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Complex History of Precious Metal Deposits, Southern Toquima Range, Nevada

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Contents

ABSTRACT

Precious metal deposits in the southern Toquima Range resulted from several distinct mineralizing events. At Round Mountain, base-metal-, precious-metal-, and tungsten-bearing veins formed in Cretaceous granite and in nearby Paleozoic wallrocks at 80 Ma. These veins were modified by introduction of base metals in the vicinity of a 35 Ma granodiorite stock and an associated rhyolite dike swarm. The main gold-silver mineralization at Round Mountain occurred at 25 Ma within a 27 Ma rhyolitic ash-flow tuff that was erupted nearby from the Mount Jefferson caldera; this tuff overlies Cretaceous granite and Paleozoic rocks. Recrystallization of minerals to form new phases in the 80 Ma veins adjacent to the zone of 25 Ma gold-silver mineralization suggests reworking of those veins and possible remobilization of precious metals from them into the younger gold-silver deposits. The youngest mineralizing event, possibly at 10 Ma, formed low-temperature, silver-, arsenic-, and manganese-bearing veins within the Round Mountain gold-silver deposit.

At Manhattan, base-metal- and precious-metal-bearing vein and tactite deposits formed in Paleozoic carbonate rocks near Cretaceous granite at about 75 Ma. A younger somewhat similar episode was probably related to an inferred early Tertiary(?) intrusive event that introduced arsenic, antimony, and mercury minerals into the eastern part of the Manhattan belt. The main gold-silver mineralizing event at Manhattan took place at 16 Ma within Paleozoic phyllitic argillite, quartzite, and carbonate rocks along the south margin of the 25 Ma Manhattan caldera. The 16 Ma event formed deposits such as those on Gold Hill, and reworked the arsenic-antimony-mercury mineralized zone to form other deposits such as that at the White Caps mine.

Silver-rich base-metal-bearing veins in Paleozoic rocks at Belmont formed near Cretaceous granite, probably at about 75-80 Ma. Tertiary reworking of the deposits is uncertain. Silver- and gold-bearing veins at Jefferson were deposited at and near the margin of the Mount Jefferson caldera at 25 Ma. The silver-rich deposits may have been derived in part from reworking of deposits associated with an inferred 35 Ma intrusive just south of the caldera.

The mineralized zones in the southern Toquima Range offer many exploration targets for precious-metal deposits. Perhaps the most promising is a Fortitude, Nevada-type gold-bearing tactite deposit near or underlying the White Caps mine in the east part of the Manhattan district.

INTRODUCTION

Several mineralizing events characterized by unique metal assemblages but all carrying significant to trace amounts of gold and (or) silver took place at different times, but partly coincident in space, in the southern Toquima Range (fig. 1). The older mineral deposits are of marginal economic significance but some of the younger deposits have produced substantial amounts or have substantial reserves of gold and silver. Where the later mineralizing events overlapped areas of mineral deposits formed in earlier episodes, the older deposits were modified. During the younger events components were added in places to earlier-formed deposits, and some components locally were remobilized from the older deposits into the younger deposits. Whether or not the overlap of younger on older deposits had a significant effect on economic viability (size and grade) is uncertain.

Mineralized rocks in the southern Toquima Range are greatly varied. They include several varieties of quartz veins and other veins, mineralized Paleozoic rocks of several lithologies, Cretaceous granite, and Tertiary dikes and extrusive volcanic rocks (see figs. 2, 3, 4, and 5). About 340 mineralized rocks of all types were collected and analyzed, and they are classified in the tables of analytical data according to their metal content. Samples that contain 1,000 parts per million (ppm) or more, in sum, of the base metals copper, lead, zinc, arsenic, and antimony are called metal rich and those with less than 1,000 ppm of these base metals are called metal poor. Metal-rich rocks are subdivided into a group that contains Cu+Pb+Zn>As+Sb and a group that contains As+Sb>Cu+Pb+Zn. Most metal-poor rocks contain anomalous amounts (in ppm) of either gold (>0.05), silver (>10), mercury (>1), bismuth (>10), molybdenum (>10), or tungsten (>50). Generally the few metal-poor rocks that do not contain anomalous amounts of these metals contain several hundred ppm of the base metals. The contents of gold, silver, mercury, bismuth, molybdenum, and tungsten in the samples are described as low, moderate, or high. The categories are arbitrarily set as follows (in ppm): Au, <0.05 (low), 0.05-1 (moderate), and >1 (high); Ag, Bi, and Mo, <10 (low), 10-100 (moderate), and >100 (high); Hg, <1 (low), 1-10 (moderate), and >10 (high); and tungsten, <50 (low), 50-500 (moderate), and >500 (high). For convenience, and to clarify certain geologic correlations, metal-rich rocks with Cu+Pb+Zn>As+Sb are called Group 1 mineralized rocks, metal-rich rocks with As+Sb>Cu+Pb+Zn are called Group 2 mineralized rocks, and metal-poor rocks are called Group 3 mineralized rocks. Descriptions of the mineralized rocks and of their geochemistry are presented in following pages, from which is drawn an interpretation of a complex history of the currently producing gold-silver deposits in the area. Numerous occurrences of veins and mineralized rocks were not sampled in this study although probably all of the significant mineralized rock types in the southern Toquima Range were sampled, and are represented in the analytical data presented here. Analytical data have not yet been acquired on most mineralized samples collected in the north part of the Jefferson quadrangle (fig. 5), and the mineral deposits there cannot be adequately assessed at this time.

For the tables of analytical data that follow, the following notes identify methods, analysts, and limits of determination: Semiquantitative spectrographic analyses for Ag (in part), As, Sb, Bi, Mo, W, Cu, Pb, and Zn are by J. C. Hamilton, Merle Solt, H. G. Neiman, L. Mei, M. J. Malcolm, L. A. Bradley, and N. M. Conklin (approximate lower limits of determination for elements analyzed by the 6-step spectrographic method are in parts per million (ppm): Ag (0.5), As (500), Bi (7), Cu (1), Mo (3), Pb (7), Sb (100), W (50), and Zn (200)). Au and Ag (in part) were determined by fire-assay plus atomic absorption method by W. D. Goss, G. D. Shipley, Lorraine Lee, J. G. Crock, Joseph Haffty, and A. W. Haubert and by optical spectroscopy by P. H. Briggs, H. G. Neiman, J. A. Thomas, G. T. Mason, Jr., V. M. Merritt, J. G. Crock, and K. R. Kennedy (approximate lower limits of determination for Au by the respective methods, in ppm: 0.05 and 0.1; approximate lower limits of determination for Ag by the respective methods, in ppm: 20 and 2). Hg was determined by the wet oxidation plus atomic absorption method by J. A. Thomas and G. O. Riddle and by optical spectroscopy by P. H. Briggs, H. G. Neiman, J. A. Thomas, G. T. Mason, Jr., V. M. Merritt, J. G. Crock, and K. R. Kennedy (approximate lower limits of determination for Hg by the respective methods, in ppm: 0.01 and 0.02).

DESCRIPTIONS OF THE MINERALIZED ROCKS

Quartz veins

Quartz veins in the southern Toquima Range are of two general ages and environments, Cretaceous mid-level veins and Tertiary shallow veins. Cretaceous veins that are mostly short, narrow, and lenticular are in Cretaceous granite plutons and in Paleozoic sedimentary rocks near the granite plutons. They consist of massive white quartz, locally vuggy, that contains varied, generally small, amounts of primary sulfide and oxide ore minerals, muscovite, and other gangue minerals. Many of the veins are gold and silver bearing. Some of the veins have been fractured and remineralized, probably in part long after their initial formation and when they were in different (shallower) physical-chemical environments. Great variation in the relative amounts of different ore minerals in the Cretaceous quartz veins accounts for numerous, commonly intergrading, subtypes. This variation may have resulted either from chemical zonation or from remineralization. Small, narrow, and commonly brecciated Tertiary quartz veins occur in Tertiary volcanic rocks and in Paleozoic sedimentary rocks near the volcanics. They contain drusy quartz, locally adularia, and minor sulfide minerals. They are almost universally gold bearing, and many contain silver. Some of the Tertiary veins may have been remineralized during younger hydrothermal episodes but evidence of such remineralization is uncertain.

Quartz veins east of Round Mountain that have produced a small amount of tungsten are generally steeply dipping and strike northeast, north, and northwest in narrow east-trending belts mostly in granite (Shawe and others, 1984). Their age is about 80 Ma (Shawe and others, 1986). Many of the veins carry high amounts of tungsten and only low amounts of other metals (Group 3, samples 74-64 and 74-200, table 1), whereas several of the tungsten-bearing veins near an Oligocene granodiorite stock and associated rhyolite-andesite dike swarm (35 Ma, Shawe and others, 1986) also carry abundant copper, lead, zinc, arsenic, and antimony (Group 1, sample 74-194, table 1). Probably the base metals were added at the time of stock and dike emplacement, as discussed in more detail later. Gold, silver, and mercury are low in the metal-poor tungsten veins but they may occur in high amounts in the metal-rich tungsten veins. The tungsten occurs as huebnerite and minor scheelite. Other metals such as copper, lead, zinc, molybdenum, bismuth, antimony, arsenic, and iron are in the common (that is, common in the southern Toquima Range) sulfides chalcopyrite, galena, sphalerite, molybdenite, and pyrite, and in less common sulfides bismuthinite, stibnite, marcasite, and covellite, and in the sulfosalt tetrahedrite-tennantite (Shawe and others, 1984; E. E. Foord, written commun., 1986). A paragenetic sequence of metallic minerals in the veins

Table 1.--Mineralized quartz veins [analyses in ppm; N, not detected at limit of detection; L, detected, but below limit of determination]

Round Mountain quadrangle

In Paleozoic sedimentary rocks

	Group 1					Group 2
	73-177	73-205	74-278A	74-279		73-182
Au	N	0.10	N	N	Au	N
Ag	195	675	1,620	122	Ag	1.5
Hg	18.8	1.2	23.7	1.3	Hg	0.40
As	1,000	L	N	N	As	1,000
Sb	>10,000	N	2,000	700	Sb	N
Bi	2,000	200	30	7	Bi	N
Mo	7	15	100	2	Mo	L
W	N	N	N	N	W	N
Cu	10,000	10,000	10,000	15,000	Cu	150
Pb	5,000	3,000	2,000	2,000	Pb	15
Zn	1,500	1,000	300	1,500	Zn	N

	Group 3		
	67-96	73-47	73-137
Au	0.06	N	N
Ag	N	2	1.5
Hg	0.24	3.9	0.85
As	N	N	N
Sb	N	N	N
Bi	N	N	N
Mo	1,500	100	200
W	N	N	N
Cu	2	70	70
Pb	N	10	N
Zn	N	N	N

In Cretaceous granite

	Group 1						Group 2
	74-75	74-194	74-252A	74-252B	74-260A		74-221
Au	3.61	0.11	N	N	0.21	Au	1.17
Ag	15	94	105	57	1,930	Ag	1,750
Hg	2.7	1.5	20.0	65	380	Hg	100
As	1,500	N	N	N	1,500	As	700
Sb	N	700	1,000	700	7,000	Sb	10,000
Bi	7	20	20	20	100	Bi	30
Mo	20	15	30	30	50	Mo	7
W	N	700	70	N	N	W	10,000
Cu	300	700	1,500	700	10,000	Cu	1,500
Pb	3,000	70	300	300	2,000	Pb	3,000
Zn	2,000	500	1,000	50,000	1,500	Zn	200

	Group 3		
	74-64	74-200	74-262
Au	N	N	0.06
Ag	2	N	186
Hg	0.23	0.09	0.68
As	N	N	N
Sb	N	N	N
Bi	7	N	1,500
Mo	N	N	20
W	10,000	1,000	N
Cu	7	15	200
Pb	50	N	300
Zn	N	N	N

In Tertiary volcanic rocks

	Group 1		Group 3
	74-142		68-146
Au	0.19	Au	14.7
Ag	463	Ag	100
Hg	18.5	Hg	0.14
As	N	As	N
Sb	100	Sb	N
Bi	300	Bi	N
Mo	3	Mo	3
W	N	W	N
Cu	100	Cu	1
Pb	>10,000	Pb	10
Zn	1,000	Zn	N

Table 1.--Mineralized quartz veins (continued)

Manhattan quadrangle

In Paleozoic sedimentary rocks

	Group 1			
	78-29B	78-51	78-139	78-143
Au	N	N	N	0.20
Ag	N	177	35	166
Hg	0.08	0.05	6.5	67.8
As	N	N	N	N
Sb	N	N	N	L
Bi	N	500	20	10
Mo	N	N	7	10
W	N	N	N	N
Cu	5,000	20	2,000	2,000
Pb	N	1,500	500	300
Zn	N	N	5,000	500

	Group 2				
	68-118	78-33A	78-107	79-15	79-29
Au	31.6	0.39	0.08	N	0.13
Ag	N	5	N	5	10
Hg	850	1.4	6.3	7.2	1.3
As	70,000	3,000	1,500	1,000	1,500
Sb	7,000	N	300	N	N
Bi	N	N	N	N	N
Mo	30	7	N	10	50
W	N	N	N	N	N
Cu	7	1,000	15	150	500
Pb	10	10	10	70	20
Zn	N	1,000	N	300	N

	Group 3							
	77-167	78-12	78-58	78-66	78-95A	78-119B	79-10	79-26
Au	0.29	0.06	N	N	N	0.10	0.13	N
Ag	2	10	L	1.5	1.5	7	1.5	N
Hg	1.8	0.09	0.12	0.04	18.7	0.03	1.4	0.02
As	N	L	N	N	N	L	N	N
Sb	N	N	N	N	N	N	N	N
Bi	N	N	N	N	N	10	N	N
Mo	7	7	10	7	20	N	3	N
W	N	N	N	N	N	300	N	N
Cu	50	200	700	200	20	70	150	500
Pb	10	100	N	L	N	100	N	N
Zn	500	500	N	N	N	L	N	N

In Tertiary volcanic rocks

	Group 3							
	77-20	77-33	77-51	77-141	77-158	77-159	77-165A	77-179
Au	N	2.07	1.04	0.19	6.74	9.44	0.47	0.11
Ag	N	N	N	N	10	5	7	N
Hg	8.0	0.26	0.11	0.09	0.19	0.12	0.41	0.30
As	N	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	N	N
Mo	N	3	N	N	15	100	70	N
W	N	N	N	N	N	N	N	N
Cu	7	1.5	10	7	20	5	7	5
Pb	L	50	N	N	10	15	50	N
Zn	N	N	N	N	N	N	N	N

Belmont district

	Group 1			Group 2				Group 3
	82-118	82-166		82-81A	82-83B	82-165B		82-84B
Au	N	N	Au	0.2	N	N	Au	N
Ag	700	300	Ag	700	500	15	Ag	20
Hg	0.50	0.31	Hg	4.5	0.40	0.17	Hg	0.20
As	N	N	As	5,000	N	2,000	As	N
Sb	1,000	300	Sb	700	1,000	N	Sb	N
Bi	N	N	Bi	N	N	N	Bi	700
Mo	700	7	Mo	3	30	150	Mo	150
W	N	N	W	N	N	N	W	N
Cu	5,000	1,500	Cu	1,500	500	300	Cu	700
Pb	3,000	500	Pb	2,000	500	70	Pb	100
Zn	1,500	300	Zn	500	N	1,000	Zn	N

