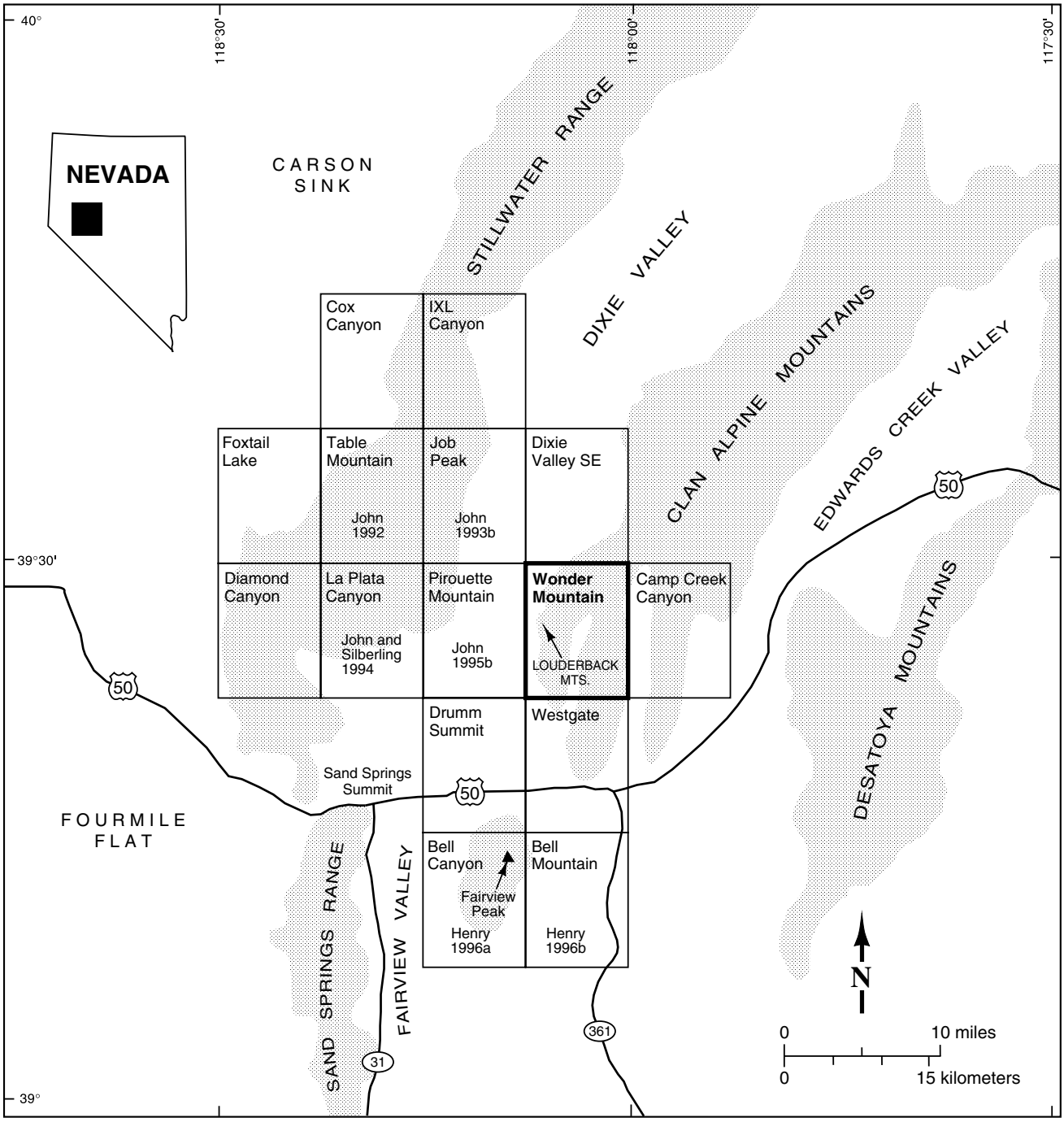

Figure 1. Index map of west-central Nevada showing location of Wonder Mountain Quadrangle and other nearby quadrangles and major physiographic and geographic features. References refer to recent geologic maps.

ROCK UNITS

Thick sequences of Oligocene to earliest Miocene ash-flow tuffs and lava flows of silicic to intermediate composition that unconformably overlie small outcrops of Mesozoic metamorphic rocks are exposed in the Wonder Mountain Quadrangle. The older Tertiary rocks are intruded by many types of silicic dikes and small intrusions of early to middle(?) Miocene age. These rocks locally are overlain unconformably by middle(?) Miocene andesite and dacite near the northeastern corner of the map area. The Mesozoic and Tertiary rocks are overlain unconformably by latest Tertiary(?) to Holocene surficial deposits, including alluvium, alluvial-fan deposits, and eolian sand.

The oldest rocks exposed in the quadrangle are Mesozoic metamorphic rocks (Mzmp) that crop out in a small exposure on the west side of the Louderback Mountains in the footwall of the surface trace of the 1954 Fairview Peak earthquake. These rocks consist of gray marble, garnet-pyroxene skarn, and platy, lineated black phyllite. These rocks are similar to Triassic and Jurassic rocks in the Clan Alpine sequence exposed in the Clan Alpine Mountains about 50 km northeast of the map area (N.J. Silberling, oral commun., 1993) and to small exposures of metamorphic rocks exposed in the Pirouette Mountain Quadrangle on the east side of Dixie Valley about 2 km to the west of the Wonder Mountain Quadrangle (John, 1995a).

The oldest Tertiary unit exposed in the quadrangle is crystal-rich rhyolite tuff comprising the older tuff unit (Tot) that crops out along the west side of the quadrangle in several locations. This ash-flow tuff was derived from an unknown source. It is undated radiometrically but presumably is early Oligocene in age (about 34 to 31 Ma) on the basis of the ages of the oldest tuffs in the region (Riehle and others, 1972; Stewart and others, 1994). The tuff is generally strongly altered hydrothermally, commonly to an assemblage of quartz + sericite + oxidized pyrite.

The older tuff unit is overlain by intermediate to silicic composition lava flows and less abundant welded tuff and epiclastic sedimentary rocks that form the older andesite (Toa) and older rhyolite (Tor) units. The older andesite unit is a heterogeneous sequence of aphyric to porphyritic andesite and dacite lava flows and minor dacite(?) tuff that forms scattered outcrops along the west edge of the quadrangle and more extensive outcrops near Pirouette Mountain just west of the map area (John, 1995a). The older rhyolite unit includes mostly crystal-poor, flow-banded rhyolite lava flows that probably are correlative with rhyolite lava flows, shallow intrusive rocks, and minor welded tuff which form large exposures in the Clan Alpine Mountains about 15 km northeast of the map area and a thick sequence (as much as 1,500 m) on the east side of the Stillwater Range in the Job Peak Quadrangle (John, 1994; fig. 2). Both units are variably altered hydrothermally, and contacts between the two are gradational on the west side of Pirouette Mountain in the Pirouette Mountain Quadrangle (John, 1995a). In the Wonder Mountain Quadrangle, neither unit has been dated isotopically, but the ages of rhyolites in the Clan Alpine Mountains are about 31 Ma (Riehle and others, 1972).

In the southwestern part of the Wonder Mountain Quadrangle, the upper part of the older rhyolite unit is locally interbedded with or overlain by a sequence of volcaniclastic sedimentary rocks (unit Tts) as much as several hundred meters thick. These rocks consist of mudstone, siltstone, sandstone, conglomerate, and less abundant bedded, water-laid(?) tuff. The conglomerate contains abundant clasts of the older rhyolite unit. Elsewhere, thin (a few meters thick) sequences of epiclastic conglomerate, sandstone, and siltstone that are rich in clasts of the older rhyolite unit commonly overlie this lava sequence but are not shown on the geologic map.

In most parts of the Wonder Mountain Quadrangle, the older rhyolite unit is overlain by the tuff of Job Canyon (Tjc). The tuff of Job Canyon is outflow ash-flow tuff from the approximately 28-Ma Job Canyon caldera, which lies in the southern Stillwater Range about 20 km to the northwest (fig. 2; John, 1995b). In the Wonder Mountain Quadrangle, at least three nearly identical ash flows separated by partial cooling breaks are present. The basal part of the unit is commonly choked with subrounded clasts of the older rhyolite unit and locally resembles a conglomerate. Outflow tuff contains about 25 to 30% phenocrysts (fig. 3) in contrast to 10 to 15% phenocrysts present in intracaldera tuff (John, 1995b). In the Wonder Mountain Quadrangle, the tuff is entirely devitrified and commonly altered to epidote-bearing assemblages. Outflow tuff of Job Canyon is generally 300 to 400 m thick in the Wonder Mountain Quadrangle, and locally reaches as much as 650 m thick in the southern Louderback Mountains.

