Text and references accompanying Nevada Bureau of Mines and Geology Map 180

Geologic Map of the Flowery Peak Quadrangle, Storey and Lyon Counties, Nevada

by

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INTRODUCTION

The Flowery Peak quadrangle is centered about 30 km southeast of Reno (fig. 1). Its major physiographic features are the southern Virginia Range, the Flowery Range, and the Carson Plains (fig. 2). The quadrangle is adjacent and to the east of the Virginia City quadrangle, which contains the historic mining town of Virginia City and the Comstock Lode. The Flowery Peak quadrangle includes modern suburban developments on the Carson Plains along U.S. Highway 50.

Epithermal deposits of the Comstock mining district, which include the famous Comstock Lode deposits, extend into the Flowery Peak quadrangle. These deposits were major sources of precious metals during the late 19th and early 20th centuries, producing 192 million ounces of silver and 8.25 million ounces of gold (Bonham and Papke, 1969). Mines near the abandoned Flowery camp were historically separated as the Flowery mining district (Couch and Carpenter, 1943; Stoddard and Carpenter, 1950), but have been included in the Comstock district more recently (Bonham and Papke, 1969; Tingley, 1992). In this report, we refer to the area containing these mines, which include the Lady Bryan, Berry, and North Bonanza Mines, as the Flowery mining area. These mines produced more than $1 million between 1862 and 1939 (Couch and Carpenter, 1943). More recently, about 6,000 ounces of gold and 58,000 ounces of silver were produced from a pit on the Lady Bryan property between 1987 and 1990 (Schilling, 1990), and about 17,000 ounces of gold and 196,000 ounces of silver were produced between 1992 and 1997 (Tingley, 1998) from the Golden Eagle Mine, an open-pit operation east of the North Bonanza Mine. The Flowery Peak quadrangle also contains an active quarry on the Naturalite dome, a source of rhyolitic lightweight aggregate.

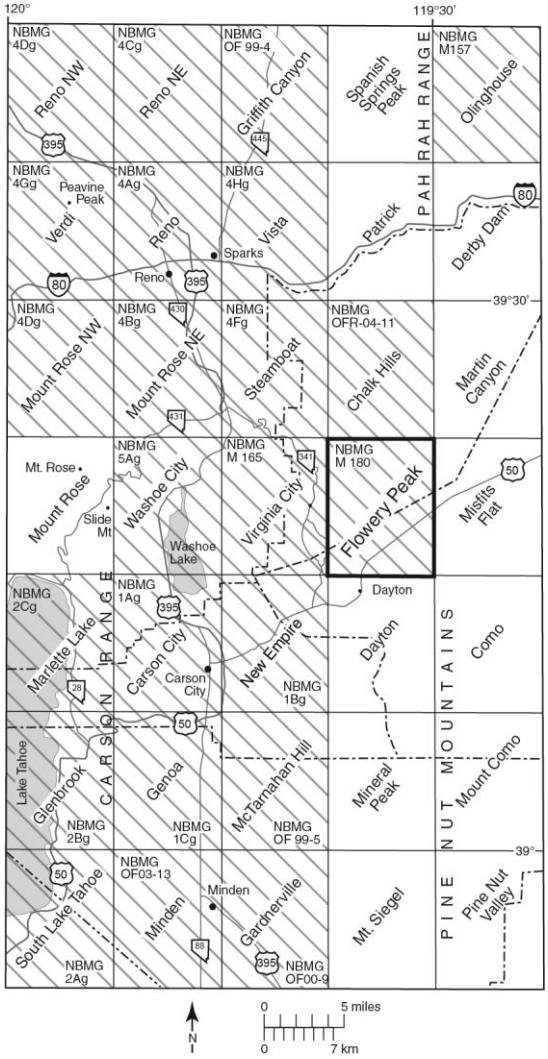

Figure 1. Regional map showing the location of the Flowery Peak quadrangle (dark outline) and nearby published 1:24,000-scale geologic maps (hachured).

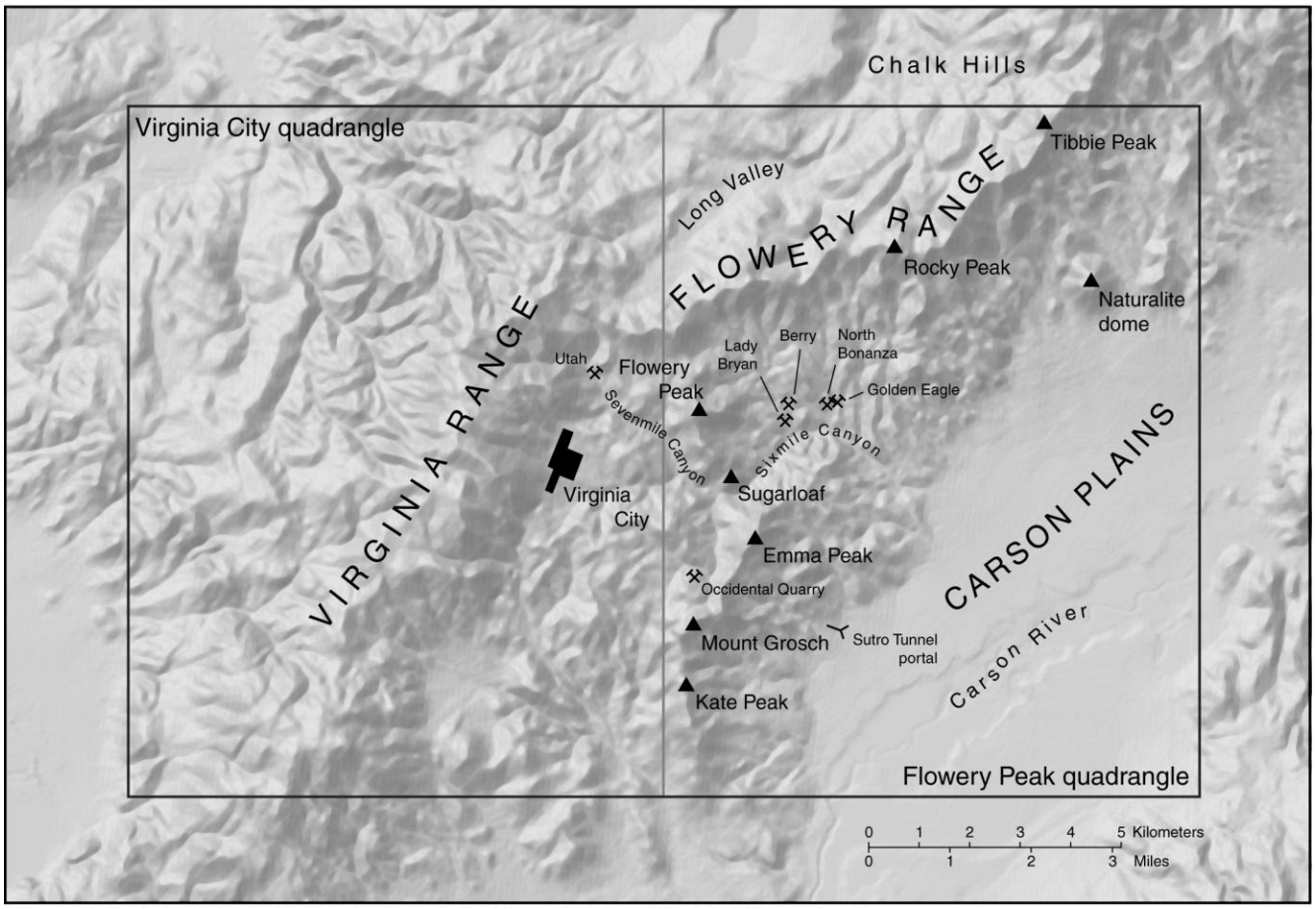

Figure 2. Shaded relief map showing locations in the Flowery Peak and Virginia City quadrangles that are discussed in this text and the unit descriptions.

Because of its economic impact, the Comstock district has been the subject of intense geologic study beginning with the work of Richthofen (1865), King (1870), and Becker (1882) and continuing to the present. Despite the large amount of previous work, including 49 K-Ar and fission-track ages (Vikre et al., 1988; Ashley et al., 1979; Whitebread, 1976; Silberman and McKee, 1972; Bonham and Papke, 1969), the age and extent of many of the area's rock units were unclear, and age relationships between magmatism and mineralization were imprecisely known. Our new geologic mapping in the Virginia City quadrangle (Hudson et al., 2009) and the Flowery Peak quadrangle along with new $^{40}Ar/^{39}Ar$ ages define several distinct Miocene magmatic and hydrothermal events in the area. On the basis of this new information, the volcanic stratigraphy has been revised, and the chronologic relationship between magmatism and mineralization in the area is better constrained.

Geologic units in the Flowery Peak quadrangle may be divided into six groups: (1) Mesozoic metamorphic rocks, (2) Cretaceous granitic rocks, (3) Oligocene to lower Miocene (27–23 Ma) rhyolitic ash-flow tuffs, (4) early and middle Miocene intermediate volcanic, hypabyssal intrusive, and sedimentary rocks, (5) late Miocene basalt, and (6) Quaternary volcanic and sedimentary deposits. The early and middle Miocene rocks, which are the most important hosts for the Comstock mineralization, were formerly divided into several formal stratigraphic units (Gianella, 1936; Calkins and Thayer, 1945; Thompson, 1956), but our new mapping and $^{40}Ar/^{39}Ar$ dating demonstrate the need for major stratigraphic revisions. This report and that of Hudson et al. (2009) document the field relations and ages of these rocks and describe our revised stratigraphy.

Previous geologic mapping in the area includes a 1:62,500 map of the Virginia City 15-minute quadrangle (Thompson, 1956), as well as earlier studies that contributed to that map (Gianella, 1936; Calkins and Thayer, 1945). Hudson (2003) presented simplified remapping of the Comstock district, and Hudson et al. (2009) updated the geology of the Virginia City quadrangle. A preliminary version of the geologic map of the Flowery Peak quadrangle was released as an open-file report (Castor et al., 2006); this map supersedes that report.

Geologic field mapping of most of the quadrangle was performed between 2004 and 2008. The geologic mapping used aerial photographs (mainly color

photographs at a scale of approximately 1:19,000 from Spencer B. Gross of Nevada, Inc. in Reno), topographic maps, and Quickbird imagery. A narrow strip along the western edge of the map was mapped by D. M. Hudson at 1:6,000 and 1:12,000 on enlarged topographic base maps.

$^{40}Ar/^{39}Ar$ Dating

Twelve new $^{40}Ar/^{39}Ar$ ages of igneous rocks in the Flowery Peak quadrangle were obtained on hornblende, plagioclase, and sanidine. These ages complement recently published ages on igneous rocks and alteration minerals in the Virginia City and Flowery Peak quadrangles (Hudson et al., 2009). The minerals were concentrated to >99 percent purity using magnetic and density separation, leaching with dilute HF (feldspars only), and handpicking. Samples were irradiated at Texas A&M University and analyzed at the New Mexico Geochronology Research Laboratory (methodology in McIntosh et al., 2003). Fish Canyon sanidine with an age of 28.02 Ma (Renne et al., 1998) was used as a neutron fluence monitor. All samples except sanidine were heated incrementally in a low-blank, resistance furnace, generally in ten to twelve 8-minute increments between about 700°C and 1650°C. Individual sanidine grains were fused with a CO_2 laser. The twelve new ages and $\pm 2\sigma$ uncertainties are listed in table 3, along with five previously published ages for Flowery Peak quadrangle rocks. All but one of the new $^{40}Ar/^{39}Ar$ ages were from spectra that show clear plateaus, defined as at least three contiguous steps that agree within analytical uncertainty and comprise more than 50% of the ^{39}Ar released. Isochron ages agree closely with plateau ages for these samples. Two plagioclase concentrates from andesite samples gave disturbed spectra that did not plateau. One of these, sample C05-384, gave a somewhat imprecise isochron age (table 3). A second sample, C06-48 (not shown in table 3), produced poor data that indicate an unacceptably old age, probably the result of the inclusion of plagioclase xenocrysts. Vein adularia ages reported in table 3 are particularly precise. Our new dating largely supplants the previous K/Ar and fission-track dating of the Tertiary rocks and mineralization, so the discussion here mostly does not repeat them. All ages that we do discuss have been calculated using the new decay constants and isotopic abundances given by the International Union of Geological Sciences Subcommission on Geochronology (Steiger and Jäger, 1977); if the age is recalculated from originally reported data, this is noted by the words "new constants."

Rock Analyses, Petrography, and Mineral Identifications

Chemical analyses of rock samples (table 4) were performed by the Washington State University Geochemical Laboratory using XRF (major oxides) and ICP-MS (trace elements). Loss on ignition analyses were performed by the Nevada Bureau of Mines and Geology Laboratory. Igneous rock names are based on the IUGS classification of Le Maitre et al. (2002).

Mineral contents reported for igneous rocks (tables 1 and 2) were estimated visually from thin sections and rock slabs using standard petrographic techniques. Plagioclase An contents were estimated using the high-temperature (volcanic) curve for A-normal determinations (Deer, Howie, and Zussman, 1966). Mineral identifications in some altered rock and vein samples were made using X-ray diffraction powder scans.

STRATIGRAPHY

Mesozoic Rocks

Metamorphic Rocks

The oldest rocks in the Flowery Peak quadrangle are metasedimentary and metaigneous rocks. These rocks range from greenschist to amphibolite facies and are cut by Cretaceous granitic rocks. The metamorphic rocks are thought to be of Triassic-Jurassic age by comparison to similar rocks elsewhere in the region.

Cretaceous Plutonic Rocks

Cretaceous granitic rocks crop out in the north half of the Flowery Peak quadrangle in several places, occurring beneath Miocene rocks in the footwall of major normal faults. A hornblende $^{40}Ar/^{39}Ar$ age on granitic rock from the quadrangle is 93.2 ±1.1 Ma (sample C06-170, table 3). Because the closure temperature for hornblende is about 500°C, this age probably records initial cooling of the granitic rock and closely approximates its time of intrusion. Granitic rock from the Utah Mine dump in the Virginia City quadrangle gave an age of 87.6±4.0 Ma (K-Ar on hornblende, recalculated from Vikre et al., 1988). Other granitic rocks in the area have given Cretaceous and Miocene (e.g., Davidson Diorite) isotopic ages (Hudson et al., 2009).