Table 1.--Mineralized quartz veins (continued)

Belmont West quadrangle

In Paleozoic sedimentary rocks

	Group 1							
	81-34B	81-202	82-19A	82-61A	82-62A	82-67A	82-76A	82-77A
Au	N	N	N	N	N	N	N	N
Ag	100	N	200	500	300	150	300	700
Hg	2.6	0.17	0.60	0.60	0.85	0.7	0.90	0.50
As	N	N	N	N	N	N	N	N
Sb	200	N	2,000	300	500	N	700	2,000
Bi	300	N	N	N	N	N	N	N
Mo	15	N	7	N	N	10	N	N
W	N	N	N	N	N	N	N	N
Cu	1,500	30	1,000	150	300	300	1,000	2,000
Pb	300	N	700	1,000	700	200	300	1,500
Zn	N	1,500	500	3,000	7,000	700	700	1,500

	Group 2
	81-35B
Au	N
Ag	1.5
Hg	1.5
As	1,500
Sb	N
Bi	10
Mo	7
W	N
Cu	30
Pb	N
Zn	300

	Group 3				
	81-43	81-211	82-8A	82-91	82-106
Au	0.1	N	N	N	N
Ag	1	N	0.7	7	3
Hg	0.12	0.07	N	0.01	0.05
As	N	N	N	N	N
Sb	N	N	N	N	N
Bi	70	N	70	N	N
Mo	15	5	15	5	7
W	N	N	N	N	N
Cu	70	150	70	30	100
Pb	N	N	N	N	100
Zn	N	N	N	N	N

In Cretaceous granite

	Group 1
	82-86A
Au	N
Ag	70
Hg	0.20
As	N
Sb	N
Bi	N
Mo	7
W	700
Cu	500
Pb	700
Zn	N

	Group 2	
	82-58	82-79A
Au	N	N
Ag	50	700
Hg	0.18	0.75
As	5,000	N
Sb	N	1,500
Bi	N	N
Mo	7	20
W	N	N
Cu	100	100
Pb	500	200
Zn	700	N

	Group 3							
	81-130B	81-131A	81-132	81-145	82-28	82-37	82-40C	82-89
Au	N	N	N	N	N	N	N	N
Ag	150	7	5	3	3	15	500	15
Hg	1.5	1.2	1.5	7.3	0.09	0.03	0.18	N
As	N	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N	N
Bi	3,000	150	150	N	N	200	300	500
Mo	30	N	3	15	10	100	15	20
W	N	N	N	N	150	N	N	N
Cu	150	30	70	70	150	20	300	30
Pb	300	30	100	100	70	200	200	30
Zn	300	N	N	N	N	N	N	N

In Tertiary volcanic rocks

	Group 3
	81-71
Au	N
Ag	1.5
Hg	0.41
As	N
Sb	N
Bi	N
Mo	30
W	N
Cu	150
Pb	N
Zn	N

Table 1.--Mineralized quartz veins (continued)

Jefferson quadrangle

In Paleozoic sedimentary rocks

Group 1

	84-3	84-48	84-52	84-84	84-99	84-153	84-158
Au	0.6	N	N	N	N	0.1	N
Ag	260	2	2	1.5	5	16	280
Hg	1.1	0.03	0.03	29	0.05	30	30
As	N	N	N	N	N	N	N
Sb	300	N	N	N	N	N	300
Bi	N	N	N	N	100	N	N
Mo	5	20	N	70	30	7	7
W	N	N	N	N	N	N	N
Cu	700	70	700	300	300	300	500
Pb	700	30	N	15	1,500	200	1,000
Zn	N	1,500	1,500	2,000	3,000	2,000	3,000

Group 2

	68-101	84-86	84-116	84-135
Au	0.06	N	0.2	73
Ag	N	1.5	3	160
Hg	0.08	4.6	0.73	1.8
As	1,500	1,000	1,000	1,000
Sb	>100,000	N	N	200
Bi	N	N	N	N
Mo	3	5	N	N
W	N	N	N	N
Cu	30	10	70	300
Pb	70	N	20	15
Zn	N	N	N	300

Group 3

	84-2	84-44	84-56A	84-65	84-69	84-89	84-96	84-97A	84-134A
Au	0.1	N	N	N	N	N	N	N	N
Ag	27	N	N	N	2	N	1	N	25
Hg	0.33	0.03	0.03	0.17	0.06	0.07	0.04	0.9	1.1
As	N	N	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N	N	300
Bi	N	N	N	N	N	N	15	N	N
Mo	3	N	N	N	N	5	N	N	N
W	N	N	N	N	N	N	N	N	N
Cu	150	100	200	30	30	50	50	150	150
Pb	50	N	N	70	100	10	N	N	15
Zn	500	N	300	700	700	700	N	N	N

In Cretaceous granite

Group 1

	82-12
Au	N
Ag	700
Hg	12
As	N
Sb	7,000
Bi	N
Mo	300
W	N
Cu	15,000
Pb	2,000
Zn	3,000

In Tertiary volcanic rocks

	Group 1 74-265
Au	0.95
Ag	492
Hg	0.87
As	N
Sb	200
Bi	150
Mo	N
W	N
Cu	30,000
Pb	10,000
Zn	30,000

	Group 3 68-111
Au	0.27
Ag	100
Hg	0.33
As	N
Sb	200
Bi	N
Mo	N
W	N
Cu	100
Pb	15
Zn	N

comprises early huebnerite deposited in a main stage of quartz, muscovite, and fluorite; common sulfides such as pyrite, chalcopyrite, galena, sphalerite, and molybdenite that fill cavities and shears in quartz; and late sulfosalt that generally is molded around, fills fractures in, or replaces the common sulfides. Some less common sulfides such as covellite and marcasite replace or fill fractures in galena.

Quartz vein material in granite was collected from a mine dump at the Fairview mine in volcanic rocks near the east edge of the Round Mountain district (fig. 2). The material on the dump suggests that the deeper parts of the mine workings encountered a quartz vein in granite beneath Tertiary volcanic rocks. The material contains molybdenite, pyrite, galena, covellite, lead-bismuth-silver sulfosalts, and sparse huebnerite. The galena is present as two distinct phases that have different cell dimensions and different, but large, contents of bismuth and silver (E. E. Foord, written commun., 1986). The two galena phases probably resulted from two distinct mineralizing events.

Some quartz veins in granite that are devoid of tungsten (Group 1 and Group 3, samples 74-75, 74-252B, 74-260A, and 74-262, table 1) are otherwise similar to the tungsten-bearing veins. These veins, like the tungsten-bearing veins, are about 80 Ma (Shawe and others, 1986). The vein represented by sample 74-262 (Group 3) contains high bismuth and silver and it contains generally low amounts of the other metals.

A few quartz veins in granite and in Paleozoic sedimentary rocks near the granite contact south of Round Mountain, and in the southeast corner of the Round Mountain quadrangle, are enriched in molybdenum and are generally low in all other metals (Group 3, samples 67-96, 73-47, and 73-137, table 1 and fig. 2). These are veins of massive white quartz that commonly have muscovite selvages and that contain scattered molybdenite flakes. The veins were formed initially about 80 Ma (samples 73-45 and 73-138, Shawe and others, 1986). At the Outlaw prospect in the southeast corner of the Round Mountain quadrangle (fig. 2), a molybdenite-bearing quartz vein contains pockets of sulfides and sulfosalts of copper, lead, zinc, bismuth, and silver (E. E. Foord, written commun., 1986). Euhedral crystals and irregular masses of pyrite, sphalerite, galena, and molybdenite are fractured and the fractures filled with sulfosalts. Tourmaline occurs locally in the vein, and as described later in this paper, it suggests remineralization related to the 35 Ma episode of stock and dike emplacement. An unusual aspect of the occurrence at the Outlaw prospect is the local presence of mercury-bearing galena and a mercurian lead-bismuth-silver sulfosalt (E. E. Foord, written commun., 1986).

Several metal-rich massive white quartz veins (Group 1 and Group 2, samples 73-177, 73-182, 74-278A, and 74-279, table 1) in Paleozoic sedimentary rocks south of the Shale Pit (fig. 2), though undated, are similar in appearance to dated Cretaceous veins elsewhere in the sedimentary rocks and in granite. They contain high amounts of silver but only low gold. Mercury occurs in moderate to high amounts, and molybdenum is moderate in some of the veins. Bismuth is generally moderate to high in Group 1 veins in this area. At the Shale Pit, a pod of milky-white quartz in argillite contains masses of galena that are several centimeters long and interconnected by numerous thin anastomosing veinlets of galena (sample 78-122, E. E. Foord, written commun., 1986; no analytical data given here). The quartz is strongly sheared and fractured, and locally it contains vugs lined with finely crystallized drusy quartz. The galena is rich in silver and bismuth (E. E. Foord, written commun., 1986). The milky-white quartz of the pod appears typical of that in the 80 Ma veins; the finely-crystalline drusy quartz is typical of the Tertiary gold-bearing deposits in the southern Toquima Range.

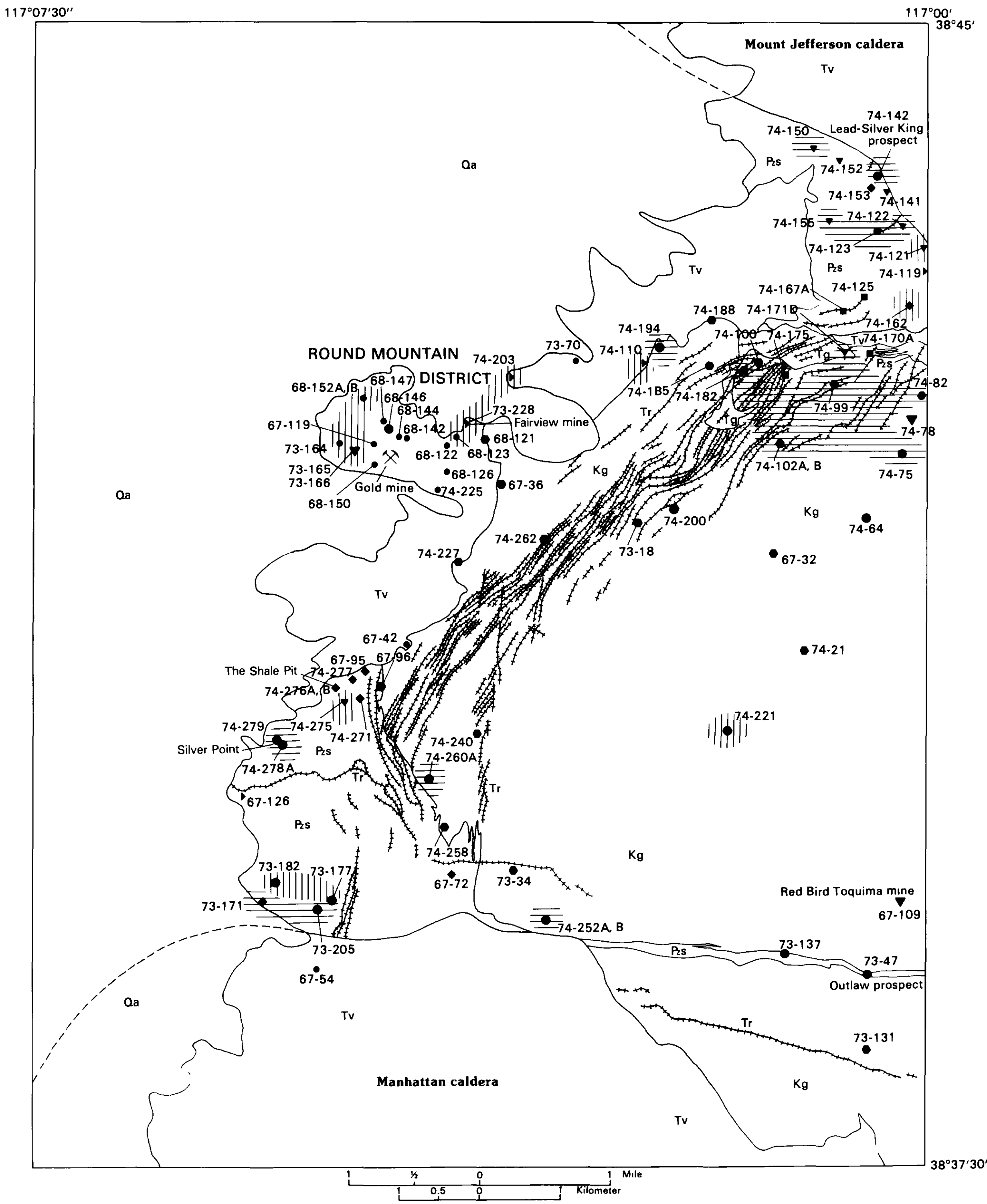

Figure 2.--Geologic map of the Round Mountain quadrangle showing mines, prospects, and mineralized rocks. Explanation given in figure 5.

Figure 2.—

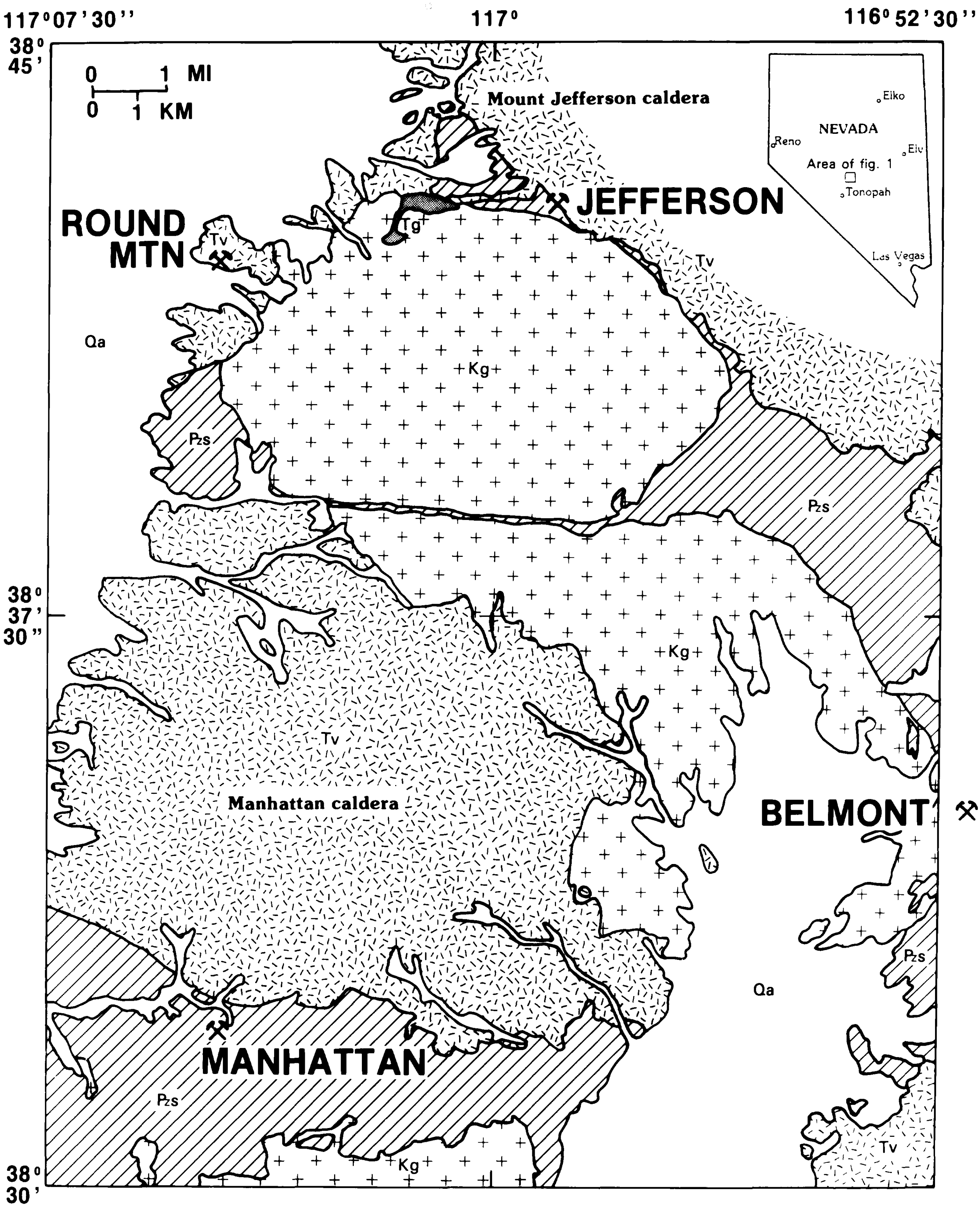

Figure 1.--Simplified geologic map of part of the southern Toquima Range, Nevada, showing locations of the Round Mountain, Manhattan, Belmont, and Jefferson precious-metal districts. Pzs, Paleozoic sedimentary rocks; Kg, Cretaceous granite; Tg, Tertiary granodiorite stock; Tv, Tertiary volcanic rocks; Qa, Quaternary alluvium.