The tuff of Job Canyon locally is overlain by thin, erosional remnants of a densely welded, locally rheomorphically flowed rhyolite ash-flow tuff (unit Trft). This tuff is undated but its age is constrained by the age of the tuff of Job Canyon (about 28 Ma) and the age of the overlying tuff of Elevenmile Canyon (about 24.6 Ma, table 1). Several other thin volcanic units are locally present between the tuff of Job Canyon and the overlying tuff of Elevenmile Canyon in the southern Clan Alpine Mountains just south of the Wonder Mountain Quadrangle.

Small exposures of the lower cooling unit of the tuff of Poco Canyon (Tpc) are present along the west edge of the quadrangle and just south of the quadrangle in the southern Clan Alpine Mountains where it lies between the rheomorphically flowed tuff and the overlying tuff of Elevenmile Canyon. The tuff of Poco Canyon is a crystal-rich, smoky quartz-rich rhyolite ash-flow tuff erupted from the Poco Canyon caldera in the southern Stillwater Range (fig. 2; John, 1995b). Two cooling units separated by the tuff of Elevenmile Canyon are present in the southern Stillwater Range (John, 1995b). Outflow tuff equivalent to the upper cooling unit is widespread in western and central Nevada (New Pass Tuff and probably the tuff of Chimney Springs; John, 1995b), but outflow tuff equivalent to the lower cooling unit has not been recognized previously.

In most of the Wonder Mountain Quadrangle, the tuff of Elevenmile Canyon (Tec) unconformably overlies the tuff of Job Canyon or the rheomorphically flowed

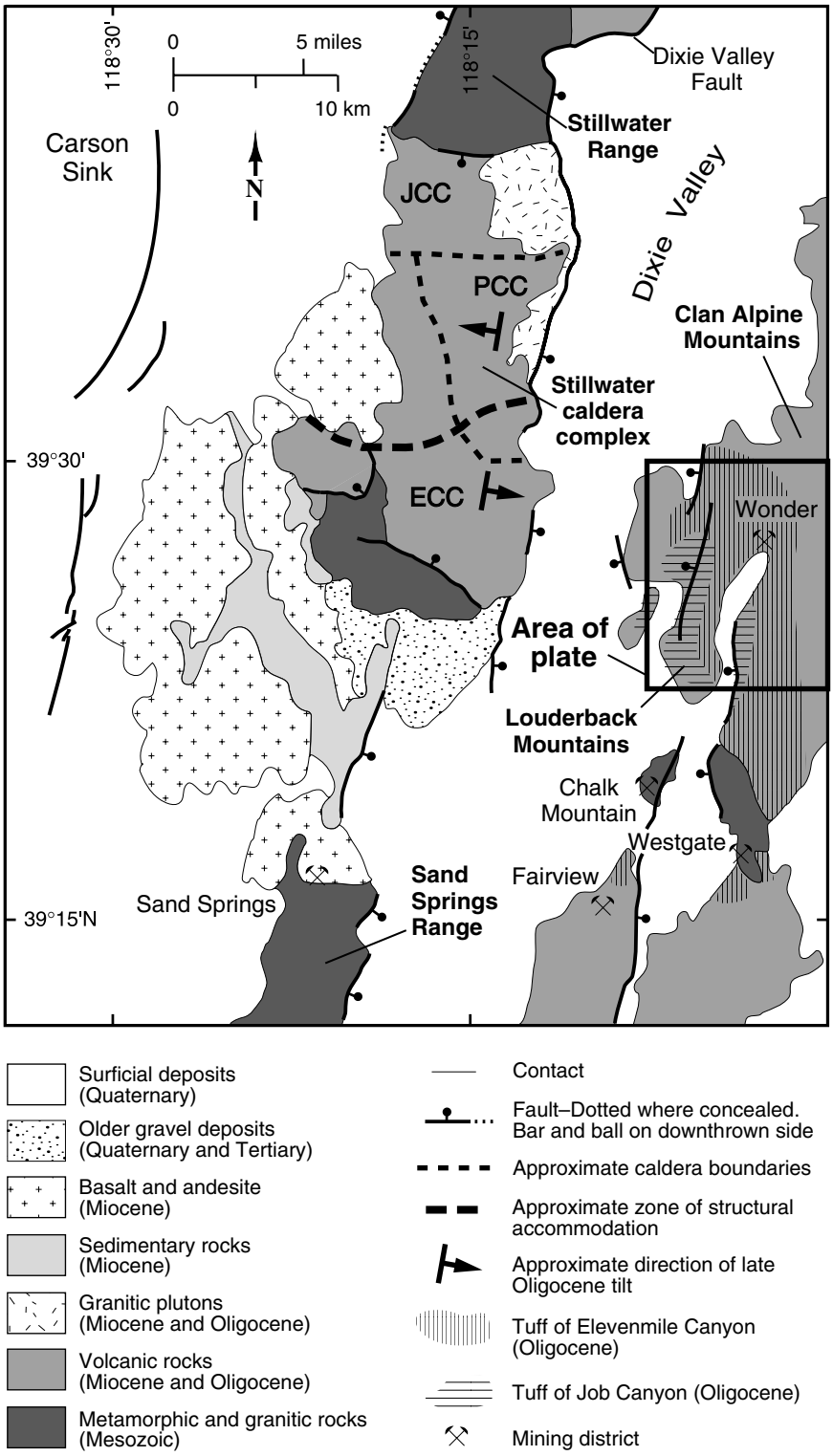

Figure 2. Simplified geologic map of the southern Stillwater Range, Louderback Mountains, and vicinity showing location of the Wonder Mountain Quadrangle, the Stillwater caldera complex, approximate outlines of the Job Canyon (JCC), Elevenmile Canyon (ECC), and Poco Canyon (PCC) calderas, and the known distribution of the tuffs of Job Canyon and Elevenmile Canyon outside of the southern Stillwater Range. Also shown is the approximate zone of late Oligocene structural accommodation in the southern Stillwater Range and average tilt direction in late Oligocene rocks.