Granitic rock in the Flowery mining area was thought to be Cretaceous by Thompson (1956) and Tertiary by Schilling (1990). We agree with the former

Table 1. Phenocryst content and plagioclase phenocryst An content in Tertiary igneous rocks, Flowery Peak quadrangle.

	Plagioclase		Plagioclase An		Hornblende		Clinopyroxene		Orthopyroxene		Biotite		Olivine		Quartz		K-feldspar		Opaque	
Rock unit	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**
Lousetown basalt (Tlb) n = 1	62.5		70.0		0.0		10.0		0.0		0.0		5.0		0.0				3.5	
Occidental dacite (Tod) n = 1	22.5		37.0		7.5		0.0		0.0		3.5		0.0		1.5				0.5	
Rocky Peak andesite (Trpa) n = 1	17.5		43.0		10.0		1.5		0.0		1.5		0.0		tr				0.5	
Mount Grosch dome (Tmga) n = 3	20.7	18–25	38.3	37–40	8.2	7.5–11	2.2	0.5–4.5	0.0		2.3	2–2.5	0.0	0–tr	0.9	tr–1.5			0.7	tr–1
Biotite-hornblende intrusions (Tbhi) n = 10	22.0	20–25	43.9	38–50	6.2	3.5–10	0.0	0–tr	0.0		2.5	tr–4.5	0.0		1.2	0–2.5			1.0	0.5–1.5
Hornblende andesite intrusions (Thai) n = 6	16.3	8.5–30	45.4	42–50	6.8	4.5–11	0.9	0–4.5	0.7	0–1.5	0.1	0–0.5	0.0		0.1	0–0.5			1.2	0.5–2
Flowery Peak magmatic suite																				
Biotite-hornblende-pyroxene andesite domes (Tfad) n = 7	15.2	10–22.5	43.8	40–48	6.8	5–12.5	1.1	tr–2	0.1	0–0.5	1.8	1–2.5	0.3	0–1	0.8	0–2			0.4	0–1
Biotite-hornblende andesite of Sugarloaf (Tfsa) n = 4	21.5	20–25	45.0	41–48	8.4	5.5–12	0.0	0–tr	0.0		2.0	1.5–2.5	0.0		0.0	0–tr			1.1	0.5–1.5
Hornblende andesite flows (Tfp & Tfha) n = 11	20.8	15–30	48.0	45–50	9.3	7–12.5	0.0	0–0.5	1.3	0.5–3	0.0	0–tr	0.2	0–0.5	0.0				1.3	1–2
Biotite-hornblende andesite flows (Tfp & Tfba) n = 15	18.4	13–22.5	41.3	35–48	7.8	3.5–12	0.4	0–1	0.2	0–1.5	2.1	1–4.5	0.4	0–1	0.9	tr–2			1.0	0.5–1.5
Virginia City magmatic suite																				
Andesites of the Kate Peak Formation (Tvka) n = 5	24.3	19–30	49.4	46–56	2.8	1–5.5	4.5	1.5–7	2.6	1–5	0.0		0.0	0–tr	0.0	0–tr			1.6	1.5–2
Olivine-pyroxene andesite (Tvkp) n = 1	17.5		55.0		0.0		4.0		1.0		tr		tr		tr				1.5	
Tuff in andesites of the Kate Peak Formation n = 1	27.5		50.0		tr		2.5		3.0		0.0		0.0		0.0				1.5	
Virginia City andesites undivided (Tvu) n = 18	23.8	15–32	51.2	43–62	6.6	tr–18	3.0	tr–6	1.4	0–6	0.2	0–2	0.1	0–2.5	0.0				1.6	0.5–3
Biotite-hornblende andesites (Tvba) n = 7	19.4	11–25	44.2	42–50	6.5	4–10	0.4	0–1	0.7	0–3	1.7	tr–3	0.0	0–tr	0.3	0–1.5			1.0	0.5–1.5
Pyroxene andesite (Tvpa) n = 1	27.0		50.0				10.0		3.0										3.0	
Silver City magmatic suite																				
Fine-grained andesite (Tsfa) n = 4	0.4	0–1.5	nd		6.3	5–7	0.0		0.0		0.0		0.0		0.8	0–2.5			0.0	
Pyroxene andesite flows (Tspa) n = 1	18.0		55.0		0.0		5.0		3.5		0.0		3.0		0.0				1.5	
Pyroxene andesite flow & clast (Tsd) n = 2	14.0	10–18	66.0	65–67	tr	tr	4.5	0.5–8.5	0.5	0–1	0.0		0.0		0.0				0.8	0.5–1
Hornblende andesite flows & clast (Tsd) n = 3	25.0	20–32	47.4	45–50	8.2	3–12	2.3	1–4	0.8	0–2	0.0		0.0		0.0				1.2	0.5–1.5
Silver City andesites undivided (Tsa) n = 9	24.3	12–32	52.7	44–67	7.8	3–12	2.2	0–5	0.7	0–3	0.0	0–tr	0.0		0.0	0–tr			1.3	0.5–2
Tuff E (TtE)																				
Upper tuff n = 3	1.7	1–2.5	26.5	22–31	tr	0–tr	0.0		0.0		0.6	tr–1.5	0.0		2.0	1–2.5	2.3	1.5–4	0.2	tr–.5
Basal tuff n = 1	9.5		35.0		tr		0.0		0.0		0.5		0.0		7.5		1.5		0.5	

Table 2. Mineral content and plagioclase An content for Mesozoic igneous units, Flowery Peak quadrangle.

Rock type	Plagioclase mean	Plagioclase range	Plagioclase An mean	Plagioclase An range	Hornblende mean	Hornblende range	Biotite mean	Biotite range	Quartz mean	Quartz range	K-feldspar mean	K-feldspar range	Opaque mean	Opaque range
Granodiorite - quartz diorite (Kg) n = 5	51.2	45-60	31.4	22–44	7.4	3–13	8.0	5–11	21.0	17–25	9.9	2.5–18	1.2	1–1.5
Leucogranite (Klg) n = 1	43.0		29.0		tr		3.5		32.0		21.0		0.5	

Table 3. $^{40}Ar/^{39}Ar$ Ages Flowery Peak quadrangle.

Sample step heating	rock type	Latitude (N)	Longitude (W)	Mineral	Ages (Ma)[2] plateau	±2s	$\%^{39}Ar$[3]	steps	isochron	±2s	$^{40}Ar/^{36}Ar_i$	±2s	MSWD	total gas	±2s
C02-15[1]	vein	39.32033	119.59367	adularia	**13.36**	0.04	86	6/10	**13.37**	0	286	3	15	13.3	0.1
CN85-25[1]	vein	39.32392	119.58755	adularia	**13.43**	0.08	55.7	7/11	**13.38**	0.1	310	9	0.87	14.0	0.2
C02-19[1]	vein	39.31100	119.62300	adularia	**13.53**	0.03	100	10/10	**13.53**	0	296	2	0.77	13.5	0.1
C02-21[1]	Tod	39.30034	119.62039	hornblende	**12.91**	0.18	99.79	11/11	**12.90**	0.2	296	4	1.7	12.9	0.2
C04-500A	Trpa	39.34928	119.57062	plagioclase	**13.20**	0.37	79.4	6/11	**13.2**	0.4	280	30	1.7	13.4	0.7
C06-194	Tfba	39.36032	119.50403	hornblende	**13.83**	0.31	77.5	6/11	**13.8**	0.3	300	30	0.75	14.5	1.2
C04-116	Tbhi	39.31893	119.60317	hornblende	**14.46**	0.30	100	11/11	**14.5**	0.3	291	12	0.36	14.1	2.3
C05-657A	Tfp	39.36878	119.53430	hornblende	**14.47**	0.32	100	11/11	**14.3**	0.4	307	17	0.29	14.6	1.2
C02-14[1]	Tfsa	39.30597	119.60535	hornblende	**14.54**	0.11	100.02	8/11	**14.61**	0.10	290	4	1.4	14.5	0.2
C04-27	Tfp (Tfha type)	39.32003	119.61370	hornblende	**14.60**	0.27	85.8	6/11	**14.7**	0.3	290	20	0.48	14.9	1.0
C04-558	Tfad, basal o/c	39.32513	119.56823	hornblende	**14.62**	0.39	85.9	10/11	**14.6**	0.4	298	14	0.93	15.1	1.8
C05-477	Tvha	39.27162	119.59233	hornblende	**15.25**	0.32	100	11/11	**15.2**	0.4	296	13	0.65	15.4	2.0
C05-384	Tspa[4]	39.26048	119.60285	plagioclase	**17.2**	1.2	24.7	1/11	**17.2**	1.2	250	40	3.1	14.7	1.7
C06-268	Tsa flow bx	39.37433	119.51992	hornblende	**18.06**	0.48	100	11/11	**18.0**	0.6	297	11	0.37	17.8	3.8
C06-159	Tsa	39.35327	119.50621	hornblende	**18.31**	0.36	92.4	10/11	**18.1**	0.4	307	14	0.26	18.8	1.2
C06-170	Kg	39.35430	119.50002	hornblende	**93.20**	1.10	75.5	8/11	**93.1**	1.3	300	40	0.85	90.0	3.6
single crystal					wtd mean	±2s		grains							
C05-695	TtE	39.36963	119.51968	sanidine	**28.98**	0.07		14/15							

$^{40}Ar/^{39}Ar$ ages of igneous rocks from the Flowery Peak quadrangle. All analyses at the New Mexico Geochronological Research Laboratory (methodology in McIntosh et al., 2003). Neutron flux monitor Fish Canyon Tuff sanidine (FC-1); assigned age = 28.02 Ma (Renne et al., 1998). Decay constants and isotopic abundances after Steiger and Jäger (1977); lb = 4.963 x 10-10 yr-1; le+e' = 0.581 x 10-10 yr-1; 40K/K = 1.167 x 10-4. Latitude and longitude location datum is NAD27. Notes: [1] previously reported age (Hudson et al., 2009); [2] ages in bold are best estimates of emplacement age; [3] $\%^{39}Ar$ = percentage of ^{39}Ar used to define plateau age; [4] Spectrum is irregular and did not plateau (the plateau age reported is the age of the L step, which had the most ^{39}Ar and the smallest uncertainty).

because the Flowery rock resembles sample C06-170 lithologically and texturally, and occurs as clasts in nearby basal Tertiary sedimentary rock (Tvs).

Miocene-Oligocene Tuffs and Sedimentary Rocks

The Mesozoic basement of the Flowery Peak quadrangle is locally overlain by Oligocene and earliest Miocene ash-flow tuffs. A 28.98±0.07-Ma tuff that lies on metamorphic rocks in the northeast part of the quadrangle is correlated on the basis of lithology and age with Tuff E (Brooks et al., 2008) in the Haskell Peak area, California, about 80 km northwest of the Flowery Peak quadrangle. A sequence of five regionally identified ash flows was described in the Virginia City quadrangle (Hudson et al., 2009). Of these, only the early Miocene Santiago Canyon Tuff (23.12±0.05 Ma, $^{40}Ar/^{39}Ar$ on sanidine, Henry and Faulds, 2010) occurs in the Flowery Peak quadrangle.

Early to Middle Miocene Intermediate Volcanic Rocks

The early to middle Miocene intermediate rocks in the Flowery Peak quadrangle have been correlated with rocks in the Virginia City quadrangle using lithology, stratigraphic succession, and new $^{40}Ar/^{39}Ar$ age determinations. As noted in Hudson et al. (2009), new mapping and $^{40}Ar/^{39}Ar$ age determinations of the middle Miocene rocks revealed difficulty in the use of unit names applied by Gianella (1936), Calkins (1945), and Thompson (1956), particularly the "Kate Peak Formation" and "Alta Formation." These old names have become entrenched in the literature as regional units, but such usage cannot be supported on the basis of new data. Therefore, as in the new Virginia City quadrangle map (Hudson et al., 2009), these names are used only in a restricted sense on the Flowery Peak quadrangle, and informal names are used for most other rocks. We divide the early and middle Miocene intermediate volcanic rocks

Table 4. Chemical analyses of rocks from the Flowery Peak quadrangle. Major oxides reported in weight percent, trace elements in parts per million.