Figure 1.—

In the Tertiary (27 Ma) volcanic rocks at the Round Mountain gold mine, which were erupted from the Mount Jefferson caldera about 6 km to the northeast, a drusy quartz vein rich in adularia (Group 3, sample 68-146) contains a high content of gold and silver but little or no other metals (table 1). The vein has been dated at 25 Ma (Shawe and others, 1986). At the Lead-Silver King prospect northeast of Round Mountain, an intensely sheared zone between Ordovician carbonate rocks and Tertiary volcanic rocks contains irregular thin quartz veins in which galena occurs as irregular masses as much as several centimeters long, either filling sheared milky quartz, or as crudely tabular masses filling quartz-lined vugs. Some of the galena contains minute veinlets of marcasite commonly oriented along the cubic cleavage (E. E. Foord, written commun., 1986). The galena occurs as two distinct phases, as at the Fairview mine. A sample of the Group 1 vein material (74-142, table 1) has a large lead content, moderate to high gold, silver, mercury, and bismuth, and some antimony and zinc.

Massive white quartz veins in Paleozoic sedimentary rocks are numerous in and near the Manhattan district (Group 1, Group 2, and Group 3, samples 77-167, 78-12, 78-29B, 78-58, 78-66, 78-95A, 78-107, 78-119B, 78-139, 78-143, 79-10, 79-15, 79-26, and 79-29, table 1; fig. 3). They are localized along high- and low-angle faults and along bedding planes; some are as thick as 2 m and as long as perhaps 100 m. Some of the veins are brecciated. None of these veins has been dated. However, quartz veins near Manhattan that contain feldspars but are otherwise similar to these veins have been dated at about 75 Ma (samples 77-183A and 78-86B, Shawe and others, 1986). The Manhattan quartz and quartz-carbonate veins (commonly white calcite is locally predominant over quartz) contain pyrite with or without other sulfides. The Group 1 veins typically contain chalcopyrite, sphalerite, and galena, whereas Group 2 veins contain, in addition to the common sulfides, late-stage tetrahedrite-tennantite. An undated massive white quartz vein north of the White Caps mine is sheared and it contains small tabular masses of chalcopyrite, galenobismutite, and lead-bismuth-silver sulfosalts in the shears (E. E. Foord, written commun., 1986). Ferguson (1924, p. 141) described small barren veins of glassy quartz older than the gold-bearing drusy quartz veinlets on Gold Hill. Coarsely crystalline muscovite in close spatial association with the barren quartz veins on Gold Hill is dated at 75 Ma (sample 68-119, Shawe and others, 1986). Gold is generally low, mercury low to high, and silver generally high in Group 1 of the Manhattan quartz veins, whereas gold and mercury tend to be moderate to high and silver tends to be low in Manhattan Group 2 veins. Bismuth is common in moderate to high amounts in the Group 1 veins. Group 3 veins near Manhattan contain generally low amounts of gold, silver, and mercury, along with low amounts of other metals.

A brecciated Group 2 vein that consists of fragments of argillite and limestone coated with thinly layered colloform quartz that is locally intergrown with apatite (sample 78-33A, table 1) contains moderate gold and mercury and low silver. The vuggy character of the vein and its content of low-temperature quartz suggest that the vein is Tertiary in age.

A Group 2 quartz vein mined at the White Caps mine, represented by sample 68-118 (table 1) that contains sulfides and minor calcite, is only one part of a complex mineralized system. As described by Ferguson (1924) the ore deposit at the White Caps is characterized by pre-ore, north-trending faults that intersect limestone layers in the Gold Hill Formation in which replacement bodies of ore developed adjacent to the faults. Northeast-trending post-ore faults offset the orebodies. The faults are gouge-filled; pre-ore faults are sporadically mineralized with sulfide-bearing quartz and calcite lenses

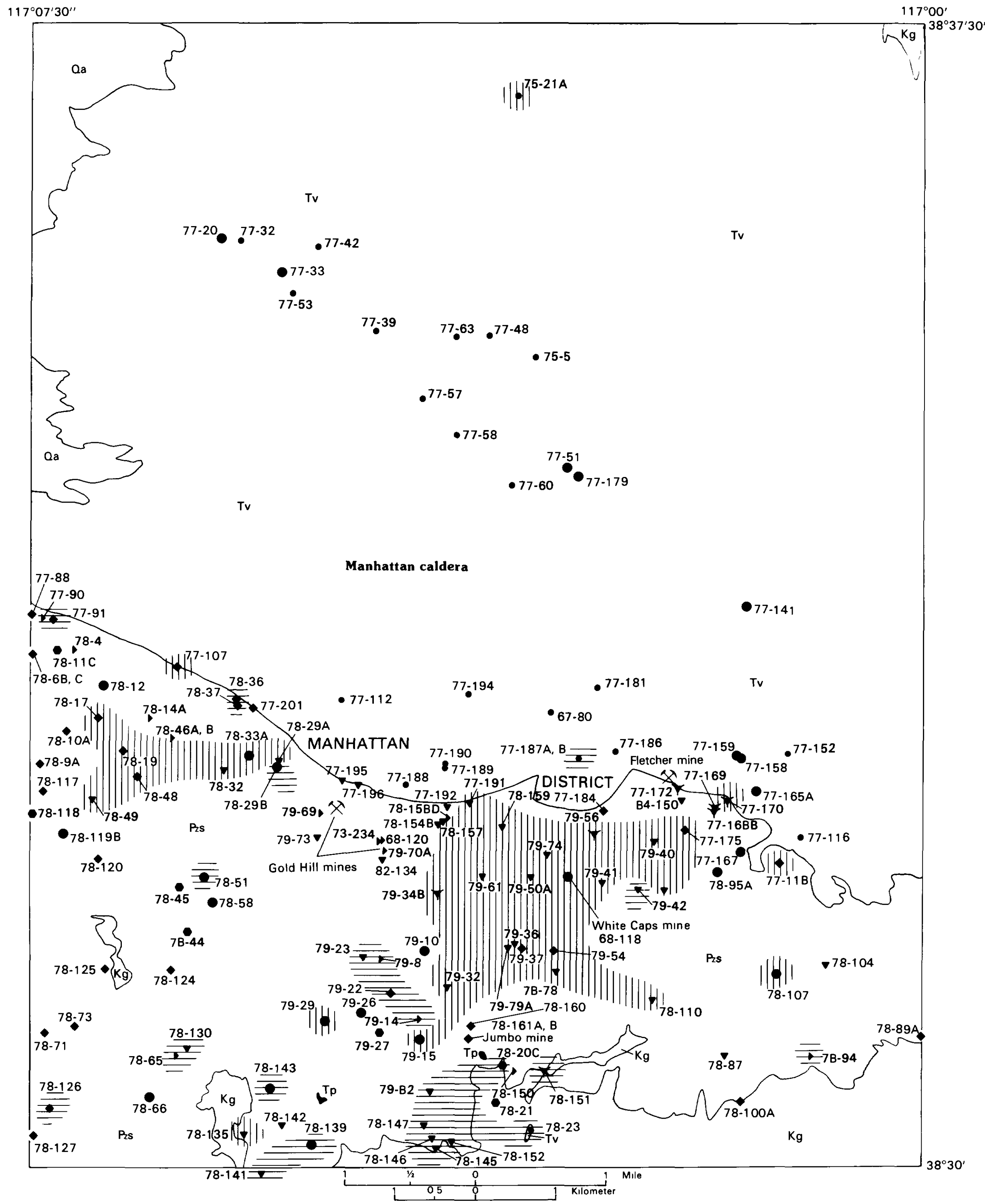

Figure 3.--Geologic map of the Manhattan quadrangle showing mines and mineralized rocks. Explanation given in figure 5.

Figure 3.—

(north-trending faults that controlled mineralization were "cemented by ore," Ferguson, 1924, p. 83), and post-ore faults contain broken pieces of ore in gouge. Most of the ore was mined from the orebodies in limestone. The orebodies in limestone contain pyrite, arsenopyrite, stibnite, realgar, orpiment, and cinnabar in a gangue of calcite and quartz with minor dolomite, fluorite, and sericite. Sparse adularia is present locally. Coarse white calcite was the first mineral formed in the orebodies, followed by dark (from disseminated carbonaceous matter) fine-grained quartz that contains very fine-grained crystals of arsenopyrite, probably gold bearing. The deposit does not contain free gold. The dark quartz provided the richest gold ore mined at the White Caps, suggesting that gold is closely associated with arsenopyrite. Stibnite, pyrite, quartz, and calcite were then deposited, and realgar and cinnabar were deposited slightly later. Orpiment appears to be mostly a late oxidation product of realgar. The stibnite-rich ores generally have little gold whereas the realgar-rich ores have considerable gold. Silver is low in the White Caps ores (sample 68-118, table 1). Stibnite, realgar, and cinnabar show significantly different distributions throughout the White Caps deposit, suggestive of some separation in time in their major periods of deposition. Faults in different parts of the deposit may have been open for solution movement at different times. A magnetic high centered near the White Caps mine (U.S. Geological Survey, 1979) may indicate a buried intrusive to which White Caps mineralization was related. Ferguson (1924) considered all of the White Caps mineralization to have been Tertiary, although he related calc-silicate mineralization of limestones in the area to the Cretaceous granite emplacement.

Quartz veins in Tertiary (25 Ma) volcanic rocks north of Manhattan are all Group 3 veins (samples 77-20, 77-33, 77-51, 77-141, 77-158, 77-159, 77-165A, and 77-179, table 1). Most contain moderate to high gold, although silver is low and mercury is low to moderate. A few of the veins contain moderate amounts of molybdenum. The veins are thin drusy to comby quartz stringers that contain minor pyrite and free gold. The quartz veins occur in two groupings, a linear northwest-trending zone north of the district, and a small cluster east of the Fletcher mine at the east end of the Manhattan gold belt. None of the veins has been dated.

Quartz veins sampled in the Belmont district just east of the Belmont West quadrangle (table 1; individual sample localities not shown on fig. 4) belong to Group 1, Group 2, and Group 3 veins. Some of the veins are several meters thick in places, and hundreds of meters long (Kleinhampl and Ziony, 1984). The veins consist of massive white quartz, commonly sheared and brecciated, localized in high-angle faults in granite and in low- and high-angle faults in Paleozoic rocks near the granite contact. The principal structural control of mineralization appears to be an east-dipping low-angle fault in the Paleozoic rocks that extends from the Belmont district several kilometers north-northwestward (marked by the zone of Group 1 samples, figs. 4 and 5). Clots and streaks of sulfides fill sheared and brecciated quartz. Pyrite, chalcopyrite, sphalerite, galena, and molybdenite are common in the veins, and tetrahedrite-tennantite is abundant in some of them. Stromeyerite ($(Ag,Cu)_2S$) and stetefeldite (described as a silver-antimony sulfide, Kral, 1951) have been reported, and ores rich in cerargyrite were mined above the water table (Kleinhampl and Ziony, 1984). Muscovite selvages occur on quartz veins in granite, as is typical of the 80 Ma quartz veins in granite in the Round Mountain area. None of the Belmont veins have been dated. Massive white quartz veins locally contain thin (1 cm) veinlets of brown chalcedony indicating a late low-temperature period of mineralization. Evidence of metal

Figure 4.--Geologic map of the Belmont West quadrangle showing mineralized areas and rocks. Explanation given in figure 5.

Figure 4 –

deposition in the late period of mineralization is lacking. All of the Belmont quartz veins, regardless of base metal content, are enriched in silver and they carry virtually no gold; mercury is present mostly in low amounts, and molybdenum is high in some veins.

Sampled quartz veins in Paleozoic sedimentary rocks near Belmont within the Belmont West quadrangle all belong to Group 1 (fig. 4; samples 82-19A, 82-61A, 82-62A, 82-67A, 82-76A, and 82-77A, table 1). These veins are mineralogically similar to the veins at Belmont; they contain high silver, no gold, and mostly low mercury. Metal-rich quartz veins (both Group 1 and Group 2) in sedimentary rocks in the southwest corner of the Belmont West quadrangle (samples 81-34B, 81-35B, and 81-202, fig. 4; table 1) are devoid of gold, contain low to moderate mercury, and mostly high silver. These veins probably are related to those in sedimentary rocks near Manhattan. Group 3 quartz veins in the Belmont West quadrangle (samples 81-43, 81-211, 82-8A, 82-91, and 82-106, fig. 4; table 1) contain low amounts of gold, silver, and mercury.

Granite west of the Belmont district contains a number of quartz veins, some high in metals (both Group 1 and Group 2), and some low in metals (Group 3). A Group 1 vein (sample 82-86A, table 1) that contains muscovite and huebnerite in addition to sulfides is similar to several tungsten-bearing Group 1 veins near Round Mountain. Group 2 veins (samples 82-58 and 82-79A, table 1) are massive white quartz, commonly sheared, that contains muscovite, pyrite, and tetrahedrite-tennantite. Locally opal has been deposited in vuggy parts of the quartz veins. Group 3 veins (samples 81-130B, 81-131A, 81-132, 81-145, 82-28, 82-37, 82-40C, and 82-89, table 1) contain massive white quartz with common muscovite selvages typical of the 80 Ma veins. The quartz contains locally abundant pyrite and small amounts of sphalerite, chalcopyrite, galena, and an unidentified lead-bismuth sulfosalt. Minor tetrahedrite-tennantite may be present locally. A few veins show late vug coatings of chalcedonic silica. The Group 3 veins in granite contain no gold, low to moderate amounts of mercury, and locally high silver. Bismuth is common and generally high.