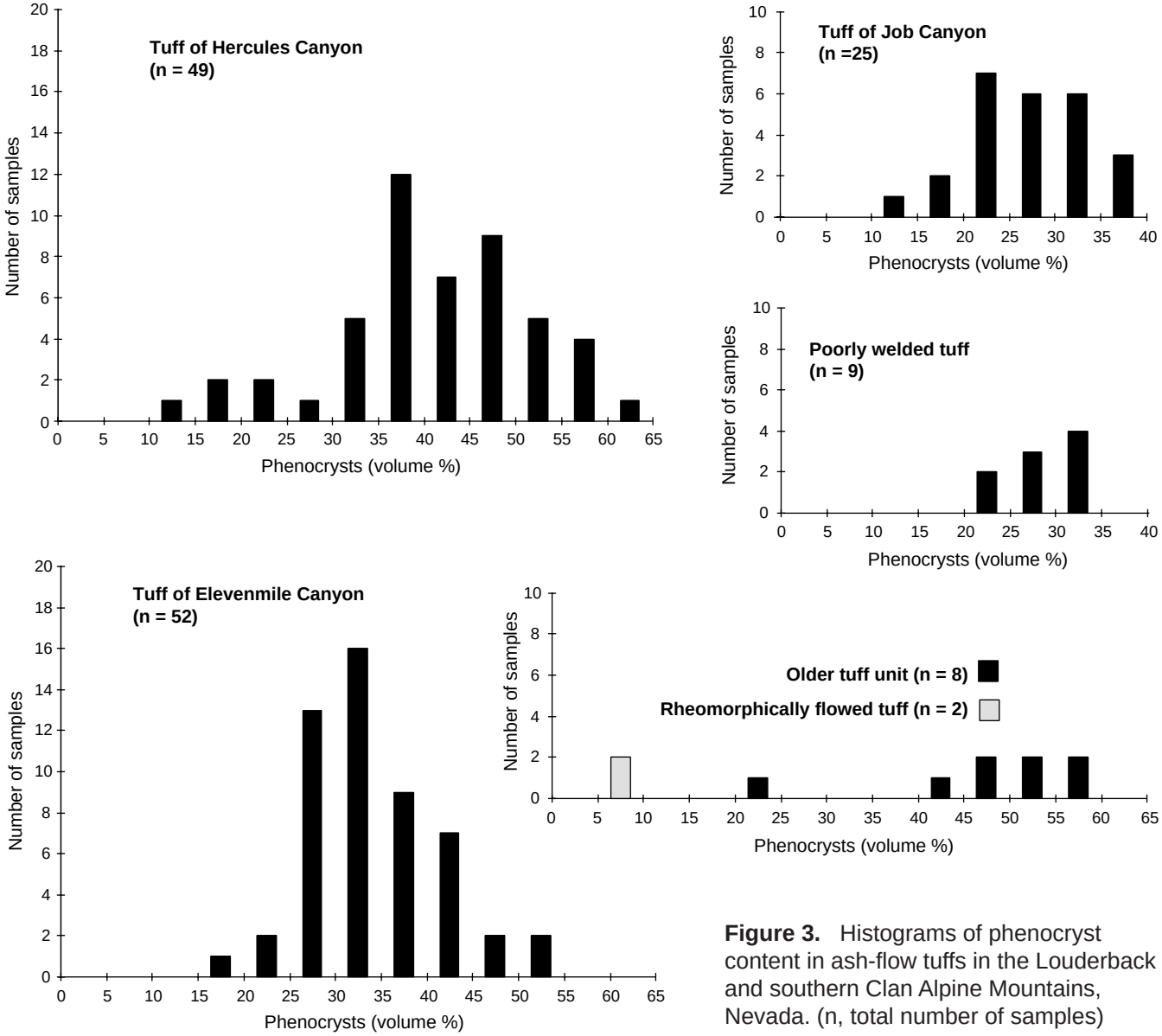

Figure 3. Histograms of phenocryst content in ash-flow tuffs in the Louderback and southern Clan Alpine Mountains, Nevada. (n, total number of samples)

tuff. The tuff of Elevenmile Canyon forms about half of the bedrock exposed in the quadrangle and probably fills a poorly understood part of the Elevenmile Canyon caldera that lies mostly to the west and north in the southern Stillwater Range (fig. 2; John, 1993a, 1995b). The tuff of Elevenmile Canyon is composed of crystal-rich dacite and rhyolite ash-flow tuff that is generally moderately to densely welded and has undergone strong propylitic or argillic alteration. The tuff commonly contains abundant lithic fragments of both Mesozoic and Tertiary rock types. Megabreccia blocks of the tuff of Job Canyon and the older rhyolite unit as much as 300 m wide locally are common within the tuff in the southern third of the quadrangle in both the Louderback and southern Clan Alpine Mountains. The basal part of the unit commonly contains relatively few lithic fragments, and in the northwestern part of the quadrangle, notably between Victor and Hercules Canyon, it contains well-bedded surge(?) deposits. In the southern Clan Alpine Mountains, notably on the west face of Twin Peaks, a partial cooling break is present. Elsewhere, multiple ash flows marked by highly variable lithic and pumice contents are present, but strong alteration masks evidence for cooling breaks. The tuff of Elevenmile Canyon is about 24.6 Ma (table 1). The tuff of Elevenmile Canyon is more than 3.6 km thick in the southern Stillwater Range (John, 1992) and probably more than 1,500 m thick in the Wonder Mountain Quadrangle (see cross sections).

The tuff of Elevenmile Canyon is overlain by or faulted against the tuff of Hercules Canyon. The tuff of Hercules Canyon is a crystal- and biotite-rich dacite to low-silica rhyolite ash-flow tuff. It petrographically and compositionally is similar to parts of the tuff of

Table 1. K-Ar and $^{40}Ar/^{39}Ar$ ages of tertiary igneous rocks and alteration minerals, Wonder Mountain Quadrangle and vicinity, Nevada.

Sample no.	Rock type (map unit)	Quadrangle	Mineral	Method of dating	Age (±1σ) (Ma)	Data source
Alteration minerals:						
Nevada Wonder Mine	quartz-adularia vein	Wonder Mtn	Adularia	K-Ar	22.2±0.6	Silberman and others, 1973
Gold King Mine	quartz-adularia vein	Wonder Mtn	Adularia	K-Ar	23.0±0.7	Garside and others, 1993
Lava flows:						
94-DJ-77	dacite flow breccia (Tad)	Wonder Mtn	Biotite	Ar-Ar, incremental heating	23.7±0.1	J.E. Conrad, 1997, unpub.
Silicic intrusive rocks:						
94-DJ-72	Rhyolite dike (Tsi)	Wonder Mtn	Hornblende	Ar-Ar, total fusion	21.5±0.2	J.E. Conrad, 1996, unpub.
94-DJ-72	Rhyolite dike (Tsi)	Wonder Mtn	Biotite	K-Ar	19.9±0.6	E.H. McKee, 1994, unpub.
93-DJ-22	Dacite plug (Tdp)	Wonder Mtn	Biotite	Ar-Ar, incremental heating	20.94±0.13	J.E. Conrad, 1996, unpub.
93-DJ-22	Dacite plug (Tdp)	Wonder Mtn	Biotite	K-Ar	21.3±0.6	Stewart and others, 1994
93-DJ-30	Rhyolite dike (Tsi)	Wonder Mtn	Biotite	K-Ar	20.2±0.6	E.H. McKee, 1994, unpub.
92-DJ-69	Rhyolite dike (Tsi)	Pirouette Mtn	Biotite	K-Ar	19.5±0.6	Stewart and others, 1994
Ash-flow tuffs:						
Poorly welded tuff						
95-DJ-29	Rhyolite tuff (Tpwt)	Wonder Mtn	Biotite	Ar-Ar, incremental heating	23.6±0.2	J.E. Conrad, 1997, unpub.
95-DJ-17	Rhyolite tuff (Tpwt)	Wonder Mtn	Biotite	Ar-Ar, incremental heating	23.5±0.2	J.E. Conrad, 1997, unpub.
Tuff of Hercules Canyon						
93-DJ-23	Dacite tuff (Thc)	Wonder Mtn	Biotite	Ar-Ar, total fusion	24.66±0.08	J.E. Conrad, 1996, unpub.
93-DJ-23	Dacite tuff (Thc)	Wonder Mtn	Biotite	K-Ar	24.2±0.7	Stewart and others, 1994
94-DJ-11	Rhyolite vitrophyre (Thc)	Wonder Mtn	Biotite	K-Ar	23.0±0.7	E.H. McKee, 1995, unpub.
Tuff of Elevenmile Canyon						
94-DJ-23	Dacite tuff (Tec)	Wonder Mtn	Biotite	Ar-Ar, total fusion	24.58±0.06	J.E. Conrad, 1996, unpub.
94-DJ-23	Dacite tuff (Tec)	Wonder Mtn	Biotite	K-Ar	24.8±0.7	E.H. McKee, 1995, unpub.
88-DJ-21	Dacite tuff (Tec)	Table Mtn	Biotite	K-Ar	24.5±0.7	Stewart and others, 1994
88-DJ-21	Dacite tuff (Tec)	Table Mtn	Biotite	Ar-Ar, incremental heating	24.3±0.2	J.E. Conrad, 1997, unpub.
93-DJ-127	Dacite tuff (Tec)	Wonder Mtn	Biotite	K-Ar	23.2±0.7	Stewart and others, 1994
93-DJ-127	Dacite tuff (Tec)	Wonder Mtn	Biotite	Ar-Ar, incremental heating	23.7±0.2	J.E. Conrad, 1997, unpub.
Tuff of Job Canyon						
86-DJ-30	Rhyolite tuff (Tjc)	Cox Canyon	Biotite	Ar-Ar, total fusion	27.64±0.08	J.E. Conrad, 1996, unpub.

Elevenmile Canyon (figs. 3 and 4, and table 2), but it generally is less strongly altered, more biotite- and pumice-rich, commonly contains coarse (5-7 mm long) blocky hornblende phenocrysts, generally contains only sparse lithic fragments, and pre-Tertiary lithic fragments are sparse to absent. Contacts with the tuff of Elevenmile Canyon range from sharp to gradational; most sharp contacts appear to be faults. Multiple cooling units locally separated by lithic, poorly welded tuff and sedimentary breccia and sandstone and densely welded vitrophyric zones are present in the southeastern and northeastern parts of the map area. The tuff of Hercules Canyon is as much as about 1,100 m thick in the southeastern part of the quadrangle. K-Ar and ^{40}Ar-^{39}Ar ages of the tuffs of Hercules Canyon and Elevenmile Canyon are nearly identical (table 1), and the tuff of Hercules Canyon probably represents a late-stage eruption of magma that formed the tuff of Elevenmile Canyon.

Poorly welded tuff (unit Tpwt) locally overlies or is faulted against the tuffs of Elevenmile Canyon and Hercules Canyon on the east side of the quadrangle. The tuff is a crystal-rich, poorly to densely welded high-silica dacite or low-silica rhyolite ash-flow tuff from an unknown source. Poorly welded parts of the tuff locally contain abundant fragments of Tertiary volcanic rocks as much as 50 cm in diameter. Bipyramidal, smoky quartz phenocrysts are common.