Sample	C02-14	C02-21	C04-27	C04-48	C04-62	C04-63	C04-116	C04-500A	C04-558	C05-384	C05-477	C05-657A	C05-695	C06-159	C06-170	C06-194	C06-268
unit	Tfsa	Tod	Tfp	Tvka	Tmga	Tmga	Tbhi	Trpa	Tfad	Tspa	Tvha	Tfha	TtE	Tsa	Kg	Tfba	Tsa
Major oxides (weight percent)																	
SiO_2	62.34	64.39	60.86	58.75	60.60	73.40	62.63	58.49	60.17	55.04	61.54	60.57	73.12	60.63	63.98	61.68	58.49
TiO_2	0.47	0.58	0.62	0.75	0.70	0.07	0.48	0.80	0.56	0.75	0.60	0.66	0.11	0.63	0.68	0.68	0.83
Al_2O_3	16.12	15.60	16.71	17.54	15.84	12.85	15.52	15.78	16.84	16.64	16.29	16.67	12.46	16.95	15.89	15.83	16.63
FeO*	4.61	4.72	5.09	5.76	5.60	0.57	3.83	6.25	4.26	7.25	5.00	5.54	0.76	5.12	4.61	4.85	6.14
MnO	0.09	0.09	0.09	0.10	0.10	0.06	0.08	0.12	0.11	0.15	0.06	0.11	0.06	0.08	0.08	0.09	0.09
MgO	2.15	2.25	2.47	2.82	3.85	0.08	2.54	4.51	2.57	5.59	2.09	2.60	0.10	2.45	1.98	2.66	3.27
CaO	4.44	4.47	5.32	6.17	5.91	0.76	3.75	6.64	5.15	8.09	4.38	5.09	0.68	5.64	3.87	4.83	6.30
Na_2O	3.55	3.90	3.68	3.98	3.79	3.74	3.13	3.59	3.40	2.96	3.78	3.61	3.50	4.23	3.32	3.58	4.13
K_2O	2.68	2.53	2.51	2.22	2.18	4.56	2.84	2.01	2.01	1.78	2.76	2.41	4.47	2.29	3.87	2.91	2.07
P_2O_5	0.17	0.16	0.23	0.21	0.23	0.01	0.19	0.21	0.21	0.16	0.20	0.23	0.02	0.28	0.13	0.24	0.35
LOI	3.40	1.10	1.15	0.76	0.93	2.62	3.65	0.52	4.03	1.36	2.45	1.09	3.22	0.73	1.56	1.46	1.43
Total	100.22	100.00	98.72	99.06	99.73	98.72	98.64	98.92	99.29	99.77	99.15	98.59	98.49	99.03	99.97	98.80	99.72
Trace elements (parts per million)																	
Ni	<7	<5	9	14	63	0	9	45	10	66	8	9	0	25	4	20	17
Cr	7	42	17	35	182	2	17	152	21	218	16	19	3	93	12	47	41
Sc			13	17	15	2	8	19	10	25	10	15	3	13	11	11	13
V	88	103	121	159	144	2	88	175	103	192	119	140	3	119	102	112	156
Ba	940	966	1096	922	969	378	1119	774	1009	661	1022	1097	660	1052	932	1000	818
Rb	64	46	53	48	43	134	65	40	109	44	61	56	150	57	142	55	40
Sr	523	645	721	686	699	78	756	686	852	519	588	699	78	709	339	697	1012
Zr	114	103	123	125	108	63	117	102	131	102	136	120	106	133	199	112	140
Y	13	13	15	14	22	15	12	16	13	17	14	17	16	14	18	13	15
Nb	6	6	5	4	6	20	5	5	5	4	5	4	11	5	6	5	6
Ga	16	18	19	19	18	14	17	18	19	17	19	18	15	18	17	20	21
Cu			21	50	19	0	18	39	16	67	38	29	2	31	21	8	34
Zn	70	67	80	80	88	33	68	86	78	82	70	80	43	82	55	85	98
Pb	9	14	15	12	13	25	18	14	17	10	15	14	28	10	11	13	9
La	25	0	23	20	19	20	21	15	23	15	17	24	39	18	13	20	22
Ce	6	60	44	36	34	36	40	36	39	28	39	49	64	36	32	37	51
Th	3	0	7	7	4	12	8	5	5	4	7	9	20	3	7	4	3
Nd	12	19	22	17	21	13	18	21	19	16	19	22	22	19	16	19	28
U	<2	<3	2	2	1	3	2	2	2	3	2	3	9	3	4	3	0

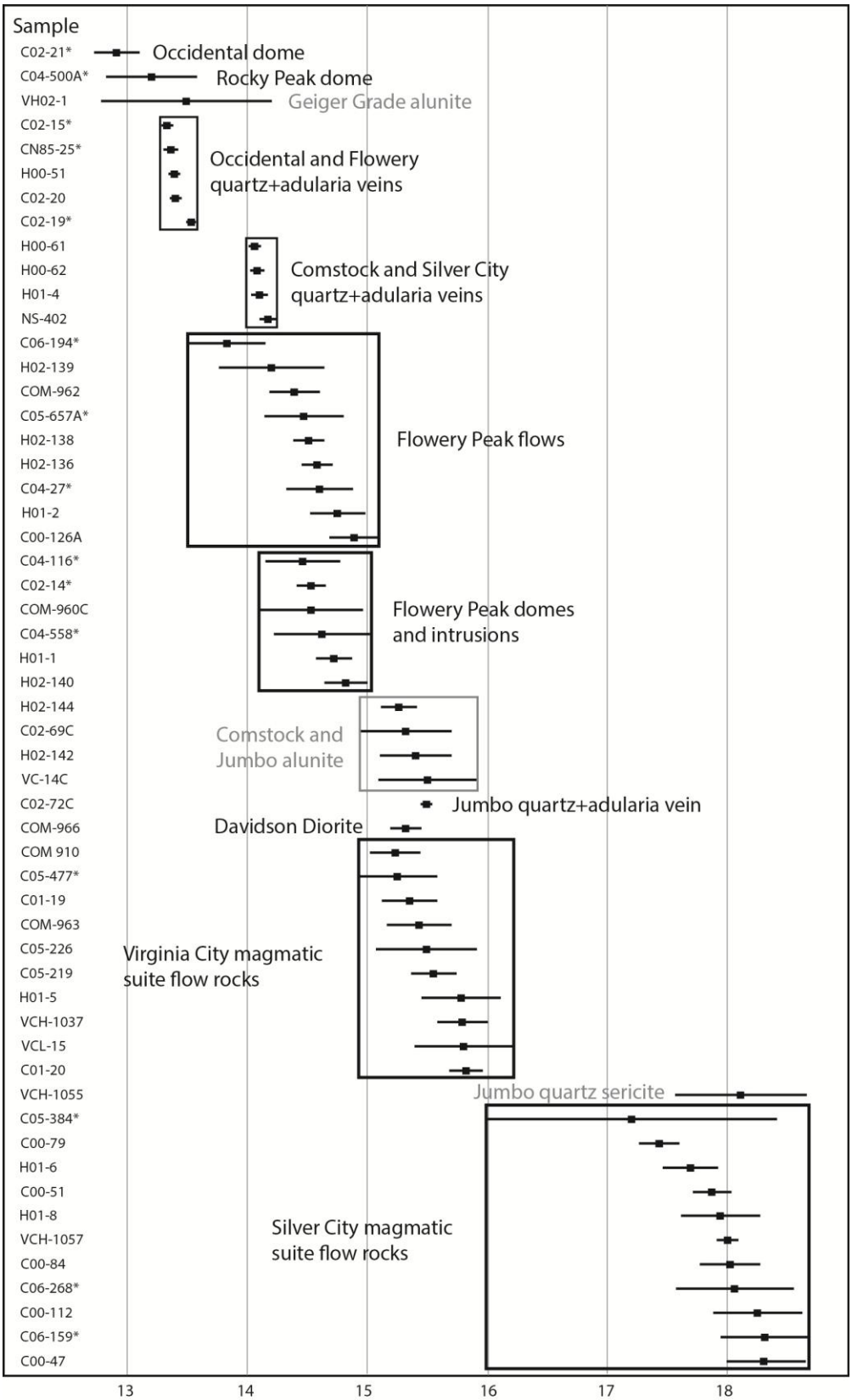

Figure 3. Plot of $^{40}Ar/^{39}Ar$ ages (small rectangles) and 2σ precision (horizontal lines) for samples of Miocene intermediate volcanic rocks and intrusions from the Virginia City and Flowery Peak quadrangles. Most ages are on samples from the Virginia City quadrangle (Hudson et al., 2009); asterisks denote samples from the Flowery Peak quadrangle (data reported in table 3).

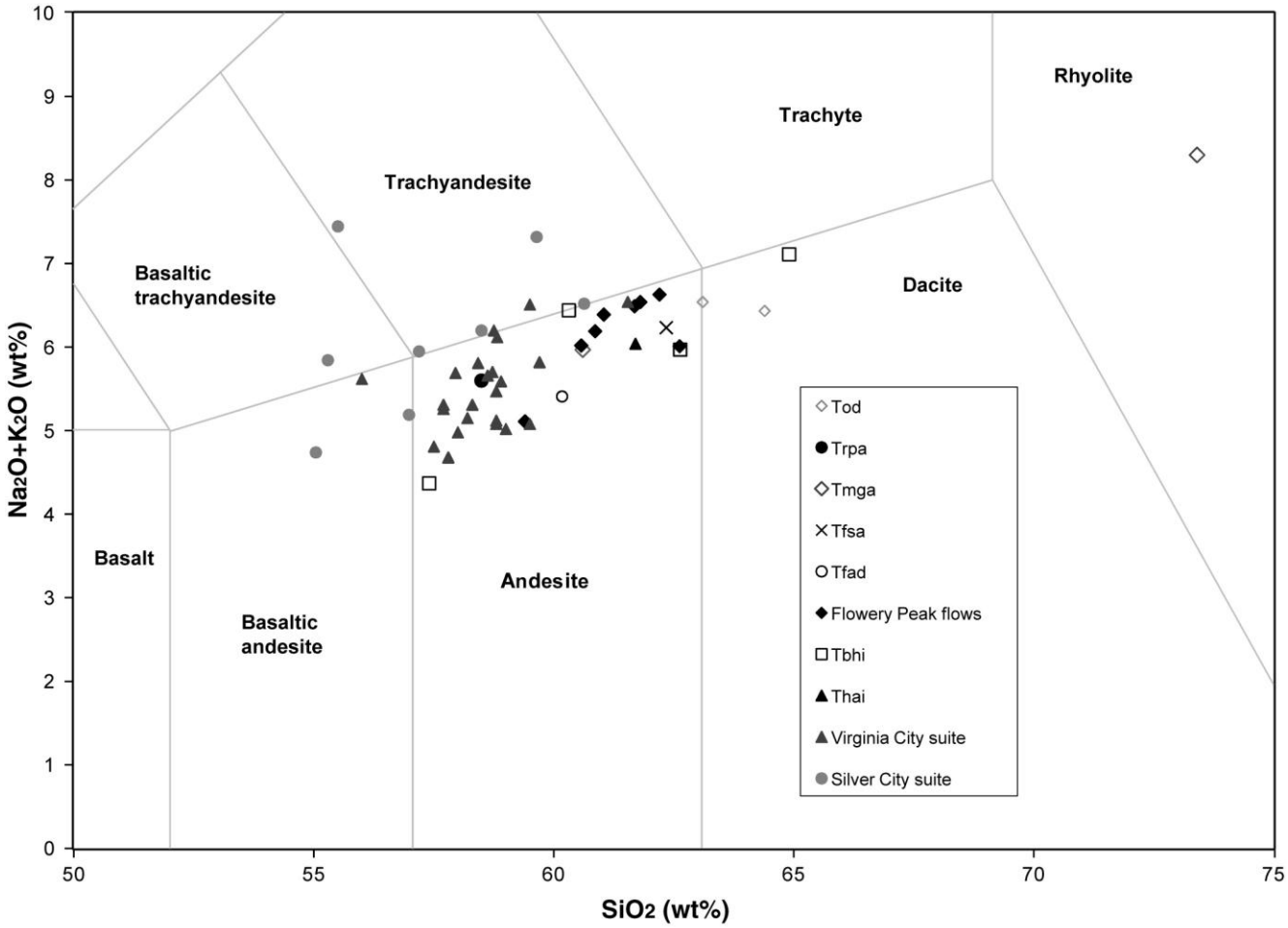

Figure 4. Alkali versus silica diagram for igneous rocks from the Flowery Peak quadrangle (table 4) and from the Virginia City quadrangle (Hudson et al., 2009). Fields for volcanic rock compositions are from Le Maitre et al. (2002).

into four groups: (1) the Silver City magmatic suite, (2) the Virginia City magmatic suite, (3) the Flowery Peak magmatic suite, and (4) the Occidental dacite and Rocky Peak andesite. In some cases, it is difficult to assign the rocks of the Flowery Peak quadrangle to a magmatic suite on the basis of mineralogy, texture, or chemistry. This uncertainty is aggravated by hydrothermal alteration in many places.

Silver City Magmatic Suite

The Silver City magmatic suite, defined by Hudson et al. (2009) in the Virginia City quadrangle, includes andesitic rocks with $^{40}Ar/^{39}Ar$ ages of between 17.2 Ma and 18.3 Ma, distinctly older (~2 million years) than the overlying 15.2- to 15.8-Ma rocks of the Virginia City suite (fig. 3). The Silver City rocks are relatively alkaline compared with rocks of the Virginia City suite (fig. 4).

The Silver City suite contains large amounts of volcanic breccias (Tsd) that are characterized by the presence of finely porphyritic pyroxene andesite clasts. Breccias dominated by hornblende andesite (Tsdl) and biotite-hornblende andesite (Tsdb) occur locally. Silver City suite flows are difficult to distinguish from some flows in the Virginia City suite. Both suites include finely porphyritic flows of two-pyroxene andesite, with or without minor hornblende, that are locally mapped (Tvpa and Tspa) in the Flowery Peak quadrangle. A distinctive andesite (Tsfa) with minor fine hornblende and plagioclase phenocrysts and xenocrysts of quartz occurs in the northeast part of the quadrangle. Tsfa is texturally similar to undated intrusive and extrusive andesites in the Virginia City quadrangle (units Tara, Tap, and Tac, Hudson et al., 2009). A small area of sandstone (Tss) in the Flowery mining area occurs beneath finely porphyritic flow rocks tentatively identified as Tsa. Similar sandstones occur in sedimentary sequences included in upper Silver City suite rocks in the Virginia City quadrangle (Hudson et al., 2009).

New $^{40}Ar/^{39}Ar$ ages for Silver City suite andesites in the Flowery Peak quadrangle range between 17.2 and 18.3 Ma (table 3), which is similar to the range in the Virginia City quadrangle (17.4 to 18.3 Ma). The youngest age is an imprecise age (17.2 ±1.2 Ma, sample C05-384, table 3) on

plagioclase from Tspa flow rock that lies above a thick section of Tsd in the southwest part of the quadrangle.

Sutro Tuff?

Tuff and sedimentary rocks (Ts) that crop out in the Flowery mining area are likely equivalent to the Sutro Tuff, which occurs in several areas between andesitic rocks of the Silver City and Virginia City suites in the Virginia City quadrangle (Hudson et al., 2009). In both quadrangles, these rocks contain ash-flow and ash-fall tuffs along with siltstone, sandstone, and conglomerate. In the Flowery Peak quadrangle they also contain blocks of pre-Tertiary granitic rock and lie above and are laterally adjacent to Cretaceous granitic rock (Kg).