One Group 3 vein in the Belmont West quadrangle is in an immense block of granite that appears to be a clast in a caldera megabreccia unit in the Tertiary volcanic rocks (sample 81-71, table 1; fig. 4). The vein contains low amounts of all metals.

Numerous quartz veins occur in Paleozoic sedimentary rocks in the Jefferson quadrangle (fig. 5). Analytical data have not yet been obtained for most mineralized samples, including quartz veins, in the north part of the quadrangle, and my descriptions of the mineralized rocks there are incomplete. Elsewhere in the quadrangle most of the quartz veins in the Paleozoic rocks consist of massive white quartz, commonly brecciated, that is locally vuggy and that contains varied amounts of calcite, and common sulfides and tetrahedrite-tennantite as pods, seams, or disseminated grains. Cinnabar and stibnite are locally abundant. A Cretaceous age for the initial formation of these veins is suggested by the presence of actinolite which is also common in associated Paleozoic rocks that were metamorphosed in Cretaceous time. Both metal-rich and metal-poor veins are present. Among the metal-rich veins, Group 1 veins (samples 84-3, 84-48, 84-52, 84-99, 84-153, and 84-158, table 1) have low amounts of gold and they contain low to high amounts of silver and mercury. Bismuth is rarely present in moderate amount. Several of the Group 1 veins form a cluster in the southeast corner of the quadrangle (fig. 5) which is an extension of the silver-rich zone of veins that extends northwestward from the Belmont district. Veins of Group 1 also occur at and near the Barcelona mine (fig. 5). Group 2 veins (samples 84-86, 84-116, and

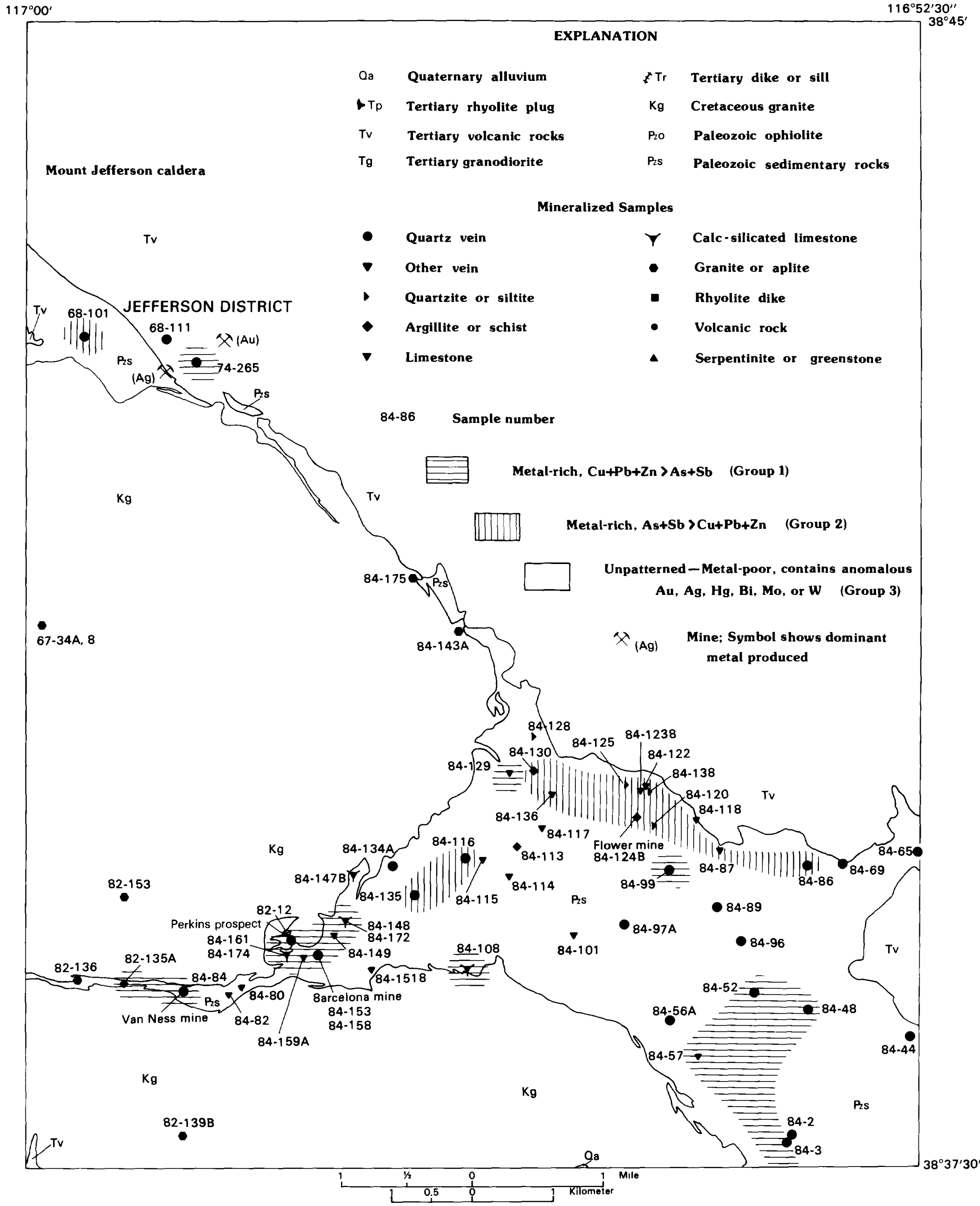

Figure 5.--Geologic map of the Jefferson quadrangle showing mines and mineralized rocks. Explanation is for figures 2, 3, 4, and 5.

Figure 5,—

84-135, table 1) have low to high amounts of gold and silver and generally moderate amounts of mercury. Group 3 veins (samples 84-2, 84-44, 84-56A, 84-65, 84-69, 84-89, 84-96, and 84-97A, table 1) typically contain no gold and low amounts of mercury; only a few contain moderate amounts of silver. One thin (15 cm) quartz vein in dark-gray carbonaceous Paleozoic rocks at the west edge of the Jefferson district (sample 68-101, table 1) contains pods and stringers of stibnite. It has a moderate content of gold, low mercury, and no silver. At the Van Ness mine (sample 84-84, table 1) cinnabar-bearing quartz veins occur in cinnabar-mineralized silicified Paleozoic rock. The sampled vein contains base-metal sulfides, but no gold and only low silver. Molybdenum is low to moderate in all of the Jefferson quartz veins in Paleozoic rocks, and they contain no tungsten.

Only one vein in granite was sampled in the Jefferson quadrangle, at the Perkins prospect (fig. 5; Group 1, sample 82-12, table 1). The vein, a meter or so wide, consists of white quartz that contains numerous small vugs and locally is fractured and veined with a second generation of somewhat vuggy white quartz. The quartz everywhere is charged with small (to 1 cm) masses of sulfides, mostly filling vugs. Pyrite, sphalerite, galena, chalcopyrite, and molybdenum occur, along with tetrahedrite that is more abundant than the combined common sulfide minerals. The vein is rich in silver, it has high mercury, but it contains no gold, bismuth, or tungsten.

At the Jefferson district two quartz veins in volcanic rocks were sampled. A Group 1 vein (sample 74-265, table 1), sampled from a mine dump, probably came from volcanic megabreccia along the contact between the volcanic rocks and Paleozoic rocks (Ferguson and Cathcart, 1954). The vein contains chalcopyrite, sphalerite, galena, and abundant black manganese oxide. It is silver rich and it contains moderate gold and low mercury. Bismuth is high, but molybdenum and tungsten are absent. A Group 3 vein (sample 68-111, table 1), probably in the same geologic setting as sample 74-265, consists of drusy quartz that contains black calcite, white calcite, and sparse sulfides. It contains moderate silver and gold, and low mercury. Thin drusy quartz veins in the northeast part of the Jefferson district (no data) are gold rich and similar in appearance and geologic setting to veins in volcanic rocks at Round Mountain.

Other veins

Several veins in the Round Mountain quadrangle that are not quartz veins but are significantly mineralized provide insight into the character of particular mineralizing events. Veins as much as a meter or so thick at the Red Bird Toquima mine (fig. 2), earlier known as the Senator mine (Bailey and Phoenix, 1944), consist mostly of white barite that contains cinnabar and metacinnabar (sample 67-109, table 2). Except for abundant mercury and minor silver, the barite vein carries virtually no other metals (Group 3). However, early thin veins of quartz in granite that consist of pyrite-bearing white quartz and have muscovite selvages appear to have been reopened by strong shearing and brecciation and filled with barite, chalcedony, and mercury minerals. A similar smaller vein in granite at the Mariposa Red Dog claim (not shown on fig. 2) about 5 km west of the Red Bird Toquima mine consists of sheared and brecciated quartz that is filled with barite, chalcedony, and cinnabar. Muscovite in selvages that bound the original quartz vein gives an age of 83 Ma for initial formation of the vein (sample 73-36, Shawe and others, 1986). The barite-chalcedony-cinnabar assemblage is clearly a lower temperature and much shallower depth product than the muscovite, and I infer that it, as well as the similar mineral assemblage at the Red Bird Toquima mine, is the result of Tertiary mineralization.

Table 2.--Other mineralized veins [analyses in ppm; N, not detected at limit of detection]

Round Mountain quadrangle

	Group 2			Group 3	
	73-165	73-166		67-109	74-78
Au	2.2	0.25	Au	N	0.07
Ag	160	670	Ag	1.5	N
Hg	4.2	2.1	Hg	>16,000	0.06
As	3,000	15,000	As	N	N
Sb	N	N	Sb	N	N
Bi	N	N	Bi	N	N
Mo	10	70	Mo	N	20
W	N	N	W	N	70
Cu	50	200	Cu	15	20
Pb	15	150	Pb	N	20
Zn	1,000	3,000	Zn	N	700

A magnetite-rich vein about 1 km southeast of the east end of the Oligocene granodiorite stock east of Round Mountain (sample 74-78, fig. 2) is similar to some other veins near the stock and it is inferred to be of about the same age as the stock (about 35 Ma). One magnetite-rich vein was emplaced in a rhyolite dike of the 35 Ma dike swarm. The veins are thin (to 5 cm) and consist of intergrown magnetite, epidote, and K-feldspar(?). Where the veins have been sheared and brecciated, vugs and fractures contain drusy quartz, hematite, and adularia. An analyzed sample (74-78, table 2) of magnetite-rich vein is low in base metals (Group 3) and it contains moderate gold, molybdenum, and tungsten and low mercury and silver.

Veins that cut the gold-bearing quartz veins in the volcanic rocks at Round Mountain consist of alternating thin colloform layers of carbonate minerals and fine-grained quartz. The veins were broken episodically during mineralization and parts were brecciated and then overgrown with additional colloform layers. Irregular patches of a white clay mineral, with wisps and granules of black manganese oxide, are scattered in the vein material, which locally is much darkened by disseminated manganese oxide. Masses of white porcelaneous alunite occur locally in the veins. Two sampled veins of this type fall in Group 2 in metal content (samples 73-165 and 73-166, table 2). They are silver rich and contain moderate to abundant amounts of gold and moderate mercury. The mineral residence of the high arsenic content is unknown, but it is probably in either scorodite ($FeAsO_4 \cdot 2H_2O$) or mansfieldite ($AlAsO_4 \cdot 2H_2O$). The veins contain moderate molybdenum but no bismuth or tungsten. Alunite from similar veins at Round Mountain has been dated at about 10 Ma (Tingley and Berger, 1985). It is unknown whether or not the alunite age represents the age of the silver-rich veins at Round Mountain.

Paleozoic sedimentary rocks

Paleozoic sedimentary rocks, some of which are low-grade metamorphic rocks near granite contacts (not classified as tactites, however), have been mineralized extensively. Mineralized samples were selected on the basis of strong iron staining and silicification, either disseminated or along fractures; the mineralogy of the samples has not been determined. The mineralized sedimentary rocks form several lithologic groups: quartzite and siltite, argillite and schist, and limestone (including argillaceous limestone and limy argillite, not distinguished here). The rocks also display different degrees of mineralization; some are metal rich (Group 1 and Group 2) and some are metal poor (Group 3). Descriptions of mineralized sedimentary and other rocks that follow generally refer only to gold and silver content; tables 3-7 show the content of other metals.

In the Round Mountain quadrangle quartzite and siltite Group 2 samples (73-228, 74-110, and 74-203, table 3) contain low to moderate gold and low to high silver. Group 3 samples (67-126 and 74-119) contain moderate gold and low silver. Quartzite samples taken in the Manhattan quadrangle contain widely varied amounts of metals. Group 1 samples (77-90, 78-65, 78-94, 79-8, and 79-14, table 3) have low to moderate amounts of gold and silver. A Group 2 sample (78-46A, table 3) is gold rich but it contains low silver. Group 3 samples (68-120, 73-234, 78-4, 78-14A, 78-46B, 78-150, 78-158D, 79-69, and 79-70A, table 3) contain low to high amounts of gold and silver. Four of these samples (68-120, 73-234, 79-69, and 79-70A) were collected from Cambrian quartzite in and near the productive Gold Hill mines at Manhattan, and they are probably representative of the mined ores. The ores were formed at 16 Ma (Shawe and others, 1986).

One Group 3 quartzite sample (81-22, table 3) from the Belmont West quadrangle contains no gold and low silver. In the Jefferson quadrangle 3 Group 2 samples (84-120, 84-125, and 84-138, table 3) were collected. They are devoid of gold and silver yet they contain moderate to high mercury. A Group 3 quartzite (sample 84-126, table 3) contains low gold and silver.

Argillite and schist are widely mineralized in the southern Toquima Range. In the Round Mountain quadrangle Group 1 samples (73-171 and 74-276B, table 4) have low to moderate gold and silver. A Group 2 sample (74-162, table 4) contains moderate gold and silver. Several Group 3 samples (67-72, 67-95, 74-153, 74-271, 74-276A, and 74-277, table 4) contain low to moderate gold and virtually no silver. In the Manhattan quadrangle Group 1 samples (77-91, 78-36, 78-37, 78-126, and 79-22, table 4) contain mostly low gold and silver. Numerous Group 2 argillite samples (77-107, 77-118, 77-175, 78-17, 78-19, 78-48, 79-37, and 79-54, table 4) contain low to moderate gold and low silver. Group 3 argillite samples collected in the Manhattan quadrangle (samples 77-88, 77-184, 77-201, 78-6B, 78-9A, 78-10A, 78-71, 78-73, 78-89A, 78-100A, 78-117, 78-120, 78-124, 78-125, 78-127, 78-160, 78-161A, and 78-161B, table 4) contain no to high amounts of gold and silver.