Andesite and dacite lava flows and flow breccias (unit Tad) locally overlie unconformably the poorly welded tuff unit in the northeast corner of the quadrangle, where they form irregular, nearly flat-lying caps on ridges. An ^{40}Ar-^{39}Ar age of 23.7±0.1 Ma was obtained from a flow breccia directly overlying the poorly welded tuff (table 1).

The Oligocene rocks are intruded by numerous silicic to intermediate composition dikes and small intrusions. In the Wonder Mountain Quadrangle, these intrusive rocks are divided into four map units: (1) silicic intrusive rocks (Tsi), (2) hornblende dacite porphyry (Thp), (3) dacite porphyry (Tdp), and (4) dacite intrusions (Tdi). Sparsely porphyritic biotite rhyolite and medium-grained hornblende–biotite–quartz–plagioclase–K-feldspar rhyolite or dacite porphyry are the most abundant types of intrusive rocks in the quadrangle and comprise the silicic intrusive rocks (Tsi) unit. These rocks form a swarm of west-northwest-trending dikes that extend about 30 km to the west to the southern Stillwater

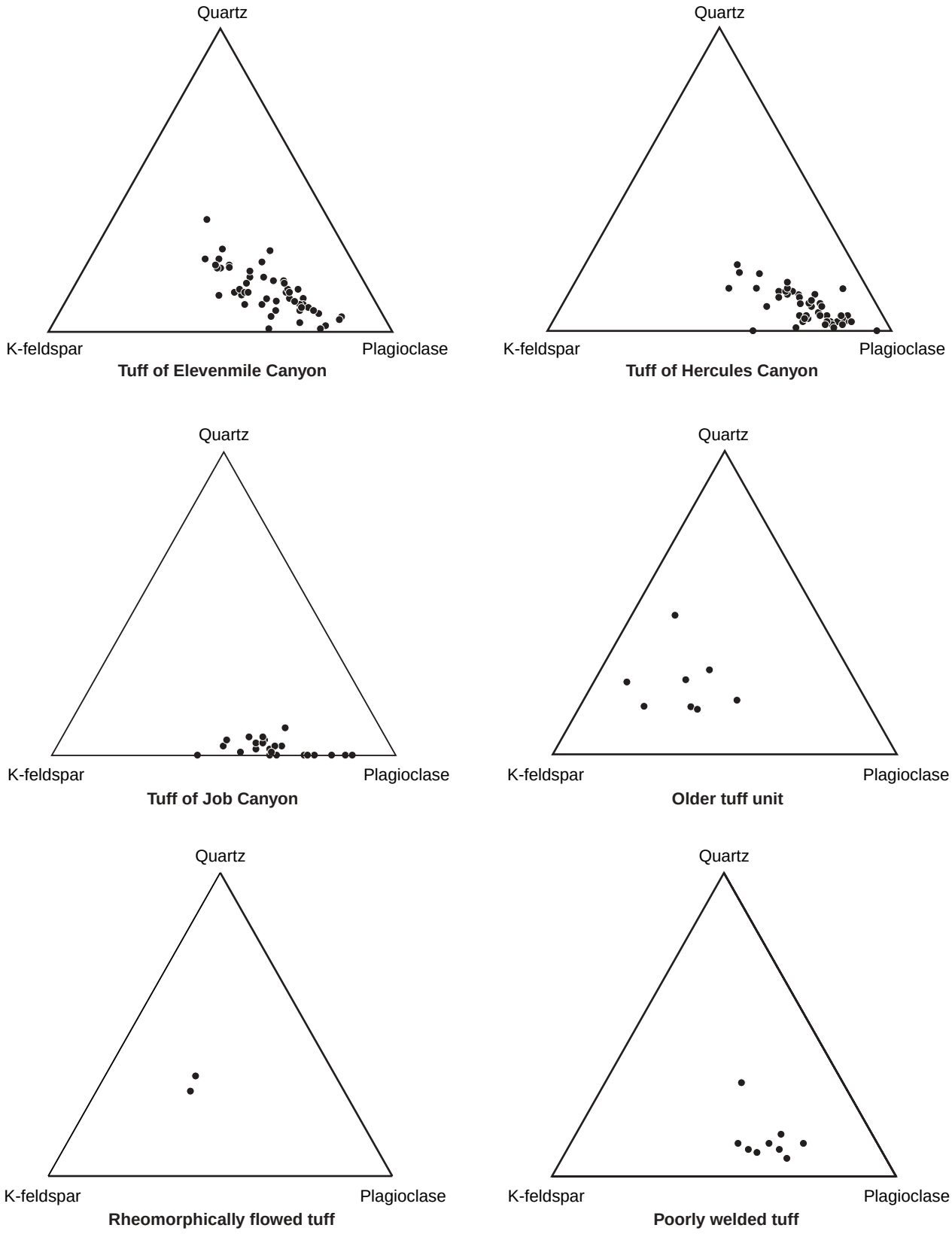

Figure 4. Modal proportions of quartz, K-feldspar and plagioclase phenocrysts in ash-flow tuffs in the Louderback Mountains and southern Clan Alpine Mountains, Nevada.

Table 2. Chemical analyses of Tertiary igneous rocks in the Wonder Mountain Quadrangle, Nevada.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sample #	92-DJ-15	93-DJ-75C	93-DJ-75E	93-DJ-75G	94-DJ-6	94-DJ-19	94-DJ-23	94-DJ-33	92-DJ-93	93-DJ-109	93-DJ-109P	92-DJ-19	93-DJ-23	94-DJ-17	95-DJ-43
Unit[1]	Tor	Tjc	Tjc	Tjc	Tec	Tec	Tec	Tec	Tec	Tec	Tec-pum	Thc	Thc	Thc	Thc
Laboratory[2]	1	1	1	1	2	2	2	2	1	1	1	2	2	2	2
Major element oxides (weight percent)															
SiO_2	70.3	69.6	75.1	70.7	70.5	63.81	69.6	65.05	75.2	61.4	62.7	65.16	67.2	65.13	66.94
Al_2O_3	14.2	14.9	12	14.3	13.7	17.04	15.32	16.62	12.5	17	17.6	15.62	15.64	16.44	16.04
Fe_2O_3	2.65	2.63	2.74	2.64	2.02	3.15	2.31	4.02	1.59	3.95	4.28	4.31	2.85	3.62	3.78
MnO	0.03	0.09	0.06	0.03	0.06	0.08	0.07	0.09	0.02	0.1	0.09	0.05	0.04	0.06	0.07
MgO	0.14	0.56	0.15	0.37	0.26	0.51	0.39	0.61	0.33	0.82	0.72	0.93	0.6	0.55	0.32
CaO	0.33	0.47	0.19	0.41	1.66	2.98	1.69	2.31	0.38	2.98	1.19	2.14	2.08	2.8	2.68
Na_2O	4.2	4.01	2.7	4.09	2.05	4.55	3.76	3.57	2.06	4.15	5.68	3.53	3.71	4.28	3.98
K_2O	5.41	4.52	4.98	4.46	5.51	4.16	4.74	4.42	4.9	4.08	4.21	4.36	4.53	4.35	3.71
TiO_2	0.45	0.43	0.3	0.43	0.26	0.45	0.33	0.55	0.18	0.59	0.63	0.65	0.46	0.54	0.54
P_2O_5	0.12	0.09	0.06	0.11	0.05	0.12	0.08	0.13	0.06	0.2	0.28	0.14	0.12	0.13	0.24
LOI	0.42	1.75	0.84	1.44	2.72	2.27	1.86	1.83	2.09	3.43	1.55	1.9	1.82	1.47	1.01
Total	98.24	99.02	99.12	98.96	98.79	99.12	100.15	99.2	99.31	98.38	98.82	98.79	99.05	99.37	99.31
Minor elements (parts per million)															
Ba	3300	2300	1200	2000	1120	2038	1463	2252	730	2500	2150	2120	1801	2228	1090
Nb	20	15	18	15	14.3	14.3	14.7	13.5	15	14	13	16.7	14.8	14.3	12.4
Rb	134	132	172	124	181.3	96	130.5	117.5	168	118	136	110.5	121.4	106.7	111.5
Sr	39	245	92	240	187	409	268	468	180	540	460	337	330	436	443
Y	26	28	27	27	22	21	21	22	22	25	27	22	22	23	14
Sc	—	—	—	—	4	6	5	8	—	—	—	9	7	8	7
Zr	315	240	205	230	198	375	275	364	154	385	480	345	298	355	174
Be	—	—	—	—	3	3	2	2	—	—	—	2	2	2	2
V	—	—	—	—	12	21	17	38	—	—	—	40	27	36	42
Co	—	—	—	—	1.4	4.6	2	3.8	—	—	—	3.9	2.8	3.3	6.8
Cr	<10	<20	<20	<20	—	—	—	—	<20	<20	<20	—	—	—	11
Cs	—	—	—	—	15.2	2.3	3.7	8.6	—	—	—	5.2	6.3	3	4.3
Hf	—	—	—	—	5.8	9.1	7.5	8.9	—	—	—	9.3	7.7	9	5.3
Sb	—	—	—	—	2.3	1.9	1.3	1.8	—	—	—	3	1.8	0.8	1
Ta	—	—	—	—	1.29	1.01	1.22	1.01	—	—	—	1.2	1.16	1.04	1.11
Th	—	—	—	—	17.33	12.78	16.22	12.54	—	—	—	13.02	14.55	12.68	16.47
U	—	—	—	—	4.98	5.4	4.58	3.83	—	—	—	4.3	4.66	3.89	4.15
Cu	<10	<10	<10	<10	<5	8	6	7	<10	<10	<10	9	16	8	12
Zn	58	88	35	60	37	47	44	56	52	83	106	64	52	59	43
Sc	—	—	—	—	4	6	5	8	—	—	—	9	7	8	7
As	—	—	—	—	10	—	7	—	—	—	—	—	—	—	—
Ni	<10	<10	<10	<10	9	—	—	—	<10	<10	<10	—	—	—	20
Rare earth elements (parts per million)															
La	<30	<30	37	31	46.9	48.7	48	50.2	66	<30	32	50.4	45.4	49.5	37.7
Ce	85	63	89	86	84.7	85.2	84.4	87.8	69	58	68	91.3	81.9	87.1	64.8
Nd	—	—	—	—	30.8	32	32.9	33.4	—	—	—	37.4	32.2	36.4	25.1
Sm	—	—	—	—	5.6	5.8	6	6.1	—	—	—	7.4	5.8	6.7	4.5
Eu	—	—	—	—	1.05	1.47	1.4	1.63	—	—	—	1.67	1.56	1.61	1.08
Tb	—	—	—	—	0.8	0.7	0.7	0.8	—	—	—	0.9	0.7	0.8	0.5
Yb	—	—	—	—	2.2	2	2.2	1.9	—	—	—	2.2	2.2	2.1	1.5
Lu	—	—	—	—	0.37	0.36	0.37	0.34	—	—	—	0.38	0.38	0.37	0.26