Virginia City Magmatic Suite

The Virginia City magmatic suite was defined in the Virginia City quadrangle (Hudson et al., 2009), where it includes more than 20 extrusive and intrusive andesitic to rhyolitic units. The Virginia City suite includes parts of the Kate Peak and Alta andesite series of Gianella (1936) and the Kate Peak and Alta Formations of Thompson (1956). Twelve units were mapped in the Flowery Peak quadrangle. Virginia City suite rocks have relatively tightly grouped $^{40}Ar/^{39}Ar$ ages of 15.2 to 15.8 Ma (fig. 3).

Most of the Virginia City suite rocks in the Flowery Peak quadrangle are mapped as undivided Virginia City andesites (Tvu), which are dominated by flows but include locally abundant debris-flow and flow-breccia. They are, in part, equivalent to rocks of the Alta Formation of Hudson et al. (2009), but probably also contain rocks of the Kate Peak Formation of Hudson et al. (2009). In addition, Tvu flows contain biotite north of the Flowery mining area, and may be equivalent to Tvba mapped in the southwest part of the quadrangle.

Virginia City suite rocks in the southwest part of the Flowery Peak quadrangle are subdivided lithologically, from lowest to highest, into hornblende-andesite flow-rock (Tvha), a lower debris-flow unit (Tvd), pyroxene-andesite-flows (Tvpa), and biotite-bearing flows (Tvba) and debris-flows (Tvbd). On the basis of work in the Virginia City quadrangle, the presence of biotite in Virginia City suite rocks is unusual; however, biotite occurs locally in some Alta Formation flows (Hudson et al., 2009). Above this lower sequence in the Flowery Peak quadrangle are rocks mapped as Kate Peak Formation, which include three units also mapped in the Virginia City quadrangle (Tvka, Tvkb, and Tvkl) and two units that have only been observed in the Flowery Peak quadrangle (Tvkdb and Tvkp). The only $^{40}Ar/^{39}Ar$ age on rocks of the Virginia City suite in the Flowery Peak quadrangle is 15.25 ± 0.32 Ma (hornblende, sample C05-477, table 3) on hornblende andesite (Tvha).

Virginia City suite rocks are absent between Silver City suite rocks and overlying Flowery Peak suite rocks in the northeast part of the quadrangle. This depositional and/or erosional gap is locally occupied by volcaniclastic sedimentary rock and tuff (unit Tfs).

Flowery Peak Magmatic Suite

Rocks of the Flowery Peak magmatic suite, as defined by Hudson et al. (2009) in the Virginia City quadrangle, are flows and breccias that range in age from about 14.2 to 14.9 Ma. Extrusive rocks of the Flowery Peak suite are generally unaltered and unconformably overlie altered Virginia City suite rocks. In the Flowery Peak quadrangle, Flowery Peak suite rocks have yielded $^{40}Ar/^{39}Ar$ ages of 13.8 to 14.6 Ma. The youngest age (13.8 Ma, sample C06-194, table 3) was obtained on rock that rests directly on rock assigned to the Silver City suite in the northeast part of the quadrangle.

Most Flowery Peak suite rocks are mapped in a single undivided unit (Tfp) in the Flowery Peak quadrangle. On the basis of petrologic examinations of more than 30 samples from the Virginia City and Flowery Peak quadrangles, two types of flow rock are typical of this suite: hypersthene-hornblende andesite and biotite-hornblende andesite. The latter contains no hypersthene and commonly contains minor olivine, quartz, and clinopyroxene. In some areas, flows in the Flowery Peak suite are mapped as the two types: Tfha (hypersthene-bearing andesite) and Tfba (biotite-bearing andesite) on the basis of these different phenocryst assemblages. Mappable debris-flow sequences, which commonly contain clasts of both flow types, are shown as Tfd.

Rock that we assign to the Flowery Peak suite was previously included in the Kate Peak Formation by Thompson (1956) and Hudson (2003). However, the andesite that underlies the topographic feature of Kate Peak is older than Flowery Peak suite rocks (15.43±0.26 Ma, sample COM 963, Hudson et al., 2009), and is in the Kate Peak Formation of the Virginia City suite.

Intrusive rocks in the Flowery Peak magmatic suite include biotite-hornblende andesite with minor quartz as dike rock (14.46±0.30 Ma, sample C04-116, table 3) and the Sugarloaf plug (14.54±0.11 Ma, sample C02-14, table 3). In addition, three exposures of dome rock, which is probably extrusive, east of the Flowery mining area are also biotite-hornblende andesite with minor quartz (14.62±0.39 Ma, sample C04-558, table 3).

Younger Volcanic Domes

Two volcanic domes in the Flowery Peak quadrangle have given significantly younger ages than rocks of the Flowery Peak magmatic suite. The Rocky Peak domes, two masses of coarsely porphyritic andesite (Trpa) with

quartz, were emplaced at 13.20± 0.37 Ma (sample C04-500A, table 3). The southern boundaries of these Trpa domes are horizontal to shallowly north-dipping, suggesting extrusive emplacement; however map patterns indicate steep, possibly near-vertical contacts to the north, suggesting intrusive emplacement. The Trpa domes are offset by a fault to the north and may represent partly exogenous features atop the Flowery Peak suite sequence in that area.

The Occidental dome (Tod) is similar to Trpa in that it is coarsely porphyritic, contains quartz, mostly has near horizontal basal contacts, and is indistinguishable in age (12.91± 0.18 Ma (sample C02-21, table 3). However, it contains considerably more silica than Trpa (fig. 4). Tod is roughly coeval with rhyodacite lava from about 15 km to the northeast in the Chalk Hills quadrangle, which gave 12.64±0.21 Ma (recalculated from $^{40}Ar/^{39}Ar$ on hornblende, Schwartz and Faulds, 2004).

Chalk Hills Sedimentary Rocks

A sequence of sandstones and conglomerates that includes tuffaceous and diatomaceous rocks extends into the north part of the Flowery Peak quadrangle from the Chalk Hills quadrangle. An age obtained on tuffaceous rock from this sequence about 1 km north of the Flowery Peak quadrangle is 12.73±0.14 Ma (recalculated from $^{40}Ar/^{39}Ar$ on hornblende, Schwartz and Faulds, 2004), indistinguishable from the age for Tod.

Lousetown Basalt

The Lousetown basalt forms shallowly north-pitching plateaus in the northwest part of the Flowery Peak quadrangle. Formerly called the Lousetown series (Thayer, 1937) and Lousetown Formation (Thompson, 1956), we modify slightly (by change of case) the "Lousetown Basalt" usage of Schwartz and Faulds (2004) who mapped the unit to the north in the Chalk Hills quadrangle and of Hudson et al. (2009).

Quaternary and Tertiary Deposits

The Virginia Range contains remnants of gravelly sediments that may be Pliocene or early Pleistocene age (QTa) on the basis of their morphology and high-standing location. These deposits are cut by range-front faults west of the Mark Twain Estates. In addition, hot-spring altered sediments along the edge of the range (QTs) may be of Tertiary or Quaternary age.

Early Pleistocene Deposits of the Naturalite Dome Area

An exogenous dome of highly siliceous glassy rhyolite lies at the north end of a reentrant of Carson Plains alluvium into the Flowery Range. The dome is easily visible from U.S. Highway 50 because it is scarred by quarrying as a source of lightweight aggregate. The quarry workings and access roads have enhanced exposures of the dome, which show that it includes a mound of friable, massive to well-bedded rhyolite, andesite, and granitic ejecta (Qnt) interpreted as the remnants of a tuff-ring deposit. The rhyolite includes brecciated and relatively solid rock (Qnb and Qnr, respectively) that seems to have filled the tuff ring and partially protected it from erosion. K/Ar ages on the rhyolite reported by Silberman et al. (1979), who referred to the feature as the "Sutro rhyolite dome," are 1.55±0.22 Ma on alkali feldspar, and 1.55±0.06 Ma on obsidian (recalculated from originally reported ages). Diatreme breccia, common beneath tuff rings (Lorenz, 1986), is shown extending as deep as granitic basement in section A-A". Nearly flat-lying friable diatomaceous sandstone beds (Qns) occur in places around the dome and north of it. Qns is mostly andesitic debris but locally contains glass shards with the same refractive index as Qnr. Qns was probably deposited behind and adjacent to the rhyolite dome, probably in a local lacustrine environment.

The refractive index (R.I.) of nonhydrated glass from Naturalite dome deposits is 1.484, whereas glass shards and hydrated glass give R.I. of 1.496. The different values are within the 0.006–0.014 difference between hydrated and dehydrated R.I. measurements for the same volcanic glass reported in Nakamura et al. (2002).

Early to Middle Pleistocene Deposits

Deposits of coarse sand and gravel near the Virginia Range front (Qao) may be as old as early Pleistocene.

Middle to Late Pleistocene Deposits

The Carson Plains are underlain by deposits of Lake Lahontan that include fluvial-lacustrine deposits (Qfl) likely correlative with the ~130- to 350-ka Eetza Alloformation (Morrison, 1964; 1991) and undivided lacustrine mud to sand deposits (latest to middle Pleistocene) which may include deposits of the Eetza and 8- to 35-ka Sehoo Alloformations, and possibly older lacustrine units associated with Lake Lahontan (Morrison, 1964; 1991). These units occur with the 35- to 130-ka interlacustrine (Morrison, 1991) mud to gravel and eolian sand of the Wyemaha Alloformation (Qw) that locally overlie Qfl. Deposits of silt to gravel at the foot of, and in, the Virginia Range (Qai) are probably of middle to late Pleistocene age, and local landslide deposits (Qls) may also be of this age.

Pleistocene and/or Holocene Deposits

Slope-mantling deposits of coarse gravel (Qc) and basalt talus (Qtb) are of poorly defined age, possibly as old as Pleistocene.

Holocene Deposits

Deposits on the Carson Plains, including piedmont deposits, alluvial deposits, and eolian deposits, are considered Holocene on the basis of their morphology and relationship to Pleistocene deposits. Mappable, active or recently active Holocene alluvial deposits in the Virginia Range occur mainly along Sixmile Canyon and Long Valley. Relatively high-standing hillslope and mass-wasting deposits, such as talus and landslide deposits, are also thought to be of Holocene age. Spring deposits (Qsp) that mostly occur in the Sutro Springs area were probably formed by the local accumulation of fine eolian sediment trapped by locally abundant vegetation.

Mine waste and mill tailings (Qt) date from as early as the 1860s to as recent as the 1990s in the Flowery mining area. Mill tailings along Sixmile Canyon may have been deposited as early as the 1860s and as late as the 1930s. Other disturbed areas (Qx) mostly represent earthwork activity since the 1980s.

STRUCTURE

Bedding and flow-foliation attitudes in the early and middle Miocene volcanic rocks in the Flowery Peak quadrangle mostly dip west to northwest at low to moderate angles. Flowery Peak suite strata in the Long Valley area in the northwest part of the quadrangle differ significantly from this pattern, dipping shallowly to the north or northeast and forming the west limb of a shallow syncline, with Flowery Peak suite rocks between Rocky and Tibbie Peaks forming the east limb. This syncline was probably produced by local eastward primary flow dips on the flanks of a dome. On the basis of topographic contact positions and our cross sections, the basal contact between Flowery Peak suite rocks and underlying Virginia City suite rocks has horizontal to shallowly north-, west-, or east-dipping attitudes, suggesting an angular unconformity of as much as 20 degrees.

Many of the faults in the Flowery Peak quadrangle are poorly exposed, and mapped on the basis of juxtaposition of rocks of different ages and in places by alteration. Faulting in the quadrangle is dominated by north-northwest- to north-northeast-striking, east-side-down normal faults that placed hanging-wall Miocene volcanic rocks against footwall rocks as old as Mesozoic granitic and metamorphic rocks. Several faults have arcuate, concave-eastward, traces. The north-northeast-striking Flowery fault, which dips 60–70° southeast in the open-pit mine near the North Bonanza Mine, is the best-exposed example. A 45°-southeast-dipping fault about 3 km to the south is also well constrained. A 60–65° east-dipping fault exposed in Sevenmile Canyon near the west border of the quadrangle is also well exposed in places. These faults resemble a series of important, arcuate, down-to-the-east, normal faults that dominate structure in the Virginia City quadrangle to the west (Hudson et al., 2009) and are probably part of a regional extensional system. The dominant west to northwest dips of Miocene volcanic rocks and associated sediments in the Flowery Peak quadrangle are consistent with a general pattern of westward tilting related to this extension. The slight angular unconformity present between Flowery Peak suite rocks and Virginia City rocks suggests greater extensional tilting of the older rocks.

The north-northwest- to north-northeast-striking faults in the Flowery Peak quadrangle are locally marked by quartz veins and alteration that have yielded adularia ages of 13.33±0.04 to 13.53±0.03 Ma (table 3), so they were the locus of activity at or prior to that time. As pointed out by Hudson et al. (2009), a period of normal faulting was apparently synchronous with, or earlier than, Comstock Lode mineralization along the Comstock fault zone, which occurred at 14.06±0.04 to 14.17±0.06 Ma. In the northeast part of the Flowery Peak quadrangle, Flowery Peak suite andesites as young as 13.83±0.31 Ma are downdropped against 17.2- to 18.3-Ma Silver City suite andesites, so displacement there must be younger than about 14 Ma.

Berger et al. (2003) proposed that the productive part of the north-northeast-striking Comstock fault zone in the Virginia City quadrangle developed in an extensional stepover between two parallel and overlapping west-northwest-striking right-lateral to right-oblique faults. They showed one such fault extending east-southeast from northwest of the Virginia City quadrangle, past the north end of the Comstock fault, and into the Flowery Peak quadrangle in the vicinity of the Flowery mining camp. Although east- to east-southeast-striking, 14.5-Ma Tbhi dikes occur along this trend, we found no compelling evidence for a major strike-slip fault here. East- and east-northeast-striking faults and dikes are present in several places in the Flowery Peak quadrangle, and these may be part of an older structural regime that controlled dike emplacement and some mineralization in the area. Hudson et al. (2009) mapped faults associated with Virginia City magmatic suite dikes and early mineralization and considered them to be the oldest Tertiary fault set in the quadrangle. Alunite and adularia yielding 15.3- to 15.5-Ma ages occur along these structures, which form a crudely radial pattern to the east, south, and west of a hydrothermal center about 6 km west of the Flowery Peak quadrangle. In the Flowery Peak quadrangle, east-

northeast-striking quartz-alunite and clay veins about 1 km north of Flowery Peak are probably part of this structural set. Some east-striking quartz-alunite veins along the Sutro Tunnel and east- to east-northeast-striking faults in the Kate Peak area may also be part of this set.