Argillite collected in the Belmont West quadrangle is represented by one Group 2 sample (82-114, table 4) and one Group 3 sample (82-97, table 4). The Group 2 sample contains no gold and moderate silver, whereas the Group 3 sample contains neither gold nor silver. In the Jefferson quadrangle a Group 1 sample (82-135A, table 4) contains moderate gold and silver. Two Group 2 samples (84-124B and 84-130, table 4) have no gold and low silver. A Group 3 sample (84-113, table 4) contains no gold or silver.

Limestone is the most widely mineralized lithologic type in the southern Toquima Range. It is commonly silicified and iron mineralized (jasperized). Locally, small patches of gossan occur along faults and shears in limestone, and brecciated limestone has been mineralized in many places. A great variation of metal associations in the mineralized limestones has been observed. In the Round Mountain quadrangle Group 1 samples (74-122, 74-150, and 74-155, table 5) have moderate to high gold and low to moderate silver. Group 2 samples (74-121 and 74-275, table 5) contain moderate amounts of gold and low silver. One of the Group 2 samples (74-275) is from The Shale Pit (fig. 2), a small gold deposit in Paleozoic carbonaceous argillite and

Table 3.--Mineralized Paleozoic quartzite and siltite* [analyses in ppm of mineralized sedimentary rocks; N, not detected at limit of detection; L, detected, but below limit of determination]

Round Mountain quadrangle

	Group 2				Group 3	
	73-228	74-110	74-203		67-126*	74-119
Au	0.34	0.07	N	Au	0.09	0.12
Ag	1	1,810	N	Ag	N	1.5
Hg	0.41	15.0	2.3	Hg	2.5	0.25
As	3,000	7,000	5,000	As	N	700
Sb	N	10,000	200	Sb	N	N
Bi	N	50	N	Bi	N	N
Mo	5	N	5	Mo	10	N
W	N	N	N	W	N	N
Cu	5	5,000	20	Cu	15	70
Pb	N	300	70	Pb	10	N
Zn	N	300	500	Zn	700	N

Manhattan quadrangle

	Group 1						Group 2
	77-90	78-65	78-94	79-8	79-14		78-46A
Au	N	0.17	0.07	N	N	Au	3.39
Ag	1	30	N	1.5	7	Ag	2
Hg	0.51	5.6	22.6	0.47	2.2	Hg	0.26
As	N	N	1,500	1,000	N	As	1,000
Sb	N	300	N	N	N	Sb	200
Bi	N	N	N	N	N	Bi	N
Mo	10	N	20	10	10	Mo	10
W	N	N	N	N	N	W	N
Cu	300	3,000	200	70	100	Cu	150
Pb	10	15	7	150	150	Pb	30
Zn	1,000	N	1,500	1,000	5,000	Zn	1,000

	Group 3								
	68-120	73-234	78-4	78-14A	78-46B	78-150	78-158D	79-69	79-70A
Au	0.12	1.1	N	1.10	0.57	1.46	N	13.0	0.48
Ag	N	265	N	5	2	23	2	21	N
Hg	0.60	3.1	2.8	2.8	0.18	1.5	0.07	0.13	0.10
As	N	N	N	L	L	L	N	N	N
Sb	N	N	N	L	N	L	N	N	N
Bi	N	N	N	N	N	N	100	N	N
Mo	N	7	5	N	10	7	10	7	N
W	N	N	N	N	N	N	N	N	N
Cu	15	20	70	7	30	150	100	15	7
Pb	10	15	20	10	N	10	10	10	N
Zn	N	N	500	L	500	N	N	N	N

Belmont West quadrangle

	Group 3
	81-22
Au	N
Ag	0.7
Hg	0.19
As	N
Sb	N
Bi	N
Mo	N
W	N
Cu	30
Pb	N
Zn	700

Jefferson quadrangle

	Group 2				Group 3
	84-120	84-125	84-138		84-126
Au	N	N	N	Au	N
Ag	N	N	N	Ag	1
Hg	110	8.3	4.9	Hg	4.9
As	20,000	1,500	20,000	As	N
Sb	N	500	N	Sb	N
Bi	N	N	N	Bi	300
Mo	7	N	10	Mo	5
W	N	N	N	W	N
Cu	15	7	50	Cu	70
Pb	70	30	N	Pb	30
Zn	500	700	1,000	Zn	N

Table 4.--Mineralized Paleozoic argillite and schist* [analyses in ppm of mineralized sedimentary rocks; N, not detected at limit of detection; L, detected, but below limit of determination]

Round Mountain quadrangle

	Group 1			Group 2
	73-171	74-276B		74-162
Au	N	0.30	Au	0.57
Ag	35	.7	Ag	10
Hg	0.90	0.87	Hg	0.25
As	N	1,000	As	3,000
Sb	N	N	Sb	100
Bi	N	N	Bi	N
Mo	5	10	Mo	30
W	N	N	W	N
Cu	2,000	70	Cu	100
Pb	70	15	Pb	20
Zn	3,000	1,000	Zn	N

	Group 3					
	67-72*	67-95*	74-153	74-271	74-276A	74-277
Au	0.06	0.05	0.07	N	0.07	0.07
Ag	N	N	N	N	N	0.5
Hg	N	0.12	0.31	0.11	0.23	0.11
As	N	N	N	500	N	N
Sb	N	N	N	N	N	N
Bi	N	N	N	N	N	N
Mo	N	3	N	15	15	5
W	N	N	N	50	N	N
Cu	30	20	200	200	15	30
Pb	N	N	50	15	N	10
Zn	N	N	500	N	N	200

Manhattan quadrangle

	Group 1				
	77-91	78-36	78-37	78-126	79-22
Au	N	0.06	N	N	N
Ag	1	N	N	1	N
Hg	0.62	0.36	0.16	0.07	0.43
As	N	N	N	L	N
Sb	N	N	N	N	N
Bi	N	N	N	N	N
Mo	15	20	10	20	20
W	N	N	N	N	N
Cu	500	3,000	100	150	500
Pb	30	10	N	20	N
Zn	500	L	5,000	2,000	500

	Group 2							
	77-107	77-118	77-175	78-17	78-19	78-48	79-37	79-54
Au	0.09	N	N	N	0.69	N	0.14	N
Ag	1.5	1.5	N	N	3	N	N	N
Hg	0.43	7.5	1.9	0.08	1.2	0.07	24.8	21.2
As	2,000	2,000	1,500	1,500	1,000	3,000	30,000	1,000
Sb	N	200	1,000	200	N	N	700	N
Bi	N	N	N	N	N	N	N	N
Mo	30	7	300	15	15	30	15	N
W	N	N	N	N	N	N	N	N
Cu	150	50	100	100	150	50	50	20
Pb	30	N	10	10	10	15	N	15
Zn	1,000	500	L	1,000	N	1,000	500	300

Table 4.--Mineralized Paleozoic argillite and schist* (continued)

Manhattan quadrangle (continued)

	Group 3					
	77-88	77-184	77-201	78-6B	78-9A	78-10A
Au	N	0.69	0.10	0.06	N	0.32
Ag	N	7	7	10	N	N
Hg	0.20	2.3	2.0	0.44	0.39	0.18
As	N	L	N	N	N	N
Sb	N	N	N	N	N	N
Bi	N	N	N	N	N	N
Mo	10	20	15	5	10	N
W	N	N	N	N	N	N
Cu	300	150	300	300	200	100
Pb	30	15	30	30	15	20
Zn	500	N	N	500	N	N

	78-71	78-73	78-89A	78-100A	78-117	78-120
Au	N	N	N	N	0.48	0.28
Ag	5	N	1	2	5	2
Hg	0.15	0.05	0.11	0.48	0.13	0.12
As	N	N	N	N	N	L
Sb	N	N	N	N	N	N
Bi	N	N	N	N	N	N
Mo	10	5	50	N	20	20
W	N	N	N	N	N	N
Cu	150	300	300	70	200	150
Pb	N	N	N	20	20	20
Zn	L	L	N	700	N	L

	78-124	78-125	78-127	78-160	78-161A	78-161B
Au	0.06	N	0.05	3.21	1.38	0.30
Ag	N	1	10	317	15	10
Hg	0.03	0.04	0.09	12.0	3.5	0.41
As	N	N	L	N	N	N
Sb	N	N	N	N	N	N
Bi	N	N	N	N	L	N
Mo	L	20	15	5	N	10
W	N	N	N	N	N	N
Cu	200	150	200	150	30	150
Pb	N	10	20	100	30	20
Zn	N	500	300	N	N	N

Belmont West quadrangle

	Group 2		Group 3
	82-114		82-97
Au	N	Au	N
Ag	15	Ag	N
Hg	1.3	Hg	1.4
As	3,000	As	N
Sb	150	Sb	N
Bi	N	Bi	N
Mo	N	Mo	N
W	N	W	N
Cu	150	Cu	150
Pb	N	Pb	N
Zn	N	Zn	N

Jefferson quadrangle

	Group 1		Group 2			Group 3
	82-135A		84-124B	84-130		84-113
Au	0.3	Au	N	N	Au	N
Ag	50	Ag	2	N	Ag	N
Hg	14	Hg	960	10	Hg	0.17
As	N	As	3,000	20,000	As	N
Sb	N	Sb	700	700	Sb	N
Bi	N	Bi	N	N	Bi	N
Mo	30	Mo	3	N	Mo	N
W	N	W	N	N	W	N
Cu	150	Cu	30	20	Cu	30
Pb	3,000	Pb	70	70	Pb	15
Zn	N	Zn	N	N	Zn	700

limestone similar to the Carlin gold deposit. Several gold-bearing argillite samples were collected in the vicinity of The Shale Pit. Group 3 samples (74-141 and 74-152, table 5) from the northeast corner of the Round Mountain quadrangle have moderate or high gold and low silver. In the Manhattan quadrangle Group 1 samples (78-130, 78-141, 78-145, 78-146, 78-147, 78-152, 79-23, 79-42, and 79-82, table 5) contain low to moderate gold and low to high silver. Numerous Group 2 samples (77-191, 78-29A, 78-32, 78-49, 78-78, 78-110, 78-135, 78-157, 78-159, 79-32, 79-36, 79-40, 79-41, 79-43, 79-50A, 79-61, 79-74, and 79-79A, table 5) and Group 3 samples (77-192, 77-195, 77-196, 78-87, 78-104, 78-142, 78-154B, 79-73, 82-134, and 84-150, table 5) contain low to high amounts of gold and low to moderate silver.

Mineralized limestone collected in the Belmont West quadrangle includes five Group 1 samples (81-18, 81-46A, 82-108, 82-120, and 82-124, table 5). They contain no gold and low silver. Among Group 2 samples (81-26, 81-67, 81-76, 82-69B, 82-95, 82-101, 82-113, and 82-123, table 5), gold is virtually nil (moderate amount in only one sample), but silver ranges from low to high (in one sample). Group 3 samples (82-64A, 82-90, 82-92A, 82-119, and 82-122, table 5) contain no gold and low silver. In the Jefferson quadrangle Group 1 samples (84-57, 84-129, 84-149, 84-159A, and 84-161, table 5) contain no gold, and low to moderate amounts of silver. Group 2 samples (84-87, 84-122, 84-123B, and 84-136, table 5) contain low gold and silver. Group 3 samples (84-80, 84-82, 84-101, 84-114, 84-115, 84-117, 84-118, and 84-151B, table 5) have low to high amounts of gold and low to moderate silver.

Tactite

Mineralized calc-silicated limestone, or tactite, though not voluminous in the southern Toquima Range, is widespread. Most is spatially and genetically related to the Cretaceous granitic plutons; it is thus of essentially the same age as the plutons, about 95-80 Ma (Shawe and others, 1986). A few tactite samples were collected 2-3 km from a granite contact; as explained later in this paper I believe they are related to a buried Tertiary intrusive. One tactite sample was collected from a limestone block enclosed in Oligocene granodiorite. The tactites consist of varied amounts of calc-silicate minerals such as garnet, idocrase, diopside, epidote, wollastonite, actinolite, and tremolite, together with quartz, potassium feldspar, carbonate minerals, and several sulfide minerals.

In the Round Mountain quadrangle one tactite sample (Group 1, 74-171D, table 6) was collected from a limestone block enclosed in granodiorite near the margin of an Oligocene stock east of Round Mountain (fig. 2). The stock is dated as about 35 Ma (Shawe and others, 1986), and I infer that this tactite, which consists of intergrown idocrase, epidote, calcite, and minor sulfide minerals, formed at the time of granodiorite emplacement. The analyzed sample contains abundant zinc, some antimony, moderate amounts of bismuth and gold, and low mercury and silver. Tactites in the Manhattan quadrangle are both metal rich and metal poor, and they have metal associations similar to those in the quartz veins. In fact sample 77-172 (fig. 2) consists of a thin quartz vein enclosed in tactite. The Manhattan tactites contain idocrase, diopside, and wollastonite together with minor sulfides such as pyrite, chalcopyrite, and arsenopyrite(?). A Group 1 tactite (sample 78-151, table 6) contains moderate silver and no gold. Group 2 tactites (samples 77-170, 79-34B, and 79-56, table 6) contain moderate to high gold and mercury and low to moderate silver. Group 3 tactites (samples 77-168B, 77-169, and 77-172, table 6) contain low to high amounts of gold and low to moderate silver. The Group 1 tactite (sample 78-151) is at the contact of the Cretaceous granite pluton south of Manhattan, whereas the other six

Table 5.--Mineralized Paleozoic limestone [analyses in ppm of mineralized sedimentary rocks; N, not detected at limit of detection; L, detected, but below limit of determination]

Round Mountain quadrangle

	Group 1				Group 2			Group 3	
	74-122	74-150	74-155		74-275	74-121		74-141	74-152
Au	1.47	0.06	0.10	Au	0.11	0.17	Au	2.02	0.07
Ag	10	.5	1	Ag	1.5	2	Ag	7	1.5
Hg	0.75	4.4	1.5	Hg	0.55	0.50	Hg	0.50	0.80
As	500	700	700	As	10,000	1,000	As	500	500
Sb	N	N	N	Sb	100	N	Sb	N	N
Bi	N	N	N	Bi	N	N	Bi	N	N
Mo	7	10	20	Mo	20	10	Mo	N	20
W	N	N	N	W	N	N	W	N	N
Cu	1,000	1,000	70	Cu	50	200	Cu	50	30
Pb	20	30	70	Pb	15	20	Pb	15	10
Zn	N	500	5,000	Zn	1,000	500	Zn	N	300

Manhattan quadrangle

	Group 1								
	78-130	78-141	78-145	78-146	78-147	78-152	79-23	79-42	79-82
Au	0.09	0.12	0.07	N	N	N	N	N	N
Ag	10	138	30	N	N	N	N	10	N
Hg	1.9	14.9	9.0	1.5	1.0	7.8	0.33	1.1	3.4
As	N	L	L	N	N	L	N	L	N
Sb	L	N	L	N	N	N	N	N	N
Bi	20	10	N	N	N	N	N	N	N
Mo	N	7	2	N	N	10	N	N	20
W	N	N	N	N	N	N	N	N	N
Cu	5,000	700	2,000	100	30	200	50	5,000	50
Pb	70	20,000	1,000	20	N	N	N	N	N
Zn	500	300	2,000	3,000	5,000	3,000	1,000	N	2,000