[1]Units: Tec, tuff of Elevenmile Canyon; Tec-pum, pumice blob, tuff of Elevenmile Canyon; Tjc, tuff of Job Canyon; Thc, tuff of Hercules Canyon; Thcv, vitrophyric tuff of Hercules Canyon; Tpcl, lower cooling unit, tuff of Poco Canyon; Tpwt, poorly welded tuff unit; Tor, older rhyolite unit; Tsi, silicic intrusive rocks

[2]Laboratory: 1, USGS Denver, CO. Analysis by X-ray fluorescence methods; 2, ACTLABS, Inc., Wheat Ridge, CO. Analysis by ICP-MS methods.

Table 2 (continued)

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
95-DJ-60	95-DJ-45	95-DJ-39	94-DJ-11	94-DJ-26	94-DJ-27	95-DJ-47	95-DJ-52	95-DJ-56	96-DJ-16A	94-DJ-8	94-DJ-29	95-DJ-57	95-DJ-59	94-DJ-72
Thc	Thc	Thc	Thcv	Thcv	Thcv	Thcv	Thcv	Thcv	Tpcl	Tpwt	Tpwt	Tpwt	Tpwt	Tsi
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Major element oxides (weight percent)														
69.48	67.45	70.41	67.43	73.07	64	65.43	65.81	70.42	72.1	69.83	69.81	70.33	70.51	72.78
14.93	15.63	14.88	15.25	12.54	16.92	16.93	16.77	14.49	13.65	14.27	14.61	14.45	13.69	13.64
2.41	2.76	2.4	2.64	0.93	3.95	3.65	3.64	2.17	1.51	2.07	2.36	2.16	2.63	1.7
0.06	0.04	0.05	0.06	0.07	0.08	0.05	0.04	0.05	0.04	0.08	0.05	0.05	0.03	0.03
0.53	0.55	0.37	0.53	0.08	0.71	0.73	0.74	0.33	0.19	0.44	0.62	0.33	0.39	0.54
1.94	2.1	1.55	2.09	0.64	3.02	2.62	2.71	1.45	1.14	1.82	1.5	1.42	1.94	1.59
3.68	4	3.91	3.87	3.35	4.37	4.34	4.31	3.71	3.51	3.45	3.59	3.71	3.55	3.24
4.68	4.47	4.64	4.35	5.07	4.13	4.3	4.17	4.77	4.89	4.82	4.58	4.81	4.61	4.15
0.35	0.43	0.32	0.38	0.1	0.59	0.57	0.56	0.36	0.19	0.36	0.32	0.35	0.38	0.24
0.13	0.1	0.09	0.08	0.02	0.15	0.14	0.14	0.11	0.03	0.06	0.18	0.1	0.1	0.06
1.78	1.09	0.94	2.26	3.42	0.86	1.07	1.01	0.99	2.32	1.59	1.94	1	1.49	1.08
99.97	98.62	99.56	98.94	99.29	98.78	99.83	99.9	98.85	99.57	98.79	99.56	98.71	99.32	99.05
Minor elements (parts per million)														
1506	9601	1437	1615	491	2197	20166	13579	1340	886	1472	1002	1338	806	1021
14.4	14.5	14.8	14	16.7	13.5	13.7	13.8	16.8	16.4	17.1	16.4	16.9	14.4	8.4
121.6	118.5	127.5	111.5	133.5	98.5	99.7	106.1	136.4	169.3	140.5	110.7	144.3	137.1	107.5
275	344	245	326	31	501	458	460	249	177	233	207	248	215	288
21	19	20	20	16	20	21	21	24	23	26	23	24	21	8
6	6	5	6	2	9	8	8	6	3	6	5	6	6	3
277	321	293	290	105	325	356	349	238	153	204	206	229	187	98
2	2	2	2	3	2	2	2	2	3	3	3	3	3	2
16	24	16	19	<5	43	34	39	12	7	12	18	12	26	20
2.7	2.6	2.1	1.9	1	4.4	2.9	3.6	1.1	1.4	2.2	1.6	3.3	3.4	1.9
19	—	20	—	23	—	—	—	—	22	—	14	16	36	—
2.8	3.6	5	5.3	6.2	2.9	2.4	1.9	5.5	2.1	9.8	2.5	5.9	4.1	3.9
8.3	8.4	8.9	7.9	4.2	8.4	8.8	8.8	6.8	6	6.2	6.6	7.4	6.5	3.3
1.1	1	2.5	0.9	0.9	1	1	0.7	1.1	2	1.3	0.7	1.5	0.9	1.1
1.18	1.23	1.19	1.26	1.63	0.95	1.19	1.11	1.41	1.57	1.47	1.46	1.36	1.25	1.1
18.53	15.38	19.07	15.45	16.8	11.22	12.01	12.15	18.35	26.08	17.52	19.6	19.8	21.64	19.12
5.36	4.78	4.94	4.88	5.99	3.54	3.8	3.84	5.71	8.9	5.87	4.55	6.37	4.83	5
6	7	6	<5	13	12	10	7	8	10	<5	11	7	12	8
56	49	62	51	35	56	64	59	48	68	151	47	74	64	23
6	6	5	6	2	9	8	8	6	3	6	5	6	6	3
—	—	7	9	7	—	—	—	13	5	6	—	17	—	—
40	8	21	—	12	—	—	—	7	10	—	104	15	12	—
Rare earth elements (parts per million)														
50.1	50.9	51.8	53	34	49	43	42.5	48.4	56.6	49.8	54	55.1	50	27.7
81	87.4	74.6	91.4	59.6	82	74.7	73	85.5	90.6	87.1	91	89	76.9	44.3
34.9	32.5	35.1	34.1	20.2	34.7	31.7	30.5	33.3	34.5	35.3	35.4	38.6	34.1	14.4
6.5	5.9	6.2	5.9	3.7	5.9	5.8	5.9	6.7	6.3	7.1	6.4	7.3	6.3	2.3
1.53	1.15	1.57	1.57	0.39	1.8	1.85	1.48	1.36	0.94	1.46	1.15	1.6	1.09	0.71
0.7	0.7	0.7	0.7	0.5	0.8	0.7	0.7	0.8	0.8	0.9	0.8	0.9	0.7	0.3
2.1	1.9	1.9	2.1	1.8	1.8	1.9	2	2.5	2.5	2.4	2.4	2.4	2	0.9
0.35	0.32	0.32	0.34	0.31	0.34	0.35	0.36	0.41	0.41	0.46	0.39	0.38	0.32	0.15

Range (John, 1995a; John and Silberling, 1994). In the southern Stillwater Range, K-Ar ages on units 1 and 2 range from about 25 to 18 Ma (Stewart and others, 1994), although six K-Ar and ^{40}Ar-^{39}Ar ages on these units from the Louderback Mountains and southern Clan Alpine Mountains are constrained more tightly between 21.5 to 19.5 Ma (table 1).