ECONOMIC GEOLOGY

Hydrothermal Alteration

Large areas of hydrothermally altered rocks occur in the Flowery Peak quadrangle. Hudson (2003) described twelve alteration assemblages and subassemblages and showed their distribution in the Comstock district to the west. Two generalized types of alteration that can be distinguished in the field are shown on the Flowery Peak quadrangle geologic map.

Virginia City and Silver City suite rocks in the north part of the Flowery Peak quadrangle were widely affected by propylitic alteration (chlorite + albite + calcite ± epidote). These rocks are typically greenish-gray and generally do not form resistant outcrops. This alteration is rarely seen in extrusive rocks of the 14.2- to 14.9-Ma Flowery Peak suite, although 14.5-Ma Tbhi dikes were propylitically altered in and near the Flowery mining camp. Propylitic alteration extends south of Sixmile Canyon along the Flowery fault to about the latitude of the Sutro Tunnel portal.

Virginia City and Silver City suite rocks were also affected by phyllosilicate alteration (quartz + sericite [muscovite or illite] ± kandite clay [kaolinite or dickite]). This alteration type locally contains pyrophyllite, diaspore, alunite, and svanbergite. It is white to brown, commonly contains abundant iron oxide, and includes ledges of quartz ± alunite in some areas. Phyllosilicate alteration is widespread in and east of the Flowery mining area, where it probably consists of two subtypes. Rock with common kandite clay and local minor pyrophyllite and diaspore occurs to the east of the mining area, and may represent a relatively old high-sulfidation type hydrothermal system because it is locally overlain by unaltered 14.6-Ma Tfad. Rock that is indistinguishable in hand specimen, but without pyrophyllite and diaspore, occurs in the Flowery mining area, where it contains 13.4 Ma quartz + adularia veins and likely represents the center of a relatively young low-sulfidation type hydrothermal system. The propylitic alteration that surrounds the Flowery mining area probably represents distal facies for both hydrothermal systems.

Veins

Three types of veins are present in the Flowery Peak quadrangle: quartz-adularia (± calcite) veins, clay veins, and quartz (± alunite ± pyrophyllite) ledges. Virtually all of the precious metal production in the quadrangle came from quartz + adularia veins in the Flowery mining area. Unknown, but probably minor, production came from similar veins in Sevenmile Canyon. Although locally prospected, the clay veins and quartz ledges were not productive.

Veins in the Flowery mining area consist of sheeted to braided, massive to drusy veins as much as 1 m thick that mainly strike north-northeast. Some breccia-filled veins as much 5 m thick have propylitized andesite clasts in quartz + calcite + adularia matrix. In the Lady Bryan open pit, on the west side of the area, the veins range from N05°W to N55°E (averaging about N35°E) in strike and have near-vertical to shallow westward dips. These veins occur mainly in propylitically altered andesite with pyrite, and are associated with north-northeast-striking, mostly northwest-dipping faults. Similarly oriented veins occur to the northwest of the Lady Bryan pit. Veins at the Berry Mine appear to be a continuation of the north-northeast Lady Bryan veins, but with vertical to steep southwest dips. Carpenter (1928) described the Berry Mine ore zone as "a well-defined lode of altered andesitic rock, mineralized by a network of gold-bearing quartz stringers, this lode having a N 50 ° E strike and 70 ° dip to the southeast, and an approximate width of more than 100 ft (30 m)."

Veins in the east part of the Flowery mining area around the North Bonanza Mine and in the adjacent Golden Eagle pit occur in a north-northeast zone with the Flowery fault as its southeast border. They form a sheeted to stockwork pattern and mostly strike east-northeast and dip moderately southeast but many have other orientations, including some with northwest strikes and northeast dips. The veins are massive to crudely banded and as much as 15 cm thick. They occur in propylitized to quartz-sericite altered rock with pyrite or iron oxide after pyrite.

Schilling (1990) considered the quartz veins in the Flowery mining area to be part of a single vein zone (his Flowery Lode), commonly 75–250ft (23–76 m) thick, dipping 65–70° eastward, and extending to a depth of 300 ft (91 m). He reported vein minerals to be quartz, calcite, K-feldspar, pyrite, galena, sphalerite, chalcopyrite, acanthite and a variety of other silver minerals, and electrum. He also cited an unpublished petrographic report that reported the presence of pyrrhotite, molybdenite, silver-bearing tetrahedrite-tennantite, along with secondary covellite, digenite, bornite, and anglesite.

Clay veins are widely scattered in altered rock in the north part of the quadrangle. Northwest-striking veins

within 1 km northwest of the Flowery mining area contain kandite or smectite, are associated with quartz + calcite veins, and are likely related to the low-sulfidation alteration there. Clay veins associated with high-sulfidation alteration occur in two areas. East-northeast-striking clay veins north of Flowery Peak are associated with quartz + alunite ledges there and locally contain the alunite group mineral minamiite. Clay veins east of the Flowery mining area associated with quartz + sericite ± pyrophyllite alteration.

Quartz ledges with or without pyrophyllite and alunite group minerals occur north of Flowery Peak, east of the Flowery mining area, and near the Flowery fault as far south as Sutro. They are generally massive replacement veins (hence the term ledge) and were likely emplaced during high-sulfidation-style hydrothermal activity.

GEOLOGIC HISTORY

Geologic history recorded by rocks in the Flowery Peak quadrangle began with the deposition of sedimentary and volcanic rocks in Mesozoic time. These rocks are highly metamorphosed, and their origin is obscure. They may be as old as late Triassic or early Jurassic by comparison with similar rocks elsewhere in the region (Hudson et al., 2009). They were intruded by granitic rocks during the Cretaceous, producing local thermal metamorphism. The Cretaceous granitic rocks in the Flowery Peak and Virginia City quadrangles comprise the eastern edge of the Sierra Nevada batholith, the deeper remnant of a Jurassic-Cretaceous magmatic arc related to subduction of the Farallon Plate beneath the North American Plate.

No rocks were deposited or emplaced in the Flowery Peak quadrangle between late Cretaceous and Oligocene times (about 90 Ma to 29 Ma). During this period the area was deeply eroded, producing an irregular erosional surface on the Mesozoic basement rocks. This surface was later locally covered by regionally extensive Oligocene ash-flow tuffs and younger volcanic rocks. The pattern of ash-flow tuff outcrops and the paleorelief on the underlying basement indicates deposition in paleovalleys that were likely connected westward to the auriferous gravel paleochannels in the Sierra Nevada (Garside et al., 2005). Although one such paleovalley extended across the south part of the Virginia City quadrangle (Hudson et al., 2009), only small amounts of ash-flow tuffs occur in the northeast and southwest parts of the Flowery Peak quadrangle.

A depositional gap of as much as 5 million years followed deposition of the regional ash-flow sequence in the Flowery Peak quadrangle. Intermediate volcanic rocks of the Silver City magmatic suite were deposited during a ~1-million-year episode (18.3–17.2 Ma). The surface on which Silver City suite andesites and debris flows were deposited appears to have been an erosional surface of some relief and may have included large paleochannels similar to those underlying the ash-flow tuffs. This surface was cut into Mesozoic rocks in the north part of the Flowery Peak quadrangle. The source of the Silver City suite rocks, which occur widely in both the Flowery Peak and Virginia City quadrangles, is not known. The thickest exposed sections are in the southwest part of the Flowery Peak quadrangle and the southeast part of the Virginia City quadrangle (Castor et al., 2005), so the source may have been a volcanic center to the south.

A ~2-million-year period of little or no local volcanic activity occurred between Silver City suite rocks and the overlying rocks of the Virginia City magmatic suite. Rocks deposited during this time include bedded sedimentary and volcaniclastic rocks of the Sutro Tuff, which has not been identified outside the Virginia City quadrangle. However, sedimentary rocks (Tvs) north of the North Bonanza Mine may be equivalent.

The 15.2-Ma to 15.8-Ma rocks of the Virginia City magmatic suite are mostly andesitic flows and likely represent a composite volcano that was centered at or near Virginia City. The 15.3-Ma Davidson diorite pluton and associated dikes, also centered near Virginia City, represent related, but relatively late intrusions into the volcano core. Widespread 15.3- to 15.5-Ma high-sulfidation (quartz-alunite) alteration in the Virginia City quadrangle appears to extend into the Flowery Peak quadrangle northeast of Flowery Peak. Other areas of high-sulfidation alteration in the Flowery Peak quadrangle may be coeval with this alteration.

Virginia City suite rocks wedge out northeast of the Flowery mining area, and Silver City suite rocks are overlain directly by Flowery Peak suite rocks in the northeast corner of the quadrangle. Virginia City suite rocks also appear to thin near the south border of the quadrangle. If Virginia City magmatic suite rocks represent a composite volcano centered on the Virginia City area, as suggested by Hudson et al. (2009), then rocks along the northeast-trending Quaternary-bedrock contact may have been near the distal eastern edge of this volcano prior to westward tilting and extension along north-striking normal faults.

The Flowery Peak magmatic suite, which comprises mostly unaltered flows and breccias deposited between 13.8 Ma and 14.9 Ma in the north part of the Flowery Peak and Virginia City quadrangles, lies upon quartz-alunite and propylitically altered rocks of the Virginia City suite. On the basis of our mapping, this volcanic episode may represent a widespread dome and flow field, rather than a composite volcano. Scattered small intrusive masses and abundant dikes of andesite emplaced between 14.5 and 14.9 Ma are abundant in the north part of the

Virginia City quadrangle and include west- to west-northwest-striking dikes that extend through the Flowery mining camp.

The period of mineralization that formed the highly productive ores of the Comstock Lode in the Virginia City quadrangle occurred at 14.1–14.2 Ma during the later stages of Flowery Peak suite volcanism. We found no evidence during our mapping for west-northwest-striking right-lateral deformation proposed by Berger et al. (2003) as an important factor during this mineralization. A second period of less productive 13.3- to 13.5-Ma quartz-adularia mineralization took place along the Occidental Lode and includes the precious-metal vein deposits in the Flowery Peak quadrangle. Both mineralization episodes were controlled by east-southeast- to northeast-dipping normal faults that are part of a regional set of similarly oriented down-to-the-east faults that were likely active following the Virginia City magmatic episode.

The Occidental dacite dome was emplaced near the west boundary of the Flowery Peak quadrangle at 12.9 Ma. It may be part of a magmatic episode that includes the 13.2-Ma Rocky Peak dome to the northeast, along with 12.8-Ma dacite to the north of the quadrangle (Schwartz and Faulds, 2004). The Occidental-Flowery low-sulfidation hydrothermal episode may have been related to early activity during this magmatic episode. Extensional faulting followed this magmatic episode, as is shown by tilting and displacement of the 12.7-Ma (Schwartz and Faulds, 2004) Chalk Hills tuffaceous and diatomaceous sedimentary rocks. Schilling (1990) showed a series of northwest-trending strike-slip faults that cut and offset the 13.3-Ma quartz lodes in the Flowery mining area; however, we found no evidence for such structures. Following an eruptive gap of about 5 million years, the 7.6-Ma Lousetown basalt flowed across the northeast corner of the Flowery Peak quadrangle, forming nearly flat-topped low mesas which indicate that tilting had largely ceased by that time.

Quaternary volcanism in the Flowery Peak quadrangle was limited to emplacement of the Naturalite rhyolite dome at about 1.5 Ma. Quaternary basaltic and rhyolitic rocks occur elsewhere in the region (Silberman et al., 1979; Hudson et al., 2009). Deposition of local, high-level gravels in the Flowery Range may have taken place at about this time or earlier.

The widespread late to middle Pleistocene fluvial and lacustrine sediments of Lake Lahontan extended as far west as the Dayton area in the southwest part of the Flowery Peak quadrangle. These were covered by Holocene Carson River alluvial deposits, Carson Plains piedmont alluvium, and related deposits.

DESCRIPTION OF MAP UNITS

Units may be correlated with the accompanying map using unit symbols (e.g., Qt, Qed). Except as noted, ages cited are $^{40}Ar/^{39}Ar$ with ± 2 sigma precision.

Quaternary Deposits

Anthropogenic Deposits

Qt Mine waste and mill tailings (latest Holocene)— Discarded broken rock from mining activity, mostly from recent open-pit mining in the Flowery mining subdistrict. Includes small areas of light-colored, fine mill tailings along the Sixmile Canyon drainage.

Qx Extensively disturbed areas (latest Holocene)— Disturbed ground including excavations and product piles at gravel pits and earthworks around water and sewage ponds. Does not include excavations for residential construction.

Eolian Deposits

Extensive deposits of wind-blown and reworked sand on the flat platform (‘Dayton Flat’) between the entrenched valley of the Carson River (the Carson Plains) and the piedmonts of the Virginia and Flowery Ranges and the Pine Nut Mountains.

Qed Eolian dunes (latest Holocene to latest Pleistocene)—Deposits of well-sorted medium- to fine-grained sand that form irregular dune fields and longitudinal dunes along the crest of bluffs that enclose the entrenched valley of the Carson River. Also includes local, dune-like accumulations of eolian sand within the Carson River valley. Only areas with well-discernible dune-like topography are included in this unit.

Qes Eolian sand sheet (latest Holocene to late Pleistocene)—Deposits of poorly to moderately well-sorted fine to coarse-grained sand. Unit has a generally flat to broadly undulate surface and forms an extensive but locally discontinuous veneer on the flat, platform-like surface that spans much of the quadrangle between bounding alluvial fans and the entrenched valley of the Carson River. Qes contains extensive lower and less well-defined dune forms than Qed. Unit is likely to include fine alluvial gravel and sand, particularly along its outer margins. Small areas of sand dunes, pans, and blowouts are common in this unit. Respectively, these areas contain deposits of well-sorted fine to medium sand; flat-lying typically mud-cracked deposits of silt and clay; or may reveal discontinuous patches of underlying units (in particular Qw and Qfl).