	Group 2					
	77-191	78-29A	78-32	78-49	78-78	78-110
Au	7.23	0.70	2.45	0.55	N	N
Ag	36	20	5	1.5	N	N
Hg	5.8	49.8	0.98	0.25	0.10	43.4
As	10,000	15,000	1,000	1,000	1,000	20,000
Sb	200	300	500	1,000	N	N
Bi	N	N	N	N	N	N
Mo	15	7	5	10	L	N
W	N	N	N	N	N	N
Cu	50	50	100	30	10	700
Pb	20	N	10	10	N	10
Zn	N	L	500	1,000	L	N
	78-135	78-157	78-159	79-32	79-36	79-40
Au	N	3.31	3.91	N	0.15	N
Ag	N	30	29	N	N	N
Hg	29.8	2.3	2.2	2.2	4.8	23.3
As	30,000	1,000	1,000	1,500	30,000	10,000
Sb	500	L	N	300	3,000	L
Bi	N	N	N	N	N	N
Mo	20	5	7	7	N	100
W	N	N	N	N	N	N
Cu	100	70	150	20	100	10
Pb	15	15	20	N	20	N
Zn	N	N	N	300	300	300
	79-41	79-43	79-50A	79-61	79-74	79-79A
Au	N	N	22.5	16.8	0.95	0.10
Ag	N	N	15	20	5	N
Hg	11.6	8.3	29.0	4.3	2.3	121.0
As	2,000	5,000	15,000	20,000	1,000	L
Sb	N	N	200	N	7,000	2,000
Bi	N	N	N	N	N	N
Mo	N	5	L	L	7	N
W	N	N	N	N	N	N
Cu	20	100	30	20	50	20
Pb	30	10	70	30	15	10
Zn	N	N	N	N	L	N

Table 5.--Mineralized Paleozoic limestone (continued)

Manhattan quadrangle (continued)

	Group 3				
	77-192	77-195	77-196	78-87	78-104
Au	20.3	0.17	0.12	N	N
Ag	28	N	N	N	N
Hg	0.32	0.09	0.22	1.0	0.83
As	L	N	N	L	N
Sb	N	N	N	N	N
Bi	N	N	N	N	N
Mo	50	15	N	10	N
W	N	N	N	N	N
Cu	20	10	30	150	150
Pb	20	10	10	20	10
Zn	N	N	N	500	N

	78-142	78-154B	79-73	82-134	84-150
Au	N	6.48	0.54	1.5	1.4
Ag	15	20	2	1.5	N
Hg	4.7	2.1	0.10	0.23	0.50
As	N	L	N	N	N
Sb	N	L	N	N	N
Bi	N	N	N	N	N
Mo	L	7	N	N	5,000
W	N	N	N	N	N
Cu	150	70	15	200	7
Pb	70	50	20	N	N
Zn	N	N	N	N	N

Belmont West quadrangle

	Group 1				
	81-18	81-46A	82-108	82-120	82-124
Au	N	N	N	N	N
Ag	N	15	N	2	7
Hg	0.44	0.14	0.25	0.85	2.0
As	N	N	N	N	1,000
Sb	N	N	500	N	N
Bi	N	10	N	N	N
Mo	7	N	30	N	7
W	N	N	N	N	N
Cu	200	15,000	150	300	150
Pb	N	15	N	N	30
Zn	1,500	700	1,500	1,500	1,500

	Group 2							
	81-26	81-67	81-76	82-69B	82-95	82-101	82-113	82-123
Au	N	1.0	N	N	N	N	N	N
Ag	N	N	3	700	N	1.5	1.5	1
Hg	0.82	0.70	0.24	0.60	13	3.5	0.55	1.8
As	3,000	2,000	3,000	5,000	10,000	1,500	3,000	1,500
Sb	N	200	N	700	1,500	N	N	300
Bi	N	N	N	N	N	N	N	N
Mo	7	15	30	N	7	N	N	7
W	N	N	N	N	N	N	N	300
Cu	20	20	300	1,500	70	70	70	150
Pb	30	N	70	1,500	N	N	N	N
Zn	N	N	1,000	1,500	200	N	N	700

	Group 3				
	82-64A	82-90	82-92A	82-119	82-122
Au	N	N	N	N	N
Ag	3	1.5	N	7	N
Hg	0.04	0.10	2.4	0.45	0.15
As	N	N	N	N	N
Sb	N	N	N	N	N
Bi	N	N	N	N	N
Mo	N	5	N	20	N
W	N	N	N	N	N
Cu	150	200	30	300	70
Pb	20	N	N	70	N
Zn	700	N	700	500	300

Table 5.--Mineralized Paleozoic limestone (continued)

Jefferson quadrangle

Group 1

	84-57	84-129	84-149	84-159A	84-161
Au	N	N	N	N	N
Ag	1.5	3	80	4	1
Hg	0.08	30	16	0.10	0.03
As	N	1,500	1,500	N	N
Sb	N	700	N	N	N
Bi	N	N	N	N	N
Mo	N	N	15	1,000	300
W	N	N	N	N	N
Cu	1,500	300	700	1,000	1,000
Pb	N	1,500	N	N	N
Zn	N	7,000	2,000	500	300

Group 2

	84-87	84-122	84-123B	84-136
Au	N	N	0.2	N
Ag	N	N	N	2
Hg	0.15	52	9.3	130
As	2,000	5,000	1,000	20,000
Sb	N	500	5,000	700
Bi	N	N	N	N
Mo	50	3	3	N
W	N	N	N	N
Cu	30	50	20	70
Pb	10	50	20	100
Zn	700	N	N	700

Group 3

	84-80	84-82	84-101	84-114	84-115	84-117	84-118	84-151B
Au	N	N	N	0.3	1.3	N	N	0.1
Ag	1	64	N	3	5	1.5	15	2
Hg	4.6	5.5	0.10	0.04	0.37	0.09	0.19	2.4
As	N	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	200	N
Mo	10	15	7	5	N	30	15	30
W	N	N	N	N	N	N	N	N
Cu	100	100	30	50	70	100	100	70
Pb	N	70	N	30	10	100	150	N
Zn	500	N	500	300	300	300	300	N

samples (Group 2 and Group 3) were collected in an east-northeast-striking linear zone in the east part of the Manhattan gold belt that may reflect the position of a buried intrusive. The intrusive may be a subsurface apophysis of the pluton, or more probably it is a younger hypabyssal intrusive. Sulfide-bearing calc-silicated limestone veined with drusy quartz characteristic of the Tertiary gold-bearing rocks in the district was observed on mine dumps just west of the White Caps mine.

Tactites sampled in the Belmont West quadrangle, mostly at the contact of the granitic pluton that lies south of Manhattan (fig. 4), consist of garnet, diopside, and quartz, locally with arsenopyrite(?), pyrite, and chalcopyrite. Two Group 2 tactites (samples 81-52 and 81-65, table 6) and two Group 3 tactites (samples 81-49A and 81-51, table 6) contain no gold and low amounts of silver. Tactites sampled in the Jefferson quadrangle, all at the contact of granite plutons with Paleozoic sedimentary rocks (fig. 5), consist of garnet, epidote, diopside, and quartz, locally with minor fluorite, sericite, and K-feldspar. Minor sulfides include pyrite, molybdenite, sphalerite, pyrrhotite, and chalcopyrite. Group 1 tactites (samples 84-108, 84-148, and 84-174, table 6) and Group 3 tactites (samples 84-147B and 84-172, table 6) contain low gold and silver.

Granite and aplite

Mineralized granite and aplite samples consist of several geochemical types similar to the quartz veins and the Paleozoic rocks. These samples were selected primarily on the basis of strong iron staining either as impregnations or fracture coatings. Metal-rich rocks (Group 1) and metal-poor rocks (Group 3) are represented. The mineralogy of these mineralized rocks was not investigated and the samples cannot be categorized by their mineral compositions. In the Round Mountain quadrangle, Group 1 rocks (samples 74-82, 74-99, 74-102B, and 74-182, table 7) contain high gold and generally high silver. Group 3 mineralized granite and aplite (all mineralized aplite samples in the southern Toquima Range are in Group 3) (samples 67-32, 67-36, 68-121, 73-18, 73-34, 73-131, 74-21, 74-100, 74-185, 74-188, 74-227, 74-240, and 74-258, table 7) contain low to high gold, and they contain low to moderate silver. Muscovite from one of the Group 1 Cretaceous granite samples from the Round Mountain quadrangle (sample 74-102B, fig. 2) has been dated at about 62 Ma (Shawe and others, 1986). The muscovite in this sample is interpreted to have been partly reset to a younger age by a thermal event related to emplacement of the nearby Oligocene granodiorite stock. Muscovite from another sample of mineralized granite (sample 74-97B, not analyzed for metal content) that was collected nearer to the granodiorite stock gave an age of about 40 Ma (Shawe and others, 1986), which suggests that this muscovite was reset at a higher temperature than muscovite in sample 74-102B. Cretaceous granite and Oligocene dikes were mineralized with secondary tourmaline in a halo that surrounds the stock for as far as 1 km. I infer that some of the metal components of sample 74-102B (also sample 74-102A from the same location) as well as the tourmaline were introduced at the time of emplacement of the granodiorite stock.

In the Manhattan quadrangle one sample (78-20C, table 7) falls in Group 1. It is strongly enriched in gold, silver, and mercury. Group 3 samples (78-11C, 78-21, 78-44, 78-45, 78-118, and 79-27, table 7) are devoid of gold and they contain low silver. Only samples of Group 3 mineralized granite and aplite were collected in the Belmont West quadrangle (samples 81-143, 81-146, 82-54, 82-85, and 82-88, table 7). Gold is absent in these, and silver is low to moderate. In the Jefferson quadrangle a Group 1 sample (82-139B, table 7)

Table 6.--Mineralized tactite [analyses in ppm; N, not detected at limit of detection; L, detected, but below limit of determination; (--), not looked for]

Round Mountain quadrangle

	Group 1
	74-171D
Au	0.06
Ag	N
Hg	0.01
As	N
Sb	500
Bi	15
Mo	N
W	N
Cu	1
Pb	N
Zn	2,000

Manhattan quadrangle

	Group 1
	78-151
Au	N
Ag	24
Hg	0.11
As	N
Sb	N
Bi	N
Mo	10
W	N
Cu	20,000
Pb	N
Zn	2,000

	Group 2		
	77-170	79-34B	79-56
Au	0.14	1.08	1.89
Ag	N	1	25
Hg	14.8	1.5	9.8
As	1,000	2,000	5,000
Sb	200	N	L
Bi	N	N	N
Mo	5	N	10
W	N	N	N
Cu	20	7	30
Pb	N	N	70
Zn	N	N	700

	Group 3		
	77-168B	77-169	77-172
Au	0.05	N	29.3
Ag	N	N	54
Hg	0.03	0.04	5.7
As	N	N	N
Sb	N	N	N
Bi	N	N	N
Mo	N	N	10
W	N	N	N
Cu	200	700	20
Pb	N	N	N
Zn	N	N	N

Belmont West quadrangle

	Group 2	
	81-52	81-65
Au	N	N
Ag	N	1.5
Hg	0.61	0.48
As	3,000	2,000
Sb	N	N
Bi	N	N
Mo	30	15
W	N	N
Cu	150	30
Pb	N	N
Zn	N	N

	Group 3	
	81-49A	81-51
Au	N	N
Ag	3	0.5
Hg	N	0.08
As	N	N
Sb	N	N
Bi	10	10
Mo	30	N
W	N	N
Cu	500	7
Pb	15	N
Zn	N	300

Jefferson quadrangle

	Group 1		
	84-108	84-148	84-174
Au	N	N	0.2
Ag	3	3	7
Hg	1.0	63	0.16
As	N	N	N
Sb	N	N	N
Bi	N	N	N
Mo	N	150	700
W	N	150	N
Cu	300	300	7,000
Pb	N	N	N
Zn	70,000	2,000	500

	Group 3	
	84-147B	84-172
Au	N	N
Ag	3	N
Hg	0.07	--
As	N	N
Sb	N	N
Bi	N	N
Mo	15	300
W	N	N
Cu	200	7
Pb	N	N
Zn	700	500

Table 7.--Mineralized Cretaceous granite and aplite* [analyses in ppm; N, not detected at limit of detection; L, detected, but below limit of determination]

Round Mountain quadrangle

Group 1

	74-82	74-99	74-102A	74-102B	74-182
Au	0.24	0.13	1.36	3.59	0.60
Ag	188	113	315	274	1.5
Hg	2,200	1.5	13	1.3	0.40
As	3,000	N	N	N	N
Sb	5,000	200	N	N	N
Bi	70	7	L	N	7
Mo	N	7	1,000	30	N
W	50	50	N	N	50
Cu	30,000	500	700	150	100
Pb	2,000	2,000	10,000	2,000	150
Zn	10,000	N	200	N	700

Group 3

	67-32*	67-36	68-121	73-18	73-34	73-131	74-21
Au	0.23	0.23	1.7	0.08	0.05	0.07	0.07
Ag	N	1.5	5	N	N	N	N
Hg	0.02	0.30	0.58	1.4	0.74	0.01	1.3
As	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	N
Mo	N	10	5	5	20	N	N
W	N	N	N	N	N	N	N
Cu	1.5	1.5	1.5	70	70	5	7
Pb	30	20	20	50	30	20	200
Zn	N	300	N	N	N	N	N

	74-100	74-185	74-188	74-227	74-240	74-258
Au	0.44	0.09	N	0.06	N	N
Ag	1	N	N	.7	3	28
Hg	0.10	0.09	0.15	1.5	1.9	2.3
As	N	N	N	500	N	N
Sb	N	N	N	100	N	N
Bi	N	N	N	150	50	7
Mo	N	N	N	50	70	100
W	N	N	50	N	N	N
Cu	30	7	1.5	7	20	300
Pb	70	N	N	100	50	100
Zn	N	N	N	N	N	N

Table 7.--Mineralized Cretaceous granite and aplite* (Continued)

Manhattan quadrangle

	Group 1		Group 3					
	78-20C		78-11C*	78-21*	78-44*	78-45*	78-118*	79-27*
Au	68.8	Au	N	N	N	N	N	N
Ag	1,180	Ag	1.5	7	3	5	N	1.5
Hg	131.0	Hg	0.18	0.09	0.19	2.7	0.09	0.01
As	N	As	N	N	N	N	L	N
Sb	L	Sb	N	N	N	N	N	N
Bi	N	Bi	N	N	N	N	N	N
Mo	N	Mo	30	N	7	10	15	N
W	N	W	N	N	N	N	N	N
Cu	50	Cu	150	1	70	70	200	150
Pb	1,000	Pb	15	50	10	10	70	10
Zn	500	Zn	300	N	L	N	L	N

Belmont West quadrangle

	Group 3				
	81-143	81-146	82-54	82-85	82-88
Au	N	N	N	N	N
Ag	N	3	1	1.5	10
Hg	0.85	0.87	0.05	0.04	N
As	N	N	N	N	N
Sb	N	N	N	N	N
Bi	N	10	N	15	N
Mo	70	15	7	15	15
W	N	N	N	N	N
Cu	20	10	30	15	50
Pb	30	30	200	30	50
Zn	N	N	N	N	N

Jefferson quadrangle

	Group 1		Group 3					
	82-139B		67-34A*	67-34B	82-136	82-153	84-143A	84-175
Au	N	Au	0.11	0.09	N	N	N	0.1
Ag	N	Ag	N	N	N	3	5	2
Hg	0.25	Hg	0.01	N	0.16	37	5.8	0.10
As	N	As	N	N	N	N	N	N
Sb	N	Sb	N	N	N	N	N	N
Bi	N	Bi	N	N	N	N	N	N
Mo	N	Mo	7	N	15	70	10	20
W	N	W	N	N	N	N	N	N
Cu	15	Cu	1.5	20	150	150	5	50
Pb	20	Pb	30	20	70	20	30	100
Zn	1,000	Zn	N	N	N	N	N	N

contains no gold and silver. Group 3 samples (67-34A, 67-34B, 82-136, 82-153, 84-143A, 84-175, table 7) contain low to moderate gold and low silver.