Latest Tertiary(?) and Quaternary surficial deposits cover Badger Flat in the central part of the quadrangle, blanket much of the west edge of the map area, and cover the east side of the Clan Alpine Mountains. These deposits consist of alluvium and colluvium, alluvial-fan deposits, eolian sand, and talus. Many of these deposits are dissected alluvial-fan deposits that are part of an extensive set of older alluvial fan deposits on the east side of Dixie Valley in the adjacent Pirouette Mountain Quadrangle (John, 1995a). Older alluvial deposits are present along the east edge of the quadrangle on the east side of the southern Clan Alpine Mountains.

STRUCTURAL HISTORY

Faulting and tilting of the Oligocene and older rocks are complex in the Wonder Mountain Quadrangle. At least two major periods of extensional faulting and tilting are evident: latest Oligocene to earliest Miocene and late Miocene to Holocene (John, 1993b). A third period of early Miocene extension might be represented by early Miocene (ca. 22–20 Ma) west-northwest-trending rhyolite dikes; these dikes intrude west-northwest-striking high-angle faults that are present throughout the Wonder Mountain Quadrangle and are similar to dikes that extend about 30 km west and southwest across Dixie Valley to the southern Stillwater Range and the north end of the Sand Springs Range (Page, 1965; John, 1993a; John and Silberling, 1994).

Three types of faults are shown on the map: (1) faults whose traces are marked by offset stratigraphy, (2) linear zones of hydrothermal alteration that were commonly explored by prospect pits which expose small fault zones, and (3) faults inferred where there are major discontinuities in the orientation or amount of tilting. Many faults inferred on the basis of alteration zones or discontinuities in tilting are entirely within one unit, most commonly the tuff of Elevenmile Canyon. Some of the inferred faults may actually be folds, although exposures are generally inadequate to document the presence of folds. Three major orientations of faults are evident in the Wonder Mountain Quadrangle. These orientations, in generally decreasing age, are north to northwest, west-northwest, and north-northeast. Northeast-striking faults of intermediate age are less common.

Tilting and fault patterns in the Oligocene rocks are highly irregular, particularly in the northern half of the quadrangle (fig. 5), and commonly the relationship between tilting and mapped faults is not obvious. In general, the late Oligocene tuffs of Elevenmile Canyon and Hercules Canyon and older rocks are moderately (20°-60°) tilted, but tilt directions and amounts of tilting are highly variable (cross sections, fig. 5). In contrast, earliest Miocene lava flows (andesite and dacite unit) that unconformably overlie the Oligocene rocks in the northeast corner of the quadrangle appear to be nearly flat lying.

On a regional scale, the Wonder Mountain Quadrangle lies just south of the eastward projection of a late Oligocene zone of structural accommodation in the southern Stillwater Range, where there is a change from steep west dips in Oligocene rocks north of this zone to steep east dips in the tuff of Elevenmile Canyon and other units south of this zone in the Pirouette Mountain and La Plata Canyon Quadrangles due west of the Wonder Mountain Quadrangle (figs. 1 and 2). The accommodation zone may extend into the northern part of the quadrangle resulting in the complex fault and tilt patterns exposed there. In addition, the Wonder Mountain Quadrangle lies just east of Dixie Valley where there is a regional change in late Cenozoic Basin and Range tilt directions. To the west in the southern Stillwater Range, late Cenozoic (≤13 Ma) basin-and-range extensional faulting has tilted the Stillwater Range gently to the west, whereas the Louderback Mountains and the Clan Alpine Mountains are gently tilted to the east (Stewart, 1980). Furthermore, the Wonder Mountain Quadrangle probably lies within the eastern part of the Elevenmile Canyon caldera which is well defined to the west in the southern Stillwater Range (see section below entitled “Elevenmile Canyon caldera”). Although structural doming resulting from magma resurgence within the caldera has not been recognized, some of the tilting may be the result of caldera collapse and/or resurgence. Thus, the complex tilt and fault patterns present in Oligocene rocks in the Wonder Mountain Quadrangle are probably the result of multiple processes including caldera formation, several faulting and tilting events, and the possible presence of a late Oligocene structural accommodation zone.

Latest Oligocene to Earliest Miocene Faulting and Tilting

Faulting and tilting of the Oligocene rocks initially occurred during latest Oligocene to earliest Miocene time (about 24.5 to 23.7 Ma), shortly after eruption of the tuffs of Elevenmile Canyon and Hercules Canyon and formation of the Elevenmile Canyon caldera. In the southern Stillwater Range, early faulting and tilting that are thought to be related to large magnitude (>100%) crustal extension, are shown by angular unconformities between late Oligocene ash-flow tuffs, including the tuff of Elevenmile Canyon, and overlying

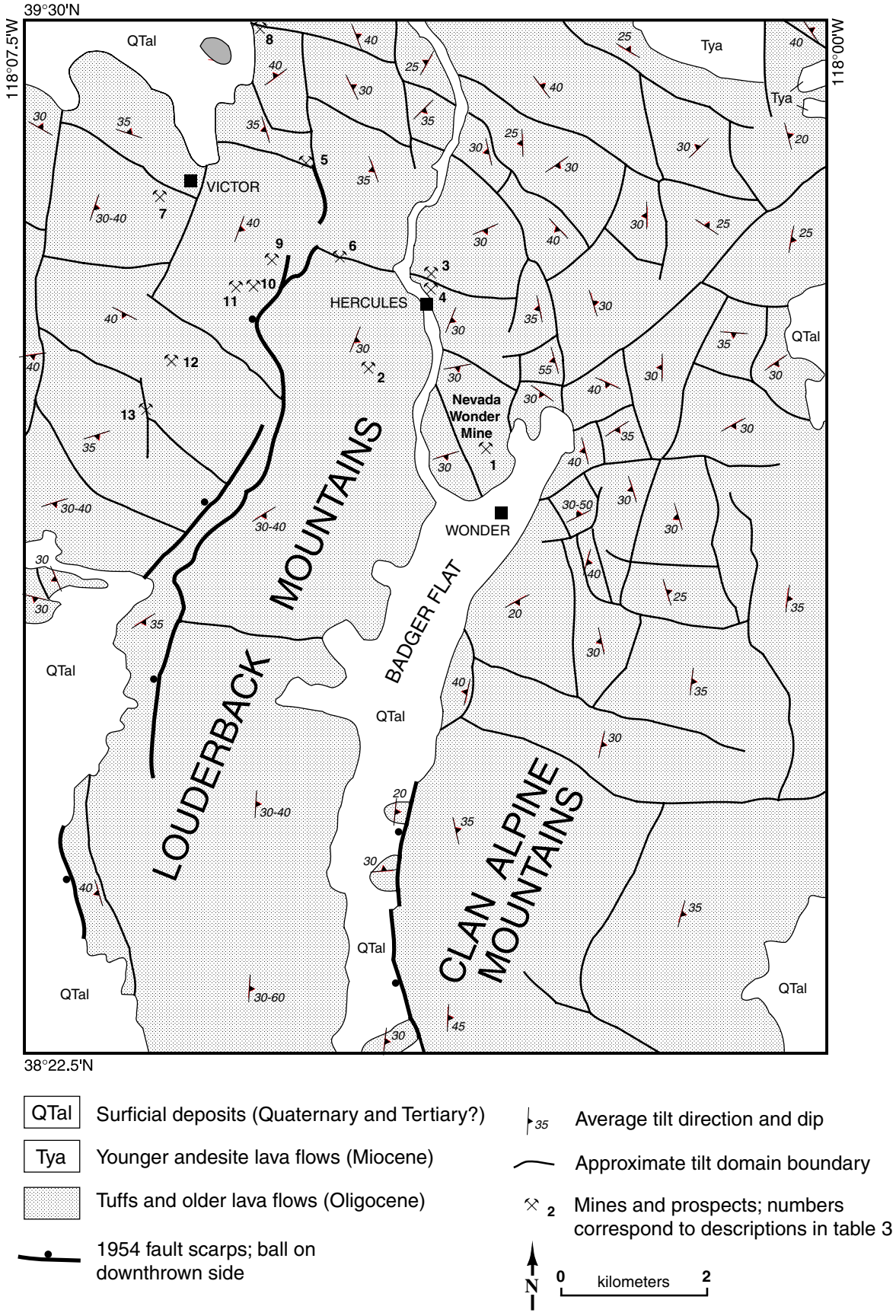

Figure 5. Tilt domains and average tilt directions in Oligocene volcanic rocks in the Wonder Mountain Quadrangle. Also shown are surface traces from the 1954 earthquakes.