Piedmont Alluvial Deposits

Deposits of alluvial fans and washes that drain the Virginia Range, the Flowery Range, the Pine Nut Mountains, and minor local sources. Includes sediments ranging in size from large boulders to fine sand. Debris-flow deposits and bouldery flood deposits are common in steep interior mountain drainages and near the heads of alluvial fans.

Qau Undivided piedmont alluvium (latest Holocene to Pleistocene)—Deposits of silt, sand, and gravel that occur in various settings throughout the quadrangle including stream channels, fluvial terraces, and alluvial fans.

Qay Undivided young piedmont alluvium (latest Holocene to latest Pleistocene)—Deposits of silt, sand, and gravel on active alluvial fans, in stream channels, and on broad piedmont slopes. Includes some fluvial terraces that flank ephemeral wash channels and bouldery debris-flow deposits in narrow valleys in the Virginia and Flowery Range fronts.

Qay_3 Youngest active alluvium (latest Holocene)—Deposits of silt, sand, and gravel in active single-thread stream channels and principal distributary channels on active alluvial fans. Includes some bouldery debris flow deposits in the Virginia Range interior and upper piedmont. No soil development. Map pattern of Qay_3 in Sixmile Canyon and its alluvial fan reflects channel shifts, erosion, and deposition associated with flooding in the winter of 2006.

Qay_2 Young active alluvium, (recent to middle Holocene)—Deposits of sand and gravel associated with active alluvial fans, low, channel-flanking terraces, and broad alluvial slopes in areas of coalescing alluvial fan toes. Includes bouldery debris-flow deposits in interior mountain drainages and proximal to medial alluvial fan areas. Includes Qay_3 deposits where they are too small or widely dispersed to be divided. Qay_2 surfaces are characterized by well-defined bar-and-channel to bar-and-swale depositional topography, particularly in proximal and medial alluvial fan areas. Surface morphology of distal fans and alluvial slopes is flat to broadly undulate. Soil development is generally nil to weak. Some surface clasts on older Qay_2 surfaces are moderately weathered. In Sixmile Canyon, this unit includes terraces underlain by alluvial strata that contain reworked mine tailings.

Qay_1 Young inactive alluvium (middle? Holocene to latest Pleistocene)—Deposits of sand and gravel associated with inactive alluvial fans. Includes bouldery debris-flow deposits in interior mountain drainages and proximal to medial alluvial fan areas. Associated alluvial fan surfaces are characterized by weakly to moderately subdued bar-and-swale morphology to planar morphology with protruding gravel bar crests. Coarser-grained deposits have the best-preserved depositional morphology. Moderate surface weathering includes sparse cracked and split rocks; weak to moderate varnish patina on some clasts; and sparse lichen cover. Soil development is weak to moderate and includes Bw and stage I Bk horizon development. In some areas, Qay_1 surfaces are mantled with a thin veneer of medium- to coarse-grained eolian sand.

Qw Alluvial and eolian deposits of the Wyemaha(?) Alloformation (Morrison, 1964, 1991) (late Pleistocene)—Deposits of poorly to moderately well-sorted sand, mud, and minor gravel. Extensive surficial outcrops restricted to the interface between the lower piedmont/alluvial slope of the Virginia Range and the valley flat astride the entrenched valley of the Carson River. Elsewhere, unit occurs as thin stratum overlying unit Qfl in bluff exposures on the margin of the Carson River floodplain. We interpret this unit as a distal alluvial fan/alluvial slope deposit that contains intermixed eolian sand. It is likely correlative to younger parts of piedmont unit Qai. Qw overlies Qfl along an unconformity and is characterized by a moderately well-developed soil with a strong Bw horizon, a weak to moderate Bt horizon, and a stage I to II Bk horizon. Surface outcrops of Qw in the south-central part of the quadrangle are characterized by brown clayey soils with extensive networks of surface cracks likely owing to shrink-swell processes.

Qai Intermediate-age alluvium (late to middle? Pleistocene)—Deposits of silt, sand, and gravel on inactive alluvial fans at the foot of the Virginia Range and in isolated patches within the range. Surface morphology ranges from bar and swale (mainly in bouldery proximal and medial fan areas) to planar with protruding coarse gravel clasts. Surface weathering is moderate to strong and includes abundant split rocks, moderate to dark varnish patina, and moderately dense lichen cover on some clasts. Soil development is moderately strong and includes argillic (Bt) horizon and stage II–III calcic (Bk) horizon development.

Qao Old alluvium (middle to early Pleistocene)—Deposits of coarse sand and gravel on inactive alluvial fans and terraces near the Virginia Range front. Moderate to strong soils characterized by strong stage III calcic (Bk)

and strong argillic (Bt) horizon development. Surface morphology is planar but with abundant protruding boulders on the surface locally.

Carson River Alluvial Deposits

Qry Carson River alluvial deposits, undivided (Holocene)—Gravel, sand, and mud associated with active and abandoned meander-belt and floodplain surfaces of the Carson River. The unit is divided into three subunits that are discriminated on the basis of inset topographic relations and surface morphology. Particularly intricate relations within and among the units have been generalized for clarity.

Qry_4 Active channel and bars of the Carson River (latest Holocene)—Well-sorted deposits of gravel, sand, and silt associated with the active channel of the Carson River. Unit includes sand splays and gravel bars, and overflow channels; it also reflects bank retreat and includes areas of bank erosion associated with floods in 1997 and 2006 and thus does not correspond precisely with the channel trace shown on the base map.

Qry_3 Young mud, sand, and gravel deposits of the Carson River (latest to late Holocene)—Unit includes intermittently active and recently abandoned meander belts, floodplain surfaces, and some channel bars/islands. These areas are inundated with moderate to low frequency and are generally part of the active channel-floodplain environment. Abandoned channel segments and overflow channels are commonly associated with oxbow lakes and marshy areas. They are marked in places by sinuous tracts of riparian trees and shrubs. Floodplain surfaces that flank these meander belts are generally flat and characterized by overlapping and crosscutting paleochannels that are evident to various extents in aerial imagery. Several agricultural fields are situated on this surface.

Qry_2 Intermediate-age mud, sand, and gravel deposits of the Carson River (late to middle? Holocene)—Includes meander-belt and floodplain deposits and related surfaces. Morphology typically characterized a flat floodplain surface. Undisturbed areas typically characterized by a series of relatively high-standing floodplain surface remnants dispersed amidst overlapping, sinuous paleochannel complex. Agricultural activity in the Carson River valley is concentrated primarily on this surface.

Qry_1 Older Carson River alluvial deposits (middle to early? Holocene)—Includes the highest fluvial terrace remnants within the incised valley of the Carson River, typically composed of sand and mud. Distribution of this unit limited primarily to the outer margins of the Carson River valley in the form of inset terraces and small, isolated floodplain remnants. Unit may include more than one generation of fluvial terraces.

Hillslope and Mass-Wasting Deposits

Qc Holocene and Pleistocene colluvium—Slope-mantling deposits of coarse gravel. Unit is particularly common in areas downslope from surfaces underlain by unit QTa. May include weathered bedrock locally.

Qls Landslide deposits—Three landslide deposits have been mapped. The largest, southeast of Mount Grosh, is mainly composed of Tmga. A smaller landslide was mapped on the basis of topographic expression to the northeast on the south slope of Emma Peak. A small deposit consisting of Tertiary andesite debris occurs in the east half of the quadrangle north of the Mark Twain Estates.

Qtb Basalt talus—Talus composed exclusively of angular fragments of Lousetown basalt (Tlb). The talus covers slopes that are underlain by Tcs, Tfha, and Tfba.

Fluvial and Lacustrine Deposits of Lake Lahontan

Ql Undivided lacustrine deposits (latest to middle Pleistocene)—Deposits of sand, silt, and mud associated with pluvial Lake Lahontan. May also include interrelated fluvio-lacustrine deposits of the Carson River (Qfl). This unit may include deposits of the Sehoo and Eetza Alloformations, and possibly older lacustrine units associated with Lake Lahontan (Morrison, 1964; 1991). Only small outcrops of Ql are found in the quadrangle in isolated areas of the upper piedmont of the Virginia Range.

Qfl Fluvio-lacustrine deposits (late to middle Pleistocene)—Deposits of well-sorted fine fluvial gravel, sand, silt, and interbedded lacustrine mud. Elaborate cross-stratification and soft-sediment deformation features common in sand, silt, and gravel; muds generally flat-lying and massively bedded. Unit contains abundant granite-rich sand and fine silt indicating Carson River source. Qfl is extensively exposed along the bluffs bordering the Carson River floodplain and locally exposed in deeply incised washes that flow to the Carson River. In section, unit Qfl is characterized by interstratification of complexly structured fluvial silt, sand, and pea gravel with beds of massive lacustrine clay. Some sand and pea-gravel beds are strongly oxidized to dark yellowish orange

color and commonly indurated. Qfl strata indicate an overall upward-coarsening trend with some marked by relatively thin fining-upward intervals. We interpret this unit as a deltaic deposit from the Carson River into Lake Lahontan. Qfl is unconformably overlain by unit Qw and units Qed and Qes, and because of scale limitations of the map, the latter units may be included in Qfl except where they are extensively exposed. Relation with Qw indicates that Qfl is probably correlative to the Eetza Formation (Morrison, 1964; 1991). It may also include older units.

Other Quaternary Units

Qsp Spring deposits (latest Holocene to late Pleistocene)—Deposits of silt and fine sand with some pebbles occur adjacent to some of the active highland springs along the south slope of the Flowery Range. Deposit morphology typically includes terraces or mounds of fine-grained sediment, commonly dark-gray to brown organic-rich silt and sand. These sediments and related terraces and mounds may occur on steeply sloping terrain, as is the case in the Sutro Springs area.

Deposits of the Naturalite Dome Area

Qns Sedimentary deposits—Nearly flat-lying, friable, diatomaceous sedimentary strata that consist mostly of white to very-light-brownish-gray, pale-olive-green, or pale-ochre (Geological Society of America Rock Color Chart, 1991), poorly stratified, fine-grained sand to granule beds. Diatoms, mostly pennate in form, make up major to minor amounts of Qns. Mineral grains include quartz, feldspar, hornblende, biotite, and pyroxene. Glass shards absent to abundant. Larger detritus consists of scattered pebbles and local accumulations of pebbles. Most detritus is andesitic. However, to the southwest of the Naturalite dome, Qns is dominated by rhyolitic material, and may represent explosive activity at the dome. A tephra bed from this area contains abundant glass shards with refractive index (RI) of 1.496.

Qnw Welded rhyolite airfall—A small exposure of resistant pyroclastic rhyolite on the northwest side of the Naturalite dome. Mainly consists of lapilli and bombs of glassy hydrated (RI = 1.496) rhyolite (Qnr) that are welded together. In addition, contains as much as 20% of andesitic fragments and minor nonhydrated glass with refractive index (RI) = 1.484. Small, sparse granitic clasts noted in thin section, along with small fragmental crystals of feldspar, biotite, hornblende, and quartz. The westernmost (and basal) portion of the Qnw outcrop is crudely stratified, and these strata form a shallow west-plunging synform.

Qnr Glassy rhyolite—White to very light-gray, nearly aphyric glassy rhyolite forming the core of the Naturalite dome. Includes a smaller exposure in a pit to the west, where Qnr intrudes andesitic rock along nearly vertical intrusive contacts. Commonly flow-banded, weakly to strongly vesicular, and moderately to strongly shattered. Nearly aphyric macroscopically, but sparse oligoclase phenocrysts to 1 mm long generally present with smaller quartz and sanidine phenocrysts, and traces of black biotite flakes. Feldspar microlites and small spherulites commonly minor, but some flow bands contain as much as 50% microlites + spherulites. Flow-stretched vesicles make up as much as 40% of the rhyolite. RI of the glass is 1.496. K/Ar ages are 1.55±0.22 and 1.55±0.06 Ma (recalculated from Silberman et al., 1979). Mined as aggregate for use in lightweight concrete.

Qnb Rhyolite breccia—Breccia comprised completely of loose angular fragments of rhyolite in a discontinuous carapace or envelope around Qnr in the Naturalite dome. Likely produced by crushing during dome intrusion or by explosive breakup on the surface of the dome. Similar, but strongly welded, breccia in exposures too minor to show on the map is present in the southeast part of the western Qnr exposure, where nearly vertical contacts suggest intrusive origin. Contact with Qnr is gradational in places.

Qnt Tuff ring deposits—Poorly indurated, well-stratified sedimentary to massive pyroclastic deposits around the Qnr and Qnb core of the Naturalite dome. Mostly covered by Qnr talus and soil, but excellent exposures are in mine workings and access roads. Well-sorted volcanic breccias common. Poorly sorted pyroclastic flows occur in places. Includes some well-sorted ash to lapilli beds likely formed as bedded falls or as surge, but some deposition may have taken place in water. Most Qnt detritus is accessory Qnr. Accidental andesitic and granitic clasts common in some beds. Juvenile bombs of friable perlite containing cores and kernels of nonhydrated glass present locally. Nonhydrated glass has RI = 1.484. Strata generally dip shallowly inward toward the rhyolitic core and probably represent intracrater deposition. In places, core rhyolite (Qnr and Qnb) seems to overlie Qnt. The relatively resistant rhyolite likely filled the tuff ring crater, protecting the loose pyroclastic material from removal by erosion.

Quaternary and Tertiary Deposits

QTa Pleistocene to Pliocene alluvium—Deposits of coarse alluvium, typically occurring as high-standing fan and pediment remnants in the foothills of the Virginia Range. Commonly present as coarse gravelly veneers on eroded bedrock surfaces. Strong soil development (strong Bt and/or stage III Bk horizon) present in many

exposures. Many QTa surfaces are stripped to a lag of coarse gravel, and may include weathered bedrock locally where underlying unit composition is similar to the alluvial deposit.