Rhyolite dikes

A few mineralized samples were collected from the Oligocene rhyolite dikes, or at contacts between the dikes and wallrocks in the Round Mountain quadrangle. These samples represent mineralization that occurred at, or later than the age of the dikes, about 35 Ma. A Group 1 sample (74-123, table 8) contains high amounts of gold, silver, and mercury. Noteworthy is the absence of arsenic and the abundance of antimony. Several Group 3 samples (74-125, 74-167A, 74-170A, and 74-175, table 8) contain low to moderate gold and low silver.

Table 8.--Mineralized Tertiary rhyolite dikes [analyses in ppm; N, not detected at limit of detection]

	Group 1		Group 3			
	74-123		74-125	74-167A	74-170A	74-175
Au	1.02	Au	N	0.05	0.05	N
Ag	743	Ag	1	N	N	N
Hg	26	Hg	0.65	0.16	0.04	0.20
As	N	As	N	N	N	N
Sb	5,000	Sb	100	N	N	N
Bi	200	Bi	N	N	N	N
Mo	N	Mo	10	5	N	N
W	N	W	N	N	N	100
Cu	10,000	Cu	100	5	1.5	10
Pb	50	Pb	10	30	50	N
Zn	200	Zn	700	N	N	200

Volcanic rocks

All of the mineralized samples of volcanic rocks collected in the Round Mountain quadrangle, mostly near the Round Mountain gold mine, are metal poor and fall in Group 3 (sample 67-42, 67-54, 67-119, 68-122, 68-126, 68-142, 68-144, 68-147, 68-150, 73-70, and 74-225, table 9). They contain moderate amounts of gold and low silver. In the Manhattan quadrangle two Group 1 samples (77-187A, and 78-23, table 9) contain no gold and low silver. One mineralized volcanic rock in Group 2 (sample 75-21A, table 9) contains no gold and silver, but high mercury. The metal-poor volcanic rocks (Group 3) in the Manhattan quadrangle (samples 67-80, 75-5, 77-32, 77-39, 77-42, 77-48, 77-53, 77-57, 77-58, 77-60, 77-63, 77-112, 77-116, 77-152, 77-181, 77-186, 77-187B, 77-188, 77-189, 77-190, and 77-194, table 9) contain low to high amounts of gold and low to moderate silver.

Mineralized volcanic rocks in the Belmont West quadrangle are serpentinite and greenstone of a Paleozoic ophiolite assemblage (the serpentinite may have been derived from a mafic intrusive rather than from a mafic volcanic rock). Two Group 1 serpentinites (samples 82-128 and 82-129B, table 9) contain low or moderate gold and silver. A Group 2 greenstone (sample 82-99, table 9) contains no gold and low silver, but high mercury. The Paleozoic ophiolite assemblage appears to be intruded by a rhyolite plug dated (C. W. Naeser, written commun., 1985) at about 25 Ma. No data are available for mineralized volcanic rocks in the Jefferson quadrangle.

Table 9.--Mineralized volcanic rocks [analyses in ppm; N, not detected at limit of detection; L, detected, but below limit of determination; (--), not looked for]

Round Mountain quadrangle

	Group 3					
	67-42	67-54	67-119	68-122	68-126	68-142
Au	0.07	0.06	0.09	0.42	0.09	0.10
Ag	N	N	1.5	1	N	5
Hg	0.19	0.02	--	0.21	0.19	0.06
As	N	N	N	N	N	N
Sb	N	N	N	N	N	N
Bi	N	N	N	N	N	N
Mo	3	N	3	N	N	3
W	N	N	N	N	N	N
Cu	1	5	1	5	1.5	3
Pb	30	10	20	10	15	15
Zn	N	N	N	N	N	N

	68-144	68-147	68-150	73-70	74-225
Au	0.67	0.19	0.15	0.08	0.62
Ag	N	2	N	N	1
Hg	0.15	0.11	0.02	0.02	0.12
As	N	N	N	N	N
Sb	N	N	N	N	N
Bi	N	N	N	N	N
Mo	15	3	N	N	2
W	N	N	N	N	N
Cu	5	1.5	1	7	3
Pb	15	10	10	20	20
Zn	N	N	N	N	N

Manhattan quadrangle

	Group 1	
	77-187A	78-23
Au	N	N
Ag	N	2
Hg	0.07	0.19
As	N	N
Sb	N	N
Bi	N	N
Mo	10	N
W	N	N
Cu	150	700
Pb	N	N
Zn	1,000	5,000

	Group 2
	75-21A
Au	N
Ag	N
Hg	6.2
As	1,500
Sb	N
Bi	N
Mo	N
W	N
Cu	2
Pb	15
Zn	N

Table 9.--Mineralized volcanic rocks (continued)

Manhattan quadrangle

	Group 3						
	67-80	75-5	77-32	77-39	77-42	77-48	77-53
Au	0.05	0.05	0.09	22.3	1.58	1.05	5.80
Ag	N	2	N	25	2	1.5	10
Hg	0.04	1.2	4.5	3.0	3.1	11.0	0.34
As	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	N
Mo	N	5	5	L	L	10	7
W	N	N	N	N	N	N	N
Cu	1.5	7	1.5	2	2	3	10
Pb	20	20	20	50	200	10	15
Zn	N	N	N	N	N	N	N

	77-57	77-58	77-60	77-63	*77-112	*77-116	77-152
Au	0.78	10.9	14.2	0.06	N	0.20	0.25
Ag	1	2	21	N	N	2	N
Hg	0.31	0.36	0.58	0.10	0.05	2.4	0.37
As	N	N	N	N	N	L	N
Sb	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	N
Mo	N	N	20	7	7	30	5
W	N	N	N	N	N	N	N
Cu	3	3	5	5	150	50	3
Pb	10	30	20	10	10	15	N
Zn	N	N	N	N	300	N	N

	77-181	77-186	*77-187B	*77-188	*77-189	*77-190	*77-194
Au	0.05	0.22	17.8	N	N	N	0.10
Ag	N	1	28	N	N	N	N
Hg	2.2	0.22	0.12	0.19	0.35	0.36	0.29
As	N	N	N	N	N	N	N
Sb	N	N	N	N	N	N	N
Bi	N	N	N	N	N	N	N
Mo	N	50	30	7	7	15	7
W	N	N	N	N	N	N	N
Cu	5	15	50	200	300	200	200
Pb	10	15	10	15	15	10	15
Zn	N	N	N	700	300	500	L

Belmont West quadrangle

Serpentinite and greenstone*

	Group 1	
	82-128	82-129B
Au	0.1	N
Ag	10	1.5
Hg	0.03	0.03
As	N	N
Sb	N	N
Bi	N	N
Mo	N	N
W	N	N
Cu	30,000	300
Pb	N	15
Zn	300	700

	Group 2
	82-99*
Au	N
Ag	1.5
Hg	6.4
As	15,000
Sb	N
Bi	N
Mo	30
W	N
Cu	70
Pb	N
Zn	N

SUMMARY

The geological and geochemical data presented here allow certain age and chemical characterizations of the studied mineralized areas in the southern Toquima Range. The mineralized areas generally are in separate quadrangles, and it is convenient to describe them quadrangle by quadrangle.

Cretaceous (80 Ma) quartz veins in or near the Cretaceous granite pluton in the Round Mountain quadrangle are of several metal types, some of which appear to have been modified by younger mineralizing episodes. Tungsten (huebnerite)-bearing veins are one type; quartz veins with sparse common sulfides such as pyrite, chalcopyrite, galena, and sphalerite are another, and quartz veins with molybdenite are a third type. Some copper-lead-zinc-dominant (Group 1) veins with high silver, such as at Silver Point and farther south, seem typical of Cretaceous veins formed in the Paleozoic sedimentary rocks marginal to the Cretaceous granite plutons. In the vicinity of the Oligocene (35 Ma) granodiorite stock and associated rhyolite dike swarm (fig. 2), the addition of copper, lead, zinc, arsenic, antimony, or bismuth to the quartz veins, both as the common sulfides and as sulfosalts, and the addition of gold, silver, and mercury, took place at the time of emplacement of the stock and dikes (for example, Shawe and others, 1984), and possibly during later mineralizing events. Tungsten-bearing quartz veins in granite that underlies Tertiary volcanic rocks at the Fairview mine at the east end of the Round Mountain district contain lead, bismuth, and silver in addition to molybdenum and tungsten. They show evidence of multiple mineralizations, one of which may have been related to the Oligocene intrusives. Deposition of antimony, bismuth, gold, and mercury in tactite in limestone enclosed in the granodiorite stock suggests that these metals, where they occur in the quartz veins, may have been in part deposited by a hydrothermal system related to the stock. The high amounts of gold, silver, molybdenum, and lead in metamorphosed and mineralized Cretaceous granite near the stock may have been introduced by this hydrothermal system. Oligocene rhyolite dikes that contain significant antimony, bismuth, molybdenum, gold, silver, and mercury also may have been affected by the mineralizing system related to the stock. Another manifestation of stock-related mineralization was formation of magnetite-bearing veins near the stock that contain minor amounts of gold, mercury, molybdenum, and tungsten. Inasmuch as the magnetite-bearing veins were formed within the zone of Cretaceous tungsten veins, the tungsten associated with the magnetite may have been derived from the older veins.

The 80 Ma quartz vein at the Outlaw prospect in the southeast corner of the Round Mountain quadrangle probably had a complex history of multiple mineralizations similar to quartz veins in granite at the Fairview mine. At the Outlaw, copper, lead, zinc, and bismuth were added to a molybdenite-bearing vein. One episode of mineralization may have been related to the 35 Ma rhyolite dike south of the Outlaw (fig. 2) as suggested by the presence of tourmaline in the vein. Further complexity resulted from the late addition of mercury to the Outlaw vein. Cretaceous quartz veins, such as at the Red Bird Toquima mine and a vein 5 km farther west in the south part of the quadrangle, were remineralized to produce veins of barite, chalcedony, and cinnabar. The character of the veins suggests that this mineralization took place in Tertiary time. Mercury in the vein at the Outlaw prospect may also have been added at this time.

Mineralized Paleozoic sedimentary rocks and Cretaceous granite commonly show metal associations similar to those in nearby quartz veins (fig. 2). The similarity suggests that the sedimentary rocks and granite were mineralized contemporaneously with the quartz veins.

The gold-bearing quartz veins at Round Mountain formed in 27 Ma rhyolitic volcanic rocks at the time of formation of the 25 Ma Manhattan caldera 5 km south of Round Mountain (Shawe and others, 1986). Gold and silver are the principal metals in the veins (Ferguson, 1921). The metals possibly were derived from a low temperature reworking of older gold- and silver-bearing veins in underlying Paleozoic sedimentary rocks and Cretaceous granite. If so, it is not evident why other metals besides gold and silver that were present in the older veins were not remobilized also. Mineralized rhyolitic volcanic rocks in the vicinity of the veins, though gold and silver bearing, also show low contents of the other metals.

The manganese oxide-rich veins at the Round Mountain gold mine are distinctly different from the older gold-rich quartz veins that are characteristic of the principal mineralizing event at Round Mountain. The abundance of silver, mercury, arsenic, and zinc with the manganese, relative to the older quartz veins, suggests that the manganese oxide-rich veins were hypogene rather than supergene.

The galena-bearing quartz veins at the Lead-Silver King prospect are no older than the 27 Ma volcanic rocks that constitute one wall of the vein system. However, they contain significant lead, bismuth, silver, antimony, and mercury, characteristic of the mineralization related to the 35 Ma granodiorite stock and associated rhyolite dikes. They may represent material reworked from deposits formed at the time of stock and dike emplacement, or they may constitute similar but younger and unrelated mineralizations. The presence of two distinct galena phases in the veins is suggestive of two mineralizing episodes.

Metal-rich quartz veins in the Manhattan quadrangle constitute two well defined groups (Group 1 and Group 2 veins). Group 1 veins, which contain significant copper, lead, and zinc, and generally high amounts of silver and some bismuth but low gold, are most likely about 75 Ma and related to the 80 Ma granite south of Manhattan. A Group 1 tactite that formed at the contact of the granite contains moderate silver but low gold and mercury. Group 2 veins in which tetrahedrite-tennantite is common as a late mineral contain very little silver but they tend to be much more enriched in gold than the Group 1 veins. Mercury is locally high in veins of both groups, but mercury-rich veins occur only within a broad northeast-trending zone centered on the White Caps mine (fig. 3). Coincidence of the northeasterly zone of arsenic-, antimony-, and mercury-enriched quartz veins with an alignment of undated Tertiary(?) rhyolite plugs (fig. 3) and the magnetic high near the White Caps mine suggests a possible genetic tie. Group 2 tactites that occur in a northeasterly zone near the White Caps mine and cross the cited magnetic high, contain sulfides (including probable arsenopyrite) and high gold and mercury, and they indicate a buried mineralizing intrusive. A several square-kilometer zone of tourmaline-mineralized rocks coincides closely in position with the area of Group 2 metal enrichment centered on the White Caps mine. As in the Round Mountain quadrangle, where a halo of tourmaline-mineralized rock surrounds the Oligocene granodiorite stock, the tourmaline zone centered on the White Caps denotes proximity to a stock. I infer that the intrusive is younger than the 80 Ma granite south of Manhattan, and is probably of Tertiary age.

Mineralized Paleozoic rocks, including limestone, argillite, and quartzite, as well as Cretaceous granite and aplite, show generally the same metal enrichments as spatially associated quartz veins and tactites (fig. 3). This relationship enhances the likelihood of specific zones of age-related mineral occurrences.

The undated thin quartz veins in volcanic rocks and the Group 3 mineralized volcanic rocks north of Manhattan are gold bearing but they contain generally low amounts of other metals. A northwesterly linear distribution of many of the mineralized rocks in the volcanics is suggestive of a deep-seated major fault control on mineralization. Also, intrusive rocks probably have been emplaced in the inferred fault zone in deeper parts of the volcanics, or at subvolcanic levels, to account for the mineralizing activity in the northwesterly zone. A few Group 1 and Group 2 mineralized volcanic rocks in the Manhattan quadrangle contain no gold, but they are locally somewhat enriched in some other metals.