Table 3. Summary of mines and prospects in the Wonder mining district, Wonder Mountain Quadrangle, Nevada.

No. (fig. 5)	Name	Other Names	Production and exploration	Host rock	Main structural features	Mineralogical features	Age	Comments	References
1	Nevada Wonder Mine	Hidden Treasure, North Star, Badger	390,000 tons containing 6,350,000 oz Ag and 66,000 oz Au in 1911-1919; explored to 2000 ft depth; most production from <1300 ft depth	tuff of Elevenmile Canyon	Nevada Wonder fault and vein system, N25°W 75°NE	quartz-adularia veins; oxidized to 1300 ft depth	22.2±0.6 Ma (adularia)	most of district production; Ag:Au=90	Schrader (1947); Silberman and others (1973); Quade and Tingley (1987)
2	Jack Pot Mine		$40,000; explored to 600 ft depth	tuff of Elevenmile Canyon	4 veins; N80°W 75-80°NE	quartz-adularia veins		Ag:Au=5	Schrader (1947); Quade and Tingley (1987); this study
3	Silver Center Mine		drilling and small open pit; no production(?)	tuff of Elevenmile Canyon	NW-striking veins				Quade and Tingley (1987)
4	Vulture Mine		small production	tuff of Elevenmile Canyon	N10°W vertical dipping veins	AgCl ore		first production in district	Schrader (1947); Quade and Tingley (1987)
5	Gold King Group		adits; no production(?)	tuff of Elevenmile Canyon	N40-60°E 70-85°NW veins along faults	quartz-adularia veins	23.0±0.7 Ma (adularia)		Quade and Tingley (1987)
6	Kiowa prospects		adits and shafts; no production(?)	tuff of Elevenmile Canyon	N70°W 80°SW faults; NE striking vein/fault system?	quartz veins			Quade and Tingley (1987); this study
7	Spider and Wasp Mines	Treasure Hill claims	small or no production; many shallow workings (<200 ft)	tuff of Elevenmile Canyon, rhyolite dikes	W to WNW veins along faults; steep NE dips	quartz veins		Victor townsite	Quade and Tingley (1987)
8	Purple Spar prospect		shallow cuts; no production	tuff of Elevenmile Canyon	WNW-striking, 75S dipping fault	4 ft wide fluorite vein			Quade and Tingley (1987); this study
9	Christmas-Faustiene Fault		adit and crosscuts	tuff of Elevenmile Canyon	intersection of N20°W vertical and WNW faults	quartz vein and silicified tuff			Quade and Tingley (1987); this study
10	Quartzite Fault prospect		two 75-100 ft shafts	tuff of Elevenmile Canyon	N40°W fault and N85°W fault	silicified tuff and quartz vein			Quade and Tingley (1987); this study
11	Owl and Gold Rock Fault prospect		shallow shaft	tuff of Elevenmile Canyon	intersection of two faults	silicified tuff			Quade and Tingley (1987)
12	Marie-Ruby Fault-vein prospect		shallow shaft	tuff of Elevenmile Canyon	NW to NNW fault	silicified tuff			Quade and Tingley (1987); this study
13	Colorado and Hope Fault-vein prospect		short adits	tuff of Elevenmile Canyon	intersection of N25°W 60°NE veins with N70°W 80°SW vein	silicified tuff			Quade and Tingley (1987); this study

silicic tuffs and lava flows and by the presence of synextensional intrusive rocks there (Hudson and others, 1993; John, 1992, 1993a,b; Stewart and others, 1994). Paleomagnetic data and ^{40}Ar-^{39}Ar dating of tilted rocks and weakly to untilted rocks tightly constrain the age of early faulting in the southern Stillwater Range between about 24.40 and 24.25 Ma (D.A. John, M.R. Hudson, and J.E. Conrad, unpub. data, 1996). The age of early faulting in the Louderback Mountains is bracketed between the age of the tuff of Hercules Canyon (24.66 Ma, table 1) and the 23.7±0.1-Ma age of a dacite flow breccia that unconformably overlies the poorly welded tuff unit which overlies the tuff of Hercules Canyon in the northeast corner of the map. This age is also consistent with the 22.2±0.6-Ma age of adularia which fills an early north-northwest-striking fault in the tuff of Elevenmile Canyon at the Nevada Wonder Mine (recalculated age from Silberman and others, 1973). Early faults in both the southern Stillwater Range and the Louderback Mountains mostly strike north to northwest, although paleomagnetic data indicate that tilting may have been accompanied by approximately 20° (Louderback Mountains) to 40° (southern Stillwater Range) of counterclockwise vertical-axis rotation (Hudson and others, 1993; M.R. Hudson, oral commun., 1997).

Early Miocene(?) Faulting

A second period of early Miocene faulting and extension may be indicated by a swarm of west-northwest-trending silicic dikes that intrude tilted Oligocene rocks throughout the Wonder Mountain Quadrangle and extend westward more than 30 km to the southern Stillwater Range and north end of the Sand Springs Range (Page, 1965; John, 1993b). These dikes are about 22 to 20(?) Ma in age in the Wonder Mountain Quadrangle (table 1) and commonly intrude steeply dipping (>50°) faults that apparently have moderate amounts of displacement (hundreds of meters). However, it is not known if the sense of movement on these faults is primarily dip-slip, oblique-slip, or strike-slip. The west-northwest-striking faults commonly cut the north- to northwest-striking faults, as also noted by Schrader (1947) in underground workings at the Nevada Wonder Mine. However, several productive vein systems, such as the Jack Pot Mine, formed along west-northwest-striking faults (table 3; Schrader, 1947). Adularia-sericite gold-silver deposits in the Sand Springs and Fairview mining districts that are similar to those in the Wonder mining district are also localized along west northwest-striking faults that are about 20 to 19 Ma in the Sand Springs district (Garside and others, 1981) and ≤19 Ma (Henry, 1996a).

The west-northwest-trending dikes may indicate small amounts of north-northeast–south-southwest extension, in contrast to earliest Miocene and Holocene extension directions that are oriented approximately east–west to west-northwest–east-southeast. Emplacement of the dikes may have been coincident with development of a small sedimentary basin that extended from the southern Stillwater Range to Sand Springs Summit (fig. 1; John, 1993b), as suggested by transport directions in middle Miocene sedimentary rocks (Stewart, 1993) and by the age of west-northwest-striking normal faults, hydrothermal alteration, and mineralized rocks in the Sand Springs mining district at Sand Springs Summit (about 20 to 19 Ma; Willden and Speed, 1974; Garside and others, 1981) and west-northwest-striking faults and mineralized rocks in the Fairview mining district (Henry, 1996a). However, age of sedimentary rocks filling this basin is poorly constrained—only the approximate 14 Ma age of the top of the sedimentary sequence is known on the basis of the ages of tuff beds interbedded near the top of the sedimentary rock sequence and the ages of overlying basalt flows (John, 1993b; Stewart and others, 1994).