QTs Spring deposits—White to light-gray, locally limonite-stained, sandy to silty material in small range-front exposures northwest of Sutro. The age of this material, which appears to be hydrothermally altered in places, is unknown. It was probably deposited during hot spring activity along a range-front fault. It may be of late Tertiary or early Quaternary age.

Miocene Rocks

Tlb Lousetown basalt—Gray, fine-grained, locally vesicular basalt forming gently northwest-dipping mesas in the northwest part of the quadrangle. Distinct flow foliation in places is more steeply dipping than the overall dip of the unit. Contains crystals of labradorite-bytownite, olivine, and clinopyroxene (table 1) generally <1 mm long. Plagioclase and pyroxene sizes range down to groundmass grains that average 30 μ. Groundmass also contains opaque microlites and brown glass. Tlb north of the quadrangle gave $^{40}Ar/^{39}Ar$ ages of 7.60±0.08 Ma and 7.63±0.45 Ma (recalculated from Schwartz and Faulds, 2004).

Tcs Sedimentary rocks of the Chalk Hills—Poorly exposed white, light-gray, very-pale-orange, pale-greenish-yellow, and light-brown pebble conglomerate, sandstone, fine-grained tuff, lapilli tuff, and diatomaceous siltstone near the north border of the quadrangle. Sandstone is fine- to coarse-grained and dominated by andesitic and dacitic rock fragments and mineral grains derived from such rock. Tuffs mostly crystal-lithic tuffs of dacitic composition. In many places, white diatomaceous chips provide the only indication of the extent of Tcs, which is better exposed in the Chalk Hills quadrangle to the north (Schwartz and Faulds, 2004). Includes stream-polished pebbles of volcanic rock locally mixed with basalt talus (Qtb) below basal outcrops of Tlb. Tuffaceous rock in Tcs 1 km north of the Flowery Peak quadrangle gave 12.63±0.14 Ma (hornblende $^{40}Ar/^{39}Ar$ age, Schwartz and Faulds, 2004).

Tod Dacite of Occidental Quarry (12.91±0.18 Ma, table 3)—Biotite hornblende dacite in a nearly circular exposure >0.5 km in diameter along the west edge of the quadrangle. Typified by large phenocrysts, including commonly conjoined andesine-oligoclase to 1.5 cm, hornblende to 1 cm, and minor biotite books to 6 mm across (table 1). Also contains minor quartz as rounded and embayed grains to 2 mm, sparse opaque grains, and traces of tiny, clear apatite prisms. Matrix pilotaxitic, dominated by plagioclase laths ~ 50 μ long in a field of granular potash feldspar, hornblende, and opaque microlites. Tod is relatively silica-rich compared with other intermediate rocks in the Virginia City area (fig. 4). Mined for building stone at the Occidental Quarry.

Trpa Biotite-hornblende-pyroxene andesite of Rocky Peak (13.20±0.37 Ma, table 3)—Gray, coarsely porphyritic pyroxene-biotite-hornblende andesite with trace to minor accessory quartz in two domes in the north part of the map area. The largest, on Rocky Peak, has a nearly horizontal lower contact on the south, but steeply dipping contacts to the northeast. A smaller body of similar rock occurs to the northeast. Trpa contains moderately abundant stubby andesine phenocrysts to 1.2 cm, hornblende to 8 mm, sparse biotite to 3 mm, and minor clinopyroxene to 1.5 mm (table 1). Orthopyroxene absent. Minor olivine in some rock. Hornblende orange-red to olive-green in thin section, and locally replaced by iron oxide. Biotite deep-reddish-brown to brown. Quartz phenocrysts range from small anhedra to rounded, wormy, equant grains to 2 mm. Matrix contains weakly flow-aligned to felty plagioclase microlites, along with hornblende, clinopyroxene, and opaque microlites.

Tmga Biotite-hornblende-pyroxene andesite of Mount Grosch—Coarsely porphyric light-gray to light-brownish-gray pyroxene-biotite-hornblende andesite with trace to minor accessory quartz on Mount Grosch. Contains abundant andesine phenocrysts as commonly conjoined grains to 1.2 cm. Hornblende occurs as wholly altered (iron oxide+pyroxene+plagioclase) phenocrysts as much as 5 mm long, biotite as slightly rounded reddish-brown books to 8 mm across, and clinopyroxene as unaltered grains to 1.5 mm (table 1). Also contains trace to minor quartz as rounded, vermiform, equant phenocrysts to 3 mm. Trace olivine in one specimen. Commonly contains fine-grained biotite-hornblende diorite xenoliths. Texturally similar to Tod (which crops out 1 km to the north) and may be equivalent, but Tod does not contain pyroxene. Phenocryst assemblage similar to Tfad. Tmga locally includes minor flow-banded, vesicular rhyolite (e.g., sample C04-63, table 4).

Intrusive Rocks

Tbhi Biotite-hornblende intrusive rocks (14.46±0.30 Ma, table 3)—Gray to light-gray biotite-hornblende andesite or dacite occurring as dikes and larger intrusions. Typically contains abundant andesine phenocrysts to 1 cm, sparse to moderately abundant hornblende to 1 cm, and minor biotite to 3 mm (table 1). Quartz generally present as rounded and weakly embayed phenocrysts to 3 mm. Pyroxene absent. In thin section, hornblende is brown to olive-green and biotite is typically

brown. Mafic minerals generally not replaced by iron oxide. Matrix ranges from finely microgranular (average grain 20 μ) to finely felty (average grain 75 μ) or weakly pilotaxitic (average microlite 100 μ). Phenocrysts distinctly larger than matrix grains. Equivalent to Tbhap in the Virginia City quadrangle (Hudson et al., 2009). Most Tbhi intrusions cut rocks of the 15.2- to 15.8-Ma Virginia City magmatic suite, and are likely part of the 14.2- to 14.9-Ma Flowery Peak magmatic suite, but some may be related to the younger (12.9 Ma) dacite of Occidental Quarry and some Tbhap in the Virginia City quadrangle may be Virginia City suite rocks (15.2–15.8 Ma, Hudson et al., 2009). Tbhi dikes in the Flowery mining area are altered, and thus older than quartz-adularia veins dated at 13.4 Ma (table 3).

Thai Hornblende andesite intrusive rocks—Dikes and larger intrusions of hornblende andesite with little or no biotite, particularly abundant in and near the Flowery mining area. Typically gray or dark-gray with sparse to abundant stubby calcic andesine phenocrysts to 1 cm long (table 1). In some dikes, border zones contain fewer plagioclase phenocrysts than core rock. Hornblende phenocrysts locally abundant and large (to 1.5 cm long). Biotite typically absent, but locally present as rare corroded grains. Quartz generally absent. Pyroxene, where present, occurs as small grains of clinopyroxene and hypersthene. Equivalent to Thap in the Virginia City quadrangle, which gave 14.53±0.42 Ma (hornblende $^{40}Ar/^{39}Ar$ age, Hudson et al., 2009), so at least some Thai is part of the Flowery Peak magmatic suite.

Rocks of the Flowery Peak Magmatic Suite

Rocks of the Flowery Peak magmatic suite range in age from about 13.8 to 14.9 Ma, and typically contain relatively abundant hornblende. In addition, sparse to moderately abundant biotite is common, and plagioclase phenocrysts are mostly stubby grains more than 3 mm long. Rocks of this suite are andesites on the basis of alkali/silica (fig. 4).

Tfp Andesites of Flowery Peak, undivided—Mostly hornblende-orthopyroxene andesite and hornblende-biotite andesite flows with related debris-flow deposits. Phenocryst content 20–50%, dominated by commonly stubby, conjoined andesine grains to 1 cm (table 1). Hornblende, the most abundant mafic, is generally brown and <4 mm long, but locally to 1.2 cm. Hornblende commonly rimmed or completely replaced by iron oxide. Brown biotite phenocrysts, where present, generally have iron oxide rims, are corroded, and <3 mm across. Hypersthene, as small prisms rarely >1 mm, is commonly the dominant or only pyroxene. Minor clinopyroxene and olivine in some rocks. Quartz rarely present. Minor opaque grains to 1 mm. Matrix consists of variable proportions of plagioclase, mafic minerals, and opaque microlites in devitrified glass or glass. Phenocrysts and matrix microlites generally distinctly different in size. Ages of Tfp in the Virginia City quadrangle are 14.75±0.22 and 14.39±0.20 Ma ($^{40}Ar/^{39}Ar$ on hornblende, Hudson et al., 2009).

Tfba Biotite-hornblende andesite (13.83±0.31, table 3)—Light-brownish-gray-weathering, light-gray to gray rock containing ~ 30% phenocrysts in the north part of the quadrangle. Phenocrysts are moderately abundant stubby andesine to 5 mm, elongate hornblende to 2 mm, distinctive large biotite books as much as 2x5 mm, minor bottle-green augite, and local traces of rounded pale-pink quartz grains and rounded olivine (table 1). Matrix light gray. Tfba in the Virginia City quadrangle gave 14.20±0.43 Ma ($^{40}Ar/^{39}Ar$ age on plagioclase, Hudson et al., 2009).

Tfha Hornblende andesite (14.60±0.27; 14.41±0.32; table 3)—Medium- to light-gray andesite occurring with Tfba in the north part of the quadrangle. Phenocrysts mostly separate and stubby conjoined calcic andesine crystals to 4x5 mm, and elongate brown hornblende prisms to 1 cm long (table 1). Biotite rare and quartz absent in most specimens. Hornblende phenocrysts variably rimmed by iron oxide. Minor pyroxene and traces of biotite in some samples. Hypersthene is the only pyroxene identified in thin section. Matrix pilotaxitic with plagioclase microlites averaging 50–100 μ long, opaque grains, and devitrified glass.

Tfsa Biotite-hornblende andesite of Sugarloaf (14.54±0.11 Ma, table 3)—Light-brownish-gray to light-gray biotite-hornblende andesite with local traces of quartz forming an imposing landmark in Sixmile Canyon that is thought to be an intrusive dome on the basis of mapped geometry. Contains abundant blocky andesine to sodic bytownite phenocrysts as much as 7 mm long, mottled reddish-brown and olive-green hornblende to 1.5 cm long, and biotite books to 3 mm (table 1). Hornblende is mottled reddish-brown and olive-green in thin section, with thin iron oxide rims. Biotite locally altered to chlorite. Quartz as rare irregular grains to 2 mm. Pyroxene absent or present in trace amounts.

Tfad Biotite-hornblende-pyroxene andesite domes (14.62±0.39 Ma, table 3)—Coarsely porphyritic light-gray to gray pyroxene-biotite-hornblende andesite with minor quartz in three small domes or a single discontinuously exposed dome east of the Flowery mining area. Contains abundant calcic andesine phenocrysts as conjoined grains to 1.2 cm, hornblende as phenocrysts to 8 mm long, biotite as books as much as 5 mm across, and

clinopyroxene ± orthopyroxene as unaltered grains to 1 mm (table 1). Also contains minor quartz as vermiform phenocrysts to 5 mm. Some specimens contain minor olivine. Hornblende and biotite locally replaced by iron oxide. Rarely scoriaceous or glassy. Basal contact brecciated in places.

Tfd Debris flows—Sequences of debris-flow breccias in and at the base of Tfp. The lowest sequence lies, locally with angular discordance, on Tvu. Relatively thick (~150 m) in places, particularly on the south side of Rocky Peak, on the northeast side of Flowery Peak, and on the east side of Emma Peak. Contains subrounded light-gray biotite-hornblende andesite and gray hornblende andesite clasts to 2 m. Mostly matrix supported. Contains relatively fine-grained sandy to pebbly beds in places. A hornblende andesite clast from similar rock in the Virginia City quadrangle gave 14.51±0.12 Ma (hornblende $^{40}Ar/^{39}Ar$ age, Hudson et al., 2009).

Tfs Sedimentary rocks—A thin sequence of bedded, fine to coarse volcaniclastic sedimentary rocks and tuffs between andesitic rocks of the Silver City and Flowery Peak magmatic suites in two small exposures in the northeast part of the quadrangle. Includes white to very-light-gray, thin-bedded to laminated, fine- to medium-grained sandstone, pale-olive massive to bedded fine-grained shard to coarsely lithic tuff, and heterolithic volcaniclastic conglomerates. Conglomerate contains pebble-to boulder-size clasts, mostly finely porphyritic rock thought to be from the underlying Silver City andesites, but some clasts are coarsely porphyritic hornblende andesite with biotite, supporting inclusion in the Flowery Peak suite. Tfs is likely equivalent to the lowest sequence of Tfd.

Rocks of the Virginia City Magmatic Suite

Rocks of the Virginia City magmatic suite range in age from 15.2 to 15.8 Ma on the basis of $^{40}Ar/^{39}Ar$ ages on specimens from the Virginia City quadrangle (Hudson et al., 2009).

Tvu Virginia City andesites, undivided—Mineralogically and texturally variable unit composed mostly of flows but with some breccias. Locally contains minor, unmapped sedimentary rock exposures. Flows include biotite-hornblende andesite, pyroxene-hornblende andesite, and two-pyroxene andesite. Phenocrysts 25–40% of the rock (table 1), dominated by plagioclase, with subordinate pyroxene and hornblende, and rare biotite. Calcic andesine to labradorite phenocrysts generally <3 mm long, but locally to 7 mm. Trace to abundant hornblende, commonly partly to wholly replaced by iron oxide, generally less <4 mm long, but as prisms to 8 mm in some rocks. Pyroxene phenocrysts <2 mm, with clinopyroxene generally more abundant than hypersthene. Biotite locally present as small grains to 2 mm. Tiny opaque grains, commonly in clusters, make up as much as 3.5% of the rock. Trace apatite as stubby, gray to light-brown prisms to 400 mm long. Matrix in most rocks has flow-aligned plagioclase microlites averaging 50–100 long (distinctly smaller than phenocryst plagioclase), and mafic and opaque microlites. Tvu is widely altered, with plagioclase partially replaced by albite and calcite, and mafic minerals replaced by chlorite and opaque or sericite and sphene. More intense alteration, typified by strongly bleached and iron oxide-stained rock, occurs in and east of the Flowery mining area. Partly equivalent to Tva (Hudson et al., 2009), which yielded five $^{40}Ar/^{39}Ar$ ages ranging from 15.23±0.20 Ma to 15.80±0.40 Ma in the Virginia City quadrangle.