The principal economic gold mineralization at Manhattan occurred at 16 Ma, centered on the Gold Hill mines. The mineralization was characterized by a general paucity of metals, but gold and silver are locally abundant. A low-level molybdenum anomaly coincides with the Manhattan zone of gold mineralization (Shawe, 1984). This episode of gold-silver mineralization was distinct from the arsenic-antimony-mercury-rich mineralization that occurred in the vicinity of the White Caps mine. Probably gold mineralization that was structurally controlled by the south margin of the Manhattan caldera was superimposed upon an older northeast-trending White Caps zone of mineralization. The White Caps zone must have contained gold initially, and more may have been added during a younger event. Gold, silver, and mercury mineralization at and near the Jumbo mine south of the White Caps was characterized by low content of most metals; it may be more closely akin to the Gold Hill ores than to the White Caps ores.

Several mineralized veins and volcanic rocks just north of the south margin of the Manhattan caldera, including those near the Fletcher mine (fig. 3), may have resulted from post-volcanic hydrothermal reworking of older deposits in the Paleozoic sedimentary rocks. The margin of the caldera, however, is a likely zone for intrusion of Tertiary hypabyssal rocks, and the mineralization may have been related to buried hypabyssal stocks, plugs, or dikes in the zone. Some samples from the mineralized volcanic terrane within the Manhattan caldera are actually of fragments of mineralized Paleozoic sedimentary rocks in volcanic breccias (table 8), and it is unknown whether the fragments were mineralized before or after inclusion in the volcanics.

A low-temperature Group 2 vein that contains gold, silver, and mercury, in Paleozoic sedimentary rocks about 1 km northwest of the westernmost of the Gold Hill mines (fig. 3), lies in a zone of Group 2 mineralized Paleozoic rocks. The vein and associated mineralized rocks probably were mineralized in Tertiary time.

Quartz veins and other mineralized rocks in the southwest corner of the Belmont West quadrangle (fig. 4) appear to be related to similar rocks farther west in and near the Manhattan district. Group 1 veins, tactites, and mineralized Paleozoic sedimentary rocks probably are related to the Cretaceous granite south of Manhattan. Group 2 mineralized rocks, as at Manhattan, may represent a younger mineralizing episode. Most of the quartz veins in Paleozoic rocks near Cretaceous granite in and near the Belmont district are Group 1 veins that are rich in silver, low in mercury, and virtually devoid of gold. I believe they, like the chemically similar veins at and near Silver Point in the Round Mountain quadrangle, are related to the Cretaceous granite. Quartz veins in granite are mostly metal poor. They contain no gold and low mercury, but silver may be locally high, and bismuth is common. A few quartz veins in granite near Belmont are huebnerite bearing, like some of those east of Round Mountain. The metal-poor veins in granite may be genetically related to the granite, but judged from relations in the Round

Mountain and Manhattan quadrangles they may be somewhat younger than the granite. A few veins and mineralized rocks in and near the Belmont district are of Group 2. Whether or not these mineralized rocks are reworked older veins, or formed during a younger episode, is unknown.

Mineralized rocks of the ophiolite assemblage in the Monarch area in the southeast part of the Belmont West quadrangle are concentrated in two places, one place characterized by Group 1 carbonate rocks, argillite, and greenstone, and the other characterized by Group 2 carbonate rocks and serpentinite (fig. 4). All of the mineralized rocks are devoid of gold and they contain generally low amounts of silver and mercury. Probably the mineralization was not related to magmatism that occurred during formation of the ophiolite assemblage; it may have taken place after the assemblage was tectonically emplaced in its present position. A rhyolite plug in the area that is about 25 Ma may have been a source of hydrothermal mineralization.

In the south part of the Jefferson quadrangle (data are incomplete for the north part of the quadrangle) metal-rich mineralized rocks, including quartz veins, various Paleozoic rocks, and tactites, form two general associations. Group 1 mineralized rocks, characterized by virtually no gold and low to high amounts of silver and mercury, are spatially associated with the Cretaceous granite plutons (fig. 5). The Van Ness mercury mine and the Barcelona silver mine are in mineralized zones of this type. Some of the rocks in the southeast corner of the quadrangle form an extension northward of the mineralized zone at and near the Belmont district. Group 2 mineralized rocks occur mostly in a narrow belt bounding the volcanic rocks that occupy most of the north part of the Jefferson quadrangle (fig. 5). They contain low to high amounts of gold, silver, and mercury; the Flower mercury mine is situated in this belt. Because of its spatial proximity to the Tertiary volcanic rocks, the narrow mineralized belt in which the Flower mine occurs is believed to be genetically related to the Tertiary volcanism.

The mercury enrichments associated with the Van Ness mine, with some of the mineralized rocks at and near the Barcelona mine, and with the Flower mercury mine, are an eastward extension of the zone of high mercury values that includes the Red Bird Toquima mine farther west in the Round Mountain quadrangle (fig. 2). The continuity of this east-trending zone of mercury enrichment suggests emplacement of the mercury during a single mineralizing event. Mineral textures and paragenesis indicate that a young mercury mineralization was superimposed on older quartz veins at the Red Bird Toquima mine, at the Outlaw prospect, and at the Mariposa Red Dog prospect in the west part of the zone. The silver-rich quartz veins and the molybdenum-rich tactites at and near the Barcelona mine that reflect mineralization related to the Cretaceous granite should not be expected to be enriched in mercury unless they were remineralized during a younger event.

Principal metal production from the Jefferson district has been of silver, from veins at or near a fault contact between Paleozoic sedimentary rocks and a volcanic megabreccia unit in the Tertiary volcanic rocks of the Mount Jefferson caldera. Where mineralized rock is metal rich, it is of Group 1 type. Minor gold production came from mineralized Tertiary rhyolitic tuff in the vicinity of a Tertiary rhyolite stock (not shown on fig. 5); the deposits are similar to gold-mineralized volcanics at Round Mountain, and they probably are of the same age (25 Ma). Presence of secondary tourmaline in a small area (about 1 km^2) of granite just south of the Jefferson district suggests the occurrence of an Oligocene mineralizing event that was similar to the one associated with the Oligocene granodiorite stock farther west in the Round Mountain quadrangle. If mineralization of that age took place near a buried Oligocene stock, it could have been partly remobilized to contribute to formation of the younger (25 Ma) precious-metal deposits in the Jefferson district. Age and igneous association of the antimony-rich vein at the west edge of the Jefferson district are not known.

CONCLUSIONS

The great variety of types and ages of mineralized rocks in the southern Toquima Range, and evidence that younger mineralized systems have been superimposed on older systems, indicate that most of the mineral deposits have had a complex history. Some of these deposits have produced significant precious metals, and from the standpoint of establishing exploration guides for deposits like these, or for deposits that might be associated with them, it is important to recognize whether a deposit formed essentially during one mineralizing event, or whether it is the product of more than one event. The economic viability of a deposit may depend on the presence of an older deposit that contributed metals to the younger mineralization. Or, the possibility of unrecognized precursor deposits in the vicinity of a known deposit might enhance the economic potential.

I recognize that some of the variations in mineralogy and metal content of the mineralized rocks described in this paper may have resulted from temperature and pressure gradients along mineralizing solution pathways, or from the influence of varied lithologies upon metal precipitation. Nevertheless, I have seen no compelling evidence that such zoning of metals accounts for the main variations observed. Instead, there is clear geologic evidence, including radiometric ages, for separate mineralizing events; the separate events in general can be recognized by mineral and metal associations.

The environs of the principal mineral districts of Round Mountain, Manhattan, Belmont, and Jefferson will now be discussed in the context of broad features established for the southern Toquima Range in general. Some of the possibilities I suggest seem probable and others are more speculative. In any case, further study will be required to confirm or refute the suggestions. Exploration geologists may make other interpretations based on the data presented in this paper that will suggest targets for precious metal or other mineral deposits in these districts and elsewhere in the studied area of the southern Toquima Range.

Some generalizations apply to the entire area studied. Most Group 1 mineralized rocks are associated with the Cretaceous granite plutons. The Group 2 mineralized rocks seem related to a younger magmatic episode(s), but these mineralized rocks in general have not yet been satisfactorily dated. Possibly they are mostly related to Oligocene (about 35 Ma) igneous activity. Some Group 3 mineralized rocks have been dated as belonging to the younger (Tertiary) mineralizing events, whereas many appear to be related to older episodes. Gold and (or) silver are enriched in some mineralized rocks of all ages. Mercury is related only to the Tertiary mineralizing events.

At Round Mountain, early quartz veins that carry huebnerite, or copper, lead, and zinc sulfides, or molybdenite were deposited in or near Cretaceous granite. These veins possibly represent a chemically zoned system. Sulfide-bearing veins in the Paleozoic rocks such as at Silver Point are silver rich. At the time of emplacement of the Oligocene (35 Ma) granodiorite stock and associated rhyolite dike swarm, some of the older veins were remineralized with addition of sulfides and sulfosalts, including those of arsenic, antimony, and bismuth, and other veins carrying these metals may have been deposited. During this episode gold, silver, and mercury were deposited in the veins in a broad zone surrounding the Oligocene intrusives. Potential for economic deposits related to the Oligocene intrusives in the granite seems low, but it may be significant for economic deposits of the Shale Pit type in the Paleozoic sedimentary rocks that border the granite.

An extensive gold-silver mineralization occurred in the volcanics following emplacement of the rhyolitic tuffs derived from the Mount Jefferson caldera. The mineralization probably was related to emplacement of hypabyssal intrusive rocks beneath Round Mountain at about the time of formation of the Manhattan caldera (25 Ma). Possibly some of the gold and silver was derived from hydrothermal reworking of older widespread and numerous veins in rocks underlying the volcanics. A younger mineralizing event, perhaps at about 10 Ma, formed silver-, manganese-, and arsenic-rich veins within the 25 Ma Round Mountain gold-silver deposit. The possibility that older (pre-25 Ma) gold- and silver-rich veins (or other types of mineralized rock) occur as a precursor beneath the Round Mountain deposit suggests that deep exploration in the area may be warranted. In addition, targets may exist for deposits proximal to the inferred 25 Ma intrusive rocks.

At Manhattan quartz veins and tactites characterized by copper, lead, and zinc sulfides and silver enrichment were deposited in association with Cretaceous granite. Later, probably in Tertiary time, a hypabyssal intrusive was emplaced into Paleozoic sedimentary rocks in the east part of the Manhattan district. Radiometric age data (Shawe and others, 1986) indicate an early Tertiary thermal event near the granitic pluton south of Manhattan. The inferred intrusive, marked by a magnetic high centered near the White Caps mine, and two rhyolite plugs south of Manhattan, form a northeasterly alignment. The plugs are undated but they are clearly of shallow emplacement and of Tertiary age. They may be offshoots of the postulated hypabyssal intrusive. The northeasterly alignment is marked by widespread mineralized rocks of great variety that are characterized by enrichment of arsenic, antimony, mercury, gold, and silver. The most notable occurrence in the zone is the White Caps ore deposit which, however, yielded very little silver. A significant aspect of the northeasterly zone of mineralization is the occurrence of several mineralized tactites and tourmalinized rocks in the north part of the zone. The tactites and tourmalinized rocks surely are associated with a buried intrusive (the postulated Tertiary hypabyssal body). The likelihood of arsenopyrite in these gold- and arsenic-rich tactites, and arsenopyrite in the early-stage ores in the White Caps, indicate a higher temperature mineralization than has traditionally been attributed to the White Caps. Ferguson (1924) rejected his own speculation that the abundant realgar in the White Caps deposit may have been derived as a result of hydrothermal reworking of arsenopyrite deposited during an early stage of mineralization, because he believed that the volume of arsenopyrite in the deposit was inadequate to account for the abundance of realgar. However, Ferguson did not consider that a large volume of arsenopyrite might underlie the White Caps. I propose that indeed a large body of arsenopyrite-mineralized rock, like that in the tactites north of the White Caps, does underlie the deposit, and that the White Caps may have been derived from it by hydrothermal reworking. The postulated large tactite deposit might have significant gold remaining in it.

A model for the inferred gold- and arsenic-mineralized tactite deposit that might have been a precursor for the White Caps deposit is the Fortitude gold deposit presently being mined at Battle Mountain, Nevada. The Fortitude deposit (Wotruba and others, 1986) has 16 million short tons of ore with a grade of about 0.15 oz/t gold and 0.87 oz/t silver. The deposit is a calc-silicated body within Paleozoic limestone near a Tertiary (38.5 Ma) granodiorite porphyry stock. The tactite is characterized by pyrrhotite, pyrite, chalcopyrite, marcasite, arsenopyrite, sphalerite, and galena in a calc-silicate mineral gangue. Gold is present as free particles at sulfide mineral boundaries; silver is mostly associated with galena.

The postulated tactite body in the Manhattan district is most likely hosted in Ordovician limestones that underlie a south-dipping fault just north of the White Caps. The fault separates the Ordovician rocks from Cambrian rocks in which the White Caps deposit occurs (see Shawe, 1981). The obvious potential for a Fortitude-type ore deposit underlying the White Caps system, and the clearly defined geologic relations at the surface in the vicinity of the White Caps, indicate that the environs of the mine present an excellent exploration objective.

Another gold-mineralizing event took place, at 16 Ma, in the Manhattan district along the south margin of the Manhattan caldera. Abundant gold-bearing drusy quartz veinlets were deposited in Cambrian phyllitic argillite and quartzite, to form the low-temperature, low-grade ores that have been mined on Gold Hill and in other nearby areas at Manhattan. The event may have been related to emplacement of inferred buried intrusive rocks along the structural margin of the caldera. The undated rhyolite plugs south of Manhattan that I have suggested may be related to an inferred Oligocene hypabyssal intrusive near the White Caps may instead belong to the 16 Ma episode. As the single identified young episode of gold mineralization at Manhattan, the 16 Ma event seems the likely agent to have reworked the postulated tactite ores near the White Caps mine to form the low-temperature realgar-, stibnite-, and cinnabar-bearing gold ores in that deposit. Undiscovered gold and silver ores of the 16 Ma episode of mineralization may occur in the district at several places along the structural margin of the Manhattan caldera.

In the Belmont district silver-rich ores of Group 1 type were formed in Paleozoic sedimentary rocks near the Cretaceous granite contact. They were controlled structurally mostly by an east-dipping low-angle fault within the Paleozoic rocks. Most likely, other concentrations of mineralized rock occur elsewhere along this structure, perhaps for a considerable distance both down dip and along the strike of the structure, subparallel to the granite contact. The presence of some Group 2 mineralized rocks at Belmont suggests a possible local reworking of the Cretaceous deposits in Tertiary time. If there was such an event, its significance is unknown.

Gold ores related to a rhyolite plug and that formed at about 25 Ma in the Jefferson district are similar to contemporaneous ores that were deposited at Round Mountain about 7.5 km farther west. Silver-rich ores of the same age at Jefferson, emplaced along the structural margin of the Mount Jefferson caldera, are similar to some mineralized rocks that formed in the vicinity of the Oligocene stock and dikes near Round Mountain. The indication, based on the presence of secondary tourmaline in granite south of Jefferson, that an Oligocene intrusive may underlie the area supports this speculation. A possibility that the silver-rich ores at Jefferson also are reworked from earlier mineral concentrations affords an intriguing exploration objective, but much further work is needed to strengthen this speculation.

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