Basin-and-Range Faulting and Extension

Modern basin-and-range extension and normal faulting in the area postdates middle Miocene (about 14 to 13 Ma) basalt and basaltic andesite lava flows that are exposed in the southern Stillwater Range (Page, 1965; John, 1993b). This extension continues to the present day as shown by historic (1903 and 1954) faulting along both the west side of the Louderback Mountains and the west side of the Clan Alpine Mountains (fig. 5). Extension is oriented west-northwest–east-southeast (Zoback and others, 1981) and formed the present topography of north-northeast-trending ranges—the Stillwater Range and the Louderback and Clan Alpine Mountains—and intervening basins in Dixie Valley and Badger Flat (figs. 1 and 5). Both the Louderback and Clan Alpine Mountains have been gently tilted east by basin-and-range faulting. High-angle normal faults (about 60° dip) related to modern extension have been active in Holocene time, including the 1954 Fairview Peak earthquake which produced scarps as much as 2 m high along the west side of the quadrangle and along the west flank of the Clan Alpine Mountains in the south-central part of the quadrangle (fig. 5; Slemmons, 1957; Slemmons and others, 1959; Bell, 1984; Caskey and others, 1996). Many other Quaternary-age normal faults are present in surficial deposits in Dixie Valley just west of the Wonder Mountain Quadrangle (Bell, 1984; John, 1995a). The lateral continuity of the early Miocene rhyolite dike swarm westward across Dixie Valley indicates that little oblique-slip displacement has occurred along the late Cenozoic normal faults forming Dixie Valley, in accord with observations of the 1954 fault scarp in Dixie Valley

(Slemmons, 1957; Bell and Katzer, 1987; Caskey and others, 1996). Total vertical displacement on the fault along the west edge of the Wonder Mountain Quadrangle that ruptured in 1954, estimated from offset contacts between the older rhyolite unit and the overlying tuff of Job Canyon, is about 700 m (cross section B-B´). Total vertical displacement along the range front fault on the west side of the Clan Alpine Mountains that also ruptured in 1954 is about 900 m, estimated from the offset contact between the tuffs of Job Canyon and Elevenmile Canyon.

Elevenmile Canyon Caldera

Most of the Wonder Mountain Quadrangle is believed to lie within the eastern part of the Elevenmile Canyon caldera. The Elevenmile Canyon caldera is well defined in the southern Stillwater Range where parts of the north and south walls and the caldera floor are exposed in steeply tilted fault blocks (fig. 2; John, 1995b). Within the Wonder Mountain Quadrangle, well defined structural features of the caldera have not been recognized. However, presence of thick (>1,500 m) sequences of the tuff of Elevenmile Canyon that lack cooling breaks and locally contain coarse megabreccia blocks as much as 300 m wide suggest that the tuff is intracaldera. In addition, the presence of as much as 1,100 m thickness of the tuff of Hercules Canyon, which has an ^{40}Ar-^{39}Ar age and chemical composition indistinguishable from those of the tuff of Elevenmile Canyon, also suggests accumulation within a caldera or major tectonic depression. Small outcrops of Mesozoic rocks and of megabreccia that has a strongly altered tuff matrix similar to the tuff of Elevenmile Canyon about 2 km west of the southwest corner of the Wonder Mountain Quadrangle might mark part of the caldera margin. However, reconnaissance mapping of parts of the southern Clan Alpine Mountains in the Westgate Quadrangle between the south edge of the Wonder Mountain Quadrangle and U.S. Highway 50 about 10 km to the south shows presence of thick sequences of tuff of Elevenmile Canyon and the absence of an obvious caldera margin. Consequently, the Wonder Mountain Quadrangle is believed to lie within the Elevenmile Canyon caldera, but the eastern margins of this caldera remain undefined.

HYDROTHERMAL ALTERATION

Hydrothermal alteration is widespread in the Wonder Mountain Quadrangle, and nearly all rocks in the western two-thirds of the quadrangle are altered hydrothermally. Numerous mines and prospects are present in these altered volcanic rocks. Three major types of alteration are present but have not been studied or mapped in detail: (1) propylitic alteration, (2) argillic and/or sericitic alteration ("bleaching"), and (3) silicification. Pyrite is disseminated widely in the bleached zones and is present locally in rocks that are silicified or propylitically altered. Adularia can be locally present in silicified rocks and quartz veins, commonly as a pseudomorphic replacement of bladed calcite (Schrader, 1947; Silberman and others, 1973; Quade and Tingley, 1986).

Propylitic alteration is the most widespread alteration type and affects most rocks in the western two-thirds of the quadrangle. Major effects of propylitic alteration include sericite±calcite±epidote alteration of plagioclase and K-feldspar phenocrysts, chlorite alteration of biotite and other mafic mineral phenocrysts, and disseminated, vein, and vug-filling calcite. Nearly all exposures of the older rhyolite and the tuffs of Job Canyon and Elevenmile Canyon are strongly propylitized in the western two-thirds of the quadrangle. In the southern Clan Alpine Mountains in the eastern third of the quadrangle, the basal part of the tuff of Elevenmile Canyon and older units are generally strongly propylitized, but the intensity of alteration decreases upward so that the upper part of the tuff of Elevenmile Canyon is devitrified but not visibly hydrothermally altered.

Zones of bleaching, which probably consist mostly of argillic and/or sericitic alteration commonly with disseminated pyrite and locally surrounding zones of silicified rock and quartz veins, are less widespread than propylitic alteration. The largest area of bleaching covers several square kilometers on the north side of Red Top Gulch near the west edge of the quadrangle. Here, oxidized disseminated pyrite in bleached rocks produces a distinctive reddish color, thus lending the name of the gulch. Most bleached rock formed in the tuff of Elevenmile Canyon, although numerous silicic dikes are common in areas of bleaching and the older tuff unit (Tot) is commonly sericitically altered and contains disseminated pyrite. The silicic dikes generally appear to postdate alteration. Other notable areas of bleaching include the east side of Wonder Mountain surrounding the Wonder vein, the west side of Queen Peak, the southeast side of Porphyry Peak, and the north side of the large porphyry dike just west of Geiger Gap.

Silicification is present irregularly in the quadrangle, most commonly along high-angle fault zones. Schrader (1947) described more than 50 quartz "veins" in the Wonder mining district and provided a map showing many of these veins (see plate 5 in Willden and Speed, 1974). In surface exposures, most veins are 2- to 15-m-thick zones of silicified breccia and quartz replacement of wallrock. Most veins are exposed discontinuously on the surface but many form linear zones as much as 5 km long. Schrader (1947) and Quade and Tingley (1987) note that most silicified zones do not extend more than a few tens of meters below the surface. The silicified zones commonly contain minor amounts of oxidized sulfide minerals.

Pseudomorphs of bladed calcite are locally present. Schrader (1947) and Quade and Tingley (1987) report adularia forming pseudomorphs of bladed calcite in some of the silicified rocks.

MINERAL DEPOSITS

Most of the Wonder mining district lies within the Wonder Mountain Quadrangle—small parts of the mining district extend to the north and west of the quadrangle. The Wonder mining district is known mostly for its rich silver- and gold-bearing quartz veins that were discovered in April 1906 resulting in formation of one of the last bonanza silver-gold camps in Nevada (Schrader, 1947; Shamberger, 1974). Most production occurred in the period 1911-19 after construction of a 200 ton/day cyanide mill at the Nevada Wonder Mine. The Nevada Wonder Mine closed in December 1919 due to the lack of ore; closure of this mine effectively ended major production in the district (Schrader, 1947; Willden and Speed, 1974; Quade and Tingley, 1987). Irregular small-scale mining took place in the mining district until World War II, several exploration programs were undertaken in the 1980s, and waste dumps from the Nevada Wonder Mine were reprocessed in the mid-1980s (Quade and Tingley, 1987). Although Schrader (1947) reported the presence of more than 50 quartz veins, nearly all production came from the Nevada Wonder Mine and the Nevada Wonder vein system (Vanderburg, 1940; Quade and Tingley, 1987). Total production during the period 1911 to 1919 was about 66,000 ounces of gold and 6,350,000 ounces of silver from 392,000 tons of ore. Small amounts of lead and copper also were recovered during 1916-18. More detailed accounts of the history and production of the mining district are given in Vanderburg (1940), Schrader (1947), Shamberger (1974), Willden and Speed (1974), and Quade and Tingley (1987).

Most mineral deposits in the Wonder mining district are adularia-sericite (low sulfidation or Comstock-type) gold-silver veins. The main vein systems and mines are summarized in table 3. The veins crop out irregularly throughout the district, forming craggy, resistant ledges 1 to 15 m wide and extending as much as 5 km along strike. The Nevada Wonder vein was explored to depths of more than 600 m (Schrader, 1947). Most other veins only were explored to shallow depths, either because of their low gold-silver contents or because the veins pinched out rapidly at depth (Quade and Tingley, 1987). The veins are largely replacement deposits mostly formed in the tuff of Elevenmile Canyon. The veins consist of milky quartz±adularia with Fe-Mn oxide minerals, and local fluorite, calcite, and barite (Schrader, 1947; Quade and Tingley, 1987). Quartz and adularia are partly pseudomorphous after calcite and are commonly banded, sheared, brecciated, or crushed (Schrader, 1947). The gouge is commonly strongly mineralized. Most veins are oxidized and boxwork zones are present locally. Principal ore minerals are argentite, cerargyrite, and silver halogen salts. Gold is both native and associated with argentite. Most ore was oxidized and secondarily enriched. Oxidation was particularly deep in the Nevada Wonder Mine where most production came from secondarily enriched ore above the 1,300-foot level.

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