Tvka Andesites of the Kate Peak Formation—Pyroxene andesite and hornblende-pyroxene andesites in the Kate Peak area in the southwestern corner of the quadrangle. Typified by distinctly flow-aligned calcic andesine phenocrysts to 1 cm and several percent black and pale-green pyroxene phenocrysts to 2 mm (table 1). Plagioclase typically seriate from phenocrysts to matrix. Some flows contain no hornblende, but others contain sparse hornblende phenocrysts as much as 1 cm long and the lowest flows contain as much hornblende as pyroxene. Traces of brown apatite prisms to 300 microns noted in thin section. Rare olivine and biotite to 1 mm found in one specimen. Flow rock on the west side of Kate Peak in the Virginia City quadrangle gave 15.43±0.26 Ma (hornblende $^{40}Ar/^{39}Ar$ age, Hudson et al., 2009).

Tvkp Olivine-pyroxene andesite—Flows of pyroxene andesite with minor olivine near the top of the Kate Peak Formation andesites. Light-gray to white bedded tuffs containing clinopyroxene, hypersthene, and rare hornblende occur just above this unit and are mapped as part of it.

Tvkbd Biotite-bearing debris flows—Debris flows containing biotite cap a ridge southwest of Kate Peak. Debris is composed mostly of subrounded andesite clasts as much as 1.5 m across in gray matrix. Andesite contains abundant plagioclase phenocrysts to 4 mm, sparse hornblende to 4 mm, and subordinate brown biotite phenocrysts to 2 mm in a black glassy to gray devitrified groundmass. Some reddish-brown oxidized hornblende andesite clasts. Unit locally contains lapilli tuff and granule sand to silt beds.

Tvkb Biotite-hornblende andesite flows—A flow or a sequence of flows with minor biotite phenocrysts

to 2 mm, a few percent hornblende to 3 mm, and stubby plagioclase phenocrysts to 3 mm.

Tvkd Andesite debris flows—Debris-flow units, most <10 m thick, interbedded with Tvka. Generally too thin or poorly exposed to show on the geologic map. Clasts of several types of andesite are typically subrounded, generally <30 cm, and rarely as much as 50 cm. Matrix consists of gray silt, sand, and mud. Equivalent to Tvkl in the Virginia City quadrangle (Hudson et al., 2009).

Tvba Biotite-hornblende andesite flows—Biotite-bearing flows and associated breccias that dominate the lower part of the Virginia City suite flows on the east flank of Kate Peak. Gray to light-reddish-brown or pale-red with 20–35% phenocrysts, mostly andesine phenocrysts to 1 cm (table 1). Contains olive-green or oxidized reddish-brown hornblende prisms to 8 mm long, rare to minor biotite books to 2 mm, and sparse small clinopyroxene phenocrysts. Small opaque grains to 0.5 mm and traces of brown apatite to 300 µ present. Some flows have trace olivine. Orthopyroxene absent or rare.

Tvbd Biotite-hornblende andesite debris flows—Sequences to 90 m thick of clast- to matrix-supported debris flows interbedded with Tvba. Contains angular to rounded pebbles to boulders as much as 3 m in diameter. Dominated by pale-red and light-gray biotite-hornblende andesite. Clasts of fine-grained microdiorite locally common. Small amounts of clasts of finely porphyritic pyroxene andesite and fine-grained sedimentary rock occur locally. Matrix mostly light-gray to pink fragmental material. Rare sandy to pebbly layers.

Tvpa Pyroxene andesite flows—Flows with little or no hornblende in the Virginia City suite section, commonly at or near its base but also higher in the section above Tvba flows. Abundant andesine to labradorite phenocrysts, generally small but as much as 5 mm long. Unaltered rock nearly black with clinopyroxene > hypersthene. Commonly altered, with plagioclase partly replaced by calcite and mafic minerals wholly replaced by chlorite ± calcite ± albite.

Tvd Debris flows—Heterolithic, clast-supported breccia beneath Tvbd in the southwest part of the quadrangle. Clasts are angular to subrounded, pebbles to boulders of Tspa and hornblende andesite. Biotite-hornblende andesite clasts occur locally near the top of the unit.

Tvha Hornblende andesite flow rock (15.25±0.32 Ma, table 3)—Gray andesite with relatively sparse plagioclase phenocrysts to 8 mm and a few percent hornblende phenocrysts to 4 mm. Dense to vesicular and locally cut by well-developed columnar joints. Occurs along the base of the Virginia Range east of Kate Peak.

Ts Sedimentary rocks and tuff—Fine- to coarse-grained sedimentary rock and tuff at the base of Virginia City suite andesites north of the North Bonanza Mine. Contains well-lithified siltstone, fine- to coarse-grained sandstone, and beds that contain pebble to boulder-sized clasts of andesite, metasedimentary rock, and granitic rock. Includes basal lithic ash-flow tuff that is overlain by fine-grained sediment with sparse to abundant rounded boulders of granitic rock to 1 m. Siltstone, sandstone, pebble breccia, and possible air-fall tuff overlie the conglomerate. In part overlies Kg, but also overlies andesite mapped as Tsa to the north. May be equivalent to the Sutro Tuff in the Virginia City quadrangle (Hudson et al., 2009).

Rocks of the Silver City Magmatic Suite

Rocks of the Silver City magmatic suite range in age from 17.4 Ma to 18.3 Ma on the basis of $^{40}Ar/^{39}Ar$ ages reported below and for specimens from the Virginia City quadrangle (Hudson et al., 2009). They are dominated by heterolithic debris flow breccias, but include some flow rock. Flow rocks and debris-flow clasts mostly range from nearly aphyric andesite, through pyroxene andesite to hornblende andesite. A few debris flows have biotite-bearing clasts.

Tsfa Fine-grained andesite—Distinctive andesite with minor fine hornblende phenocrysts and rare plagioclase phenocrysts (table 1) in the upper part of the Silver City suite in the northeast part of the quadrangle. Mapped by Thompson (1956) as an intrusive equivalent to the Lousetown basalt (Tlb), but there is no evidence of intrusive origin (unit probably extrusive on the basis of its consistent stratigraphic location) and the mineral assemblage is different from that of Tlb (table 1). Hornblende occurs as moderately abundant phenocrysts to 4 mm, mostly replaced by clinopyroxene+iron oxide+plagioclase. Sparse plagioclase phenocrysts are mostly unaltered. An content not determined. Quartz, sparsely present as grains to 4 mm, surrounded by clinopyroxene reaction rims and probably xenocrystic. Matrix mostly fine, flow-aligned labradorite laths with lesser amounts of clinopyroxene and opaque grains.

Tspa Pyroxene andesite flows (17.2±1.2 Ma, table 3)—Resistant, dark-gray pyroxene basaltic andesite flow rock that weathers reddish-brown. Mostly dense flows with locally vesicular tops. Minor flow breccia. Flow rock is finely porphyritic with 20–25% labradorite phenocrysts to 4 mm, fine pyroxene phenocrysts, and little or no

hornblende (table 1). Some flows contain as much as 3 percent olivine phenocrysts to 1 mm that are mostly serpentinized.

Tsa Silver City andesite flows, undivided (18.06±0.48 Ma; 18.31±0.36 Ma, table 3)—Finely porphyritic to aphyric two-pyroxene basaltic andesite with local hornblende. Mostly similar to Tspa. Occurs above Tsd in the southwest part of the quadrangle. Occurs above and below Tsd in the northeast part of the quadrangle. Contains sparse to abundant hornblende in the northeast part of the quadrangle. Clinopyroxene is the only or dominant pyroxene in many of the hornblende-bearing flows. Biotite absent or extremely rare. Near the south edge of the quadrangle, Tsa includes a flow breccia with distinctive clasts of andesite that contains abundant flow-aligned plagioclase plates as much as 1 cm across.

Tss Andesitic sandstone—Massive to thinly bedded, fine- to coarse-grained sandstone with some pebble beds exposed northeast of the North Bonanza Mine. Color brownish-gray but locally bleached to nearly white. Detritus appears to consist solely of andesite.

Tsd Debris flows—Heterolithic debris flows that form a thick sequence beneath Tspa in the southeast part of the quadrangle and above, below, or within Tsa in the northeast part of the quadrangle. Generally heterolithic, but mostly contains angular to subrounded pebbles to boulders of finely porphyritic gray to dark-gray two-pyroxene andesite. Light-gray hornblende-bearing andesite is also common, and reddish-brown to dark-gray scoria and white pumice clasts occur locally. Debris-flow matrix consists of sand to granule fragmental material and is generally gray, but locally light-brownish-gray, light-brown, light-gray, or nearly white. In the southwest part of the quadrangle, Tsd includes some medium-grained to granule sandstone and pebble gravel beds in sequences as much as 2 m thick, particularly in the upper part of the unit. Some gravel beds contain opalized wood. Unmapped, discontinuous, thin flows, generally of finely porphyritic to aphyric two-pyroxene andesite occur in Tsd in the southwest part of the quadrangle. Interbedded flows in the northeast part of the quadrangle are mostly hornblende andesite. Pyroxene andesite clasts and flows contain bytownite phenocrysts to 3 mm, minor hypersthene and clinopyroxene to 1.5 mm, minor opaque grains, and traces of hornblende. Hornblende andesite has small calcic andesine grains and hornblende phenocrysts to 1 cm long.

Tsdb Biotite-bearing debris flows—Local light-colored breccias with biotite-hornblende andesite clasts in Tsd near the top of the unit near the south edge of the quadrangle.

Tsdl Lower debris flows—Light-colored, heterolithic, clast-supported debris flows beneath Tsd along the east flank of the Virginia Range in the south part of the quadrangle. Most clasts subrounded light-gray to gray hornblende andesite pebbles to boulders as much as 1 m across. Sparse well-rounded clasts locally. Clasts of plagioclase-rich andesite with little or no hornblende also present. Light-gray to light-brownish-gray matrix.

Miocene and Oligocene Ash-Flow Tuffs

Tts Santiago Canyon Tuff—Light-gray to pinkish-gray, moderately to strongly welded rhyolitic ash-flow tuff near the southwest corner of the quadrangle. Contains abundant phenocrysts of plagioclase, quartz, and sanidine to 4 mm, minor biotite and hornblende phenocrysts to 1.5 mm, and rare sphene. Also contains light-gray, moderately to strongly compressed pumice to 2 cm and sparse pinkish-gray felsite lithic fragments to 1.5 cm. Age 23.12±0.05 Ma, ($^{40}Ar/^{39}Ar$ on sanidine, Henry and Faulds, 2010).

TtE Tuff E (28.98 ± 0.07 Ma)—White to pinkish-gray, moderately to strongly welded rhyolitic ash-flow tuff in the northeast part of the quadrangle. Commonly resistant, forming spheroidal outcrops with nubbly surfaces. Contains phenocrysts of plagioclase, sanidine, and quartz with trace to minor biotite and opaque grains, rare hornblende, and trace zircon (table 1). Quartz phenocrysts are pale gray and equant to wormy. Matrix mostly glass shards. Upper part, as much as 70 m thick, is mostly pinkish-gray, relatively crystal-poor, (generally < 10% phenocrysts, table 1), and devitrified, with white collapsed pumice fragments to 2 x 10 cm. The upper part has traces to 3% of lithic fragments that include intermediate volcanic rock, dark metavolcanic rock and fine-grained Mesozoic sedimentary rock. Locally has a thin lower layer of friable unwelded to poorly welded white tuff that is crystal-rich (~ 10% phenocrysts) with relatively abundant biotite and lithic fragments, mostly of intermediate volcanic rock. At one locality, this lower tuff contains granitic boulders. Basal gray vitrophyre locally. Thin, poorly exposed similar tuff occurs between Kg and Tsd near the east border of the quadrangle. Correlated with Tuff E in the Haskell Peak area, California (Brooks et al., 2008) on the basis of lithology and age.

Pre-Tertiary Rocks

Klg Leucogranitic rock—Light-colored, quartz-rich granite to granodiorite with minor biotite and sparse opaque grains (table 2) in thin northeast-trending dikes and large elongate masses associated with Kg west of the Naturalite Quarry. Ranges from aplitic to pegmatitic, but

most large masses are medium-grained. Generally partly altered to chlorite, white mica, calcite, and albite and commonly stained with iron oxide. Minor hornblende may have been present prior to alteration. Probably Cretaceous in age.

Kg Quartz diorite to granodiorite (93.2 ±1.1 Ma, table 3)—Granitic rock in the Flowery mining area and in several exposures in the northeast part of the quadrangle. Mostly light-colored friable rock altered to muscovite + quartz ± pyrite or limonite in and near the mines, but relatively unaltered gray granodiorite with hornblende > biotite near the North Bonanza Mine. Similar rock to the northeast ranges from quartz diorite with hornblende ≥ biotite, to granodiorite with biotite > hornblende (table 2). Generally equigranular with average grain size <1 mm to 1.5 mm, but some potash feldspar grains to 3 mm. Contains minor opaques and traces of sphene and zircon. Weathered to grus in some areas.

Jm Metamorphic rocks—Gneiss, schist, and hornfels in the northeast part of the quadrangle, mostly with mafic to intermediate volcanic protoliths. Fine-grained amphibolite gneiss or massive pyroxene+amphibole+zoisite+sphene hornfels near contacts with granitic rocks. Massive hornfels (amphibole+albite+diopside+sphene) occurs some distance from exposed granitic contacts in the large exposure in the northeast part of the quadrangle. Jm west of the Naturalite Quarry includes greenschist-facies metavolcanic rocks (chlorite+calcite+albite+quartz) cut by intrusive rocks (mostly leucogranitic) and locally includes breccia with porphyry and granitoid clasts in a fragmental matrix. A mappable Jm xenolith in Kg in this area has amphibolite-grade borders and a greenschist (chlorite+calcite+albite+quartz+pyrite) core.

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